The Rhode Island Shellfish Management Plan

Version II, November 2014

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LIST OF ACRONYMS

ACCSP – Atlantic Coastal Cooperative Statistics Program
ACFCMA – Atlantic Coastal Fisheries Cooperative Management Act
AFS – American Fisheries Society
AG – Attorney General
APA – Administrative Procedures Act
ARPA – Archaeological Resources Protection Act
ASMFC – Atlantic States Marine Fisheries Commission
ASP – Amnesic Shellfish Poisoning
BDM – Biomass Dynamic Model
BMP – Best Management Practice
BU – Boston University
BI – Block Island
CDC – Center for Disease Control
CFL – Commercial Fishing License
CFRF – Commercial Fisheries Research Foundation
CFU – Colony Forming Units
CODEX – Codex Alimentarius Commisssion
COVIS – Cholera and Other Vibrio Illness Surveillance
CRC – Coastal Resources Center, URI
CRMC – Rhode Island Coastal Resources Management Council
CSF – Community Supported Fisheries
CSO – Combined Sewer Overflow
CT – SMP Coordinating Team
CWA – Clean Water Act
CZMA – Coastal Zone Management Act
DDT – Dichlorodiphenyltrichloroethane
DEM – Rhode Island Department of Environmental Management
DEM OWR – Department of Environmental Management Office of Water Resources
DFO – Department of Fisheries and Oceans, Canada
DFW – Division of Fish and Wildlife (DEM)
DOH – Rhode Island Department of Health
DOI – Department of the Interior, USA
DSP – Diarrhetic Shellfish Poisoning
ECSGA – East Coast Shellfish Growers Association
EIA – Environmental Impact Assessment
EPA – Environmental Protection Agency
EQIP – Environmental Quality Incentives Program
ESA – Endangered Species Act
FDA – U.S. Food and Drug Administration
GSP – Global Positioning System
GSO – Graduate School of Oceanography
HACCP – Hazard Analysis and Critical Control Points
ICSSL – Interstate Certified Shellfish Shippers List
ISSC – Interstate Shellfish Sanitation Conference
ISSP – Interstate Shellfish Sanitation Program
JAM – Jamestown Aquaculture Movement
JOD – Juvenile Oyster Disease
LTL – Low Tide Level
MFC – Marine Fisheries Council
MMPA – Marine Mammal Protection Act

MOU – Memorandum of Understanding
MPN – Most Probable Number
MPURP – Multipurpose License
MSA – Magnuson-Stevens Fishery Conservation and Management Act
MSX – Multinucleated Sphere Unknown
MTL – Mean Tide Level
NBC – Narragansett Bay Commission
NEFMC – New England Fisheries Management Council
NEPA - National Environmental Policy Act
NMFS – National Marine Fisheries Service
NGO – Non-Governmental Organization
NOAA – National Oceanic and Atmospheric Administration
NRAC – Northeast Regional Aquaculture Center
NRCS – Natural Resources Conservation Service
NSSP, MO – National Shellfish Sanitation Program, Model Ordinance
ORGE – Oyster Gardening for Restoration and Enhancement
OSAA- Ocean State Aquaculture Association
OWR – Office of Water Resources, Rhode Island Department of Environmental Management
PEL – Principle Effort License
PHP – Post-Harvest Processing
PSP – Paralytic Shellfish Poisoning
QPX – Quahog Parasite Unknown
RICRMP – Rhode Island Coastal Resources Management Council Regulations
RI DEM – Rhode Island Department of Environmental Management
RIMFC – Rhode Island Marine Fisheries Council
RIGL – Rhode Island General Law
RISA – Rhode Island Shellfishermen's Association
RISD – Rhode Island School of Design
RISG – Rhode Island Sea Grant
RISMC- Rhode Island Seafood Marketing Collaborative
RWU – Roger Williams University
SAFIS – Standard Atlantic Fisheries Information System
SAP – Shellfish Advisory Panel
SCUBA – Self-Contained Underwater Breathing Apparatus
SMA – Shellfish Management Area
SMP – (Rhode Island) Shellfish Management Plan
SNECRI – Southern New England Collaborative Research Initiative
SSCA- State Shellfish Control Authority
STB- Save The Bay
TAC – Technical Advisory Committee
TMDL – Total Maximum Daily Load
TNC – The Nature Conservancy
UNE – University of New England
UNH – University of New Hampshire
USA COE or USAACOE – United States Army Corps of Engineers
US EPA – United States Environmental Protection Agency
USFDA – United States Food and Drug Administration
USDA/NRCS- United States Department of Agriculture/ Natural Resources Conservation Service
URI – University of Rhode Island
USFDA- United States Food and Drug Administration
VIMS – Virginia Institute of Marine Science
WWTF – Wastewater Treatment Facility

EXECUTIVE SUMMARY

1. The Rhode Island Shellfish Management Plan (SMP) is the culmination of two years of effort and engagement by the Rhode Island shellfish community inclusively, facilitated by the Coastal Resources Center/ Rhode Island Sea Grant at the Graduate School of Oceanography, University of Rhode Island. The shellfish community, or stakeholders, involved in crafting and editing the plan include state and federal management agencies, the commercial wild harvest shellfish industry, the aquaculture industry, non-profit and citizen organizations, recreational harvesters, and the academic communities at URI, Roger Williams University, and others throughout the state. Guided by the principles of conducting an open, transparent, stakeholder-driven process that would honor and further existing activities on the Bay and coastal salt ponds, the SMP strived to identify key issues then craft management and science recommendations that the state agencies can use to ensure sound management of shellfish resources into the future.
2. The SMP process involved dozens of stakeholder meetings, educational seminars from academics and agencies, as well as public education through citizen clamming classes. Every effort was made to ensure all voices were heard and that all issues were considered. Technical Advisory Committees were chosen to help decipher which issues were critical and warranted a management or science recommendation;all decisions were vetted through a Coordinating Team of agency members and made available for public comment. Several authors were selected to assist in writing the descriptive sections of the SMP based on their experience and knowledge of the subject. This Version II of the SMP will be available for additional public comment and it is encouraged that the SMP is reviewed and adapted based on need and availability of funding every few years.
3. In addition to the crafting of recommendations and describing aspects of shellfish and associated industries through the SMP chapters, the SMP team chose to address several key issues that were raised as important throughout the process. These issues were seen as "low hanging fruit" in that they were distinct actions that were needed and could be solved with the current team in the two year SMP development time period. Working across groups, the SMP was able to achieve the following "early successes" or accomplishments with regard to shellfish. Chapter 1 provides more detail on each accomplishment:
   a. Noon-time re-opening of shellfish grounds
   b. Replacing/repairing shellfish signs/range markers throughout the state
   c. Reorganization of DEM's shellfish regulations
   d. Aquaculture regulation reform
   e. MOA between DEM and CRMC on aquaculture lease inspections
   f. Providing $1.2M to support shellfish science
   g. Evaluating the effectiveness of shellfish spawner sanctuaries
   h. Creating a Vibrio Control Plan for oysters
   i. Mapping uses on the water
   j. Improving marketing of shellfish
   k. Creating a shellfish ecological history
   l. The Baird Symposium
   m. Involvement and responsiveness of DEM Division of Agriculture to aquaculture activities and needs
4. The efforts expended to craft the SMP and its early successes was beyond the mandated scope of Rhode Island's state agency leaders, and represents a concerted and exhaustive process to better

understand the concerns and issues regarding shellfish resources and industries. The SMP Team was diverse and many in number, from the formal Coordinating Team, to the individual technical teams, informal working groups who helped achieved the aforementioned "early successes", and the facilitating team at CRC/RI Sea Grant. Instrumental was the financial support from the various private foundations, the URI Coastal Institute, and RI Sea Grant. Just as critical was in-kind staff support and countless hours devoted by DEM and CRMC, as well as technical support, writing, and problem-solving by Roger Williams University and various URI colleges. The culmination of these immense efforts combined is bigger than the sum of their parts; it demonstrates Rhode Island's firm dedication to support healthy shellfish resources, industries, and opportunities for all who wish to pursue and enjoy this state treasure.

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CHAPTER 1. Introduction

By Jennifer McCann, Coastal Resources Center, URI

Section 100. Introduction

5. Shellfishing is part and parcel of the Rhode Island way of life, and has been for centuries. Native Americans used the local quahog for food and trade and taught European colonists how and where to gather them in Narragansett Bay. Early twentieth century tourists left their hot New England cities in the summer for cooler Bay shores, taking part in clambakes and collecting shellfish on their own. The enjoyment of slurping down oysters on the half shell is increasingly becoming a local tradition. And Rhode Islanders have steadfastly turned to shellfishing for year-round subsistence and income, and the science, art and lore of shellfishing – whether that be quahogging with your feet or a bullrake, or the farming of oysters and mussels – being handed down generation to generation.

6. Today, shellfishing – both the wild harvest (e.g., quahogs, oysters, steamers, whelks, bay scallops and mussels) and aquaculture (e.g., oysters, mussels and quahogs) – remains an important part of Rhode Island's cultural and economic story; the quahog is the official shell of the state, and local cartoonist Don Bousquet has built a national following for his humorous illustrations – "Beware of the Quahog"© and the like – that speak to Rhode Islanders' close relationship to shellfish and the sea. Statewide in 2012, wild harvesters earned more than $7 million selling their product to wholesalers, with the market value likely tripling by the final step of consumer purchase. In addition, in 2013, oysters sold from aquaculture farms were valued at over $4 million. The true economic value of wild harvested and cultured shellfish, though, likely triples by the time the product reaches the market and consumers. Furthermore, although the exact figure is unknown, it is clear that this resource contributes to the tourism and recreation industries in the state.

7. Yet, significant problems impact shellfishing in Rhode Island. In the regulatory arena, state agencies voice difficulties in balancing the needs of the resources with those of the wide ranging group of stakeholders – all connected to shellfishing in integrally personal and economic ways – in a rapidly changing environmental, economic, and social paradigm. Major environmental issues, from shellfish bed closures caused by pollution to ocean acidification caused by climate change, impact the health and resiliency of the resource. Furthermore, user conflict issues – Who may gather or grow shellfish? When and where may they do so? – have impacted both the commercial and recreational aspects of the industry. Growth in aquaculture over recent years and decline in the number of quahoggers entering the trade have significant implications for management and has forced the agencies to re-evaluate their approach and strategy to include more collaboration and communication between all involved. In all, the economic, environmental and regulatory issues have placed extraordinary pressures on shellfishing constituencies to arrive at an equitable means of using, protecting and enhancing Rhode Island's array of shellfish resources and habitats.

8. In 2012, with these concerns front and center, the Rhode Island Department of Environmental Management (DEM) and the Rhode Island Coastal Resources Management Council (CRMC), both with with responsibilities for developing management plans for coastal resources which includes shellfish, agreed to work together to develop the first comprehensive, multi-species statewide Shellfish Management Plan (SMP). Note: Other management plans have been developed by DEM for quahogs explicitly for Narragansett Bay, Greenwich Bay, and the salt ponds but these plans did not consider multiple shellfish species and engage a wider stakeholder process. The decision to develop the SMP was a choice, not a requirement, made by these agencies to deliberately and proactively coordinate decisions to: 1) Build an understanding of the economic, environmental and cultural values of the local resources and industries; 2) Evaluate and, when needed, propose alternative management strategies and new mechanisms for implementation; and 3) Promote science-based shellfish management decisions by increasing scientific research and outreach activities. Both DEM and CRMC have committed to the implementation of the Plan.

Section 110. Authority and Responsibility

1. Based on the Rhode Island Constitutional mandate, there are three major concerns in regulating the shellfish industry within state waters: protecting the ecological integrity of the resource, protecting public health, and minimizing the burden that restrictive measures may impose on the industry that conveys this resource to the consumer. As described more thoroughly in Chapters 9, the Rhode Island Department of Environmental Management, the Rhode Island Coastal Resources Management Council, and the Rhode Island Department of Health all have regulatory authority for upholding this mandate as directed by the Rhode Island General Assembly. Although these agencies have the authority, it is also the responsibility of the people of Rhode Island to ensure that the policies and recommendations of this SMP are upheld and implemented to meet the vision, goals and objectives described below.

Section 120. SMP Focus Area

1. The SMP focus area boundary includes all Rhode Island state waters except for those surrounding Block Island. Information about the Block Island shellfish resource will be included in this Plan, however because New Shoreham has special authority to manage the shellfish resource within its Great Salt Pond (in collaboration with DEM) where their shellfish resources occur, there will be no directed policies and recommendations.

   Note: While Block Island is part of Rhode Island, the town manages shellfish (in partnership with DEM) and thus Block Island was not part of the SMP process. This was also at the request of the Town of New Shoreham.

Figure 1.1. Detailed map of SMP study area.

Section 130. The Resource

1. This plan will work towards the management of all bivalve shellfish species. Table 1.1 outlines the species being considered. Illustrations of all of the shellfish species considered in the SMP can be found in Figure 1.2.

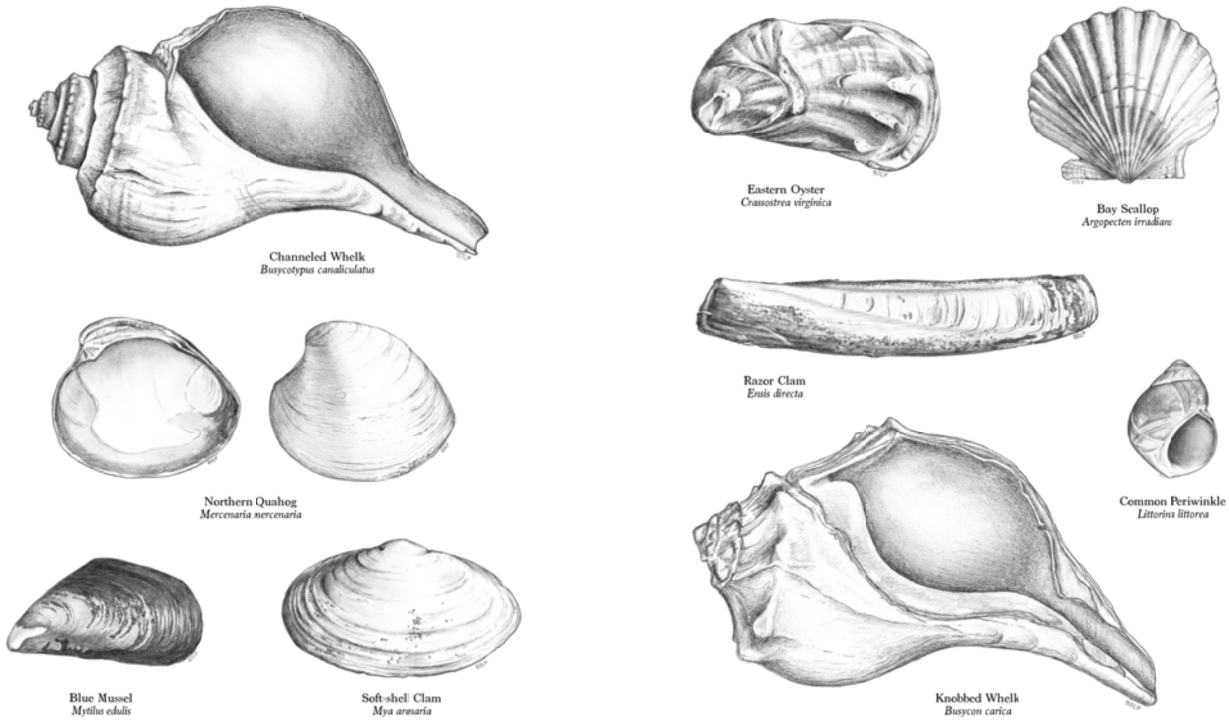

Figure 1.2. Illustration of the shellfish species considered in the SMP (Illustrations by Brandon Fuller, 2014).

Table 1.1. List of species included in the Shellfish Management Plan.

Common name	Scientific name
Quahog*; hard clam	*Mercenaria mercenaria*
Oyster; eastern oyster	*Crassostrea virginica*
Soft-shell clam; steamer	*Mya Arenaria*
Blue mussel	*Mytilus edulis*
Bay scallop	*Aquipecten irradians*
Razor clam; American razor clam	*Ensis directus*
Channeled whelk; conch	*Busycotypus canaliculatus*
Knobbed whelk; conch	*Busycon carica*
Periwinkle	*Littorina littorea*

*Note: The official spelling and that used by RI DEM is “quahaug.” However, the informal and more colloquial spelling is “quahog” and is the form used throughout the SMP document. The term “quahaug” may have originated from the Narragansett tribe word, “poquahock” for hard clams and was later Anglicized and abbreviated (Huling, “Harvesting the Bay, 2012).

Section 140. The Process

1. To ensure the SMP process and products were “owned” by Rhode Island government, industry, citizens, civic and environmental organizations, the SMP team implemented a strong and diverse process that engaged all stakeholders in Plan development and implementation. The success of the SMP depended on the expertise and opinions from all of stakeholder groups. Co-facilitated by DEM, CRMC, RWU, and the University of Rhode Island, the process aimed to: 1) Identify and prioritize stakeholder and client issues; 2) Design a public process that will provide stakeholders with both information and influence over decisions; and 3) Collect available information to direct recommendation and policy development, and research. The results served as the foundation for the SMP and future efforts.
2. Plan development was directed through the SMP Coordination Team (CT). Shellfish experts at DEM, CRMC, and URI served on the CT with the responsibility of informing and ensuring coordination and engagement from their respective organizations. These organizations committed to contributing appropriately to the completion of deliverables, which included providing existing research, writing and reviewing products, and assisting in the communication of this information to all stakeholders. CT representatives were also responsible for making the CT aware of other efforts/issues that that could potentially impact the Plan. Roger Williams University and the Rhode Island Sea Grant College Program provided additional technical assistance to the CT.
3. CT decisions were made by consensus. If consensus was not possible then the agency that had the regulatory authority made the final decision. Scientific information as well as resource management expertise and local knowledge were critical to making SMP decisions.
4. The SMP process included the implementation of a communication/outreach strategy to provide all stakeholders – including but not limited to federal, state, and local government representatives, the private sector, researchers, not-for profit organizations, and members of the public – with a variety of informative, fun, and productive dialogues aimed at making the SMP accessible and useful for the people of Rhode Island. Proactive outreach to the public and press was provided through frequent public meetings and one-on-one conversations, as well as the development of a web site, listserv and other social media outlets. In addition, this process included:
    a. The SMP Stakeholder Group: From the outset, the SMP stakeholder group, a group open to everyone, was an integral part of both determining the scope and contents of the document as well as refining the described policies and recommendations. New and existing research and findings were shared and developed in coordination with the stakeholders as a mechanism to ground truth and enhance findings. The SMP goals and objectives upon which the SMP was produced were refined and approved by the stakeholders. The SMP stakeholder process provided the public with an opportunity to stay up to date on current research, learn about Rhode Island’s shellfish resources, ask questions and express concerns, as well as engage in the process of determining chapter scope and content.
    b. The Technical Advisory Committees: CRMC and DEM established a Technical Advisory Committee (TAC) for several SMP chapters (see Appendix 1.1 for a list of all TAC members). The TAC was made up of scientists, government agency representatives, and resource users with expertise in the chapter topic. The purpose of the TAC was to provide expert advice on the contents and scope for each chapter and provide recommendations to improving management of shellfish. TAC members assisted DEM and CRMC in refining and enhancing the chapters.
    c. Throughout the SMP process, the respective state agencies maintained their authority and responsibilities with regards to manging aspects of shellfish. The SMP did not restrict, halt, or stall any of these mandated responsibilities with regard to management. In fact, the process involved an additional set of tasks that likely increased the workload of the already resource-

strained agencies; however, these agencies recognized the importance of the process and were active throughout.

Section 150. Early Actions

1. Recognizing the urgency to respond to some of the issues identified through the SMP process, the CT, with guidance from stakeholders, chose to implement select early actions – tangible, short-term, straightforward activities that provide the lead agencies and stakeholder's opportunities to succeed in solving issues identified early in the plan. These actions – that also support an adaptive management approach – test new procedures and demonstrate the commitment by all to implement the SMP. Successful early actions included:
2. Noon-time re-opening of shellfish grounds. The noon-time re-opening was a request made by the commercial shellfish industry during a SMP seminar presentation by DEM's OWR in April 2013, a presentation that was considered by industry to greatly clarify the complicated subject of water quality regulations and their intended purpose. The request was to change the time when areas that were previously closed due to rainfall would open. The request was considered and approved, ultimately allowing industry an extra half day of harvest time while still ensuring water quality standards are met after excessive rainfall.
3. Shellfish signs/range markers – Signs and markets indicting "Notice of Polluted Shellfishing Grounds" show where harvest is permitted in the Bay and salt ponds. There are 58 range markers as well as 35 pollution signs, many, stakeholders note, that were in need of replacement or repair. In response to this need, DEM's OWR conducted extensive field inventory and repair of damaged or missing signs in 2014, additionally taking GSP coordinates of these locations that will accompany the current landmark locations descriptions. While field inventory and sign repair is conducted annually and is an ongoing effort by OWR, the concerted attention and collection of GSP locations was recognized as a meaningful accomplishment to industry working daily on the water.
4. DEM's reorganization of shellfish regulations – DEM recognized redundancies and inconsistencies in some of their shellfish regulations. As a result, these shellfish-specifc regulations were reviewed and re-organized, making no substantive or regulatory changes, but rather simplifying the language and consolidating the regulations from six places or Parts to one, and from 66 pages to 26 pages. While not a direct action of the SMP, the issue of improving communication was raised repeatedly through the SMP process. DEM took the initiative to review and consolidate their shellfish regulations in part as a response to this issue.
5. Aquaculture regulation reform – In response to both agencies (DEM and CRMC) and the aquaculture industry's concern over the current aquaculture regulations, the SMP team facilitated changes in these regulations. Changes include: 1) shifting authority for much of the aquaculture lease permitting and inspections from DEM to CRMC who would serve this role on behalf of DEM, 2) removing duplicative and unnecessary language regarding aquaculture from DEM regulations and adding it appropriately to CRMC regulations, and 3) through CRMC authority, allowing seed from uncertified waters to purge for 6 months (instead of 12) before it can be sold. At the time of writing (Nov.2014) these proposed changes were being approved by both agencies and readied for public comment with an expected formal approval and reform in Winter/Spring 2015.
6. MOA on Lease Inspections – While CRMC generally conducts and oversees inspection of aquaculture operations in the state, the formal authority has been with DEM to perform these inspections, even though CRMC was the recognized, capable, and practicing inspector. With urgings from CRMC, DEM, and the aquaculture industry, and support from DEM Division of Agriculture, a Memorandum of Agreement was signed between the two agencies recognizing CRMC as the designated lease inspector on DEM's behalf.
7. Supporting shellfish science – The Rhode Island Sea Grant College Program devoted its 2014-2016 Research Omnibus to shellfish exclusively. The six funded projects focus on better understanding the biology of whelks and assisting industry with co-management of that resource; looking at quahogs

larval dispersal in the Bay; understanding disease in blue mussels; looking at uses on the salt ponds; understanding recreational activity; and looking at shellfish aquaculture and water quality relationships. The SMP will continue to help integrate the results from these projects into management decisions and translate tough concepts and results to the public.

8. Spawner Sanctuary evaluation – In response to shellfish stakeholder concerns aired through the SMP, DEM, CRMC, and the commercial harvest industry worked in collaboration to evaluate the effectiveness of one spawner sanctuary for shellfish in Ninigret Pond. This pilot effort was funded by RI Sea Grant and intended to provide data to managers as to whether the sanctuaries are effective in meeting their original purpose to allow protected areas for shellfish to spawn with the hopes that the larvae would spread and help ensure the population more broadly. The intention is to conduct similar assessments in the other spawner sanctuaries throughout the state and provide data to managers to consider whether the current locations are effective in meeting the sanctuary goals.
9. Vibrio Control Plan for oysters – The US FDA recommended that Rhode Island create a Vibrio Control Plan for oysters and the aquaculture industry as a proactive measure to ensure minimal illnesses occur due to the bacteria which is naturally-occurring but quick to multiply in harvested shellfish if not properly and quickly cooled. In 2014, the SMP team facilitated a cooperative effort between the aquaculture industry (who had already voluntarily crafted and was following a vibrio plan), DEM Division of Agriculture, others at DEM, CRMC, and universities to create a formally recognized Vibrio Control Plan. The plan was modeled after the industry plan which takes conservative measures to ensure oysters are cooled quickly and adequately. While the plan affects oysters only, in 2015 a Vibrio plan for hard clams will be instituted and this model process and collaboration will be used to guide the new plan for clams.
10. Use maps – In response to stakeholder concerns over mixed and often perceived competing uses on the Bay and coastal salt ponds, the SMP team facilitated a series of mapping exercises in 2013. The mapping project solicited users of the water to categorize where and what uses they perform by writing these uses on nautical charts. The maps have been digitized in GIS and made available to managers as a subjective dataset to aid in policy decision-making.
11. Improved marketing of shellfish – A clear concern from the wild harvest shellfish industry is the low return they receive when selling their product, namely quahogs, to shellfish dealers. Through various efforts, the SMP has and will continue to assist the industry in identifying opportunities to improve their bottom line. These efforts include working with Hope & Main to sell directly through this innovative food center, working with the current RI Seafood Marketing Collaborative to include shellfish-related marketing programs, and assisting industry in receiving grant opportunities to educate the public on the quahog fleet and the choice to buy local clams.
12. Shellfish Ecological History – While the SMP describes shellfish resources and industries in detail, it was not intended to describe the more personal aspects that make shellfish meaningful to Rhode Islanders. To accomplish this task, the SMP Team, working with author Sarah Schumann, and editors at RI Sea Grant, created “Rhode Island’s Shellfish Heritage: An Ecological History” in 2014. The document provides historical perspective to both the oyster aquaculture industry and the wild harvest industry – past and present – through stories, interviews, archive articles and historic photographs. The document highlights the importance of shellfish to Rhode Island through both historical and current perspectives of those who live and work on the Bay and salt ponds.
13. The Baird Symposium – Rhode Island Sea Grant annually hosts a science symposium, bringing together experts on topics of relevance and concern to Rhode Island’s coastal communities. The 12th Annual Ronald C. Baird Sea Grant Science Symposium was held in November 2013 and was dedicated to shellfish issues, bringing experts from the east and west coasts of the U.S. to discuss issues such as shellfish restoration, managing aquaculture growth, maximizing wild harvest, marketing, water quality, and discussions on what the future holds. The forum paired industry, managers, and scientists together to discuss latest research and paths forward, giving voice to a breadth of concerns regarding shellfish.

14. DEM Division of Agriculture's involvmenet in aquaculture – A desire was expressed by the aquaculture industry early on in the SMP process to be considered as farmers (as opposed to fishermen), triggering more involvement and assistance from DEM's Division of Agriculture in various activities and regulations related to aquaculture. DEM responded affirmatively to this concern, resulting in various outcomes such as the Vibrio plan for oysters, the inter-agency MOA for lease inspections, and indirectly through marketing efforts, the Local Agriculture and Seafood Act funding efforts, and on-going discussions between the industry and Division of Agriculture on including aquaculture in an updated RI Green Industry Economic Impact Study.

Section 160. Principles, Vision, Goals, and Objectives

1. Through the described stakeholder process, principles, a vision, goals, and objectives were developed and supported by stakeholders to guide the development and implementation of the SMP. Independently, the aquaculture industry has developed a vision (See Appendix 1.2 of this document).
2. Several key principles were created to guide the collaborative development of the SMP. The principles responded to the issues of information being available at the same time to everyone involved, and to ensure that decisions were not made behind closed doors or without input from the entire group. These principles also helped to ensure that user groups understood and actively supported the SMP goals, there was wide public support for the SMP process, and the SMP was recognized as important and legitimate by institutions that would be involved in its implementation. The principles were presented at the first SMP stakeholder meeting in January 2013 and are listed below (also in Appendix 1.3).
    a. Honor existing activities: The SMP area, Rhode Island's state waters – including the Bay and coastal ponds – is a highly employed and biologically and economically valuable place, with major uses such as fishing, recreation, tourism, and transportation activities taking place within its boundaries. These uses, along with the area's biology and habitat, must be fully understood and highly respected, as decisions for the incorporation of future activities are determined.
    b. Involve all stakeholders: Targeted outreach efforts ensure opportunity is available for all stakeholders to have access to the SMP planning process as early as possible. Stakeholder participation ensures that a broad range of issues, concerns, and creative ideas are heard and examined throughout the SMP process.
    c. Develop the SMP in a transparent manner: Transparency guides the development of all documents and procedures related to the SMP project. Project activities and phases are designed to be easily understandable to the general public. Accurate information must be made available to the public in an appropriate, diverse, and timely manner.
    d. Base decisions on the best available science: All management and regulatory decisions will be based on the best available science and on ecosystem-based management approaches. The SMP will recommend that the necessary studies be performed to better understand the impact of an activity on the ecosystem.
    e. Apply an adaptive management approach: By implementing a systematic process for continually improving management policies and practices—in other words, adaptive management— the plan will be flexible enough to react to human and biological changes, and allow actions to be revised as necessary. A strong stakeholder process, coordination among regulatory agencies, and a transparent monitoring and evaluation mechanism ensures this activity.
3. *SMP Vision for Shellfish:* The shellfish that inhabit our waters are part of the social fabric of Rhode Island and are integral components of the marine ecosystem that provide food, recreation, income, employment, and other environmental, economic, social, and cultural benefits. In order to ensure the health and proper ecological functioning of the marine ecosystem and realize the socio-economic benefits associated with healthy shellfish populations, we shall seek to preserve, protect, manage, and when necessary, restore shellfish resources and essential habitats using the best available information

and science. We shall also strive to employ sound governance to achieve fair, equitable, and safe access to shellfish resources and support the interests of those who harvest for personal use and enjoyment; those who participate in the commercial wild harvest fishery; those who engage in the aquaculture of shellfish species; those who rely upon the shellfish industry as a source of food; and those who recognize the importance of shellfish in our marine ecosystems.

4. *SMP Goals:*

   a. Honor, promote and enhance the existing shellfish resource and uses. Shellfish offer a myriad of ecological services to Rhode Island state waters, jobs and business opportunities to its residents, and recreation for all. As such, actions should strive to maintain healthy populations of shellfish while honoring the current uses of Rhode Island's natural resources and promoting Rhode Island shellfish as a source of local, sustainable seafood.

   b. Contribute to a properly functioning ecosystem that is both ecologically sound and economically beneficial. The prosperity of the shellfish industry depends on the health of our marine environment and the quality of the water that shellfish inhabit. It is therefore necessary to evaluate the current status and potential future changes to the natural resources, ecosystem conditions, and anthropogenic impacts on the marine environment and to recommend actions to protect and, where necessary, restore our marine waters.

   c. Manage marine and shellfish resources for equitable and sustainable use. Through both scientific research and practical knowledge, better understand the existing activities taking place in Rhode Island waters. Identify best management practices to support all shellfish activities for long-term sustainability while supporting compatible uses and minimizing user conflicts to ensure the equitable harvest of these marine resources.

   d. Enhance communication and improve upon the established framework for coordinated decision-making between state and federal management agencies, industry, and other interested parties. Engage management agencies, industry and other interested parties in the development of the shellfish management plan and implementation of recommendations to ensure that all concerns and appropriate legal requirements are integrated into the process. Coordination will allow for the sharing of information across all sectors, improve management, clearly establish roles and responsibilities of all parties and streamline the licensing and permitting process where appropriate.

5. *SMP Objectives*:

   a. Document and increase our understanding of the current status of Rhode Island's natural resources and ecosystem conditions to help promote the health of our ecosystem and prosperity of the shellfish industry.

   b. Identify the existing commercial, recreational, and conservation uses of our state waters as a tool towards minimizing use conflicts.

   c. Document the historical and current perspectives, memories, and narratives of Rhode Island's shellfish community in order to better understand, honor, and promote the cultural importance of shellfish to the state.

   d. Define principles for a comprehensive stock assessment program that guides management decisions for all managed shellfish species.

   e. Maintain a viable, equitable industry while identifying value added marketing opportunities.

   f. Improve understanding of state, regional, and national economic aspects of the commercial, recreational and restoration activities involving shellfish.

   g. Improve the industry's and public's understanding of management decisions and processes.

h. Support existing and identify alternative mechanisms to appropriately facilitate coordination among decision-makers, industry and other stakeholders by clarifying legal roles and responsibilities of state and federal agencies.

i. Establish a Research Agenda that identifies knowledge gaps, proposes future research needs, recognizes potential funding sources and discusses potential collaborative/partnership opportunities.

j. Identify sustainable sources of funding for implementing management plan recommendations.

k. Develop and implement a stakeholder supported shellfish management plan.

Section 170. The Contents of the SMP Document

1. The chapters that follow identify and respond to major stakeholder issues, and provide detailed descriptions of the physical, biological, social, and economic aspects of the shellfish resource. This information comes from the best available science with guidance and expertise from all SMP stakeholders. Where data did not exist, the need for research was recognized and documented and will be crafted into a Research Agenda in 2015. When possible, efforts were undertaken to collect data and interpret results; for example, DEM and CRMC, in coordination with the University of Rhode Island, conducted a project to better understand how recreational boaters, residents, and commercial and recreational fishermen used these state waters.

2. The SMP document offers policies and recommendations to DEM and CRMC that represent long – and short-term actions needed to uphold the regulatory responsibilities mandated to them by the Rhode Island General Assembly and the federal Coastal Zone Management Act. Other agencies, including the Rhode Island Department of Health, will be appropriately engaged in both the development of the findings of facts and the development and implementation of recommendations.

3. All chapters work towards establishing frameworks to coordinate decision-making between state and federal management agencies and the people engaging with the shellfish resource, developing the SMP document in a transparent manner, and promoting adaptive management. All SMP policies and recommendations are important to ensure that the shellfish resource in state waters is managed in a manner that both meets the needs of the people of Rhode Island, while protecting and restoring our natural environment for future generations. The SMP also provides thoughtful direction to economic development that considers the aspirations of local communities and industries, and is consistent with and complementary to the state's overall economic development, social, and environmental needs and goals.

4. The state of Rhode Island is engaged in a state and regional initiative to grow local food for economic, social, and environmental reasons. One major goal from the Rhode Island Food Policy Council, an effort to increase production of, and demand for local food, is that a continuously increasing proportion of Rhode Island's food supply will be grown, raised, caught, processed and distributed in Rhode Island (http://www.rifoodcouncil.org/node/2). In addition, Food Solutions New England, of which Rhode Island is a member, calls for New England to build the capacity to produce up to 70% of clean, fair, just and accessible food for all New Englanders by 2060 (http://www.foodsolutionsne.org/new-england-food-vision). This effort is considered in the development of this document.

Section 180. Applying Adaptive Management to Implement the SMP

1. Adaptive management is a systematic process for continually improving management policies and practices by learning from the outcomes of previously employed policies and practices. Adaptive management requires careful implementation, monitoring, evaluation of results, and adjustment of objectives and practices. Adaptive management usually allows more reliable interpretation of results, and leads to more rapid learning and better management. To this end, DEM and CRMC will establish several mechanisms to ensure that the SMP is implemented using this management approach.

2. DEM and CRMC will continue to develop and work to implement the SMP Science Research Agenda, in coordination with the researchers, federal, state, and local government and other parties, to improve management policies and practices. The SMP Science Research Agenda will allow DEM and CRMC to: 1) Continue to learn about Rhode Island's shellfish resources and human activities; 2) Better understand the potential effects of future development and other human impacts on this resource; and 3) Increase Rhode Island's understanding of the projected impacts of global climate change.
3. A Progress Assessment and Monitoring Process will be established with the purpose of assessing progress towards achieving the SMP goals, objectives, and principles. This process will record decisions, capture lessons learned, note achievements, and document policy and management adaptations. This process will be ongoing, available on the project web site, and formally reported to the public by the agencies as funding allows.
4. DEM and CRMC will work to implement the priority recommendations described in the SMP. Major components of this work effort include the SMP Science Research Agenda, the Progress Assessment and Monitoring Process, stakeholder involvement and education, and implementation of SMP policies and recommendations.
5. Although the SMP may be continually amended, the DEM and CRMC will conduct a major review of the SMP document every five years from adoption or as funding and availability of a neutral facilitator allows. DEM and CRMC will implement this revision process using the principles honored during the development of the SMP, including involving stakeholders and basing all decisions on the best available science.
6. DEM and CRMC will establish a mechanism to ensure that the public continues to be engaged in the implementation of the SMP. The SMP public forum will be held biannually or based on available funding and hosted through the CRC/RI Sea Grant or other neutral facilitator. The public forum will feature reports and discussions of the SMP condition and use, note progress toward goals and objectives, and recognize contributions to implementing the SMP. The forum will highlight projects underway, report on the Progress Assessment and Monitoring Process and Science Research Agenda, including new research findings and updated global climate change projections, and provide opportunities for exchanging information, ideas, and strategies to strengthen implementation. The forum will address emerging issues and identify potential SMP revisions. DEM and CRMC will use this information to prepare its work plan. The forum may be followed up by other SMP meetings that provide continuing opportunities to discuss progress, focus on specific issues, and coordinate ongoing actions by member groups. The public forum will be supported by the SMP website (www.rismp.org) and information systems maintained by DEM and CRMC.

CHAPTER 2. Ecology of Shellfish in Rhode Island Waters

By Alan Desbonnet, Rhode Island Sea Grant

Section 200. General Introduction

1. The focus of this chapter is the ecology of Rhode Island's most common recreational and commercially important molluscan bivalve (clams, oysters, mussels, scallops) and gastropod (whelks) species. The intent is to summarize the existing body of ecological knowledge for these species in order to provide for enhanced understanding that can lead to improved management from species to ecosystem-based scales[1] in Rhode Island waters. A treatment of basic biology of bivalves is provided in Chapter 3 of this document.

2. Rhode Island has a long history of shellfish harvesting. Rice *et al.* (2000) note three phases for shellfisheries in the state: (1) pre-colonial/colonial times of Native American harvests, (2) oyster aquaculture until its collapse in the late 1930s, and (3) hand tonging and then bullraking for quahogs. Shellfish harvesting has the potential to impact the ecology of shellfish populations and the surrounding ecological community, though the potential for impacts is largely dependent upon harvesting methodologies and resource management practices. Ecological change resulting from shellfish harvesting practices is considered later in this chapter. For a full accounting of the history of shellfish harvest in Rhode Island, see *Rhode Island's Shellfish Heritage: An Ecological History* at www.rismp.org.

3. Despite the importance of shellfish as both commercial and recreational species, the existing body of knowledge regarding their overall abundance and distribution in Rhode Island waters is relatively sparse. The quahog, or hard clam, possesses the richest set of available data, followed by the Eastern oyster. For other species data are generally either too sparse and/or too intermittent to allow the development of more than a casual description of their ecological role in Rhode Island's coastal ecosystems.

4. Bivalves provide ecosystem benefits in four major areas: (1) cultural—recreation and tourism, historical and educational experiences, (2) provisional—fisheries and aquaculture, fertilizer, jewelry, (3) regulating—water quality maintenance, shoreline protection, sediment trapping, and (4) supportive—nutrient cycling, biodiversity and habitat construction (Dame 2012). These services are further described in this chapter.

5. Bivalve filter feeders are intimately involved in the transfer of materials from water column to sediments, back to the water column. These circular networks accomplish intense recycling processes, and bivalves are a major component of these critically important ecological networks (Asmus and Asmus 1993; Coen and Grizzle 2007; Dame 2012; Higgins *et al.* 2013).

6. Water quality is a critical component of healthy ecosystems. Industrialization brought widespread degradation of Narragansett Bay water quality, but Desbonnet and Lee (1991) report significant improvement in water quality in Narragansett Bay since the early 1900s, a trend that has continued to present times. Nutrient reduction programs now underway are bringing further improvement and may reduce the threat of macroalgal blooms and summer hypoxia in bottom waters. The net result is that water quality has improved dramatically in Narragansett Bay in recent decades, and further improvement is underway on a continuing basis. Unfortunately the same can not be said about conditions in the state's shallow coastal waters where due to unacceptable bacteria levels, there has been a continual loss in areas open to shellfishing over the past 50 years. Currently just over 11

[1] An ecosystem as defined by Odum (1983) is: "… any unit that includes all organisms that function together in a given area interacting with the physical environment so that the flow of energy leads to clearly defined biotic structure and cycling of materials between living and non-living parts."

square miles of waters designated for shellfish harvesting are prohibited due to elevated bacteria levels – and include such popular recreational shellfishing areas as Palmer River, Barrington River and Hundred Acre Cove, Potowomut Cove, Dutch Harbor, Narrow River, portions of Pt Judith Pond, Green Hill Pond, and Pawcatuck River. DEM has completed water quality restoration studies for most of these waters closed to shellfishing due to bacteria pollution. Inadequate on-site wastewater treatment and polluted stormwater are common problems identified. Implementation of the water quality restoration plans is primarily the responsibility of municipalities, RIDOT, and private property owners.

7. Water quality, with regard to shellfish, has three major facets for consideration:

    a. Coliform bacteria concentrations, which are monitored as risk indicators for viruses and pathogens, are of concern from a public health and safety perspective because contaminated shellfish can lead to sickness, and in extreme cases death, of humans who consume them. Due to these concerns, bacteria concentrations dictate which areas are open to shellfishing and thus indirectly have an effect on ecology. From an ecological perspective, coliform bacteria are a food source for bivalves and do not cause sickness or harm to the filter feeding organism. For this reason coliform bacteria are not considered further in this chapter. See Chapter 7 of this document for issues regarding public health and safety related to shellfish.

    b. Metals, petroleum by-products, and organotoxins such as PCBs and DDT, are of concern from both public health and ecological perspectives as related to shellfish. A 35-year history of improved wastewater treatment technologies, improvements in surface water runoff management and treatment, the banning of many contaminants of concern, and changes in Rhode Island's economic and industrial foundations, have all led to major water quality improvements in Rhode Island's coastal waters (RIDEM 2000).

    c. Nutrients are of concern regarding the ecology of shellfish. When present in excess quantities, nutrients can lead to algal blooms, which along with other environmental variables can lead to low dissolved oxygen concentrations in the water column—particularly in bottom waters—fish kills, and other nuisance and/or degraded environmental conditions. Investments to improve wastewater systems, especially recent upgrades to advanced treatment, have reduced pollutant loadings of nitrogen into Narragansett Bay over last decade (Desbonnet and Lee, 1991, RIDEM, 2012). Figure 2.1 from the Narragansett Bay Commission shows a declining trend in the concentrations of dissolved inorganic nitrogen (DIN) measured in the Providence River region with 80% of stations now falling within a range defined as good by the US Environmental Protection Agency National Coastal Condition Report III. DIN is one of five parameters used by EPA to create to an overall water quality index that previously resulted in much of Narragansett Bay water quality being categorized as in fair condition (USEPA, 2008). Hypoxia continues to be detected in upper Narragansett Bay and will continue to be monitored and assessed. Scientists also continue to research and evaluate potential changes in primary productivity which are expected for sections of the upper bay; e.g. reduced phytoplankton blooms. As estimates associated with the current nutrient reduction strategy indicate there will continue to be excess nitrogen in the upper bay, it is not expected that primary productivity will become food-limiting for consumers such as shellfish in the upper bay (Governor's Narragansett Bay and Watershed Planning Commission, March 2004).

    d. Figure 2.1 shows nutrient removal trends over time in the Providence River, with 40% of stations now falling within the "good condition" category for an estuary as defined by the US Environmental Protection Agency National Coastal Condition program III; these are some of the lowest concentrations ever recorded (for all but Conimicut Point) (USEPA 2008; Narragansett Bay Commission 2014). Nutrients however, are fertilizer for phytoplankton, which are a primary food source for bivalves, and the ecology of Narragansett Bay has acclimated to high nutrient levels over the past century and more. It is unclear if current nutrient reduction plans have the potential to reduce the primary productivity of Narragansett Bay to the point that it becomes food-limiting for consumers such as shellfish.

e. In addition to food supply, there are other factors that affect the energetics, growth, and survival of shellfish, making it a complicated issue to tease apart. Among these issues, productivity of phytoplankton is negatively related to sea surface temperature as numbers of phytoplankton have been shown to decline as the average ocean surface temperatures increase. The annual GSO trawl survey has shown a rise in sea surface temperatures in Narragansett Bay, with 2013 showing an unprecedented high. This might indicate a negative response in phytoplankton levels, especially when coupled wih changes in nutrient levels (Pers. Comm, Sneider, 2014). Other important issues effecting shellfish include pH levels, where phytoplankton may be positively affected as carbon becomes available for photosynthesis (Kroeker et. al, 2013). Community composition, as not all phytoplankton are equal as a food source, may affect shellfish populations (Shumway, 1990).

f. It is important to recognize the water quality objectives of a nutrient control plan. First, it is known that excess nutrients can result in algae blooms which in tern can lead to results hypoxia (reduced oxygen in the water). Improving dissolved oxygen conditions can benefit aquatic life, including but not limited to shellfish, making it an important management consideration. It is also important to recognize areas such as the Providence River / Upper Bay, Greenwich Bay and other small embayments have differing pollutant sources and stressors and while awareness and proactive management measures are improving water quality, it is still critical to better understand specific issues affecting water quality in these embayments.

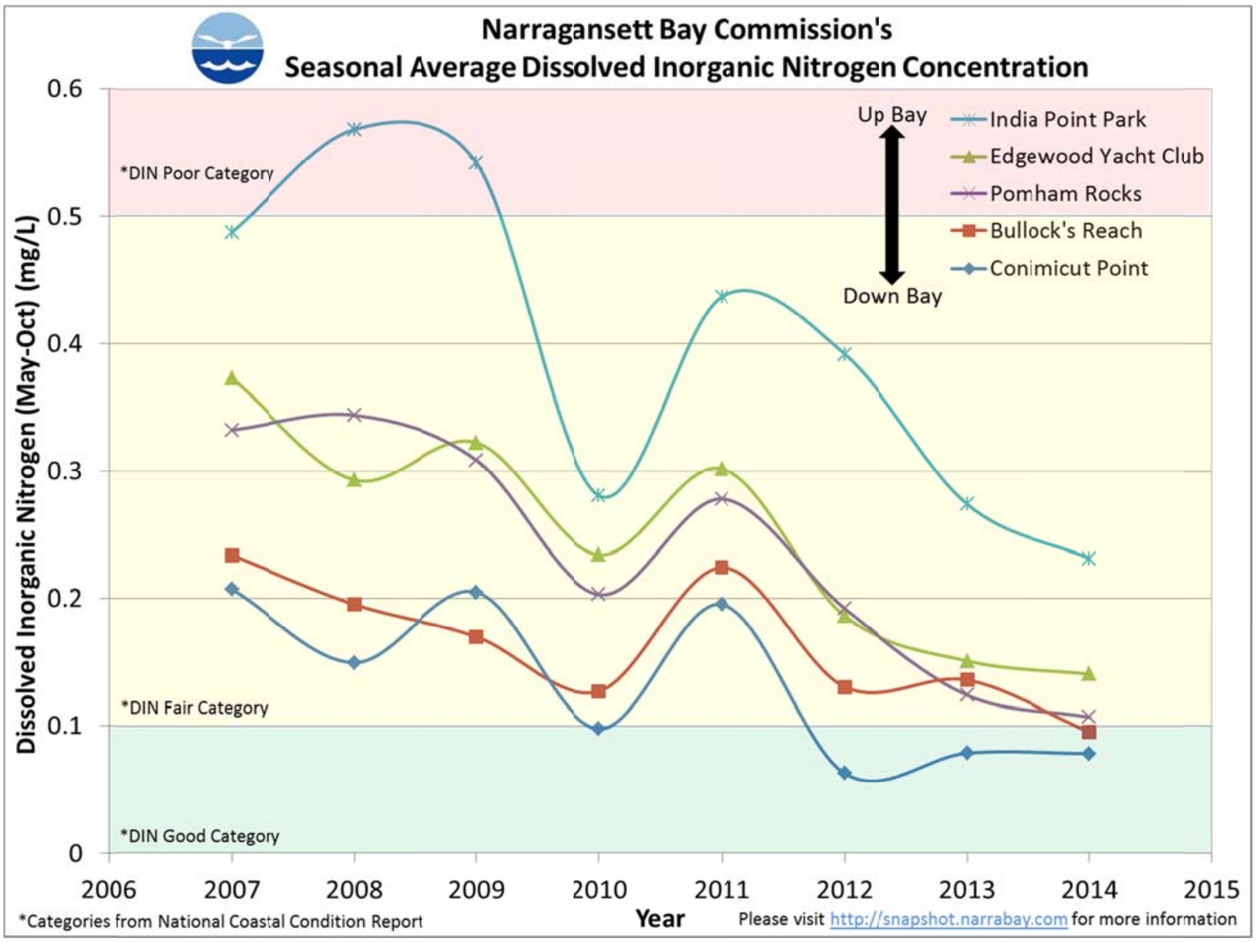

Figure 2.1. Trends in dissolved inorganic nitrogen levels in the Providence River in relation to USEPA's Coastal Condition thresholds. (Narragansett Bay Commission 2014).

Section 210. Issues As Identified By Stakeholders

1. Throughout the Shellfish Management Plan (SMP) planning process, the SMP team has met with stakeholders to identify issues and concerns regarding all aspects of shellfish, including but not limited to environmental issues, management, marketing, capacity building, and decision making. The following are the major themes concerning the ecology of shellfish stakeholders have identified (a full list of all issues identified by stakeholders can be found in Appendix 2.2). There is a need for:
   a. Increased understanding of shellfish spawning sanctuaries including: a) evaluating current locations, b) establishing sanctuary goals, and c) assessing effectiveness in achieving stated goals at the currently designated locations.
   b. Better communication and dissemination of information regarding water quality related shellfishing closures, reasons for closures, and laymen's terms explanations of "closure science" and criteria used in closing areas to shellfish harvest.
   c. Development of baselines for the evaluation of shellfish restoration efforts in the state.
   d. Discussion as to whether to permit restoration activities in closed (prohibited) waters for the purposes of overall water quality improvement.
   e. Enhanced understanding of climate-related impacts on shellfish, including ocean acidification, as well as other natural events such as harmful algal blooms.
   f. Better understanding of invasive species in Rhode Island waters and developing an effective plan to manage these species.
   g. More research to understand how the strategy of time-released sewage treatment discharge and combined sewage overflow (CSO) effluents will effect shellfish populations. For example, is there a strategy and/or time period where effluents and nutrients can be allowed into the bay, for instance during winter months to help foster the winter-spring phytoplankton bloom? Would this strategy have any positive effects on shellfish populations?

Section 220. General Ecology—Bivalves

1. Dame (2012), in a summary of bivalve physical environmental interactions, notes there are two basic life styles for bivalves—deposit feeding or filter feeding. Deposit feeders, typically found in fine sediments in low velocity environments, rework and ingest bottom sediment, while (non-reef building) filter feeders strain particles from the water column and are often found in coarse sediments in higher velocity environments. As they prefer differing environments, buried filter feeding and deposit feeding bivalves are most often not found living together.
2. Predation is considered the most significant source of mortality to bivalves, and the dominant factor controlling recruitment success. Crabs, gastropods, and sea stars are the most important predator groups, while ctenophores and jellyfishes, as well as adult bivalves, are significant predators of larval forms (Dame 2012; Bricelj 1992). Oystercatchers can be a significant bivalve predator intertidally, sea ducks in waters less than 25 feet deep, and gulls opportunistically at low tide (Meire 1993).
   a. In many bivalve species, predation is size mediated (Seed 1993). For instance, for the quahog a size of 30 mm shell length provides a refuge to most predation, and 40 mm is a refuge to nearly all predation except that of large gastropods (e.g., whelk; Arnold 1984; Bricelj 1992). Quahog density can also provide a refuge to predation (Malinowski 1985), with low density providing protection through decreased predator feeding efficiency.
   b. Substrate complexity influences predation—as the substrate becomes more complex, for instance ranging from all sand to a mix of sand, gravel, cobble, and/or crushed shell or seagrass, predator efficiency in seeking buried bivalves is reduced (Arnold 1984; Bricelj 1992; Sponaugle and Lawton 1990). The distribution of sediment types on the sea floor is a result of the interactions and dynamics of water flow, settling rates of various sediment types, and reworking of the

sediments by benthic organisms (Bertness 2007). Some species, such as the mud crab (*Dyspanopeus sayi*), a common northern species, are very effective predators of juvenile clams even in mixed substrates such as a shell/cobble blend (Day and Lawton 1988; Bricelj 1992).

c. Shell height, thickness, and gape all impact predator effectiveness (Boulding 1984; Seed 1993). Clams with permanent gapes (e.g., soft-shell clams) are most vulnerable, while thick, tightly closed, high arched shells (e.g., quahog) give optimal protection).

d. Quahogs produce thicker shells in the presence of predators, but generally at a cost of reduced tissue and gamete production (Nakaoka 2000). While much research points to slower growth when bivalves put extra energy into predator defense (Griffiths and Richardson 2006), Leonard *et al.* (1999) found that for mussels at a study site in the Damariscotta River (Maine), no reduction in tissue growth was noted for mussels secreting thicker shells and more robust byssal threads in response to predator abundance; the cause of this conflicting growth pattern was not known.

e. Smee and Weissburg (2006a, 2006b), Griffiths and Richardson (2006), and Leonard *et al.* (1999) report deeper burial by *Macoma balthica* in the presence of predator chemical cues, a trait that is shared by other bivalves (Griffiths and Richardson 2006; Flynn and Smee 2010).Burrowing is effective predator protection for some species of shellfish, though deep burrowing, while offering more predator protection, has a cost of reduced feeding efficiency (Boulding 1984; Griffiths and Richardson 2006). Flynn and Smee (2010) found that soft-shell clams burrow 15% deeper in the presence of predator chemical cues, while Griffiths and Richardson (2006) found that species with short siphons did not burrow deeper, as they would then not be able to feed efficiently. Siphon nipping—a technique employed by some crabs and fish—may result in burrowing clams having to relocate closer to the sediment surface, reducing the effectiveness of burrowing protection (Seed 1993; Dame 2012). Steimle *et al.* (2000) reports winter flounder as a major siphon nipper of the quahog—siphons made up 14% of winter flounder stomach contents in their study.

3. Mortality during the larval phase of growth, and during metamorphosis to a benthic lifestyle, can be intense—natural mortality estimated to be as high as 99% (Butet 1997). Kremer (1979) reports that *Mnemiopsis leidyi*, a common ctenophore of Narragansett Bay and voracious consumer of molluscan larvae, was once abundant July through October, with a peak from mid-August to early September. However, as water temperatures have warmed over time, *Mnemiopsis* is arriving earlier—as early as May/June in warmer years—creating direct overlap with time of larval abundances of many bivalve species (Sullivan *et al.* 2001). It is also expected that larval mortality due to predation may escalate as a result of ocean acidification, as larvae spend a longer time in the plankton while calcifying shell material and/or have a thinner, less predator-proof shell upon metamorphosis (Talmage and Gobler 2009). See section on ocean acidification for more information. In many bivalve species, predation is size mediated (Seed 1993). For instance, for the hard clam a size of 30 mm shell length provides a refuge to most predation, and 40 mm is a refuge to nearly all predation except that of large gastropods (e.g., whelk; Arnold 1984; Bricelj 1992). Clam density can also provide a refuge to predation (Malinowski 1985), with low density providing protection through decreased predator feeding efficiency.

4. Phytoplankton is the main source of filter feeding bivalve nutrition, with bacteria and organic detrital material providing additional sustenance (Dame 2012); dissolved organic matter and free amino acids also provide a nutritional source (Rice 1999). As filter feeders, bivalves will consume larval forms of other bivalve species, as well as of their own species, when growing in dense concentrations.

5. Some bivalves, such as quahogs, regulate filtering rate according to the amount of suspended matter in the water column, (Newell 2004; Newell *et al.* 2005), and others, including mussels, according to species of plankton (Asmus and Asmus 1993). Some species, like oysters (Newell 2004; Newell *et al.*

2005) continue to filter at a given rate, but produce more pseudofeces if the oyster cannot digest all of the plankton in the water.[2]

6. Not all phytoplankton are created equal as a food source for bivalves (Shumway 1990). Brown tides for instance—the last major Rhode Island outbreak was in 1985/86—are a poor nutrition source, and bivalves starve despite an abundance of plankton, as the brown tide organisms are too small to be filtered effectively. Tracey (1988) found starvation in blue mussels during brown tide outbreaks, with mortality being as high as 95% (Tracey 1985).
7. Food availability and food type can be important factors in bivalve growth. Greenfield *et al.* (2005) found that quahogs on the north shore of Long Island (New York) had significantly better growth than those on the south shore. The authors attributed this to a predominance of pennate diatoms on the south shore that have been found to reduce clearance rates[3] in quahogs, and hence reduce clam growth rates.
8. There is some evidence that bivalve larvae actively swim to position themselves in the water column in search of desirable salinities (Deshieneks *et al.* 1996). Wood and Hargis (1971) found that oyster larvae sink as salinity decreases (ebb tide) and swim upwards as salinity increases (flood tide). The net result of this behavior is that oyster larvae appear to position themselves in the water column for net up estuary movement to preferred environmental conditions, but further research would be required to document this as a behavior consistent enough to be modeled with confidence.
9. Distribution of bivalves is largely dependent upon the environmental influences experienced during the pelagic larval phase of development, and circulation dynamics are a major influence (Bowen and Hunt 2009; Dame 2012). Green *et al.* (2013) note that it is well accepted that metamorphosing bivalves use a suite of chemical cures to select an appropriate settlement site. The authors found a positive correlation between pH and larval site selection, suggesting that pH at the sediment-water interface is a major selection criteria for at least soft-shell and quahogs. Once settled, mortality incurred through predation and competition is major factors in shaping adult abundance patterns (Rice and Goncalo 1995).
10. Bivalves that form reefs, middens, windrows, or dense aggregates are considered ecosystem engineers in that they create, modify and maintain habitat that would not exist in their absence (Jones *et al.* 1994, 1997; Gutierrez *et al.* 2003; Borthagaray and Carranza 2007). For instance, on soft bottoms, shell aggregates provide attachment sites where none existed, and in rocky habitat the number of attachment sites is increased; in both cases increased diversity is promoted. While bivalve aggregates have the benefit of creating habitat and increasing recruitment, negative aspects may be predator attraction and decreased individual growth from crowding (Gutierrez *et al.* 2003; Alteiri and Witman 2006).

[2] Pseudofeces, produced when there is "too much food" or too high a concentration of suspended particulate matter, also significant in high density culture situations, are conglomerations of organic and inorganic material that are concentrated by bivalves as they filter the water column but are unable to biologically assimilate the total amount of particulate matter filtered (Dame 2012). Feces and pseudofeces, once settled on the sea floor, are termed biodeposits.

[3] Clearance rate is the volume of water completely cleared of particles per unit time; in general, the clearance rate is decreased as the concentration of particles in the water increases (Dame 2012).

220.1. Quahog (*Mercenaria mercenaria*)

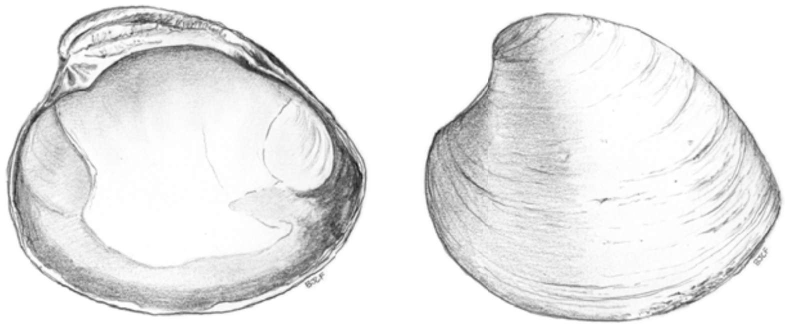

Figure 2.2. Quahog (Mercenaria mercenaria), illustration courtesy of Brandon Fuller, 2014.

220.1.1. Ecology

1. The quahog, or Northern quahog, is Rhode Island's iconic bivalve species, and makes up the largest wild fishery for shellfish in Rhode Island and single largest fishery in Narragsnett Bay. Smaller sizes are raw bar delicacies, while large sizes are a major ingredient in "stuffies"—a buttered breadcrumb and clam mixture baked in a quahog shell—and the state's unique clear broth clam chowder. See *Rhode Island's Shellfish Heritage: An Ecological History* at www.rismp.org for more detail regarding the history of this species.

2. The range of the quahog is New Brunswick (Canada) to central Florida, in estuaries and bays where salinity is greater than 15 parts per thousand (ppt), and that have good tidal exchange (MacKenzie *et al.* 2002). The quahog is slow growing but long-lived (23-46 years), with one spawning event per year in the northeast (Bricelj 1992). Jones *et al.* (1989) found a median age for quahogs in Narragansett Bay (from 10 scattered stations) to be 14 years, with 83% of the clams sampled being at least 10 years old; a 25.4 mm (1-inch) size was attained in Year 3, and 38 mm (1.5 inch) in Year 4. The approximate growing season in Narragansett Bay is April to mid-November (Jones *et al.* 1989). Pratt (1988) reported high concentrations of juvenile quahogs in upper Narragansett Bay, but noted they appeared stunted in their growth, possibly due to overcrowding.

3. Quahogs have been found to prefer sediments that are coarse yet firm, with complex surface topography that may include shell fragments—sandy areas with mixed shell fragments, for instance (Kassner *et al.* 1991; Murphy and Erkan 2006). Muddy sediments are less preferable—the authors found as much as a seven-fold increase in clam abundance in sandy substrates with shell fragments compared to muddy sediments. Kassner *et al.* (1991), in a study of quahog populations on Long Island (New York), found highest clam abundances in sediments that were coarse yet firm, not highly reworked (by other benthic organisms), had complex surface topography with a high degree of shell fragments; lowest clam abundance was found in clay/mud sediments. Quahogs are not uniformly distributed throughout Narragansett Bay, showing a pattern of decreasing abundance from north to south (Pratt 1988; Butet 1997) and patchiness throughout the Bay (Rice 1992).

4. Peak abundance of quahog larvae was found to occur mid to late June, with more larvae found on neap rather than spring tides (Butet 1997; Leavitt *et al.* 2013); Landers (1954) found maximum larvae in the water column from June to August. As with adult clam densities, larval density decreased along a north-south bay transect. Butet (1997) reports 80-99% mortality for quahog larvae in Narragansett Bay.

5. Optimal growth for quahogs is 20°C, with no growth occurring below 9°C or above 31°C (Ansell 1968). In the northern part of its range, growth is restricted to summer months, which may be extended as waters continue to warm. Jones *et al.* (1989) found a growth gradient for adult quahogs—slowest growth at the mouth of Narragansett Bay and highest in the upper bay, though less in the

Providence River, possibly due to overcrowding, poor water quality, or less ideal sediment characteristics.

6. A close relationship between current speed and quahog growth was described by Grizzle and Morin (1989)—at high current speeds growth was inhibited, as it was at high water column particulate concentrations. At moderate speeds and/or moderate particulate concentrations however, growth was enhanced (relative to low or no current). Quahog growth has been reported to be improved in sand, a sediment type indicative of higher flow velocities, which is indicative of a more rapid resupply of food (Rice and Pechenick 1992).
7. Quahogs reach a refuge from predation as they grow. Arnold (1984) found that only large blue crabs could open quahogs of 25 mm shell length and that at 50 mm no crab predation was found. The author suggests a 40 mm size class as having attained a refuge from predation. Bricelj (1992) and Carriker (1951) report similarly, adding that large whelks are able to prey upon quahogs 40 mm and larger, but at very low rates.
8. Recruitment can be highly limited into existing populations dominated by old clams. Malinowski (1992) reports that significant recruitment occurred only twice in 15 years in a population studied on Fishers Island (New York). Keck *et al.* (1974) found that sandy areas treated with clam liquor were most attractive to settling larvae, suggesting that the presence of conspecifics may be an important factor in settlement site selection, though based on Malinowski's findings, perhaps to some potential upper limit of adult density.
9. Quahogs have been found to exist at densities far below the maximum that could be sustained based on available food and space, and with little indication of intraspecific competition (Malinowski 1992); the author concludes that predation is likely a controlling factor for quahog populations (at a study site at Fishers Island, New York). Bricelj (1992) reports that predation is a controlling factor in quahog mortality and recruitment success, particularly under 20 mm shell length.

220.1.2. Distribution

1. Figure 2.3 shows the estimated distribution of legal-sized quahogs in Narragansett Bay[4] based upon the RI DEM quahog dredge survey, and Figure 2.4 shows the location of various shellfish harvest and tagging areas as managed by Rhode Island Department of Environmental Management. Highest quahog densities tend to coincide with closed and/or seasonally open areas in upper Narragansett Bay and the Providence River, as well as in Greenwich Bay. Other high density areas fall into Conditional Areas A and B, and outside the mouth of Greenwich Bay. Clam density tends to show an overall trend towards lower density with distance down bay, and overall higher densities in the West vs. the East Passage. Murphy and Erkan (2006) also reported low densities of quahogs for the Sakonnet River. A bimodal distribution of mature vs. young quahog age classes have been reported for Mount Hope Bay (Pratt *et al.* 1992), which according to the authors indicates an extended period of reduced larval recruitment.
2. Rice *et al.* (2000) and Rice (1999) found average quahog densities in the Providence River ranging from 9.1 clams m^{-2} to 12.5 clams m^{-2}.Based on dispersion patterns, Butet (1997) concluded that the Providence River is likely the dominant source of quahog larvae for Narragansett Bay. This finding adds support to the concept of closed-to-harvest waters in the Upper Bay acting as spawning sanctuaries.

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[4] Rhode Island Department of Environmental Management undertakes transplants of quahogs, often off limits to harvest in closed areas, and moves them to other areas, which may open to harvest according to applicable rules and regulations. Because clams are moved around, the distribution of clams reflects these transplant activities, and not necessarily natural abundance patterns.

3. Quahog Condition Index[5] in the Providence River has been found to be low (Marroquin-Mora and Rice 2008); the authors note that the area containing clams with the lowest Condition Index coincides with the area that experiences frequent hypoxic[6] conditions.

4. From a survey of quahogs in Greenwich Bay, Lazar *et al.* (1994) report a broad range of quahog sizes, with some areas showing signs of poor recruitment years as evidenced by adults of different ages spanned by years with no representative age classes. The authors found that areas closed to harvest had high densities of clams (0–17.9 m^{-2} in open areas vs. 0.2–33.9 m^{-2} in closed), and suggest that Greenwich Cove, Warwick Cove, Brushneck Cove, and Apponaug Cove provide the broodstock for the Greenwich Bay quahog population.

5. The RI DEM dredge survey reports Greenwich Cove as having a quahog density of 12 clams m^{-2}, Warwick Cove 30 m^{-2}, Apponaug Cove 16 m^{-2}, and Greenwich Bay proper 4 m^{-2} (Lazar *et al.* 1994). Rice *et al.* (1989) report quahog densities of 190 clams m^{-2} in Greenwich Cove (mean width 61 mm), and 78 clams m^{-2} in Greenwich Bay (mean width 31 mm).

[5] Condition Index of bivalves relates the proportion of the shell cavity that is occupied by soft body tissue, and are often used to follow seasonal change in nutrient reserves or meat quality (Dame 2012). Low Condition Index (e.g., less meat inside the shell), indicates some stressor(s) that are causing the shellfish to not grow to its fullest potential. Predator presence, lack of food, or presence of pollutants, for instance, could be mechanisms that reduce growth and lead to reduced bivalve Condition Index.

[6] When experiencing hypoxic conditions, most bivalves “clam up,” shutting the shell tightly with a cessation of pumping water and filter feeding (Dame 2012). Since the bivalve is no longer actively feeding and respiring, stress sets in and overall growth and condition is reduced.

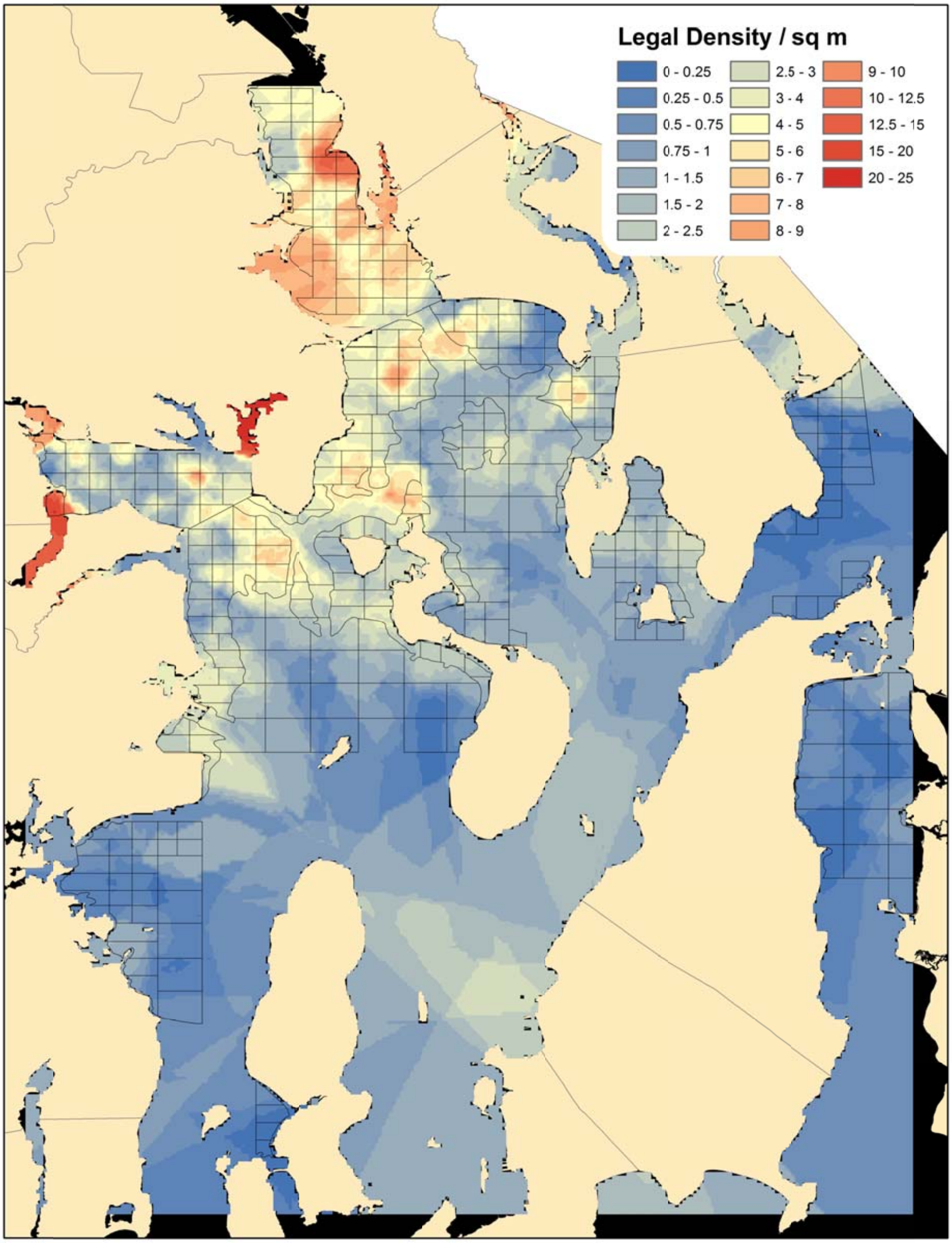


Figure 2.3. Distribution of legal-sized hard clams in Narragansett Bay (RIDEM 2013).

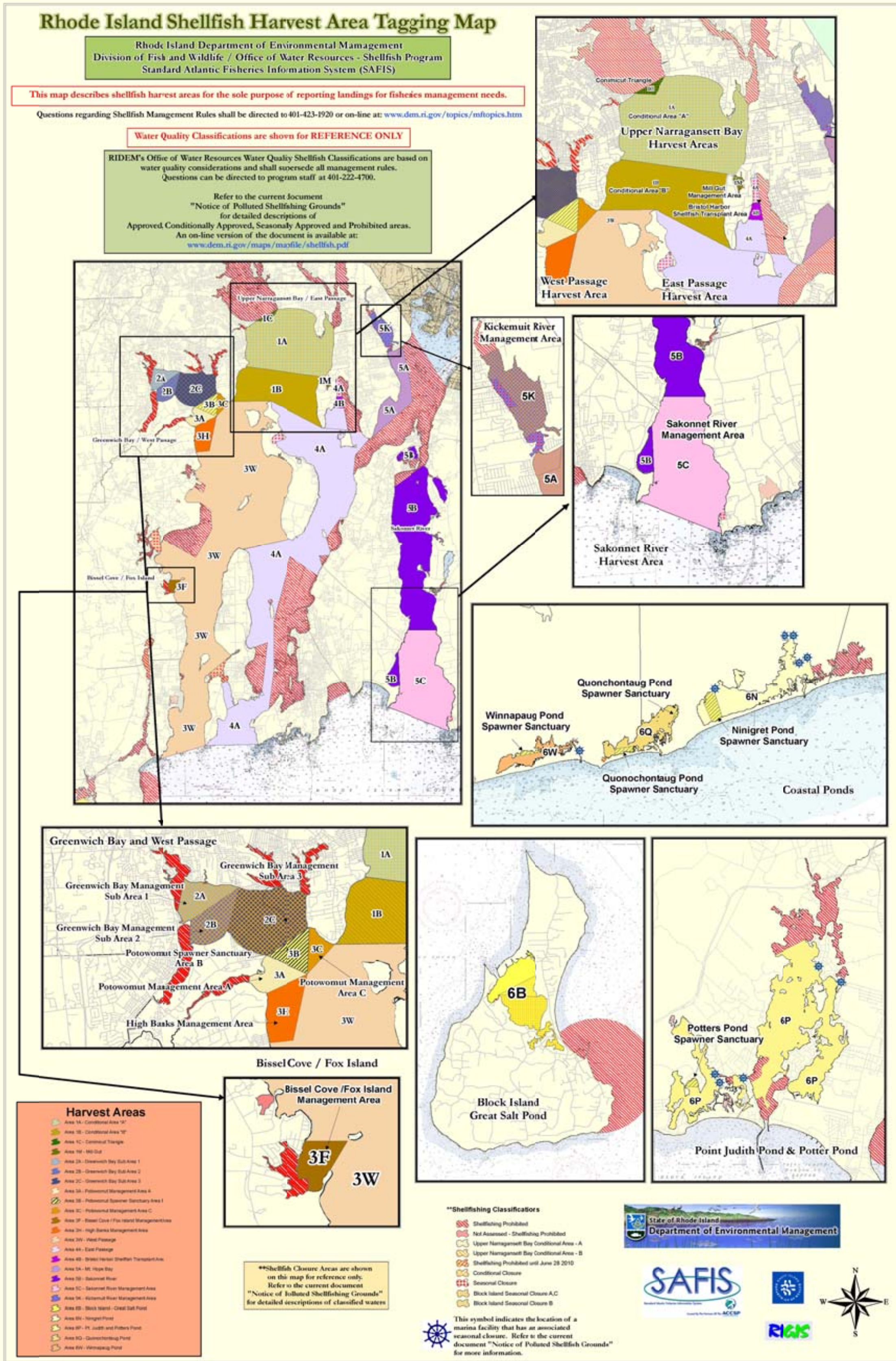


Figure 2.4. Rhode Island Department of Environmental Management Shellfish Harvest Areas.

6. Due to its warming sooner than other waters, Greenwich Cove is reported as being the first area to see quahog spawn (Marroquin-Mora and Rice 2008). Butet (1997) similarly noted that warm water coves saw quahog spawn sooner than cool water coves.
7. Based on modeling efforts to simulate the transport and distribution of quahog larvae throughout Narragansett Bay, Leavitt *et al.* (2013) identify the following findings:
    a. Larval transport from the Providence River area showed wide disbursement throughout Narragansett Bay, with more larvae ending up in the West Passage than the East Passage; 20–34% of larvae were transported out of the bay to the open ocean.
    b. Larvae produced in the spawning sanctuary at the mouth of Greenwich Bay tended to remain in Greenwich Bay, but with significant numbers moving into the West Passage; 45–51% of larvae were transported out of the bay to the open ocean.
    c. Most of the larvae released in Greenwich Cove were retained in Greenwich Bay, but with significant transport into the West Passage; 11–21% of larvae were transported out of the bay to the open ocean.
    d. Rome Point larvae were largely transported out of Narragansett Bay to the open ocean (95–96%), with small numbers remaining in the lower East and West Passages.
    e. Larvae released at Hog Island saw wide distribution throughout Narragansett Bay, with large numbers moving into the East Passage and into Mount Hope Bay, and significant numbers remaining in the upper Bay and West Passage; 35–46% of larvae were transported out of the bay to the open ocean.
    f. Larvae released at Rocky Point were predominantly found in the West Passage, with small numbers on the west side of the East Passage; 34–43% of larvae were transported out of the bay to the open ocean.
8. Quahogs were found by Campbell (1961) to be the predominant bivalve in Great Salt Pond on Block Island, with greatest densities found in the southwest region. Russell *et al.* (1973) reported quahogs south of Harris Point, in Cormorant Cove and along the north shore of Great Salt Pond. Ganz (1978; 1983; 1992) and Ganz *et al.* (2000) all report the quahog to be the most abundant bivalve in Great Salt Pond.

220.2. Eastern oyster (*Crassostrea virginica*)

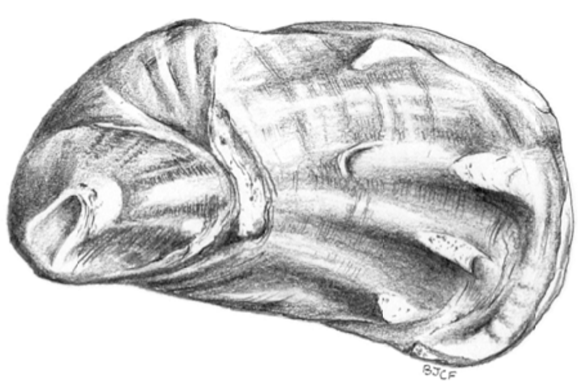


Figure 2.5. Eastern oyster (Crassostrea virginica), illustration courtesy of Brandon Fuller, 2014.

220.2.1. Ecology

1. The range of the Eastern oyster is from the Gulf of St. Lawrence (Canada) south to Key Biscayne (Florida) and into the West Indies, in estuarine waters intertidally to 30 m (Coen and Grizzle 2007).

2. The Eastern oyster was an important food source for Native Americans and early settlers to Rhode Island. Goode (1887) notes that oysters were overfished in Narragansett Bay by the late 1880s, and natural harvest gave way to broad scale oyster aquaculture (Desbonnet and Lee 1991). Wild harvest of oysters today is sporadic (Figure 2.6), though a robust aquaculture industry for oysters is present, particularly in the south shore coastal lagoon ecosystems.
3. Oysters have been commercially extinct in Narragansett Bay for decades, and those few wild populations that were observed in the 1990s appear to have succumbed to disease and/or over exploitation (Oviatt *et al.* 2003). Oysters once were common in the south shore lagoon ecosystems as well. Lee (1980) ties the loss of oysters in the salt ponds to the installation of permanent breachways.
4. Oyster reefs provide valuable ecosystem services, which have been summarized as: (1) oyster production, (2) water filtration and biodeposits concentration, (3) habitat provision, (4) carbon sequestration, (5) fishing resource augmentation, (6) stabilization of benthic and intertidal habitat, and (7) increased landscape diversity (Coen *et al.* 2007; Grabowski and Peterson 2007). zu Ermgassen *et al.* (2013) estimate a 64% decline in non-aquaculture oyster extent and an 88% loss of non-aquaculture oyster biomass in the United States between the early 1900s and the early 2000s, noting that this loss can be linked to observed water quality and/or habitat degradation.
5. The oyster is a reef building species, and reef structure influences local ecological conditions. A correlation between height of an oyster reef above bottom and oyster growth rate has been reported (Schulte *et al.* 2009). Flow rates are increased at height, replenishing food and rapidly removing wastes, resulting in increased oyster growth.

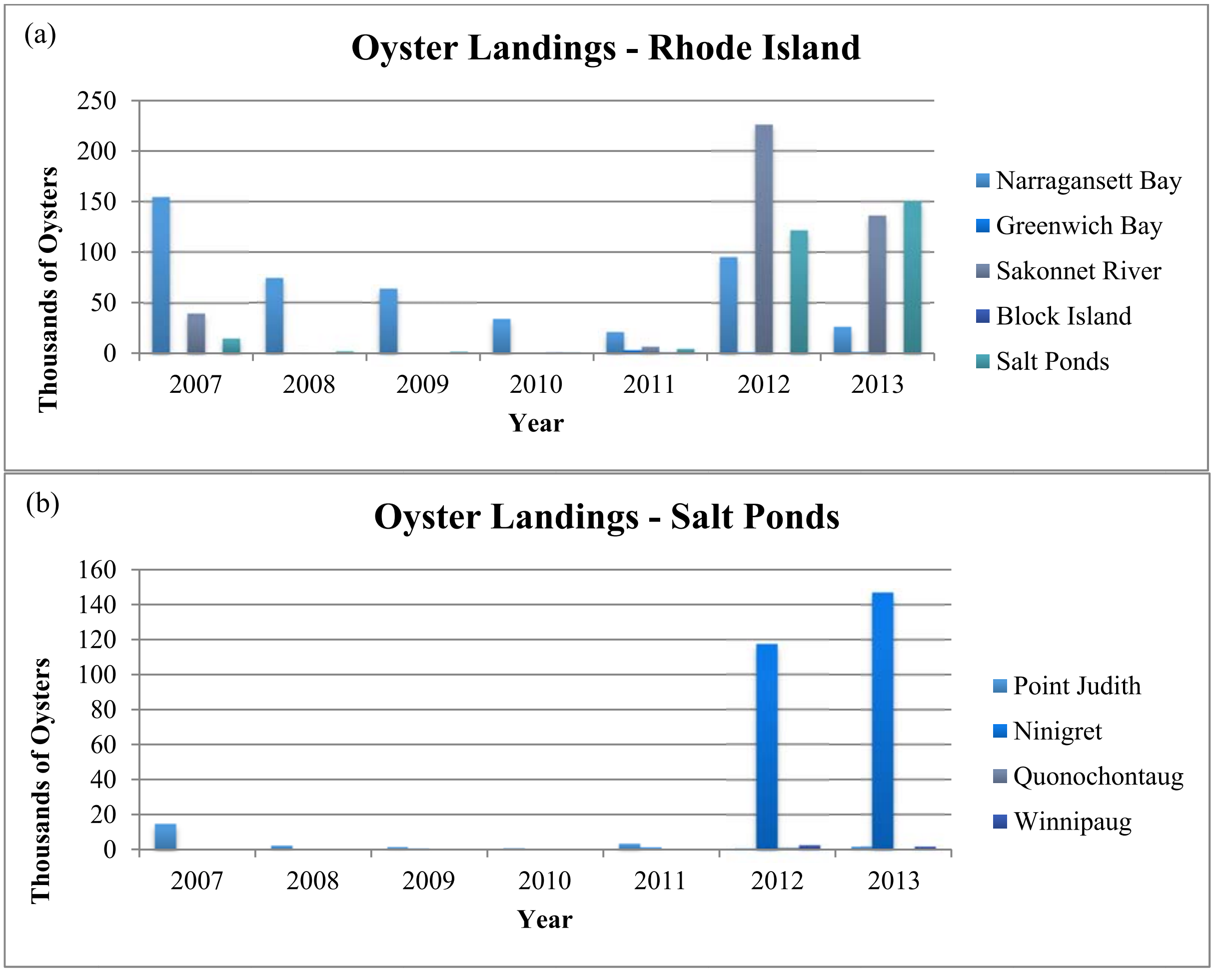


Figure 2.6. Eastern oyster wild harvest landings for Rhode Island (a), and the salt ponds (b), 2007–2013 (Atlantic Coastal Cooperative Statistics Program 2013).

220.2.2. Distribution

1. From a comparison of water quality data 1998–2007, Nau (2007) found that 95% of the ideal habitat for oysters in Rhode Island waters was degraded and not suitable for oyster restoration. "Ideal" oyster habitat in Rhode Island waters is defined by Hines and Brown (2012) as having a salinity of 12–28 ppt, dissolved oxygen concentrations of 4–6 mg l^{-1}, water temperature of 14–28°C, water depth of 0.5–3 meters, substrate consisting of sand, gravel and rock, and a sedimentary environment that has low depositional qualities, and is stable.

2. Oyster larvae have been reported in the water column from late June through September, with a peak in late August; larval settlement was found to be most intense mid-August to mid-September (Brown *et al.* 2013). The authors suggest that reestablishment of natural oyster populations from oyster aquaculture operations located in the salt ponds is both possible and probable.

3. Brown *et al.* (2013) report 56 acres of high quality habitat for oyster restoration in the northern reaches of the Narrow River ecosystem. Figure 2.7 shows the distribution of habitat suitable for the Eastern oyster in the Narrow River; highest quality oyster habitat[7] is located at the very northern

[7] The oyster habitat described by Brown *et al.* (2013) is with regard to habitat suitable for sustaining existing, or establishing new, wild populations of Eastern oyster, and should confused with suitability as sites for aquaculture.

portion of the estuarine ecosystem. Currently the Narrow River is closed to all shellfish harvest activities.

a. For Point Judith Pond, Brown et al. (2013) found overall that the quality of habitat for oyster restoration was low. Figure 2.8 shows the distribution of habitat suitable for the Eastern oyster in the Point Judith Pond ecosystem; highest quality oyster habitat is located intermittently throughout the ecosystem, though mainly in the northern extent, on the south side of Ram Island, and in Potter Pond near the designated spawning sanctuary.

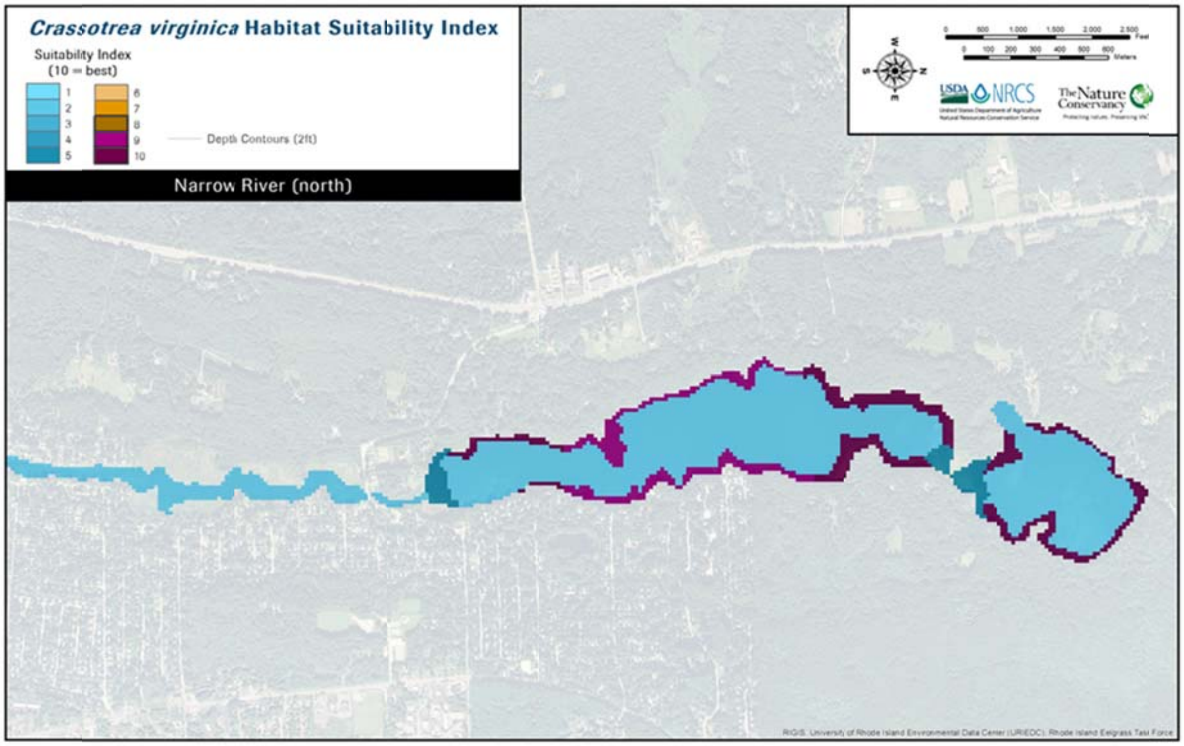
b. Within the shellfish sanctuary in Ninigret Pond, Brown et al. (2013) found higher oyster densities in the southern portion of the sanctuary, but note it could have been due to initial sanctuary stocking densities. They also note higher oyster survival in the southern portion of the pond, likely due to a lower abundance of potential predators (mud crab, blue crab, flatworms) compared to the northern pond, and the tendency for Gracilaria to bloom in the northern region and cause low dissolved oxygen conditions. Evidence of natural oyster recruitment was noted.

c. Figure 2.9 shows habitat quality for Eastern oysters in Ninigret Pond and Green Hill Pond. Overall, Brown et al. (2013) report poor quality habitat for oyster restoration in Ninigret Pond, with intermittent, sparse areas of moderately good habitat along the northern shore in the mid section of the pond; habitat quality in the spawning sanctuary is poor, with some moderate habitat quality along the northern shore of the sanctuary. For Green Hill Pond Brown et al. (2013) found that, despite no sanctuary in the pond, there is a large area of high quality habitat suitable to oyster restoration, most of it located along the southwest shoreline; pockets of good to very good habitat are found intermittently along the southern and eastern shorelines of Green Hill Pond.

d. Brown et al. (2013) report 24 acres of medium-high quality habitat for oyster restoration in the western section of the shellfish sanctuary in Quonochontaug Pond, and 6 acres in the eastern portion. Figure 2.10 shows the distribution of habitat quality in the pond, as noted above.

e. Brown et al. (2013) report 21 acres of medium-high to high quality habitat for oyster restoration in Winnipaug Pond. Figure 2.11 shows the distribution of habitat quality for Eastern oysters in the pond, showing that the northwestern shoreline contains the bulk of the highest quality habitat, and that the best habitat quality overlaps with that area designated as a spawning sanctuary.

4. The distribution of oysters were noted to be scattered in Great Salt Pond on Block Island (Ganz 1978, 1983, 1992; Ganz *et al.* 2000).



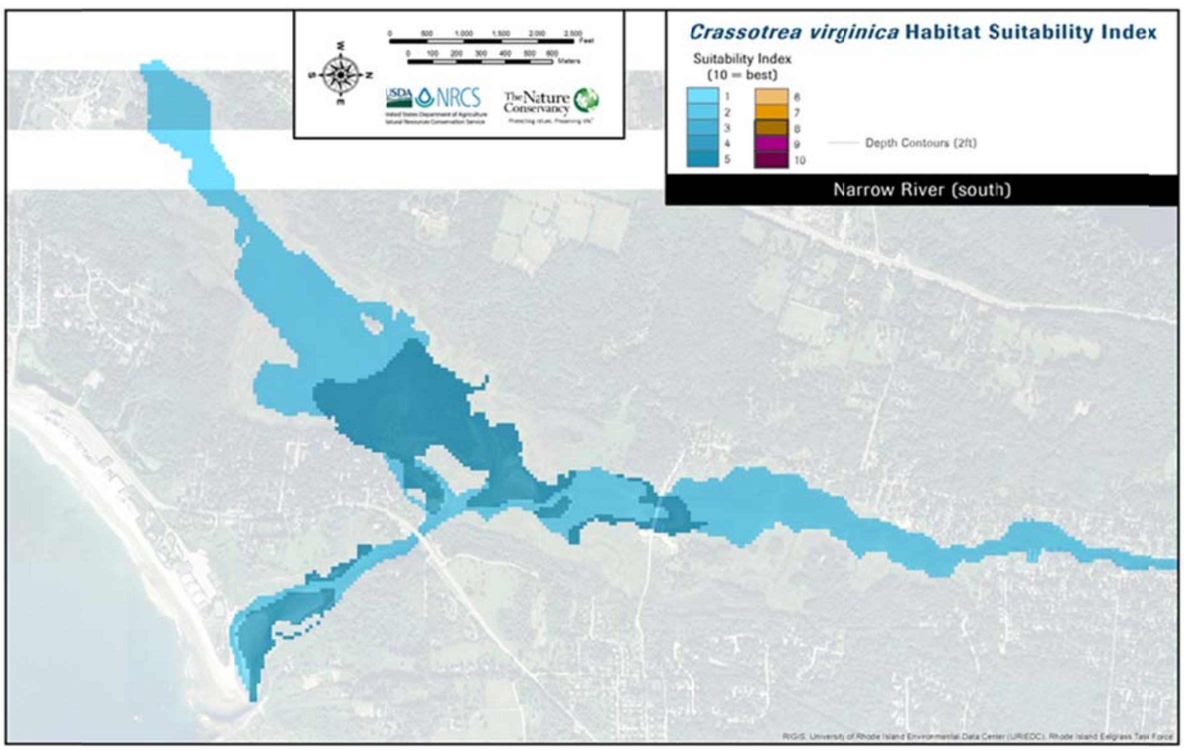
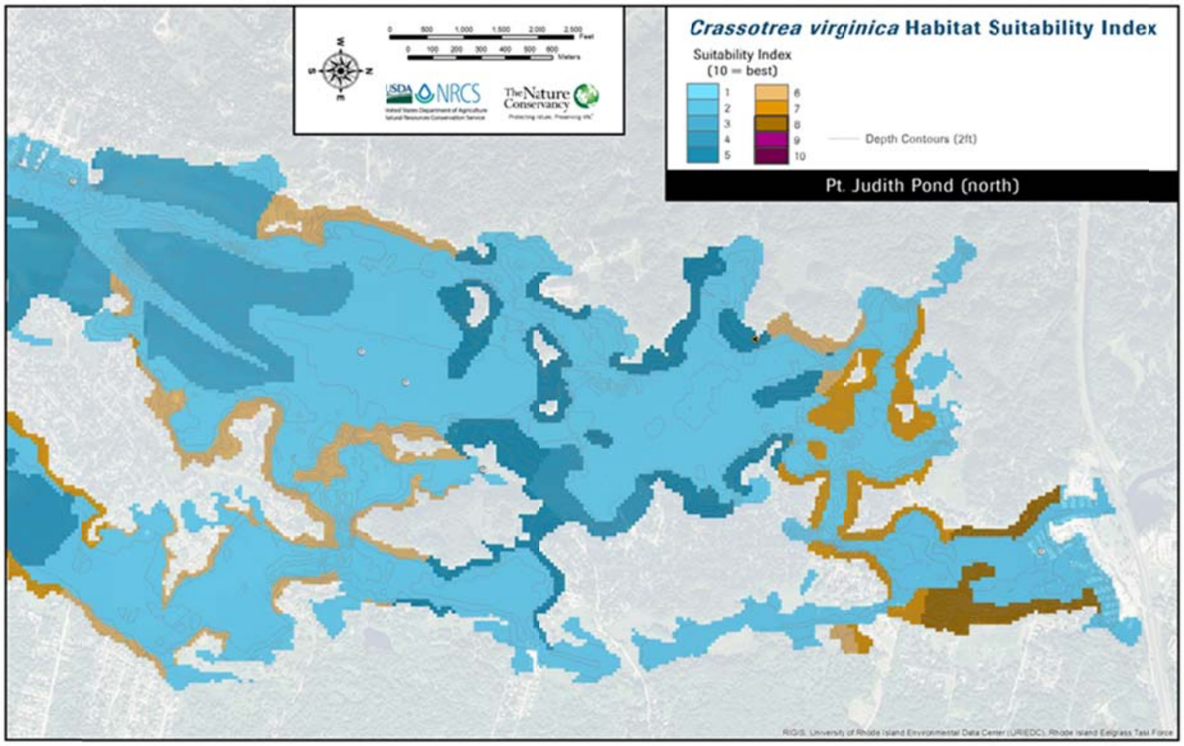


Figure 2.7. Distribution of habitat suitable for the Eastern oyster in the Narrow River (top) and southern Narrow River (bottom) (from Brown et al. 2013).



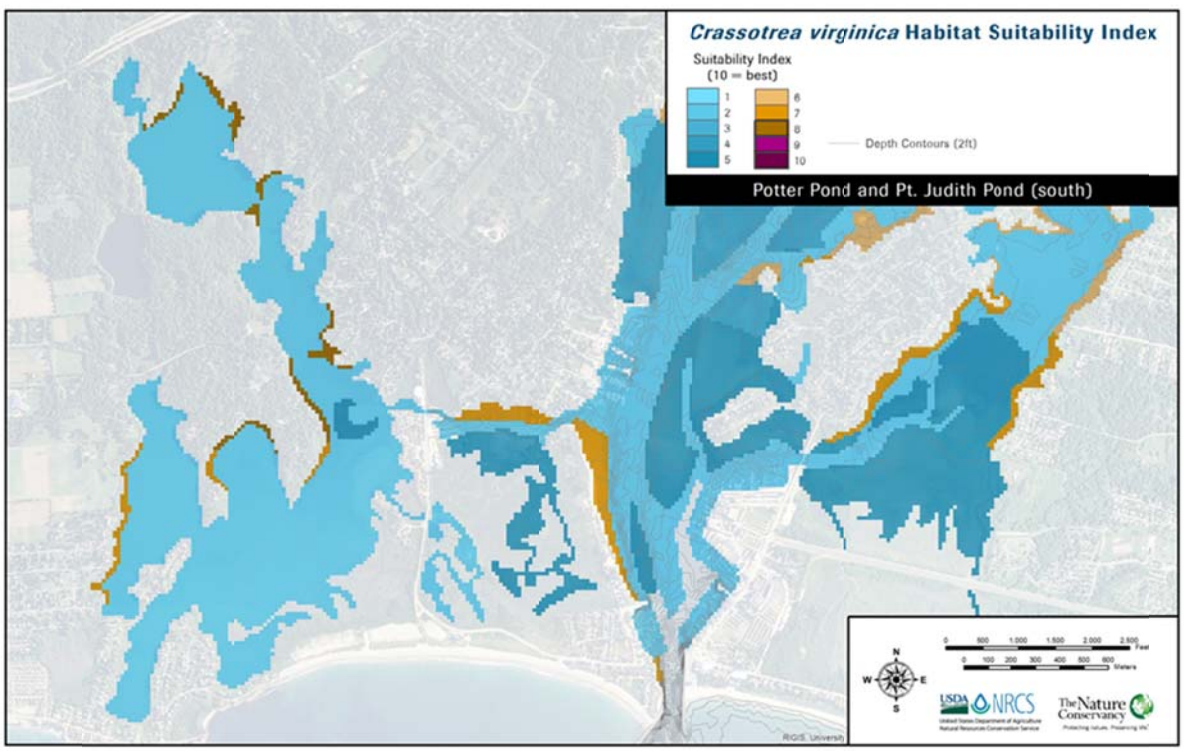


Figure 2.8. Distribution of habitat suitable for the Eastern oyster in Point Judith Pond (top) and Potter Pond (bottom) (from Brown et al. 2013).

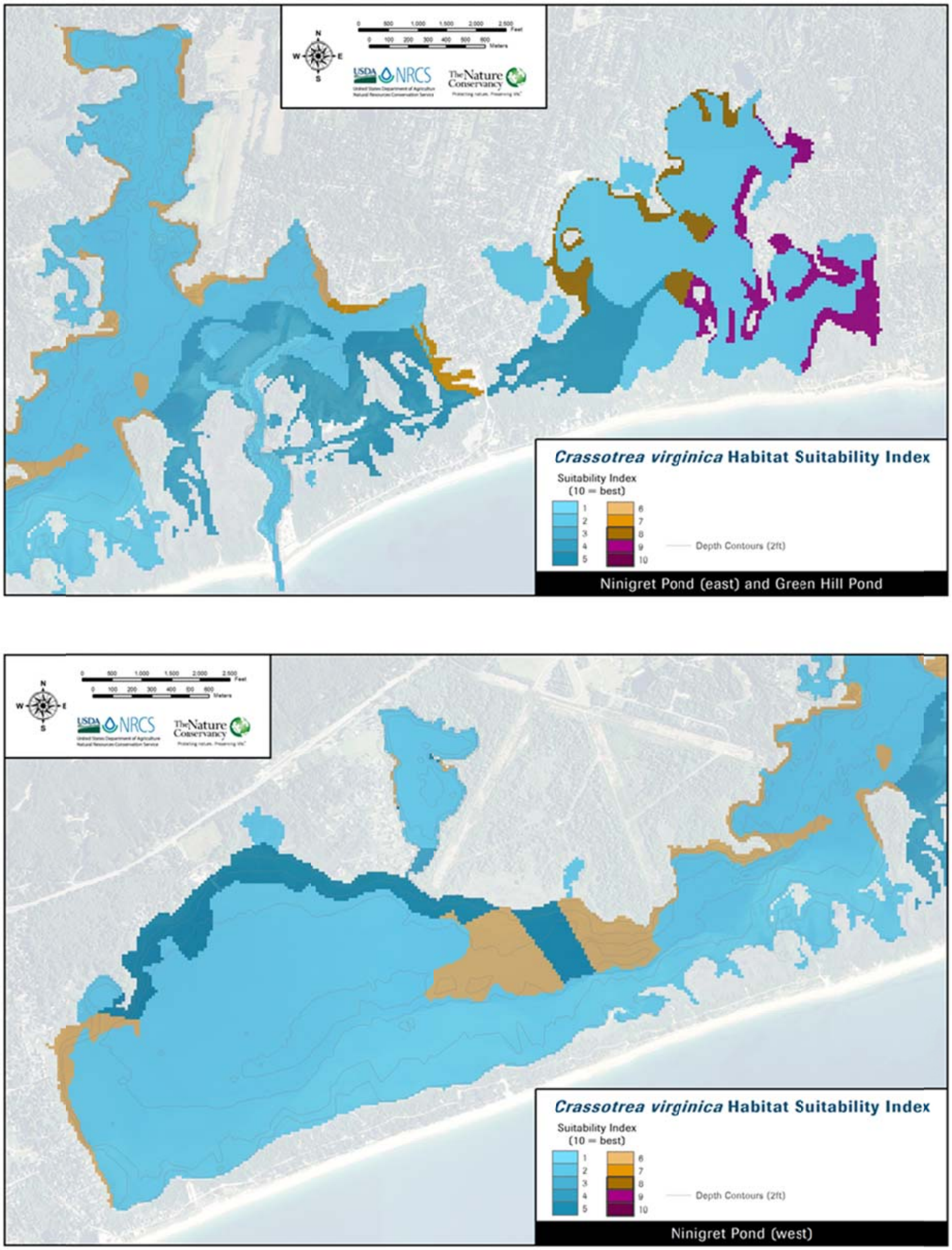


Figure 2.9. Distribution of habitat suitable for the Eastern oyster in the Ninigret Pond (top) and Green Hill Pond bottom) (from Brown et al. 2013).

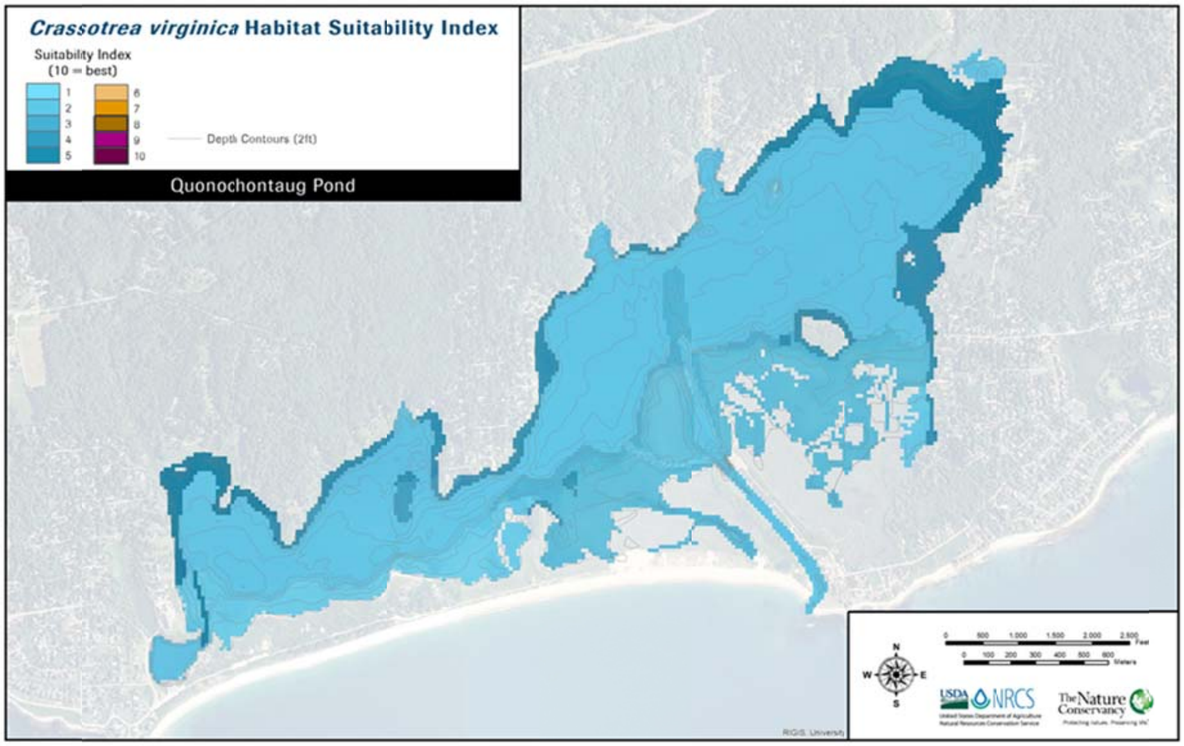


Figure 2.10. Distribution of habitat suitable for the Eastern oyster in Quonochontaug Pond (from Brown et al. 2013).

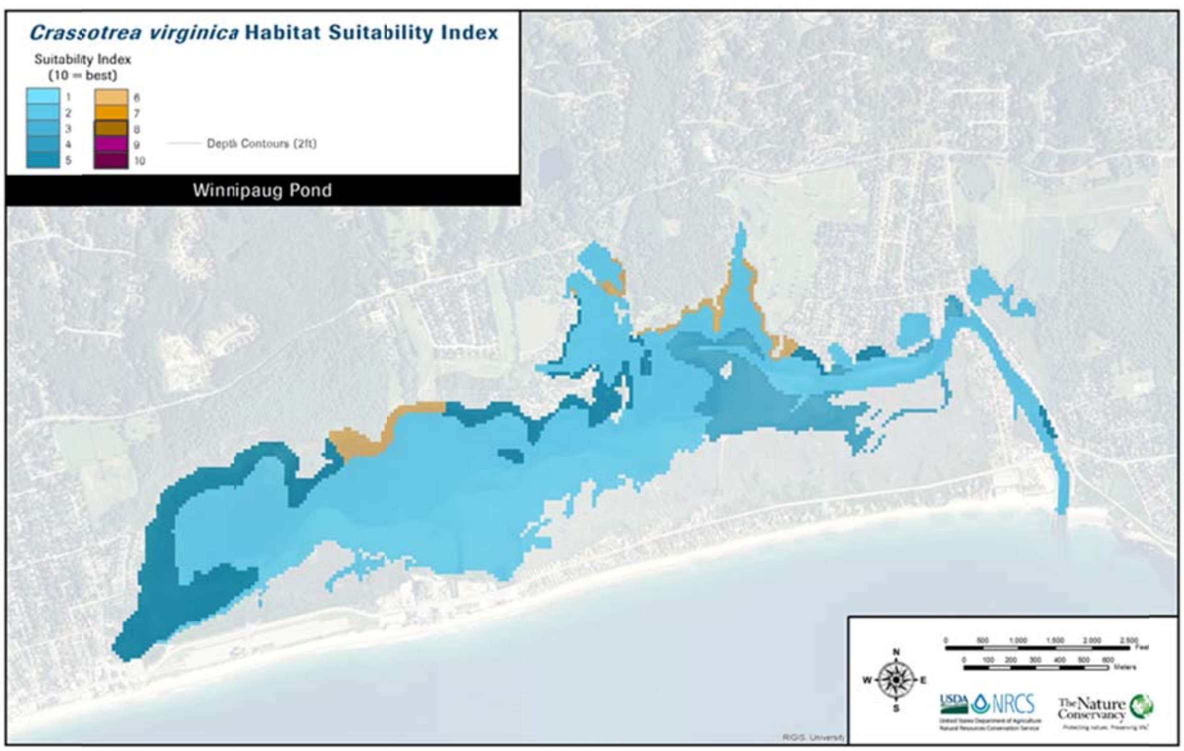


Figure 2.11. Distribution of habitat suitable for the Eastern oyster in Winnipaug Pond (from Brown et al. 2013).

220.3. Blue mussel (*Mytilus edulis*)

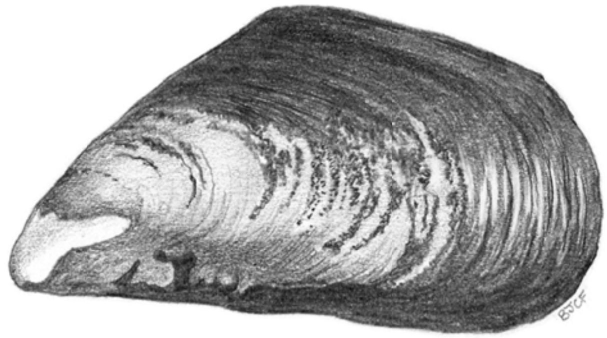


Figure 2.12. Blue mussel (Mytilus edulis), illustration courtesy of Brandon Fuller, 2014.

220.3.1. Ecology

1. The blue mussel is a common intertidal and subtidal bivalve that forms dense beds and provides ecosystem services similar to those described for oyster reefs. Wild mussel harvest is inconsistent in Rhode Island waters, but mussel culture is a burgeoning industry in Narragansett Bay; see Chapter 4 for more detail on mussel aquaculture.
2. The blue mussel ranges from Labrador (Canada) to Cape Hatteras (North Carolina), occurring in large mats that can become unstable and be uprooted during storms (Dame 2012). Major predators have been reported to be sea stars, large crustaceans, tautog, eider, and scoter (Newell 1989; Dame 2012). The dogwhelk (*Nucella spp*.) has been known to selectively feed on mussels and therefore can be a significant predator; sea stars can be a significant predatory force during times of population outbreaks (Seed 1993).
3. Blue mussels predominate in areas of good water flow that replenishes food supplies often. Mussels have been found to process higher volumes of water at low particle concentrations, then reducing feeding rates as food content of filtered water increases; optimal growth occurs at water temperatures between 10ºC and 25ºC (Brenko and Calabrese 1969).
4. The blue mussel hosts a commensal crustacean, the pea crab (*Pinnotheres maculatus*), which is most common in mussel populations south of Cape Cod (Massachusetts; Newell 1989). Bierbaum and Ferson (1986) found 69% of mussels in waters off Martha's Vineyard were infected with pea crabs; in less optimal growing conditions, pea crab infected mussels exhibited slower rates of growth. The presence of pea crabs in mussels destined for consumption is a detriment, often reducing market value or making them unmarketable.
5. Because of their relatively small size, mussels can only keep their shells closed for up to 96 hours (Newell 1989); this may be a factor in the mortality seen in Narragansett Bay mussel populations during hypoxic events reported by Altieri (2008). Altieri and Witman (2006) report reduced mussel growth in Narragansett Bay hypoxia prone areas.
6. Mussels were reported as scarce in Great Salt Pond on Block Island (Russel et al., 1973; Ganz 1978).

220.4. Soft-shell clam (*Mya arenaria*)

Figure 2.13. Soft-shell clam (Mya arenaria), illustration courtesy of Brandon Fuller, 2014.

220.4.1. Ecology

1. The soft-shell clam, often referred to as "steamers," are a staple of seafood restaurants in the form of "fried clams." Soft-shell clams were once abundant throughout Narragansett Bay (in 1865), but by 1960 their harvest had become small and insignificant, and by the early 2000s they existed largely in areas closed to shellfishing (Oviatt *et al.* 2003). Populations of soft-shell clams have historically been abundant in the south shore lagoon ecosystems but populations experience wide fluctuations that lead to abundance interspersed by scarcity (Pfeiffer-Hebert 2007.

2. As early as the mid-1950s, Ayers (1956) reports the soft-shell clam as being "drastically over fished" and that strict management was needed to sustain the species. The author found that 40 larvae per year must survive to settlement (in the area spawned) in order for the population to sustain itself (e.g., replace both parental clams).

3. In a study of soft-shell clam population dynamics in the Bay of Fundy (Canada), Bowen and Hunt (2009) found the presence of adult soft-shell clams was neither detriment nor attractant to juveniles seeking a site for settlement. Instead, they found that hydrodynamics, larval behavior, and post settlement events controlled patterns of abundance.

4. At a shell length of 12 mm soft-shell clams become permanently fixed in their burrows; only 0.1% of the eggs produced by a female clam survive to this point (Brousseau 1978). The highest mortality is seen in larval stages, especially just after settlement to the benthos; mortality then levels off at sexual maturity (45 mm shell length; 2 years of age). Bowen and Hunt (2009) found that soft-shell clams were highly susceptible to post settlement processes at 2 mm shell length. Boulding (1984) reported no refuge from predation based on clam size.

5. Filtering rate was found to be reduced in waters less than 15 ppt, and growth was faster when clams were feeding on flagellate dominated phytoplankton rather than diatom dominated phytoplankton (Matthiessen 1960).

6. Common predators of soft-shell clams are the moon snail (*Luatia heros*), and many species of crabs, especially the green crab (*Carcinus maenus*). Soft-shell clams have been found to burrow deeper (15%; 13 cm vs. 10 cm) in the presence of crabs (Flynn and Smee 2010; Thomson and Gannon 2013). Slower growth has been noted in coarse sediment vs. fine sediment, likely due to the cost of shell repair (e.g., edge chipping) in coarse sediment, but reduced predation mortality was significant for clams burrowing in coarse sediments (Thomson and Gannon 2013).

7. Figure 2.14 (a) shows wild harvest landings for 2007–2013 for soft-shell clams taken in Narragansett Bay[8] (note change in scale among graphs). Harvest from Narragansett Bay has dominated landings, but has seen a near continuous decline. Harvest from the salt ponds dominate landings from other areas (Figure 2.14 (b)), and have increased in recent years; Winnipaug Pond provides the dominant share, followed by Point Judith Pond (Figure 2.14 (c)).

   Soft-shell clams were reported as scarce in Great Salt Pond on Block Island (Russell et al., 1973; Ganz 1978), and as scarce or absent by Campbell (1961).

220.5. Bay scallop (*Argopecten irradians*)

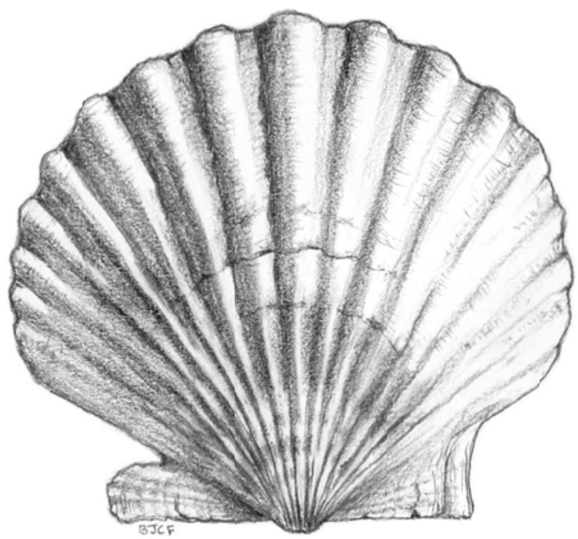


Figure 2.14. Bay scallop (Argopecten irradians), illustration courtesy of Brandon Fuller, 2014.

220.5.1. Ecology

1. The bay scallop has been historically abundant in Narragansett Bay, the Sakonnet River, and the south shore salt ponds (Brown 1991). MacKenzie (2008) reports that in the late 1800s there existed a 90 boat scallop fleet in Rhode Island waters, with Greenwich Bay and Cowesett Bay being prime harvesting areas. Oviatt *et al.* (2003) note scallops as having been most abundant in Greenwich Bay in 1865, but that essentially no bay scallops have been taken in decades, suggesting the loss of eelgrass as a major factor. Scallops however, are considered to have been largely eliminated from Rhode Island waters as a result of brown tide events in 1985 and 1986 (Brown 1991; Coen and Grizzle 2007; Carroll *et al.* 2010), as well as from habitat loss associated with nutrient loading and changing ecological community make up (Carroll *et al.* 2010).

2. In a review of scallop ecology by MacKenzie (2008), it is noted that scallops prefer shallow water (3–10 ft) with firm bottom, preferentially with eelgrass, which enhances juvenile settlement and provides an above bottom attachment site as a partial refuge from predation; 60% mortality on eelgrass fronds vs. 90% on the sediment interface. The range of the bay scallop is Cape Cod (Massachusetts) to the Carolinas (Fay *et al.* 1983).

3. The health of bay scallop populations is often tied to the presence or absence of eelgrass (*Zostera marina*), with studies finding that increased seagrass abundance equals increased bivalve settlement

(Bologna and Heck 2000; Carroll *et al.* 2010). These authors suggest that seagrass presence reduces flow velocity, and promotes epiphytic growth that again reduces flow velocity, which enhances bivalve larval settlement. Shriver *et al.* (2002) however, found that epibiont growth on scallop shell, which was correlated to increased nutrient availability (e.g., eutrophic conditions), reduced both scallop growth and Condition Index.

4. Scallop restoration success appears to be linked to eelgrass—presence improves scallop survival (Carrol *et al.* 2010). The authors note that *Codium fragile*, an introduced algae, can provide similar attributes to eelgrass for restoration, with no differences seen in scallop population recovery (on Long Island, New York) between eelgrass only and *Codium* only sites. The authors do however state that it is unclear whether or not *Codium* plays the same ecological role as eelgrass over the long term with regard to predator protection, or how hypoxia, which is common in *Codium* dominated waters, impacts scallop survival.
5. The green crab and blue crab (*Callinectes sapidus*) are the two most important predators of bay scallops in shallow waters, while sea stars are important in deeper waters, and gulls on a tidally mediated basis (Fay *et al.* 1983). MacKenzie (2008) reports oyster drill, knobbed whelk, mud crab, tautog, scup, and eider as predators of scallops. Cow-nosed rays are noted to be an important predator to the south, and may become important in New England waters as warming continues as a result of changing climate.
6. Scallop harvests in Rhode Island waters are sporadic and no trend is obvious. MacKenzie (2008), in a review of scallop ecology on the Atlantic east coast, notes that there is indication that specificity in food selection by scallops may be a factor in the high year-to-year variability seen in recruitment success.
7. It is of interest that 2010 saw a good set of scallops in Rhode Island waters, good enough to allow a commercial harvest two years later as the scallops reached legal size in 2012. The good scallop set in 2010 is coincident with intense spring flooding, though any cause and effect is not readily known.
8. Scallops were reported to be found on Block Island in Cormorant Cove and Trim's Pond (Russell et al. 1973), scattered in Great Salt Pond (Ganz 1978), and scarce or absent in the pond by Campbell (1961).

Section 230. General Ecology—Gastropods

1. Whelks, often referred to as conchs, are gastropod molluscs that live in a coiled shell and resemble large snails. Unlike bivalves, they are highly mobile, moving along by using a muscular foot that can be extended beyond the shell opening.
2. There are two major species of whelk found in Rhode Island waters: knobbed whelk (*Busycon carica*) and the channeled whelk (*Busycotypus canaliculatus*). Both exhibit a range from Cape Cod to central Florida (Power *et al.* 2009). Magalhaes (1948) however, notes the channeled whelk to be as much as 5 to 6 times more common than the knobbed whelk in the Woods Hole area (based upon data reported for 1911 by Sumner, Osburn and Cole), and that knobbed whelk appear to prefer shallower, warmer waters; channeled whelk deeper, cooler waters.
3. Whelks tend to grow episodically, undergoing long periods of no growth, which makes management relying upon average annual rates of growth potentially misleading (Kraeuter *et al.* 1989). Power *et al.* (2009) report that whelk populations exhibit boom-and-bust cycles of abundance.
4. The largest whelks can be significant predators on bivalves, and have the ability to open the largest quahogs (Carriker 1951). Magalhaes (1948) reports crabs and gulls as common predators of whelks.
5. Whelk tend to be sedentary, spending long periods immobile, interspersed with active times where average travel distance per day was found to be 18 m (Magalhaes 1948). No evidence was found for migration of either whelk species to offshore waters in North Carolina.

230.1. Channeled whelk (*Busycotypus canaliculatus*)

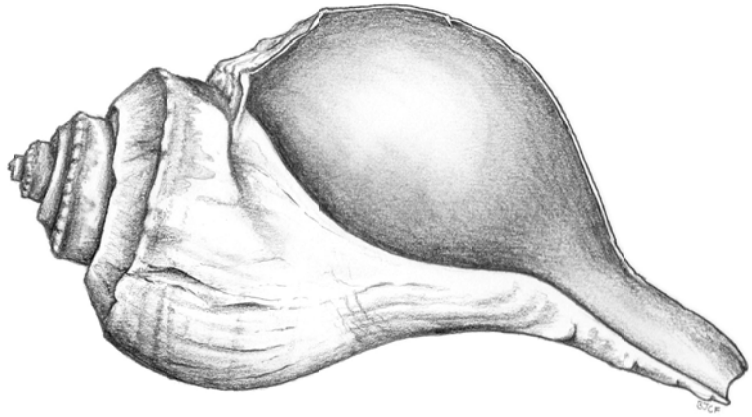


Figure 2.15. Channeled whelk (Busycotypus canaliculatus), illustration courtesy of Brandon Fuller, 2014.

1. Channeled whelk tend to bury in sediment by day, and become more active at night and/or on cloudy, overcast days (Bruce 2006). Whelk were found to spend on average 65% of their time buried in bottom sediments, making them less vulnerable to harvest by dredge or trawl (Carriker 1951); channeled whelk are primarily harvested by trap or pot gear (Bruce 2006).
2. Channeled whelk density in Nantucket Sound (Massachusetts) was found to be less than 5 whelks per 1,000 m^2 in both 1978 and 1981 (Davis and Sisson 1988). Sisson (1972) estimated a whelk density of about 10 whelks per 1,000 m^2 for Narragansett Bay, while Wood (1979) found whelk densities from 11.49 to 17.42 per 1,000 m^2 for Narragansett Bay.
3. Because of their low reproductive potential and slow growth, management concerns for channeled whelk are significant (Harding 2011; Peemoeller and Stevens 2013). With females being larger (than males), they tend to be targeted for harvest which will lead to a female-only harvest, leaving behind males and sexually immature females, which will not lead to sustainable populations (Power *et al.* 2009; Peemoeller and Stevens 2013).
4. In Buzzards Bay (Massachusetts), channeled whelk reached sexual maturity at a shell width of 89.7 mm, which is 20 mm greater than minimum legal harvest size (Peemoeller and Stevens 2013); the authors conclude that since females are harvested before they reproduce, the fishery is likely in jeopardy.

230.2. Knobbed whelk (*Busycon carica*)

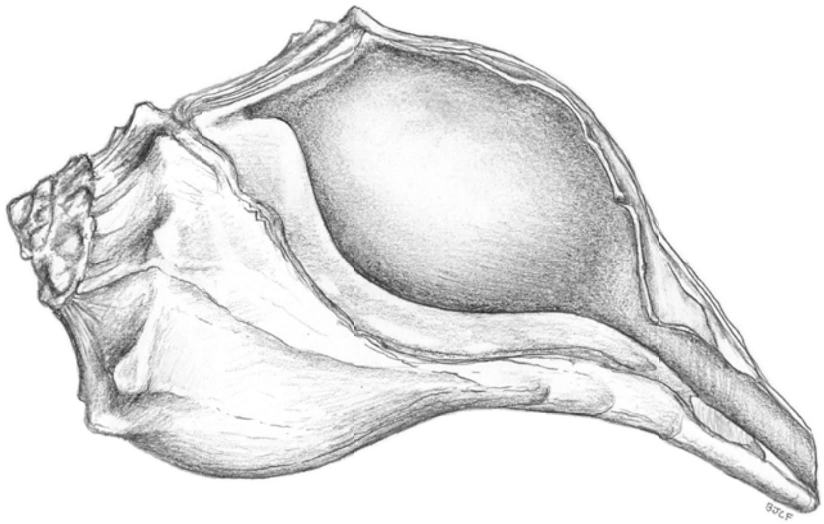


Figure 2.16. Knobbed whelk (Busycon carica), illustrations courtesy of Brandon Fuller, 2014.

1. Knobbed whelk tend to associate with mud and sand bottoms, and prefer live prey over carrion/bait (Bruce 2006), which may explain why they are less likely to enter whelk traps or pots.
2. Knobbed whelk are very adept at finding prey through chemically mediated cues, even at flow speeds as high as 15 cm sec^{-1} (Ferner and Weissburg 2005). Their slow moving nature may assist in chemical cue tracking.
3. Work done by Eversole *et al.* (2008) on knobbed whelk found that 95% of the individuals marked and recaptured over a one-month time span showed no shell growth, and that 47% showed negative shell growth due to shell loss from shell chipping, which is a common occurrence in whelk feeding on heavy-shelled bivalves such as quahogs.
4. Due to their low reproductive potential, limited movement, slow growth, and large size at maturity, knobbed whelk are highly susceptible to over harvesting (Castagna and Kraeuter 1994; Walker *et al.* 2004; Eversole *et al.* 2008).

Section 240. Ecosystem Services Provision

1. Ecosystem services are processes through which ecosystems and the species that make them up sustain and fulfill human life, providing essential life support services without which human civilization would cease to thrive (Dame 2012). Filter feeding bivalves, by the processes involved in filtering water during feeding, for instance, provide a water quality service by removing particulates in the water column. Reef building bivalves, such as mussels and oysters, provide shoreline protection services by reducing wave strength hitting the shore and thereby slowing erosional processes. The following provides a description of some of the known important ecosystem services provided by filter feeding bivalve populations.

240.1. Nutrient Reduction/Water Quality Improvement

1. Shellfish restoration, particularly for reef building species such as mussels and oysters, increases an estuaries ability to improve water quality through filtration of water by filter feeding shellfish (Needles *et al.* 2013). Asmus and Asmus (1993) conclude: "The interaction between mussel beds and phytoplankton is a key process within the material exchange between benthic and pelagic species." As major consumers of phytoplankton, a loss of filter feeder concentrations (e.g., oyster reefs, mussel

beds, quahog aggregations) in eutrophic systems provides a positive feedback mechanism for hypoxia as phytoplankton are no longer heavily consumed by the bivalves (Altieri and Witman 2006).

2. Ecosystem services provided by oyster reefs has been summarized as: (1) production of oysters, (2) water filtration and concentration of pseudofeces, (3) provision of habitat for epibenthic invertebrates, (4) carbon sequestion, (5) augmented fish production, (6) stabilization of adjacent habitats and shoreline, and (7) diversification of the landscape and ecosystem (Grabowski and Peterson 2007; Coen *et al.* 2007). The National Research Council (2005) suggests a similar listing of ecosystem services, but includes enhanced water clarity improvement and alteration of hydrography in shallow water ecosystems as it pertains to shoreline buffering.

3. Bivalves, as filter feeders, remove plankton and particulates from the water column—an adult soft-shell clam can filter 4 liters of water per hour, and an adult Eastern oyster can filter as much as 14 liters of water per hour (Bertness 2007; Rice 2001). For the Providence River, Rice *et al.* (2000) calculated a filtering capacity of 2×10^7 m^3 (5.3 billion gallons) per day (in August) by the quahog population. Newell (1988) calculated a 3.3 day clearance time[9] for the Chesapeake Bay in the late 1800s, but 325 days in 2007 due to the dramatic decline in oyster reef extent. Dame (2012) estimates that Narragansett Bay has a bivalve clearance time of 25 days.

4. Dense aggregates of bivalves can exert a controlling effect on phytoplankton abundance, resulting in improved water clarity and general eutrophication control (Alpine and Cloern 1992; Asmus and Asmus 1993; Dame 2012). As such, filter feeding bivalves serve as a critical link between primary production in the water column and the benthic ecosystem (Bertness 2007; Higgins *et al.* 2011, 2013), particularly since they do so on a consistent, long-term basis as permanent residents of the ecosystem, though impact on water quality may vary seasonally (Dame 2012). Loss of this ecosystem service in the Chesapeake Bay has been credited to have resulted in increased suspended sediments and decreased water clarity, and with those, a loss of eelgrass beds (Newell 1988; Carmichael *et al.* 2012).

5. Bivalve aggregations—oyster reefs and mussel beds for instance—are significant elements of nutrient recycling between benthos and water column (Asmus and Asmus 1993; Coen and Grizzle 2007; Dame 2012; Grabowski and Peterson 2007; Prins *et al.* 1998; Sisson *et al.*, 2011; Smaal and Prins 1993). Particulate organic matter is removed during filter feeding and returned to bottom sediments as feces and pseudofeces. Nitrogen is then recycled by sediment microbes where it is nitrified[10] for reuse by phytoplankton, or denitrified[11] and released to the atmosphere (Giles and Pilditch 2006; Sisson *et al.*, 2011; Higgins *et al.* 2013). Sisson *et al.* (2011) found that 21% of the organic N underwent nitrification, being released back to the environment for biological uptake, and 12% underwent denitrification at an oyster reef in the Chesapeake Bay. The authors do note however, that rate of nitrogen use and conversion were very seasonal (September for their work) as well as site specific, and some caution should be applied in transferring those rates to other places or times. Ammonia excretion by bivalves is rapidly taken up in the water column by phytoplankton for growth (Giles and Pilditch 2006; Newell 2004). In this way bivalve aggregates help control eutrophication while at the same time rapidly recycling nutrients to promote continued phytoplankton growth that sustains the bivalve community. Newell (2004) notes that the biggest impact to benthic-pelagic coupling will come from those species that maintain high clearance rates and produce excess pseudofeces. Smaal and Prins (1993) sum the process of benthic-pelagic coupling in shellfish aggregates as: (1) filtration of large quantities of material from the water column, (2) reduction of phytoplankton (with possible

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[9] Clearance time is the theoretical time needed for the total bivalve-suspension feeder biomass within an ecosystem to filter all particles from the entire volume of water in the aquatic ecosystem in question (Dame 2012).
[10] Nitrification is a naturally occurring process carried out by nitrifying bacteria in which ammonia, produced by the breakdown of organic materials, is converted to nitrites and nitrates which become available for use by aquatic plants.
[11] Denitrification is a naturally occurring process, performed by denitrifying bacteria, that converts nitrates back into nitrogen gas which can then be released back into the atmosphere.

local depletion), (3) biodeposition of high quality organic material, (4) remineralization of biodeposits, (5) inorganic nutrient release to the water column, and (6) increased availability of dissolved nutrients.

6. Work by Cerco and Noel (2007) on eutrophication control by oysters in Chesapeake Bay found that improvements to water clarity, while site specific, ranged from 25–100% increases in submerged aquatic vegetation biomass. Based on their model, a ten-fold increase in oyster biomass in the Chesapeake Bay would account roughly for the nitrogen added by atmospheric deposition. The authors note that while not a solution to eutrophication, increased oyster biomass can be part of an overall ecosystem-based approach to nutrient management. Newell (2004) however, points out that increased water clarity could result in increased macroalgal growth, which in turn could promote hypoxia as it dies and decays. As part of a global assessment of oyster reefs, Beck *et al.* (2009) suggest that oyster reefs should be managed for their provision of ecosystem services, not just as a harvestable commodity as is current practice.
7. Shellfish remove nutrients from the water column, and tie them up in shell and tissue. Nutrient removal however, may only be partial if harvested shellfish are consumed locally and wastes, after digestion and expulsion as human waste products, returned to the ecosystem via septic system or sewage treatment processes. Net removal of nutrients only becomes reality when shellfish are harvested and then transported out of the ecosystem (Dumbauld *et al.* 2009).
8. Newell (2004) calculated the following nutrient components for oysters—0.52 g N and 0.16 g P for a 7.6 cm oyster—3 to 4 years old—with a 150 g shell and 1 g dry tissue, which are useful in assessing nutrient removal from an ecosystem due to harvest. Evidence presented by Higgins *et al.* (2011) suggests that cultured oysters, which tend to be thinner shelled than wild oysters, will result in less nitrogen removal than that originally calculated by Newell (2004).Kellogg *et al.* (2011) give a value of 0.21% (of dry weight) for shell and 9.27% for tissue, as nitrogen content for oysters, and Sisson *et al.* (2011) give 0.15% (of dry weight) for shell and 5.96% for tissue, for quahogs. Rice (2001) estimates that 5,600 oysters harvested are the equivalent of removing the nitrogen produced by one individual human in one year, and Sisson *et al.* (2011) give a first order estimate for nitrogen removal through denitrification by oyster reefs as 103 lbs. per acre per year.
9. Shellfish aquaculture, or very dense bivalve beds, have the potential to over fertilize the benthos and reduce dissolved oxygen content (Prins *et al.* 1998), but only when found at very high densities. It is also possible that increased water column nutrient availability could result, enhancing phytoplankton growth and reducing water clarity (Dumbauld *et al.* 2009).
10. There is no clear consensus on whether or not bivalve aggregations promote nitrogen sequestration in marine sediments. Rice *et al.* (2000) note that in areas where dense bivalve aggregates exist and there is no harvest, biodeposits, such as pseudofeces, accumulate in the sediments and may increase denitrification rates and/or burial of nitrogen in benthic sediments. However, based on their findings that nitrogen is rapidly recycled in the sediments, largely as ammonia which is readily taken up by phytoplankton for growth, Higgins *et al.* (2013), and Newell (2004), conclude that oyster aquaculture does not increase, or decrease, nitrogen removal from the sediments and therefore does not provide a significant management option for storage of nitrogen in coastal sediments if they are not harvested from the environment.
11. Based on work conducted in the Chesapeake Bay, Gerritsen *et al.* (1994) found that suspension feeders (e.g., oysters) located in shallow water had a greater impact on the control of phytoplankton than those in deeper waters and that restoration (of oyster reefs) needs to be well planned to have any significant nutrient control impacts.

240.2. Habitat Provision

1. Shellfish populations establish four kinds of habitats: (1) reefs—oysters and mussels, (2) aggregations—surf clams, quahogs, (3) shell accumulations—surf clams, quahogs, and (4) aquaculture grounds (Coen and Grizzle 2007).

2. Mussel beds and oyster reefs provide a refuge from predation for infaunal organisms and influence the characteristics of the predator community, provide a refuge from physical stressors by modifying flow patterns . (Altieri and Witman 2006; Bertness 2007; Borthagaray and Carranza 2007; Coen and Grizzle 2007; Grabowski and Peterson 2007).
3. Because they create new and/or increase available niche space, species richness has been found to be significantly higher at mussel bed sites versus sites without mussel beds, regardless of exposure or tidal patterns; species richness declined as size of the mussel bed declined (Borthagaray and Carranza 2007). Rodney and Paynter (2006) found that sites with restored oyster reefs had higher species diversity for fish species and benthic macrofauna than non-restored sites.
4. Oyster reefs were found (relative to areas with no oyster reef) to have enhanced 19 species of fish—10 by enhancing recruitment and 9 by enhancing growth; pelagic bait-fish and small demersal fishes were the most enhanced species (Peterson *et al.* 2003).
5. The following points are also important when considering habitat provisioning of shellfish:
    a. Wells (1961) collected 303 different species of marine life that utilized oyster reef habitat.
    b. Reef-dwelling organisms are then consumed by transient finfish of recreational and commercial importance (Grabowski et al., 2005; Grabowski and Peterson, 2007).
    c. Harding and Mann (2001) suggested that oyster reefs may provide a higher diversity and availability of food or a greater amount of higher quality food compared to other marine habitats.
    d. Grabowski et al. (2005) found that oyster reefs constructed in soft sediments increased the growth and survival of juveniles fishes such as the black sea bass Centropristis striata.

240.3. Spawning Sanctuary

1. A spawning sanctuary is an area of the sea bottom, generally with limited access for harvesting purposes, or under outright prohibition of harvest, with the intent that existing populations of shellfish will reproduce and their larvae will settle and enhance both harvested and unharvested portions of the ecosystem. Often times spawning sanctuaries are located in Prohibited (to shellfish harvest) waters for ease of management purposes.There is no clear consensus on the utility and/or effectiveness of established spawning sanctuaries for bivalve population maintenance and sustainability in Narragansett Bay and the south shore lagoon ecosystems.
2. The entire Providence River area, historically closed to shellfishing, has been considered a *de facto* spawning sanctuary that supplies much of Narragansett Bay with quahog larvae, and is anecdotally considered by many to be an important element of a sustainable quahog fishery. Mercer (2013) suggests that Closed Areas may contribute as much as half the effective reproductive potential of the Bay. As water quality continues to improve, particularly in upper Narragansett Bay, previously closed areas may be opened to harvest, raising concern that larval supplies (of quahog) may be reduced (Leavitt *et al.* 2013).
3. Modeled runs of larval releases from various sites throughout Narragansett Bay were found to show significant variability regarding larval retention, suggesting that high adult densities do not necessarily equate to importance as a larval source in sustaining the population (Leavitt *et al.* 2013; see 220.1.2.8. for details).
4. Rice *et al.* (1989) found higher juvenile quahog densities in areas of lower adult clam densities, suggesting that spawning sanctuaries may have greatest ecological impact in reseeding areas maintained at low adults densities through harvesting.
5. In a study of quahog spawning sanctuary effectiveness in Great South Bay on Long Island (New York), Doall *et al.* (2008) reported that spawning sanctuary contribution to the population was greatest in the first year post transplant into the sanctuary, then variable afterwards (the authors note that poor clam Condition Index during transplant may be partially responsible for results).

6. Adult quahogs consume conspecifics when filter feeding (Bricelj 1992; Marroquin-Mora and Rice 2008), therefore dense concentrations of feeding adults, such as those found in spawning sanctuaries, have the potential to negatively impact larval survival and settlement.
7. Based on a comparison of quahog reproduction in fished vs. non-fished populations, Marroquin-Mora and Rice (2008), found that dense populations of bivalves, such as those typical in closed areas, resulted in lower Condition Index and reduced gonad development and reproductive output. The authors conclude that Closed Areas may have only limited value, if any, as significant larval sources to Narragansett Bay because of the reduced Condition Index associated with high density clam populations.
8. Aquaculture sites have the potential to act as sources of larvae that could assist in sustaining natural populations of shellfish or for establishing new populations.[12] Figures 2.12 (a) Narragansett Bay and (b) Salt Ponds, show the location of existing aquaculture operations in Rhode Island waters, and which may contribute larvae for establishment and/or maintenance of bivalve populations.

[12] Those operations raising triploids will not provide larval contributions as triploids are sterile.

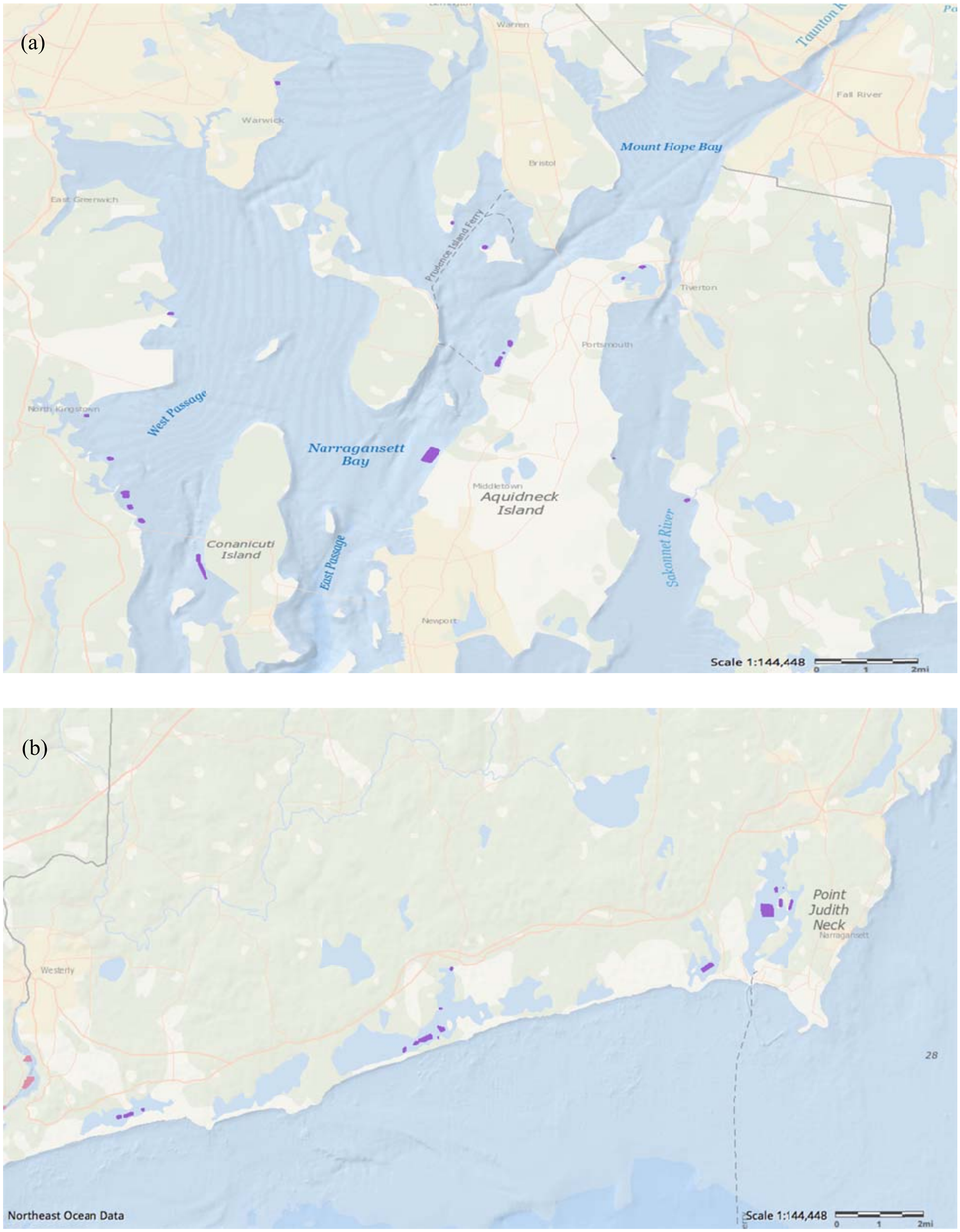

Figure 2.17. Location of aquaculture operations in Narragansett Bay (a) and Salt Ponds (b), excluding new leases as of 2014.

Section 250. Ecological Carrying Capacity

1. Shumway (2011) defines ecological carrying capacity as "… the yield that can be produced without resulting in an irreversible change to an ecosystem structure and function". An understanding of ecological carrying capacity can be used to estimate limitations of ecosystems for management purposes.

2. Byron *et al.* (2011a) developed a mass balance model that when applied to Narragansett Bay, calculated that an increase in oyster aquaculture of 625% (e.g., 0.0095 g DW m^{-2} to 5.93 g DW m^{-2}; 0.47 t km^{-2} to 297 t km^{-2})could occur before food became supply became a limiting factor in the ecosystem. At it's calculated ecological carrying capacity, approximately 26% of the Bay's surface area (1,121 t km^{-2}) would be under aquaculture use. As a point of reference, historic peak oyster biomass, which occurred in 1911, would have covered 21% of the Bay's surface if current production standards were applied (Byron *et al.* 2011a); 5% is currently the maximum allowable by state regulation (Byron *et al.* 2011c).

3. Based on modeled ecological carrying capacity, Byron *et al.* (2011b) estimate that oyster biomass could be increased by 62 times above 2010 levels in the south shore coastal lagoon ecosystems (0.233 g DW m^{-2} to 14.5 g DW m^{-2}; 11.65 t km^{-2} to 722 t km^{-2}); this is approximately 46% of total pond surface area (1,561 t km^{-2}; Byron *et al.* 2011b,c). The authors however, suggest that a target of 50% of ecological carrying capacity is a reasonable management target for the salt ponds.

4. Rhode Island currently limits aquaculture in the coastal ponds according to surface area under production, which may be misleading because changes in aquaculture technologies and methodologies may not be accounted for adequately. For instance, growers will seek to maximize their production per unit area, and if successful, can potentially exceed ecological carrying capacity that is calculated based solely upon surface area under production.

Section 260. Fished vs. Non-fished Populations

1. Oyster reefs have been referred to as "one of the most imperiled marine habitats on earth,"—an 85% reduction in oyster reefs globally (from historic levels), largely as a result of destructive fishing practices and disease, has been calculated (Beck *et al.* 2009). The decline in oysters from overharvesting (and disease) in Chesapeake Bay led to species shifts, and an ecosystem shift from suspension feeder/benthic processing domination to pelagic grazer dominated (Newell 1988; Newell *et al.* 2005).

2. Shellfish populations have been harvested in Rhode Island waters since human habitation, and by the late 1880s Goode (1881) reports on the over harvesting of oysters in Narragansett Bay. Quahogs, which became the dominant shellfish species of economic importance after collapse of the oyster industry, remained as a wild fishery. Due to water quality issues keeping large areas out of the fishery, quahog populations did not rapidly come to the same endpoint, and in 1954 the Rhode Island Department of Environmental Management began a transplant program to move quahogs from closed waters to conditionally harvested waters (Rice *et al.* 2000).

3. Quahogs in Conditionally Harvested areas in Narragansett Bay were found to mature earlier, and spawned early relative to closed areas (e.g., Providence River, Greenwich Cove; Marroquin-Mora and Rice 2008). The authors further found that Condition Index was higher in Conditionally Harvested Areas compared to closed areas, and that these areas had a clam density of about 5 clams m^{-2}, which is in agreement with optimal clam density reported by Kraeuter *et al.* (2005). Sparsis *et al.* (1992) note that bivalves in fished populations, due to larger, legal sized and/or more desirable individuals being removed, are consistently smaller and younger than those in non-fished populations; Walker (1989) concludes similarly for quahogs.

4. In a comparison of dredged vs. non-dredged clam beds, Goldberg *et al.* (2012) found that dredged beds (left fallow 3-5 years post dredging) vs. non-dredged were not significantly different with regard to a variety of species richness and species diversity indices, nor for numbers of species or numbers

of individuals of key benthic species. The authors found that season and sediment grain size had a greater influence on benthic community structure than short-term dredging impacts. DeAlteris *et al.* (1999) found that regularly harvested areas (by dredge over sand bottom) rebounded rapidly, showing little impact, while Goldberg *et al.* (2012) found that continual short-term disturbance from dredging can lead to environmental change. Conflicting conclusions suggest this is an area requiring further research effort.

5. In a study of impacts of recreational shellfish harvesting at San Juan Island (Washington), Griffiths *et al.* (2006) found that non-harvested areas had higher species diversity, and higher abundances of clam and non-clam species, than harvested sites; harvested areas experienced 400-600 user visits per year.

Section 270. Future Ecological Change

1. Ecosystems are continually changing as species respond to the pressures applied by the forces of predation and competition, and to ever changing environmental conditions. Global climate is changing rapidly in response to increased anthropogenic carbon dioxide levels in the atmosphere, and ecological change at regional and local scales is now becoming apparent.
2. Some plausible impacts to marine ecosystems from current trends in global warming have been defined: (1) increased CO_2 concentrations of 50–160%, (2) sea level rise of 0.7–1.6 m, (3) water temperature increase of 2–6°C, (4) increased precipitation, mainly in winter and spring, (5) increased intensity of precipitation received, and (6) increased intensity of tropical and extratropical cyclones (Pyke *et al.* 2008).
3. Estuarine eutrophication is expected to worsen over time as a result of climate change mediated alteration of freshwater inputs, temperature increases, and sea level rise; changes in salinity are likely to alter existing bivalve distribution and abundance (Scavia *et al.* 2002).
4. Narragansett Bay is undergoing ecological change in the face of changing climate. Fulweiler and Nixon (2009) summarize major change as a decrease in mean annual water column chlorophyll concentration—a proxy of food available to bivalves; replacement of boreal demersal fish with demersal decapods; earlier development and larger populations of a major zooplankton predator, *Mnemiosis leidyi*. The authors note a 70% decline in mean annual chlorophyll concentrations at a station located in mid-Narragansett Bay, attributing this to a change in the winter-spring phytoplankton bloom, which has become both more erratic in its time of occurrence as well as its actual occurrence, which may be linked to recent warming trends.

270.1. Warming Waters

1. Growth is generally reduced in the northern extent of a species range. For example, quahogs show optimum growth at 20°C and no growth below 9°C (Ansell 1968). Warming waters (Figure 2.13) may extend the growing season, resulting in more growth per season, though not necessarily more rapid growth (Bricelj 1992), and increasing temperatures could cause some areas to approach or exceed a species thermal maximum. Quahogs for instance, cease growth at 26ºC (Greenfield *et al.* 2005). Species will be hardest hit in those areas that make up the boundaries of their range, which is often defined by temperature (Harley *et al.* 2006). Dame (2012) suggests that major shifts in species is likely given that temperature changes are expected to be long-lived rather than episodic.
2. Shallow systems, such as Rhode Island's salt ponds, will heat faster, and could lead to reduced dissolved oxygen conditions, possibly exasperated by increased precipitation and runoff, which will enhance hypoxia/anoxia and likely impact sensitive species (Anthony *et al.* 2009). Reproductive timing of bivalves may be altered, as shallower bays and coves are reported to have earlier spawn times than deeper, cooler waters (Butet 1997). Predators may also arrive earlier as waters warm. For instance, Costello *et al.* (2006) found *Mnemiopsis leidyi*, a voracious predator of plankton, using shallow coves as over wintering sites. *M. leidyi* reproduced earlier and abundantly in the shallow coves (e.g., Greenwich Cove in Greenwich Bay), which then acted as a "source population" for a rapid population expansion of this ctenophore species throughout Narragansett Bay.

3. The Rhode Island coastal lagoons are predicted to experience significant change in the near future. An increase in air temperature of 1.9–6.9°C is expected by 2100, along with sea level rise that will cause increased incidence of barrier breaching and erosion, and extensive loss of coastal wetlands; and storms will hasten and worsen these impacts (Anthony *et al.* 2009). Seagrass will be impacted by temperature increases, increased water depth, and salinity changes, and seagrass dependent species will be impacted with resultant species shifts. Lagoon species have been found to respond to increased temperature physiologically, such as through altered feeding rates, and metabolic and growth rate changes, and it is unclear how these will be manifested in Rhode Islands south shore coastal lagoons (Vania *et al.* 2014).
4. Broad seasonal thermal shifts of temperate zones have resulted in bivalves that have broad thermal tolerance (Dame 2012). Each species however, has thermal thresholds that once approached or exceeded, because of changing climatic conditions for instance, has high potential to result in species replacement Bivalves are most sensitive to temperature during the reproductive and larval stages.
5. Some areas in Narragansett Bay, including Greenwich Cove, Warwick Cove, and Providence River, experience frequent hypoxic conditions, creating stress that results in lower clam Condition Index (Marroquin-Mora and Rice 2008). Increasing water temperatures will likely exacerbate hypoxia occurrence, further increasing stress.
6. In a study of quahog shell growth in Narragansett Bay, Henry and Cerrato (2007) found that in the 1960s to early 1970s shell growth was rapid in spring, summer and fall; slow shell growth only occurred during winter months. In the mid 1970s to early 1980s they found a shift to slower growth in summer, and by the mid 1980s slow growth was occurring frequently in summer, fall, and winter, with rapid growth only occurring in spring months. Clams collected in 2005/2006 were found to have the same shell growth patterns as quahogs collected in the late 1980s in New Jersey waters (Grizzle and Lutz 1989). The authors suggest that the 1.5°C increase in water temperature observed in Narragansett Bay causes summer water temperatures to frequently exceed 20°C, the upper limit for optimal growth of quahogs, potentially causing the trend for decreased shell growth over time. The authors also note that change in phytoplankton dynamics—change in timing and intensity of the winter-spring bloom, and phytoplankton species shifts—may play a role in changed shell growth patterns.
7. Quahog growth rate was found to be correlated to warming water temperatures, but not to chlorophyll concentrations, suggesting that change in quahog shell growth may be temperature driven (Henry and Cerrato 2007; Henry and Nixon 2008). The authors found that quahogs that settled in the 1980s and 1990s took six months longer to reach legal size (33.12 mm) than those that had settled between 1960 and 1970. The authors found reduced shell growth only in clams aged 2 years or less, and a more rapid rate of shell growth for clams 3–10 years old. The authors conclude that a shift in species dominance in the phytoplankton community may be causing the observed patterns in quahog growth rate, but that further research is needed to show if nutritional differences between phytoplankton species exists, and if that could be the driver of these changes.
8. In a study of bivalves in the Wadden Sea (Northwestern Europe), Philippart *et al.* (2003) found that warming waters decreased reproductive output and moved the spawning season earlier (for *Macoma balthica*). The authors did not find a corresponding shift in the timing of seasonal phytoplankton blooms, and so less food was available to bivalves, particularly to pelagic phase larvae. They also observed earlier spawning of a major predatory shrimp species, which would imply great predation pressure on already stressed juveniles as they settle to the benthos. The authors predict a decline in abundance of *Macoma* as a result of warming waters, noting that this could have impact upon bird populations that feed heavily on this species. Given that New England is trending towards milder winters, similar forms of ecosystem change are possible, if not likely.

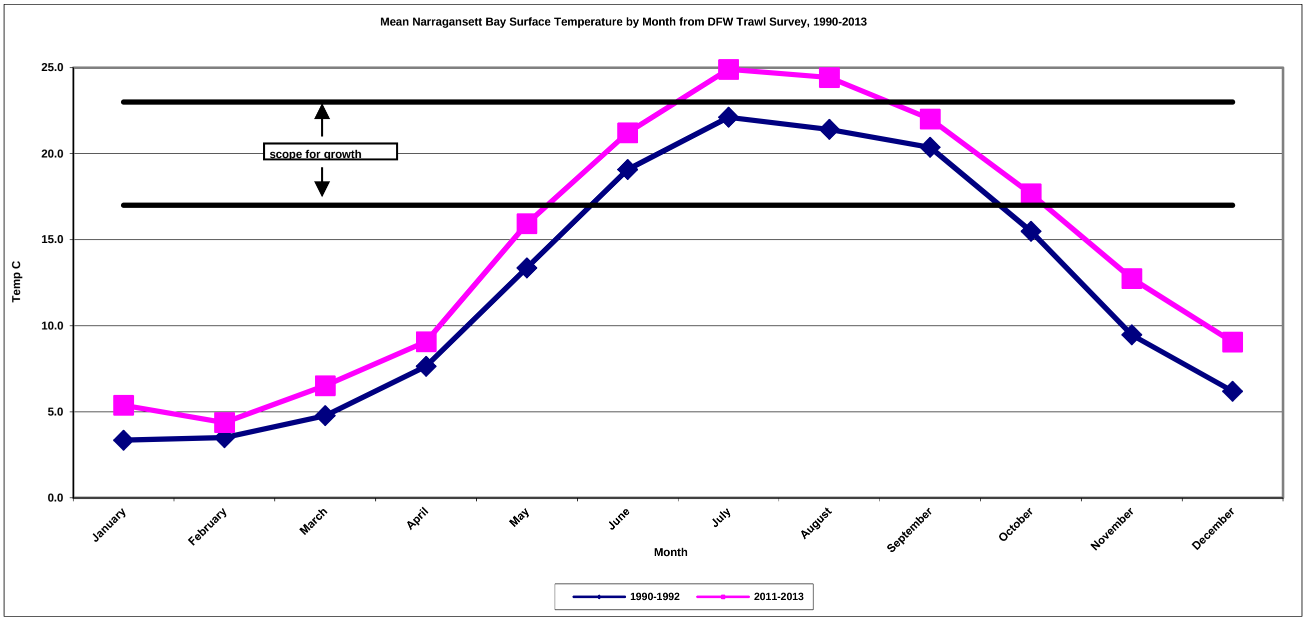

Figure 2.18. Mean surface water temperatures for Narragansett Bay, based on the DFW trawl survey between 1990 and 2013 (courtesy of RI DEM).

270.2. Changing Predators

1. Green crabs (*Carcinus maenus*) and mud crabs (*Panopeus spp*.) are significant bivalve predators in New England waters; the blue crab (*Callinectes sapidus*), while a more significant predator to the south, is a seasonally important predator (Bertness 2007) that will become more abundant, and therefore more significant as it expands its range northward as waters continue to warm (Pratt *et al.* 1992).
2. In the Wadden Sea (Netherlands) Beukema and Dekker (2005) found that a 15-year trend of mild winters has increased shrimp abundance, a major predator of commercially valuable bivalves, and attributed this as a major factor in the cockle population crash . As a result, continuing years of poor recruitment has occurred, harming the fishery for cockles significantly.
3. Henry and Nixon (2008) note that a change in Narragansett Bay from demersal fish dominance to demersal decapod dominance may play a role in observed trends in reduced quahog shell growth rates; predator preference has been shown to reduce feeding which results in reduced rates of growth in bivalves (Nakaoka 2000).

270.3. Changing Competitors

1. Long-lived, successional climax species may be challenged by short-lived, opportunistic species, especially invasive species, as changing climate mediates rapid environmental change in nearshore waters (Harley *et al.* 2006).
2. A strong correlation has been found between the successful recruitment of introduced species (e.g., ascidians) and increased mean winter temperature, and a negative correlation between increased winter water temperature and the success of native species recruitment (Stachowitcz *et al.* 2002). Given that community composition is often a result of "who gets there first in the greatest numbers," introduced species have a distinct advantage; the authors found recruitment of introduced species was three times greater than native species (at Avery Point, Groton, Connecticut) after the warmest winter, while native species recruitment was five times higher after the coldest winter (the difference between warmest and coldest winter was 3°C). It is important to note that correlations were not evident through the observation of mean annual temperatures, indicating the importance of seasonality. The authors also found more rapid growth of introduced species in warmer waters, and they conclude that

it is likely to see an increase in invasive species in the future, with a resultant decline in native species as waters continue to warm.

270.4. Increased Precipitation

1. Uncertainty exists around changes in regional patterns, but there is agreement on increased extreme rainfall events and drought-flood cycles, which could impact salinity regimes and hypoxia onset, depending upon timing and extent (Anthony *et al.* 2009).
2. Quahogs find a refuge to predation in waters undergoing hypoxic conditions, suggesting that clams are more hypoxia tolerant than their major predators found in Narragansett Bay (Altieri 2008). However, the improvement in survivorship is small, and the relationship does not necessarily hold for other species of bivalves. For instance, Altieri and Witman (2006) report mass mortality and local extinction of mussels in Narragansett Bay due to severe hypoxia.
3. Ocean circulation patterns may change as wind patterns shift with changing climate; this could alter distribution patterns of species that have planktonic larvae (Harley *et al.* 2006).
4. In a study of larval transport in Narragansett Bay, Leavitt *et al.* (2013) note the importance of the spring freshet in driving estuarine circulation. As climate change brings altercations in timing, type, and volume of precipitation to New England, circulation patterns in Narragansett Bay may change, and in so doing, alter the patterns of quahog (and other marine organisms) larval distribution. Pilson (2008) predicts changing wind patterns over Narragansett Bay as a result of warming climate, which will also likely effect circulation and larval drift.
5. Surface water runoff events to coastal waters, which carry carbonic acid from organic decomposition, have been correlated with episodic reduced pH events, which create suboptimal conditions for shell growth in bivalves (Salisbury *et al.* 2008). The authors note that increased precipitation could promote poor growth conditions for bivalves in coastal waters.

270.5. Disease

1. *Haplosporidium nelsoni* (MSX) and *Perkinsus marinus* (Dermo), two key oyster parasites of concern that at present are found in low concentrations in Rhode Island waters, have both shown recent northward expansion (Andamari *et al.* 1996; Hoffman *et al.* 2001). Both parasites affect oysters maximally during summer months (June to October), generally by reducing feeding rate and growth, though extreme infection can lead to mortality (Barber *et al.* 1988).
2. *Dermo* has been noted to be making a steady northward progression while MSX is moving northward in an irregular and patchy fashion (Hoffman *et al.* 2001). The authors suggest this pattern may be a result of Dermo being transmitted oyster-to-oyster while MSX is though some as yet to be identified intermediate host. The authors further note a positive correlation between MSX abundance and preceding winter temperatures; given that New England winters are warming faster than summers, MSX may find favorable conditions for spreading in this region.
3. *Vibrio* are naturally occurring estuarine bacteria that are capable of impacting human health. To date Rhode Island outbreaks have been rare (e.g., 1981; Cox and Gomez-Chiarri 2013), but *Vibrio* abundance has been found to be correlated to water temperature (Cox and Gomez-Chiarri 2012). As water temperatures continue to rise as a result of climate warming, increased incidence of *Vibrio* may follow.
4. Rhode Island took a proactive stance against *Vibrio* in 2014; through collaboration between the aquaculture industry, state and federal agancies, Universities, and facilitated by CRC, the state created the first Vibrio Control Plan for oysters (See Appendix 7.1).

270.6. Ocean Acidification

1. While there is great uncertainty regarding the effects of ocean acidification on coastal ecosystems (Royal Society 2005), pH has declined by 0.1 units[13] since 1760, and is expected to decrease another 0.1–0.5 units, or by 0.3–0.4 units in this century (Orr *et al.* 2005; Miller *et al.* 2009; Waldbusser *et al.* 2010). Estuaries and shallow coastal waters will be most susceptible to pH changes (Miller *et al.* 2009), and higher latitudes will see the greatest changes in pH (Pelejero *et al.* 2010). Pelejero *et al.* (2010) make note that surface pH is already more acidic than it has been in the past 20 million years, and that by the end of the century pH conditions that have not been experienced in the past 40 million years are likely. Talmage and Gobler (2009) report that some coastal areas (e.g., Shinnecock Bay, Long Island, New York) are already experiencing conditions that experiments on increased ocean acidification show are detrimental to bivalve prosperity. Impacts to bivalves are being reported as occurring at pH values as high 7.8 (Clements and Hunt 2014); the authors suggest that such conditions are more common than considered and likely play a role in globally decreasing bivalve populations. Green *et al.* (2013) report similarly, finding conditions in South Portland Harbor (Maine) that promote shell dissolution[14].
2. In coastal waters, organisms that use calcium carbonate ($CaCO_3$) to secrete shells will be impeded in the process of calcification as pH decreases, finding it more difficult to secrete shell material (Royal Society 2005). Furthermore, as ocean water acidifies (e.g., pH decreases), secreted shell material becomes more susceptible to dissolution. If shell secretion takes greater energy input, and maintenance of shell becomes more onerous as dissolution increases, then it can be expected that bivalves may see reduced growth and/or reduced reproductive output because of these energy diversions. These impacts may be felt the greatest by bivalve larvae (Talmage and Gobler 2010, 2009), which are highly susceptible to ocean acidification, particularly at the point where they take up a benthic life style where mortality can already reach as high as 98% (Royal Society 2005). Clements and Hunt (2014) found that soft-shell clam juveniles were less enticed to burrow into sediments with a reduced pH (e.g., 6.8–7.8), and that dispersal rates (via transport just above the bottom) were increased. This suggests that changing pH in shallow water marine sediments will play a role, perhaps major, in bivalve distribution patterns.
3. Shell dissolution mortality is size dependent for quahogs—clams of 0.2 mm size saw 90% mortality from shell dissolution while other size classes saw 50% mortality when tested under acidification conditions likely to be experienced in shallow, New England coastal waters (Green *et al.* 2009). The authors note that they found shell dissolution at 2 sites in Casco Bay (ME), and that surface sediments where juvenile bivalves settle after metamorphosis is exactly where pH concentrations in the sediments were lowest (Green *et al.* 2013). Waldbusser *et al.* (2010) found that all size classes of quahogs tested (0.39–2.90 mm shell height) were effected by increased CO_2/reduced pH, but that smallest sized clams were the most impacted. Smallest sized clams for instance, were unable to secrete new shell and some saw shell dissolution. Beniash *et al.* (2010) found that at pH levels around 7.5 juvenile Eastern oysters exhibited increased mortality rates, and that shell structure was reduced in hardness and was more prone to fracturing (than oysters kept at pH 8.5).
4. In a study conducted in Rhode Island waters, Still and Stolt (in review) found that despite high variability in subaqueous soil pH (e.g., 7.35 in highly organic soils to 7.97 in sandy soils), some areas already have pH soil conditions that can induce physiological stress, shell dissolution and mortality

[13] pH is a measure of the acidity (or basicity) of a solution; a pH less than 7 is acid, more than 7 is alkaline, and 7 is neutral. pH is measured on a logarithmic scale, meaning that an increase in pH of 1 is a ten-fold increase in concentration; an increase of 2 pH units is a 100-fold increase, and 3 pH units the equivalent of a 1,000-fold increase. Because of this, even small changes in pH equate to large changes in acidity (or alkalinity).
[14] Shell dissolution is the process of the calcium carbonate, which makes up bivalve shell material, dissolving as a result of being in a corrosive environment, such as that created at the sediment water interface as pH decreases.

on recently set juvenile bivalves. The authors recorded subaqueous soil pH values (from pooled samples taken in the upper 5 cm) of 7.20–7.95 in
Greenwich Bay, 7.33–8.10 in Ninigret Pond, 7.08–7.82 in Quonochontaug Pond, and 7.03–7.78 in Wickford Harbor. At one location in Ninigret Pond that was a site of groundwater input to the pond, the authors measured a pH of 6.42 in the upper 2 cm, and they noted a 10-fold increase in shell loss (e.g., shell dissolution) at this site when compared to shell loss in sandy subaqueous soils. pH measurements during this study were taken during summer months, a time that coincides with bivalve settling times in Rhode Island waters.

5. While such conditions are not predicted over the next few centuries, Kurihara *et al.* (2008) found that CO_2 levels elevated to 2,000 ppm (approximately 380 ppm today; 1,000 ppm by 2100; Royal Society 2005) had significant impacts on larval development of mussels; only 0.2% developed into normal D-shaped larvae. Gazeau *et al.* (2007) found a 25% decrease in mussel calcification rate at the 740 ppm CO_2 concentration predicted for 2100, and found that mussel shell dissolved at 1,800 ppm. Kurihara *et al.* (2007) found that only 4–5% of oyster embryos developed into normal larvae when exposed to CO_2 levels predicted by 2300.
6. Increased mortality of quahogs and bay scallops was observed at increased levels of CO_2 approximating future conditions (950–1,500 ppm; Talmage and Gobler 2010). Decreased shell thickness, altered shell hinge structure, and shell pockmarking with holes and/or actual shell dissolution was also observed. The bay scallop was more susceptible to increasing ocean acidification than was the quahog, and both were more susceptible than the Eastern oyster (Talmage and Gobler 2009).
7. Susceptibility to increased CO_2/reduced pH may be at least partially mediated by genetics. Waldbusser *et al.* (2010) found differing abilities of quahogs taken from differing sources to calcify shell. This may be an important consideration for restoration and/or aquaculture of this species.

270.7. Nutrients

1. Lagoon ecosystems will be particularly vulnerable to eutrophication impacts of climate change due to the restricted nature of their openings and how tidal exchange is limited (Lloret *et al.* 2008). The authors postulate that as water depth increases (from sea level rise) and turbidity increases (from increased runoff) that photic depth will decrease and dominant macroalgae will decline, converting the ecosystem to one that is plankton dominated.
2. Based on nitrogen enrichment patterns in quahogs, Oczkowski *et al.* (2008) suggested that Narragansett Bay clams feed upon phytoplankton grown in the upper bay on anthropogenic nitrogen, and therefore the majority of their food is from sewage derived nitrogen. One analysis of the planned 50% reduction in nitrogen from Upper Bay Waste Water Treatment Facilities during the summer months suggest some decline in clam productivity in Narragansett Bay. However, it should also be mentioned that decreasing nitrogen and increasing dissolved oxygen will likely increase larval survivability and may increase secondary productivity. Note that the state's dissolved oxygen standard is established based on data and analysis aimed at increasing larval survivability.
3. Those ecosystems most likely to show favorable conditions for eutrophication control will be shallow in depth, have an abundant nutrient supply, no critical light, temperature or turbidity limitations, be poorly flushed, and have a dense filter feeding community comprised of small animals (Officer *et al.* 1982).

270.8. Harmful Algal Blooms

1. Paralytic shellfish poisoning (PSP), diarrhetic shellfish poisoning (DSP), neurotoxic shellfish poisoning (NSP), and amnesic shellfish poisoning (ASP), are all associated with various harmful algal blooms that impact shellfish populations (Shumway 1990). While the toxins associated with bloom organisms do not directly (or rarely) effect the bivalves ingesting them, the algal species may

be of poor food quality (Shumay 1990) and/or may elicit a reduced feeding response (Tracey 1988), either of which stresses bivalves.

2. *Alexandrium* species are the most common PSP organisms found in Rhode Island waters, but have not yet increased to bloom proportions, though outbreaks are becoming both more common and more severe in the New York Bight region (Borkman *et al.* 2012). Borkman *et al.* (2012) report the presence of a new species, *Alexandrium peruvianum*, which could be a public health threat as it produces fast acting toxins, and favors near shore, low salinity, high nutrient habitats.
3. Brown tide events in 1985 and 1986 had severe impacts on scallop abundance, and Brown (1991) reports these events to be the cause of elimination of bay scallop populations in Rhode Island in all but a few isolated areas.
4. Although present, toxins that cause Diarrhetic Shellfish Poisoning (DSP) were not found to be a significant problem in Narragansett Bay waters (Maranda and Shimizu 1987).Section 280. Recommendations

Section 280. Recommendations

1. The Technical Advisory Committee (TAC) for this chapter developed a comprehensive, non-prioritized list of recommendations relating to the ecology of shellfish based on the extensive list of issues identified by stakeholders throughout the SMP process (Appendix 2.2). These recommendations can be found in Chapter 11.
2. The TAC coordinators were Azure Cygler, CRC/URI and Alan Desbonnet, RISG. The TAC for this chapter had six members:
   - Candace Oviatt, GSO/URI
   - Carrie Byron, UNE
   - Tom Uva, NBC
   - Alan Desbonnet, RISG
   - Robbie Hudson, STB
   - David Ullman, GSO/URI

   Decisions to include any recommendation put forth by the TAC was made by consensus then discussed through the SMP Coordinating Team.
3. The list of recommendations represent the initial steps to identify actions necessary to improve the way the shellfish resource and associated activities are managed in Rhode Island for the benefit of all. As such, every stakeholder group – including management agencies, industry, civic and environmental organization, and citizens – is responsible for accomplishing the listed recommendations. The recommendations do not discuss logistical items (i.e. funding, lead person/group); these items will be addressed in the SMP implementation plan and research agenda that will follow the SMP document. These recomendations are not prioritized or ordered in any way.
4. While the recommendations are all considered important and can benefit the shellfish resources/industry in many ways, it is important to note that the state agencies will need to prioritize these recommendations due to strained resources. In addition, 2015 will mark changes in administration due to the 2014 elections, which will bring new priorities which are a challenge to foresee and plan for. Therefore, while it is the hope and intention of the SMP that these recommendations will be implemented, it is likely that challenges such as funding sources, shifting government leadership, etc. will lead to prioritization of these recommendations.

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CHAPTER 3. The Biology of Shellfish in Rhode Island

By Dale Leavitt, Roger Williams University

Section 300. Introduction

1. The purpose of this chapter is to outline and describe the biological characteristics of the commercially and recreationally important shellfish species described in the SMP. Descriptions for each species also includes habitat preferences, overview of the ecology, and population dynamics. In addition, this chapter offers detailed descriptions and background information on issues identified by stakeholders that relate to the biology of shellfish. Recommendations for management and research are included in this chapter.

2. Effective shellfish management is contingent on a reasonable understanding of the biology of each of the species being managed. Knowledge of the life history of a species coupled with an understanding of the role that environment/ecosystem plays in the development of the shellfish population leads to an ability to predict population trends and to manage harvest rates that allow for a sustainable supply of product in the long-term. This chapter will summarize our current state of knowledge with respect to biology of the shellfish species that are the focus of this management plan, namely: Those species currently being harvested commercially in Rhode Island waters:

   - Quahog (*Mercenaria mercenaria*)
   - Soft Shell Clam (*Mya arenaria*)
   - Blue Mussel (*Mytilus edulis*)
   - Channelled (Smooth) Whelk (*Busycotypus canaliculatus*)
   - Knobbed Whelk (*Busycon carica*)

   e. Those species that have historically been harvested commercially in Rhode Island waters:

   - Eastern Oyster (*Crassostrea virginica*)
   - Bay Scallop (*Argopecten irradians*)

   f. Other species that may be targeted with future fishing efforts:

   - Razor Clam (*Ensis directus*)

Section 310. Issues Identified by Stakeholders

1. Throughout the Shellfish Management Plan (SMP) development process, the SMP team has met with stakeholders to identify issues and concerns regarding all aspects of shellfish, including but not limited to environmental issues, management, marketing, capacity building, and decision making. The following are the major themes concerning the biology of shellfish that stakeholders have identified (a full list of all issues identified by stakeholders can be found in Appendix 2.2). There is a need to:

   a. Collect and share more information about the biology of the important commercial and recreational shellfish species in Rhode Island.

   b. Better delineate the objectives of shellfish management in the state, including the scale managers are operating on, differentiating management of the Bay and salt ponds, etc.

   c. Better understand the relationship between habitat, resource density, population composition, and larval production in shellfish.

   d. Understand shellfish size variability and economic return to the fishermen and state as a whole.

   e. Improve our overall knowledge of the spatial distribution of shellfish in the state.

   f. Better understand concerns such as: optimizing post-set survival of shellfish, using wild stock for aquaculture, predation, maintaining genetic diversity, and natural mortality.

g. Investigate and improve management of spawner sanctuaries and broodstock enhancement in the state.

h. Investigate shellfish pests and environmental change, as well as understand and mitigate various human health risks.

Section 320. Mollusk Anatomy

1. All of the species identified as important in the development of the RI Shellfish Management Plan are in the phylum Mollusca. As such, they all have a body plan that is similar, as it was derived from the same ancestral form (Figure 3.1). The primary difference between the bivalve mollusks (clams, oysters and scallops) and the gastropods (the two whelk species) is their feeding preferences. Bivalve mollusks are filter feeders and utilize their gill apparatus as a tool to filter very small food particles (such as phytoplankton) from the water column as they move water across their gills. The food particles are then transported to the mouth for ingestion. Whelks are carnivorous gastropods and use their shell and foot to break into a variety of clam, mussel and oyster species where they consume the soft tissue for nutrition.

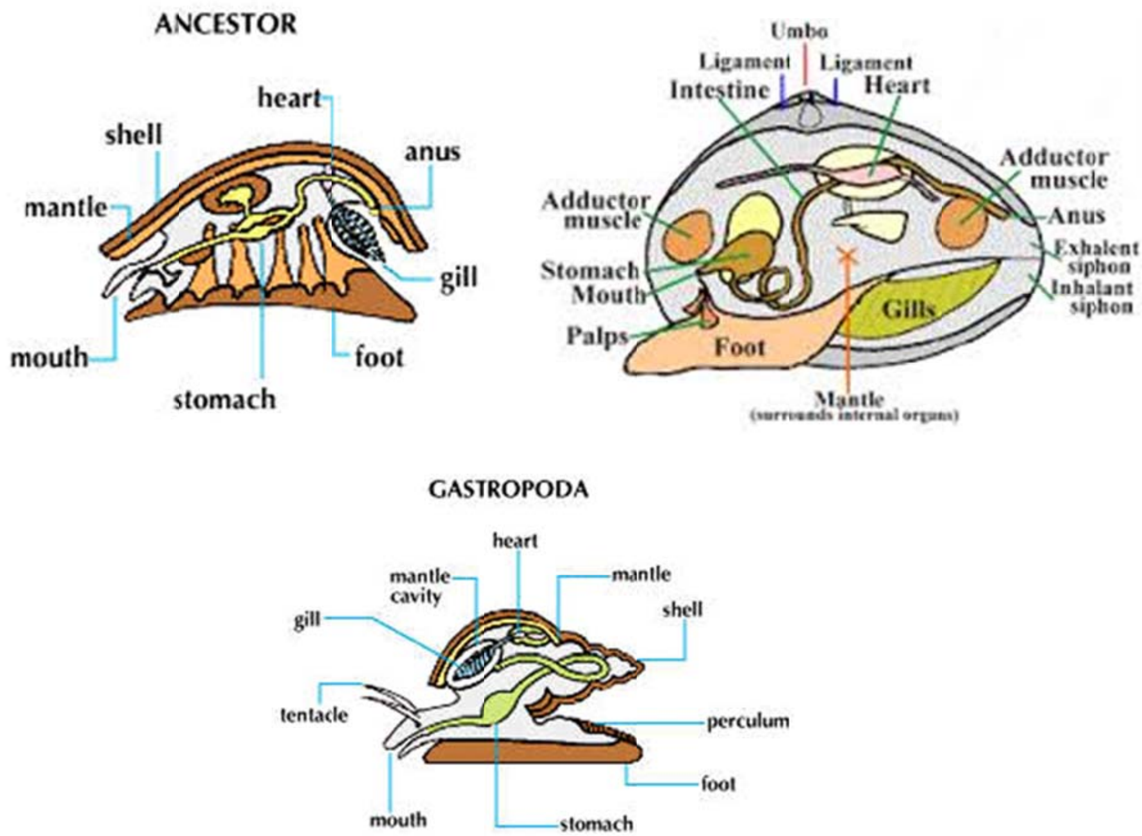


Figure 3.1. The anatomical relationship between an ancestral mollusk and modern-day bivalves and gastropods.

320.1. Generic life history stages of gastropod and bivalve mollusks

1. All animals in the Phylum Mollusca undergo a similar reproductive and development sequence that starts with the production of sperm and eggs and ends with the development of a reproductively active adult. The general development stages are identified in the schematic included as Figure 3.2.

2. Reproductive strategies in mollusks range from dioecious (separate male and female sexes throughout their life) to monoecious (having both sexes in the same organism – hermaphroditic) to individuals

that change sex as they age (often changing from male to female – protandrous). With the exception of the whelks, the majority of shellfish are broadcast spawners, in that they release their eggs and/or sperm into the water column where fertilization occurs following the chance encounter of a sperm with an egg. As such, an important factor in reproductive success of wild shellfish is the number of gametes released (usually characterized by overall egg production) and the relative nearness of one gamete to the other, often a function of the density of the adults in the environment or the pattern of water movement over the spawning population. The unique reproductive characteristics of the shellfish emphasized in this document are included in Figure 3.2.

3. As noted previously for the clams, oysters and scallops, egg and sperm are released into the water column where fertilization occurs as the two gamete types encounter each other. Once fertilized, cell division begins, leading to the formation of a multicellular, free-swimming non-feeding trochophore stage, usually within 12-24 hours of fertilization. The trochophore will rapidly start to produce a shell and a specialized structure for locomotion and feeding (the velum) as the larva transforms into a veliger in about 36-48 hours. In a series of transformational changes, the free-swimming larvae progresses through multiple veliger stages before acquiring a foot (the pediveliger) and beginning to search for an appropriate place to settle out. It is during this free-swimming phase, which can last up to 4 weeks depending on species and environment, that larvae are transported and dispersed around the bay or coastal pond, by way of wind and water currents. The duration of the free-swimming veliger stages for each of the relevant species are included in Table 3.2.

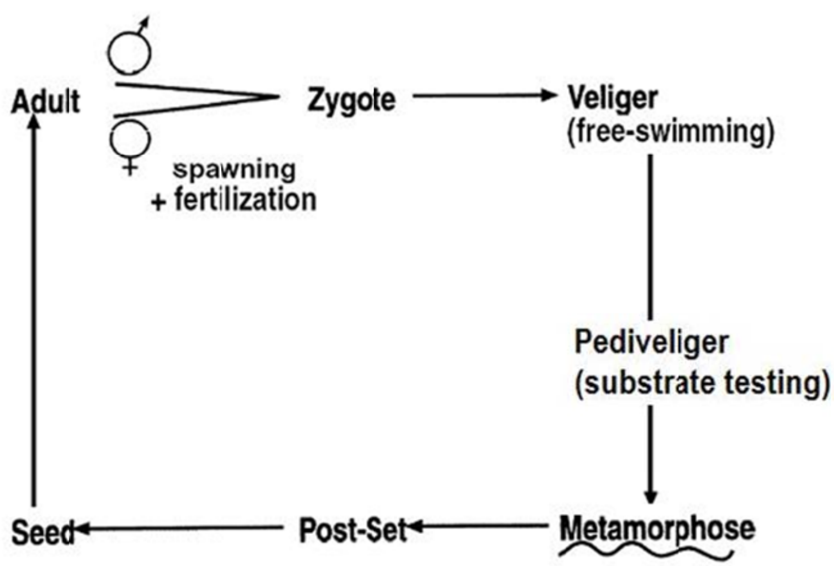
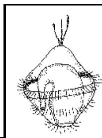
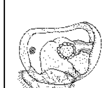
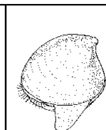
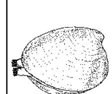


Figure 3.2. A generalized schematic of the developmental stages of a mollusk.

Table 3.1. Summary of the reproductive characteristics of commercially important shellfish in Rhode Island.

Common Name	Genus/Species	Longevity	Reproductive Strategy	Age at first spawn	Length at first spawn	Range of Egg Production	Reproductive timing in RI	References
Quahog	*(Mercenaria mercenaria)*	up to 46 years	Protandrous	2nd year	22 to 37 mm	1.6 to 24.6 x10^6	early June to late July	Bricelj 2002; Rice 2002
American Oyster	*(Crassostrea viginica)*	up to 20 years	Protandrous	♂ - 1 year ♀ - 2 years	> 35 mm	0.01 to 66 x 10^6	early June to late July	Kennedy 2009; Loosanoff 1965
Soft Shell Clam	*(Mya arenaria)*	up to 28 years	Dioecious	2nd year	29 - 30 mm	1.0 to 3.0 x10^6	early May	Newell & Hidu 1986; Belding 1910
Bay Scallop	*(Argopecten irradians)*	2 - 3 years	Hermaphroditic	2nd year	variable	0.5 to 1.0 x10^6	June	Leavitt & Karney 2005
Blue Mussel	*(Mytilus edulis)*	18 - 24 years	Dioecious	2nd year	> 25 mm	8.0 to 10.0 x10^6	April to May	Newell 1989; Newell *et al.* 1982
Razor Clam	*(Ensis directus)*	3 - 7 years	Dioecious	15 years	80 mm	≤ 12.0 x10^6	April to May	Kenchington *et al.* 1998; Cardoso *et al.* 2011
Smooth (Channeled) Whelk	*(Busycotypus canaliculatus)*		Protandrous?	♂ -6.9 years ♀ -8.6 years	155 mm	20 - 50 eggs per capsule; 20 - 150 capsule's per string	June through September	Magalhaes 1948; Peemoeller and Stevens 2013
Knobbed Whelk	*(Busycon carica)*	85 years	Protandrous?	3 - 5 years	146 mm	34 - 35 eggs per capsule; 100 - 120 capsule's per string	June through September	Magalhaes 1948; Angel 2012

Table 3.2. The approximate duration of the larval stages of shellfish important to Rhode Island waters. The duration of each stage is influenced primarily by environmental temperature and food availability.

Common Name	Genus/Species	 Trochophore	 D-stage veliger	 Umboned veliger	 Pediveliger	 Metamorphosis	Rearing temperature; Reference
Quahog	*(Mercenaria mercenaria)*	12 - 24 h	1 - 5 d	3 - 15 d	8 - 20 d	10 - 21 d	@ 24-28°C; Hadley & Whetstone 2007
American Oyster	*(Crassostrea virginica)*	12 - 20 h	20 - 48 h	6 - 7 d	10 - 12d	14 - 21 d	@ 21-21°C; Stallworthy 1978
Soft Shell Clam	*(Mya arenaria)*	12 - 24 h	1 - 5 d	6 - 7 d	10 d	10 - 35 d	@ 19-24°C; Loosanoff & Davis 1964
Bay Scallop	*(Argopecten irradians)*	12 - 24 h	17 - 48 h	5 - 6 d	10 d	10 - 14 d	@ 23°C; Leavitt & Karney 2005
Blue Mussel	*(Mytilus edulis)*	5 - 24 h	1 - 3 d	8 - 12 d	24 - 30 d	25 - 30 d	@ 15°C; Hayhurst 2001
Razor Clam	*(Ensis directus)*	12 - 15 h	1 - 4 d	5 - 7 d	8 - 12 d	13 - 16 d	@19°C; Flanagan 2013

4. Setting (metamorphosis) in bivalves is often stimulated by the exposure of a pediveliger that is competent to metamorphose to a specific habitat type. The setting cues vary with the species and our current state of knowledge is summarized in Table 3.3. When appropriate habitat is encountered, the pediveliger will attach itself to the substrate, normally through the action of byssus threads (except for oysters who cement to the substrate on their left valve), and will transform to the adult body form by resorbing the velum, developing gills and undergoing other morphological changes. With setting, the shellfish leave the larval phase and enter into the juvenile stage of development, defined as post-metamorphic but prior to reproductive maturity, commonly referred to as "spat".

Table 3.3. Setting cues for the shellfish species included in Chapter 3.

Common Name	Genus/Species	Setting Preference	Reference
Quahog	*(Mercenaria mercenaria)*	mud/sand substrate is preferred with low silt/clay and organic content	Mulholland 1984
American Oyster	*(Crassostrea virginica)*	hard substrate, preferably shell material	Kennedy 1996
Soft Shell Clam	*(Mya arenaria)*	soft muds, sands, compact clays, coarse gravel, and cobble - sandy mud preferred	Newell & Hidu 1986
Bay Scallop	*(Argopecten irradians)*	seagrass beds or similar structure	Belding 1930; Fay *et al* 1983
Blue Mussel	*(Mytilus edulis)*	stable hard substrate	Newell 1983
Razor Clam	*(Ensis directus)*	coarse sand	Flanagan 2013

5. The exception to the general reproductive cycle outlined above occurs with the whelks. Both whelk species reproduce via internal fertilization followed by the production of an elongated egg mass consisting of individual capsules linked together in a string and anchored to the substrate by a series of empty capsules. The multiple larval development stages occur within the capsule, where the larvae progress using non-fertile eggs as a nutrient source. The juvenile post-metamorphic whelks emerge

from the egg capsules through an exit port in the side of the capsule. With this form of development, the dispersal of crawling juvenile whelks is much more limited than that of bivalves, which are free-swimming for up to 4 weeks during early development. On average, both whelk species deposit 20 to 50 eggs per capsule with a string consisting of 20 to 150 capsules.

6. With the exception of the oyster which permanently attached to the substrate they have chosen, the bulk of our shellfish species have the capacity to continue to change location as they grow through the juvenile stage. Some have the capacity to actively move by swimming (bay scallop and razor clam) or "walking" with their foot (mussel and quahog) while others can initiate a passive mechanism for movement, including incorporation into the sediment bedload transport associated with tidal currents (soft shell clams or quahogs) or forming a tool for dragging in the current (byssal drifting in razor clams). Although the details of why a juvenile shellfish may initiate movement are not well understood, it is assumed that the environmental conditions associated with the initial settlement site may not be appropriate and the shellfish can initiate their variety of dispersal tools to change their location based on the chance of landing at a more suitable site. In general, as an individual clam grows larger, their ability to move becomes more restricted such that large-scale movement in adults is rarely observed.

7. Growth in individual shellfish, from larva to adult stages, is dependent on a variety of factors that mostly can be impacted by water quality parameters, such as temperature, dissolved oxygen or salinity, and food availability. Water temperature in these ectothermic animals (animals whose body temperature varies with the environment) controls the rate of metabolism and many other important biological processes, such as filtration and feeding rates. As such, shellfish growth rate varies seasonally with the fastest growth rate occurring within the range of water temperatures described as optimal for the species and the growth progressively decreasing as the temperature moves away from the optimal range. Salinity and dissolved oxygen have much the same affect on growth as conditions shift away from optimal ranges; however, these salinity changes are generally not observed as seasonal variations and while dissolved oxygen exhibits seasonal variation, summer low oxygen levels are associated with specific environmental events, such as episodes of heavy rainfall or degradation of eutrophic plankton blooms.

8. Food availability for filter feeding shellfish is a function of the plankton quality and flux. Plankton quality reflects the nutrient composition of the single-celled alga as well as the physical characteristics of the filtered particle; for example, filter-feeders target specific size ranges of particles for ingestion. Plankton flux is a function of the density of the microalgal particles in the water column combined with the rate at which the particles are available to the animal for filtration, i.e. the flow of particles across the siphonal intake of the individual shellfish. Many factors influence food flux, including the level of primary productivity in the water body, the water flow characteristics associated with the location where the shellfish settled, and the density of competing filter-feeding organisms in the vicinity of the individual clam, oyster or scallop. Situations such as reduced water flow, low plankton productivity or high densities of filtering organisms in the neighborhood, can all lead to a reduced availability of food for an individual resulting in slower growth.

9. The exception to a general discussion on mollusk feeding is the predatory gastropods, the whelks (*Busycotypicus canaliculatum* and *Busycon carica*). Rather than filter food particles from the water column, these two snails are active predators and scavengers that have a mouth part (proboscis) adapted for inserting into a mollusk that has been opened slightly and initiating a (presumptive) toxin-mediated release of saliva that relaxes and/or kills the prey and allows the valves to be opened further, to the point where the radula can tear off sections of prey flesh for ingestion. The strategy for initially opening the prey varies depending on the overall morphology of the shellfish (Carriker 1951). If it is a bivalve that cannot completely seal shut its valves (e.g. soft shell or razor clam) then the proboscis has easy access to the soft tissue once the whelk grasps the valves of the prey with its muscular foot. If the bivalve can tightly seal its valves shut (i.e. quahog or oyster), the whelk grasps the valves with its foot and waits for the bivalve to gape slightly as the bivalve starts to pump respiratory currents following the disturbance. As the bivalve gapes, the whelk inserts the edge of its shell beak into the

gap, wedging the valves open. With this foothold, the whelk works the valves open by prying until it can insert its proboscis into the valves and relax the adductor muscles of the clam or oyster further. Another strategy reported for the whelks is to hold the bivalve in its foot and hammer at the ventral margin of the shell to chip away the thinner edge of the shell and gain access to the soft tissue by breaking open a gap in the shell margin. This has consequences to the predator, in that it also break the shell of the whelk such that often it has been reported that during some time growth observations, the whelk does not grow and it is proposed that the energy normally applied to growth is reallocated to shell repair resulting in zero size increase over time (Castagna and Kraeuter 1994).

10. The overall effects of changes in the growth patterns of shellfish can impact such important shellfish population/management parameters as recruitment into the fishery, i.e. attainment of a legal size threshold; age and/or size at first reproduction; fecundity; and life expectancy. While not all projected changes in the environment are negative, for example increased water temperature may lead to more rapid shellfish growth resulting in earlier recruitment into the fishery, they are changes that will need to be recognized and accounted for as shellfish management strives to improve the production of shellfish resources in Rhode Island.
11. Before delving into the aspects of shellfish biology that directly affects issues identified as important to the management of shellfish in Rhode Island, a quick summary of the unique attributes of each of the important shellfish species are presented below.

Section 330. Unique Attributes of Shellfish Species Important to Rhode Island

330.1. Quahog (*Mercenaria mercenaria)*

(Stanley & Dewitt 1983, Eversole 1987, Pratt *et al.* 1992, Whetstone *et al.* 2005)

Other common names: hard clam, hard-shelled clam, round clam, littleneck clam, top neck clam, cherrystone clam, and chowder clam.

Table 3.4. Environmental conditions reported for the quahog (Mercenaria mercenaria).

TEMPERATURE **Culture Stage**	Overall Range (°C)	Optimal Range (°C)
Spawning	20.0 - 30.0	26.0
Larval rearing	15.0 - 33.0	22.5 - 26.6
Juvenile to Adult	0.0 - 35.0	20.0 - 31.0
SALINITY **Culture Stage**	Overall Range (ppt)	Optimal Range (ppt)
Larval rearing	15.0 - 35.0	20.0 - 32.5
Juvenile to Adult	10.0 - 35.0	24.0 - 32.0
DISSOLVED OXYGEN **Culture Stage**	Critical Levels (mg/L)	
Larval growth	>2.4	>4.2
Juvenile to Adult	>1.0 (for up to 3 weeks)	
pH **Culture Stage**	Overall Range	Optimal Range
Larval growth	6.75 - 8.75	7.50 - 8.50
TURBIDITY **Culture Stage**	Critical level (mg/L)	
Larval growth	<750	
WATER FLOW **Culture Stage**	Optimal flow (cm/s)	
Juvenile to Adult	30 - 50	
SUBSTRATE	Sand, mud, shell, gravel mixtures	

1. *Range*

   The native range of the quahog is from the Gulf of St. Lawrence to Texas with a peak in abundance from Cape Cod, Massachusetts to Virginia. It has been successfully introduced into California (Crane 1975), Hawaii (Ziegler 2002), Europe (Richardson & Walker 1991) and China (Chang *et al.* 2002).

2. *Morphology and Identification*

   This clam has a thick shell with short siphons and sometimes has a purple band on the ventral margin of the inside of the shell. It can grow up to 130 mm with morphometric ratios of length/height: 1.25, and length to width: 1.90. The elliptical shell is grayish white with concentric growth lines observable on the shell exterior.

   In wild populations, a rare reddish shell color pattern is sometimes observed at 1-2% of the population (Eldridge *et al.* 1976, Walker *et al.* 1980, Humphrey and Walker 1982). Identified as a variety of quahog (*M. mercenaria* var. *notata*), the unique shell markings are characterized as a red angular or zig-zag marking on the grey/white shell (Verrill 1873, Smith 1961). Due ot the simple genetic construct of the coloration marker (Chanley 1959), notata quahogs have been utilized by shellfish hatcheries as a marker for commercially reared quahogs, as hatcheries can enhance the overal density of notatas to 45-50% of the population through selective breeding (Dillon and Manzi 1988, Littlefield 1991).

3. *Habitat*

   The quahog is an infaunal clam that burrows near the sediment surface and preferentially settles in sand to sandy mud. Adults can be found buried to about 2 cm in depth with smaller individuals burrowing deeper. Primarily subtidal, found up to a depth of 20 m, the quahog is also found intertidally in bays and estuaries.

4. *Fisheries*

   The quahog is the fifth largest fishery landed in Rhode Island with a dockside value of approximately $5 million in 2012. It is the largest fishery within Narragansett Bay and the coastal ponds of the state, where it is harvested by bullrake or by SCUBA. Dredging for quahogs is not allowed in RI state waters. In addition, there is a significant recreational fishery for quahogs within the state, again by hand harvesting in intertidal and shallow subtidal areas, although little data are available to characterize this aspect of the fishery.

5. *Population Dynamics*

   The quahog is commonly found throughout Narragansett Bay and in all of the RI coastal ponds although the highest densities are located in the upper one-half of the Bay. It can exist in very dense assemblages in RI waters, where reported densities have been as high as 500 individuals/m^2 with an average density of 78/m^2 in an area historically known for strong quahog production (Greenwich Bay) (Rice *et al.* 1989). Based on the latest projection of standing stock in Narragansett Bay by RI-DEM Marine Fisheries, the stratified mean density of quahogs across the Bay is consistently between 2 and 3 quahogs/m^2 (RIDEM 2014). Natural mortality is similar to most bivalves, where the highest rate of natural mortality occurs during the earliest life history stages and the rate decreases as the bivalve grows (Connell 1983).

6. *Growth Characteristics*

   Quahog growth in Narragansett Bay has been carefully monitored over many years, with the current growth characteristics depicted in Figure 3.3 (Rice *et al.* 1989). The time to achieve legal size in Narragansett Bay quahogs has been getting longer over the past 50 years where the current estimate for a quahog achieving legal size is approximately 3-4.8 years (Figure 3.4, Jones *et al.* 1989, Henry & Nixon 2008).

7. *Ecology*

a. Feeding Habits: The quahog feeds by filtering phytoplankton from the water column so growth is dependent on the food quality as well as the rate of delivery of the food particle to the siphons of the clam (food flux). Recent research suggests that changes in the patterns of phytoplankton presence in RI waters may be affecting the growth and reproduction of the quahog although more research is necessary to fully understand these changes (Henry and Nixon 2008).

b. Parasites and Disease: No significant disease situations have been noted for wild quahogs in Rhode Island although monitoring of selected batches of wild quahogs has recognized numerous inconsequential maladies (Smolowitz, pers. comm.) One situation of a potentially significant quahog disease (Quahog Parasite Unknown – QPX) was reported at an aquaculture site in Winnapaug Pond (Westerly, RI) in the mid-2000's although the situation was quickly recognized and the infected organisms were removed from the pond, resulting in no further development of the disease in local waters.

c. Predation: It is widely recognized that natural mortality, i.e. predation, is the primary population control factor in wild quahogs. A list of common predators on the quahog are included in Figure 3.5, along with the maximum size of clam that can be preyed on by each predator species (from Bricelj 1992). On average, the quahog is reported to reach a size threshold where predation becomes significantly less a controlling factor at between 25 and 40 mm length, due to the degree of thickening of the shell (Arnold 1984).

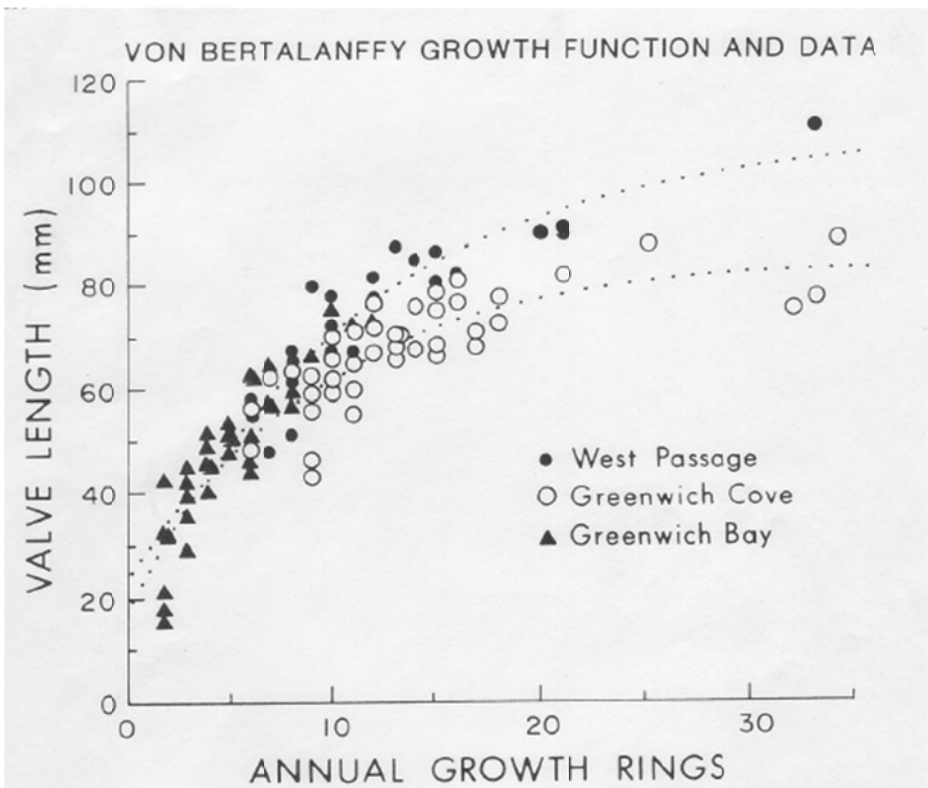


Figure 3.3. The valve length of quahogs from three Narragansett Bay sites plotted as a function of age (Rice et al. 1989).

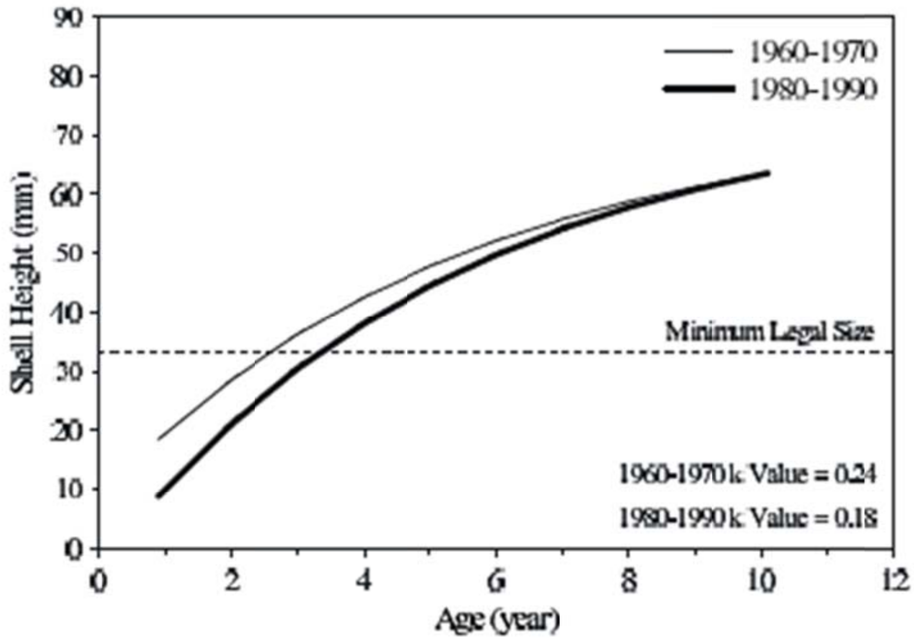


Figure 3.4. Growth curves for Narragansett Bay quahogs demonstrating the increasing time to achieving legal size (Henry & Nixon 2008).

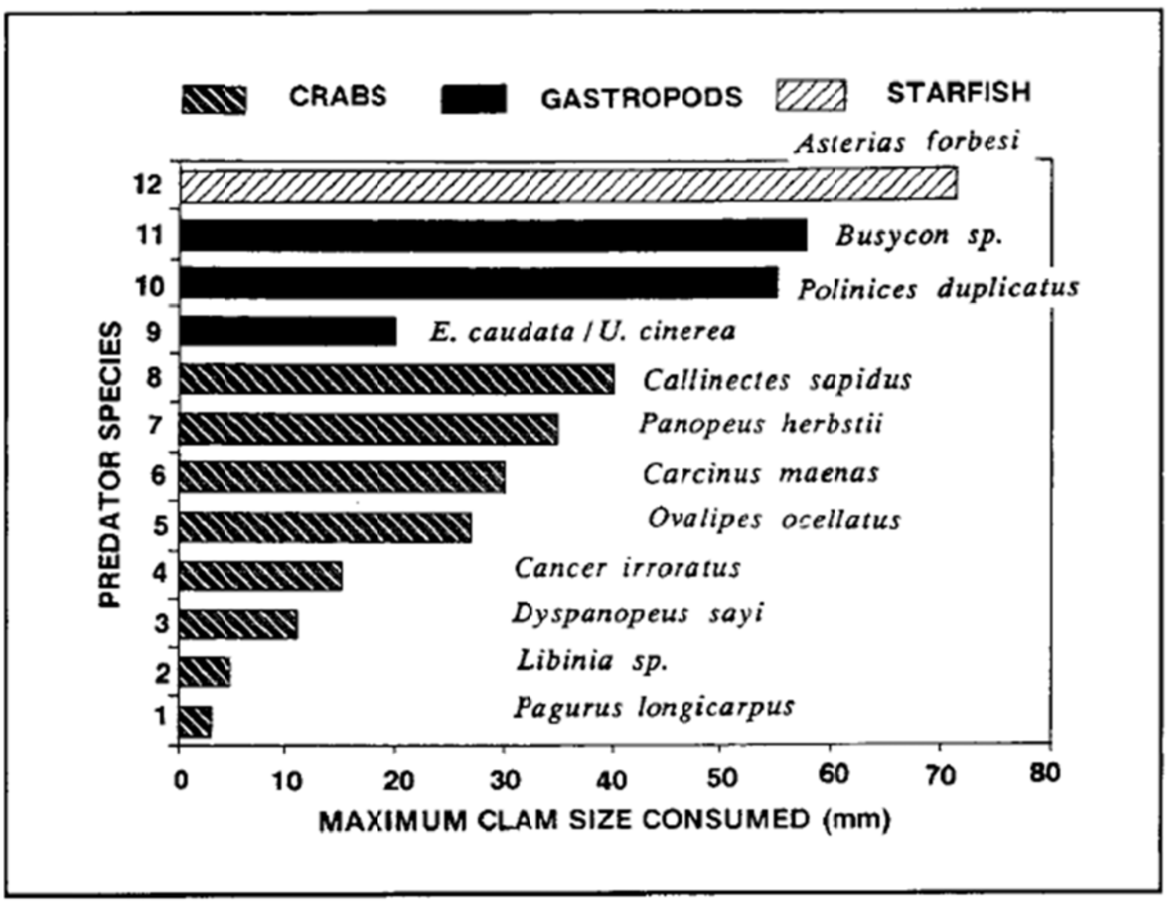


Figure 3.5. Maximum shell length (mm) of quahogs consumed by common predators of the quahog (Bricelj 2005).

330.2. Eastern Oyster (*Crassostrea virginica*)

(Galtsoff 1964, Sellers & Stanley 1984, Kennedy *et al.* 1996)

Other common names: American oyster, cupped oyster

Table 3.5. Environmental conditions reported for the American oyster (Crassostrea virginica).

TEMPERATURE Culture Stage	Overall Range (^{o}C)	Optimal Range (^{o}C)
Spawning		20.0
Larval rearing	20.0 - 30.0	25.0
Juvenile to Adult	-1.7 - 36.0	20.0 - 30.0
SALINITY **Culture Stage**	Overall Range (ppt)	Optimal Range (ppt)
Larval rearing	3.1 - 30.6	24.5 - 29.8
Juvenile to Adult	0.0 - 42.0	14.0 - 28.0
DISSOLVED OXYGEN **Culture Stage**	Critical Levels (mg/L)	
Larval growth	<1 (for 11 h); optimal > 4.0	
Juvenile to Adult	<1 (for 5 days); optimal > 4.0	
pH **Culture Stage**	Overall Range	Optimal Range
Larval growth	6.0 - 9.0	6.75 - 8.75
TURBIDITY **Culture Stage**	Minimum level (mg/L)	
Larval growth	<750	
WATER FLOW **Culture Stage**	Optimal flow (cm/s)	
Juvenile to Adult	> 10	
SUBSTRATE	Hard surface, prefer shell material	

1. *Range*

The Eastern oyster can be found from the Gulf of St. Lawrence in Canada down the Atlantic seaboard to Florida and into the Gulf of Mexico to the Yucatan. It is also found in the West Indies to Venezuela. *C. virginica* has also been introduced around the world, including the west coast of the U.S., Hawaii, Japan, Australia, and Great Britain (Ahmed 1975).

2. *Morphology and Identification*

The shell shape is highly irregular and asymmetrical, with the top (left) valve being flatter than the cup-shaped lower (right) valve. Environmental conditions influence the shell shape and thickness although in general the hard shell is ornamented with radial ridges and fluted edges and grows from a narrow umboned (hinged) end in a fan to the wider ventral edge.

3. *Habitat*

Eastern oysters are an estuarine species that are most commonly associated with hard substrate, where they attach by permanently cementing their shell to a solid surface and existing as an epifaunal organism. Although the oyster prefers to attach itself to shell hash (cultch), it will settle on a variety of hard materials if submerged in the estuary. Intertidal oysters in RI are subjected to higher mortality due to winter low temperatures and ice. Due to the oyster's high tolerance for brackish water systems, they are mostly located in the mid to upper reaches of the estuary as a result of reduced disease and predation pressure, although they can exist in full strength seawater if protected from natural mortality.

4. *Fisheries*

In Rhode Island, the oyster was a significant fishery at the turn of the 20th century although the bulk of the fishery was derived from oyster beds seeded and maintained by private companies (Rice 2006). Following the demise of the oyster industry over the 1930 to 1950 interval, there have been insignificant landings of oysters in Rhode Island until the modern-era of oyster aquaculture was introduced in the 1990's. Today, the oysters landed in RI are almost entirely farmed and they had an ex-vessel value of over $4.3 million in 2013 (Beutel 2014).

5. *Population Dynamics*

Oyster populations in RI waters have a history of being very sporadic in abundance. While the capacity of RI waters to support oyster growth is excellent, the recruitment of young oysters into local populations is extremely variable with large oyster sets occurring very infrequently (on a scale of tens of years). Oysters are capable of releasing enormous amounts of larvae so larval supply is not considered a problem in population recruitment (Table 3.1). The reason for the variability in oyster sets is not known but is most likely associated with high natural mortality. No routine assessment of oyster stocks are conducted in state waters.

6. *Growth Characteristics*

Eastern oysters grow very well in Rhode Island waters, as is exemplified in Figure 3.6 – a plot of the growth rate of three strains of hatchery produced oysters deployed on a farm in Narragansett Bay (from Gomez-Chiarri *et al.* 2010). On a farm, a market-sized oyster (~3 inches valve height) can be produced in 2 years. No data are available on oyster growth in the wild in RI.

7. *Ecology*

Where present, the oyster is considered to be an important ecological species, in that it provides a host of ecological services to estuarine communities (Newell 2004). These include water filtration with enhanced denitrification of particulate organic material through coupling pelagic-benthic processes, stabilization of submerged and intertidal sediments, and enhancement of bottom habitat complexity. Because of the economic value of oysters and the ecological services provided, there have been numerous attempts to restore oyster beds in Rhode Island waters.

a. Feeding Habits: Adult oysters feed on relatively small organic particles, predominantly phytoplankton in the 3 – 20 µm size range and are well known for the volume of water they can filter under optimal conditions (up to 5 l/h^{-1}) (Figure 3.7, zu Ermgassen et al. 2012). Given their filtering capacity, oysters are often identified as providing a filtering service that is unsurpassed under natural conditions in the estuary.

b. Parasites and Disease: There are numerous diseases that have had a profound impact on oyster populations throughout their range. In both wild populations and cultured oysters, three important diseases resulting from protistan parasites are Multinucleated Sphere Unknown (MSX) caused by Haplosporidium nelsoni, Seaside Organism (SSO) caused by Haplosporidium costale and Perkinsus Disease (dermo) caused by Perkinsus marinus. This combination of parasite-based diseases have decimated wild oyster populations through the U.S. range of the oyster and continue to be a problem wherever oysters exist. In addition, a fourth bacterial disease, Juvenile Oyster Disease (JOD) caused by Roseobacter crassostrea, has been impacting farmed nursery-stage oyster seed in Rhode Island and throughout the northeast in recent years. In all cases, there are general strategies that can be implemented to reduce the risk of disease in oyster populations but no effective cures have been developed.

c. Predation: As an epifaunal species, the oyster is susceptible to a wide variety of predators, from starfish to crabs and carnivorous gastropods. The primary means to control these predators is to exclude them from access to the individual oysters, which is relatively easy in a farm situation. However, wild and/or restored oyster beds are often susceptible to large-scale predation. Means to reduce predation pressure, particularly if managing restored oyster beds, is to seek areas with routine inundation by low salinity waters (provides a barrier to marine predators) and/or placing larger (2 inch) oysters in the beds.

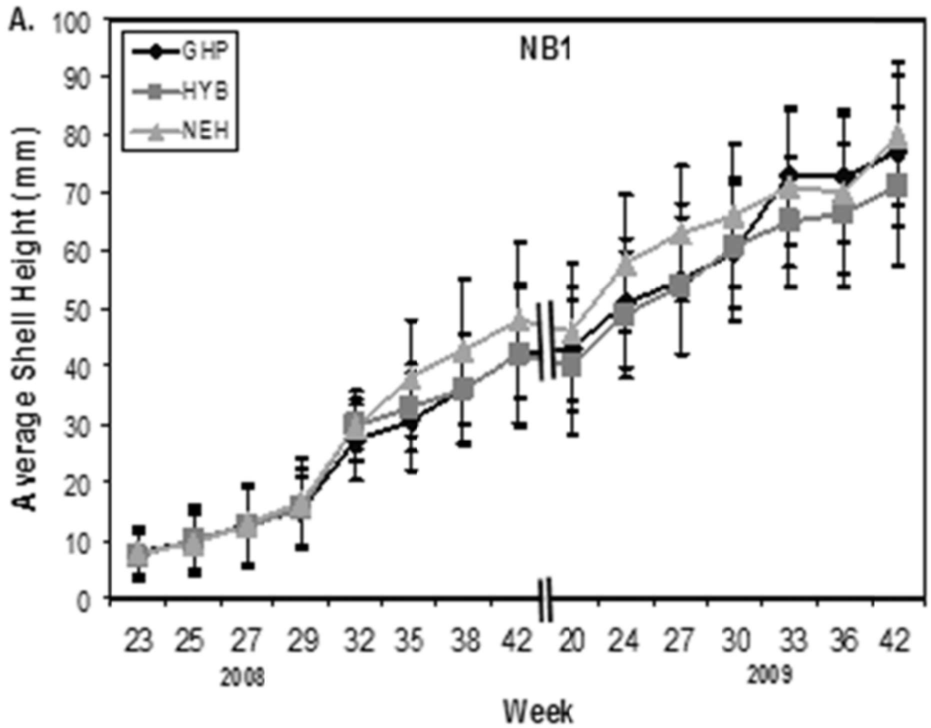


Figure 3.6. A plot of the growth performance (valve height increase) of three strains of hatchery produced oysters held on a farm in Narragansett Bay (from Gomez-Chiarri 2010).

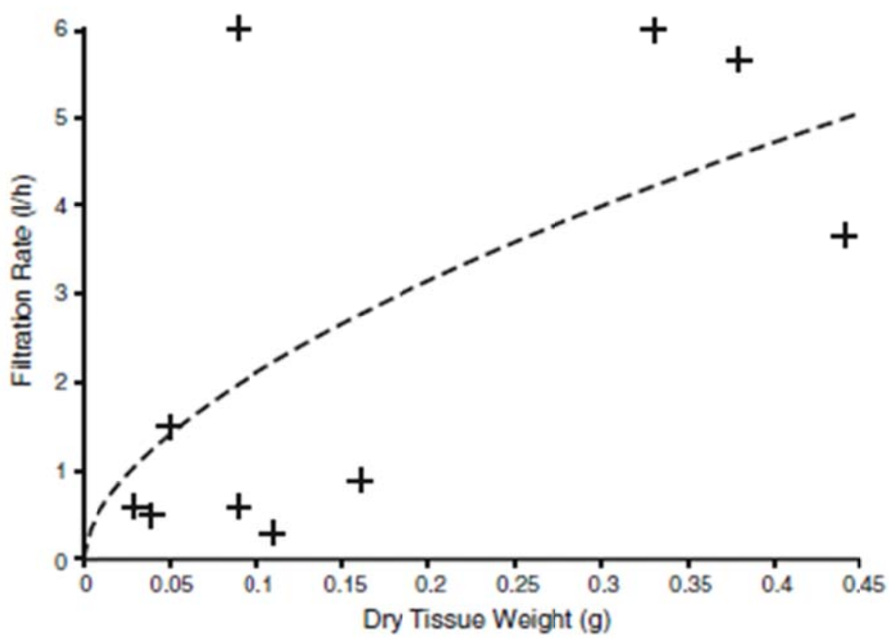


Figure 3.7. Oyster filtration model developed by zu Ermgassen et al. 2012. ($FR = 8.02W^{.058}e^{(-0.015T-27)\wedge 2}$;where FR is filtration rate (l-h), W is the soft tissue dry weight (g) and T is temperature (^oC) fitted to field collected data (R^2 = 0.71).

330.3. Soft Shell Clam (*Mya arenaria*)

(Newell & Hidu 1986, Baker & Mann 1991, Weston *et al.* 2010)

Other common names: steamer clam, nannynose clam, pisser clam, long-neck clam, sand gaper, Ipswich or Essex clam

Table 3.6. Environmental conditions reported for the soft shell clam (Mya arenaria).

TEMPERATURE Culture Stage	Overall Range (°C)	Optimal Range (°C)
Spawning	> 12	15 - 16
Larval rearing	12.0 - 34.4	22 - 24
Juvenile to Adult	-2 - 28	17 - 23
SALINITY Culture Stage	Overall Range (ppt)	Optimal Range (ppt)
Larval rearing		16 - 32
Juvenile to Adult	Apr-33	10 - 33
DISSOLVED OXYGEN Culture Stage	Critical Levels (mg/L)	
Larval growth		
Juvenile to Adult	> 2.8	
pH Culture Stage	Overall Range	Optimal Range
Larval growth		
TURBIDITY Culture Stage	Minimum level (mg/L)	
Juvenile to Adult	<300	
WATER FLOW Culture Stage	Optimal flow (cm/s)	
Juvenile to Adult		
SUBSTRATE	Soft muds, sands, compact clays, coarse gravel, and cobble - sandy mud preferred	

1. *Range*

   Commonly found from Labrador, Canada to Florida along the Atlantic coast with the highest densities from Maine to Virginia. As the population extends southward it transitions from intertidal to subtidal and can be found up to depths of 200m. It has also been introduced into Europe, from Norway to the Black Sea and on the west coast from California to Alaska.

2. *Morphology and Identification*

   The soft shell clam's general shape is elliptical (length to width ratio of 2.6 to 3.2) where the maximum length can approach 11 cm along the longest axis. The relatively thin and brittle valves are grey to white from the exposed prismatic shell layer although vestiges of a periostracum often can be observed along the ventral growth margin but is worn away by the abrasive nature of the sediment. The mantle is fused along the ventral margin with a small gap to allow for extension of the foot. The soft shell clam cannot totally close the valves so the mantle is always exposed.

3. *Habitat*

   The soft shell clam is an infaunal bivalve that can be found buried at depths in the sediment of up to 30 cm due to their ability to elongate and extend their siphons to the sediment surface. They are found in a wide variety of sediment types from gravel to fine mud and are intertidal at the northern portion of their range but become more limited to subtidal areas in the southern end of the range, due to the increasing temperature of exposed intertidal sediments as one moves south. They have been collected at depths approaching 15 m in coastal bays and estuaries.

Mya arenaria is considered a euryhaline species, capable of withstanding salinity levels from 4 to 33 ppt. With this capability, soft shell clams are often found throughout estuarine environments.

4. *Fisheries*

This clam supports both a recreational and commercial fishery in Rhode Island. Recreational harvesting is generally accomplished by shore diggers in the intertidal and shallow subtidal areas. Commercial harvesting generally is undertaken by SCUBA and can be also accomplished by bullrake if the densities are high enough, as was the case in the Conimicut area of Narragansett Bay in 2007. Because recruitment of soft shell clams in Rhode Island is highly variable, the overall commercial value of the soft shell clam fishery fluctuates widely.

5. *Population Dynamics*

Soft shell clams can settle into an area in phenomenally high densities, e.g. recorded post-settlement spat densities of >100,000/m^{-2} have been reported (Pfitzenmeyer 1962), although these high densities decline rapidly over the first growing season, due to a combination of predation and emigration from high-density areas. Optimal density for soft shell clam growth has been reported to be between 161 and 269 clams/m^{-2} (Belding 1910). The distribution of soft shell clam spat is influenced by local water currents as the small juvenile clams can move in a flow field via bedload transport, leading to high densities of spat in areas where the current flow is interrupted by structures on the sediment surface leading to aggregations of clams in the vicinity of these structures.

6. *Growth Characteristics*

Due to their susceptibility to predation, particularly when small, soft shell clam juveniles grow exceedingly fast during their first year post-settlement (Goshima 1982) as the depth of their burial is dependent on the size of the clam (Figure 3.8) and the deeper they bury the higher their capability of predator avoidance (Zaklan & Ydenburg 1992).Therefore, soft shell clam growth rate slows dramatically once it has achieved a size threshold of approximately 30-40 mm thus allowing the clam to reside deeper than 10 cm in the sediment.

Sediment type is an important factor in clam growth, along with the more recognized influences of temperature and food availability. Overall, the coarser the sediment type, the slower the clam growth rate and the heavier the shell thickness (Newell & Hidu 1982).

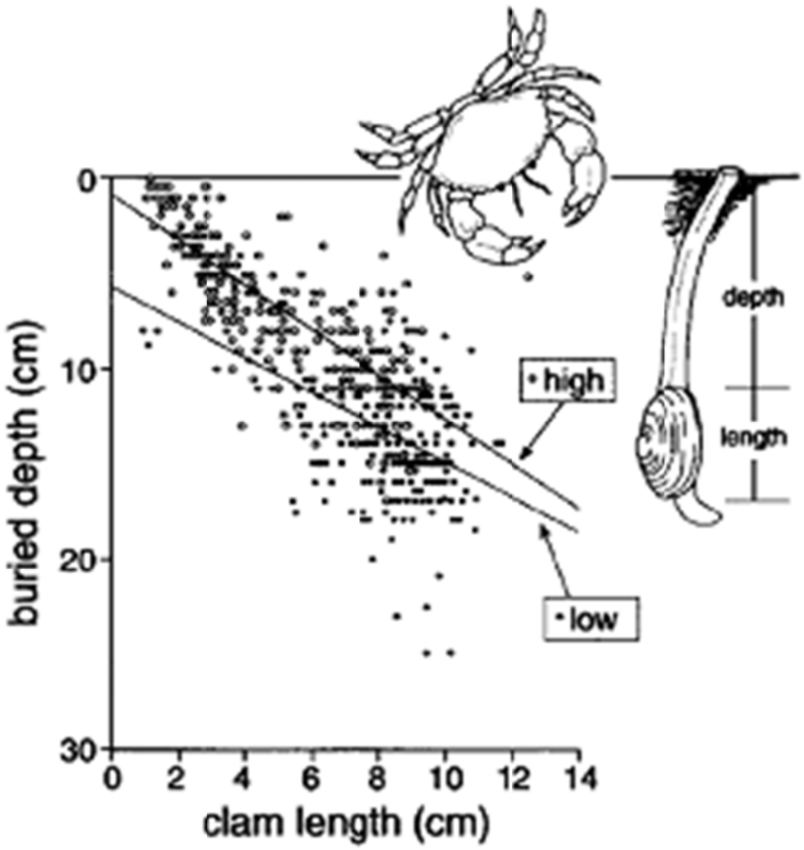


Figure 3.8. The overall relation between soft shell clam length and burial depth (from Zaklan and Ydenberg 1997).

7. *Ecology*

   a. Feeding Habits: In addition to filter feeding, where the soft shell clam targets phytoplankton in the 5 – 50 µm range, the soft shell clam is a deposit feeder, where it can ingest bacteria and benthic diatoms associated with the sediment. Hence the frequent occurrence of "grit" in the stomach, which leads to a need to purge the clam of sediment prior to preparation for eating.

   b. Parasites and Disease: Overall, there are relatively few significant pathological agents that affect the soft shell clam. Gonadal and hemocytic neoplasias have been reported for M. arenaria and have been noted in sporadic large-scale mortality events. The soft shell clam has also been reported as being affected by a protistan parasite (Pekinsus chesapeaki) although little information is currently available concerning this disease.

   c. Predation: Having only depth of burial as a defensive tool, the soft shell clam is highly susceptible to predation and it is thought that predation is the single most important factor in controlling soft shell clam populations. The list of potential predators is long, including birds, fishes, crabs, predatory worms, and carnivorous gastropods. In addition to burial depth, sediment type has also been reported as deterring predation where clams living in coarser sediments (gravel or sand with cobble) are less susceptible to predation although they also do not grow as rapidly as clams in mud or sand.

330.4. Bay Scallop (*Argopecten irradians*)

(Fay *et al.* 1983, MacKenzie 2005b, Leavitt & Karney 2006, Leavitt *et al.* 2010)

Other common names: Atlantic bay scallop

Table 3.7. Environmental conditions reported for the bay scallop (Argopecten irradians).

TEMPERATURE **Culture Stage**	Overall Range (°C)	Optimal Range (°C)
Spawning		>16.4
Larval rearing	19 - 28	25
Juvenile to Adult	0 - 32	22
SALINITY **Culture Stage**	Overall Range (ppt)	Optimal Range (ppt)
Larval rearing	19 - 35	25 - 32
Juvenile to Adult	19 - 35	31.2
DISSOLVED OXYGEN **Culture Stage**	Critical Levels (mg/L)	
Larval growth	>1.38	
Juvenile to Adult	>1.5	
pH **Culture Stage**	Overall Range	Optimal Range
Larval growth		
TURBIDITY **Culture Stage**	Critical level (mg/L)	
Juvenile to Adult	500	
WATER FLOW **Culture Stage**	Optimal flow (cm/s)	
Juvenile to Adult	<1.0	
SUBSTRATE	seagrass beds or similar structure	

1. *Range*

   Although the bay scallop can be found from Nova Scotia, Canada to Columbia, Central America, the range is generally considered to extend from Cape Cod, MA to the mid-coast of eastern Mexico. Across that range, three subspecies of bay scallop have been identified, with the northern strain common to Rhode Island (*Argopecten irradians irradians*) ranging from Cape Cod to New Jersey (MacKenzie 2005a).

2. *Morphology and Identification*

   The overall shape of the bay scallop shell is round with a pair of asymmetrical wings extending beyond the hinge line at the umbo. The shell color varies from grayish brown to a subdued rose color to a bright orange and sometimes there are white stripes radiating from the umbo to the shell margin. The lower (right) shell is frequently lighter in color to the upper (left) shell. The shell is composed of an array of folds or ribs radiating from the umbo to the shell margin to impart strength to the relatively thin and light shell.

3. *Habitat*

   Bay scallops are routinely located in eelgrass beds, as the three-dimensional structure of the eelgrass allows for protection of newly settled scallop spat from predation by providing an elevated location where they can attach themselves via byssel threadsto the upright fronds. With the demise of the extensive eelgrass beds due to eelgrass blight and other environmental factors, the bay scallop has adapted by using other structures, such as macroalgae, to provide protection from predation.

4. *Fisheries*

The fishery for bay scallops in Rhode Island waters reflects changes in bay scallop abundance throughout its range in the U.S. Bay scallops were so plentiful in Greenwich Bay in the late 1800's that a portion of the waterfront along Greenwich Cove was referred to as "Scalloptown" (Pesch *et al.* 2012.) However, with the demise of eelgrass beds due to wasting disease, coupled with overfishing and various environmental insults, the bay scallop populations crashed throughout Rhode Island by the late 1970's. Today, it is a rare occurrence to be able to harvest enough bay scallops to provide a meal, let alone a commercial catch.

5. *Population Dynamics*

Due to their relatively short life span (2.5 years at the most), the structure of a bay scallop population generally is defined as two year classes, young of the year and 1-year old individuals. Densities of bay scallops can approach 50-75 individuals-m^2 although these densities are not the norm, which is 5 – 25 individuals-m^{-2} in a productive bed.

6. *Growth Characteristics*

Given its short life span, the bay scallop is a fast growing bivalve that can reach reproductive maturity within the first year of their existence. Growth rates of 3.8 to 4.5 mm per month have been reported in Massachusetts during the summer months (Belding 1910).

7. *Ecology*

The bay scallop is was a key species currently being studied by the U.S. -Environmental Protection Agency (US EPA) to better understand the role of environment and environmental stressors in structuring the populations of important aquatic resources. Bay scallops were found in a variety of habitats, i.e. eelgrass, macroalgae, cobble, sand and mixtures of types. The models generated from these studies (e.g. Table 3.8) will provide information on the link between the environment and the population trends of this commercial resource (US-EPAindicated that habitat alone only explained half of the variation in bay scallop abundance (Figure 3-8). Other factors, such as predation, other sources of mortality, currents, larval supply, fishing pressure, and management efforts may explain the remainder of the variation in bay scallop abundance (Chinatal et al. 2014).

Feeding Habits: Growth is largely dictated by water temperature and food availability, which is a function of food particle density and delivery rate (current speed). Normal feeding position is to sit with its right valve on the bottom, often oriented in the current to allow for the current to augment the pumping action of the cilia on the gills. Flow rate across the animal is thought to influence the growth but the data are conflicting as to what levels of flow may be detrimental to growth.

a. Parasites and Disease: Mortality due to disease and/or parasites is not routinely observed in wild scallop populations, although a few specific disease situations have been described for cultured bay scallops. One problem commonly observed in wild bay scallops is the occurrence of the commensal pea crab. While they are not direct parasites, they can inflict damage to the scallop soft tissue and disrupt their feeding processes.

b. Predation: Given its epifaunal life style and its relatively weak shell, the bay scallop is highly susceptible to predation. A wide variety of predators attack bay scallops with the most effective being crabs that possess the mobility required to counter the swimming escape response that bay scallops exhibit. Scallops also retain the capacity to attach onto structures (i.e. eelgrass or macroalgae) throughout their juvenile stages, allowing them to elevate off the sediment surface to avoid the normal range of many benthic predators.

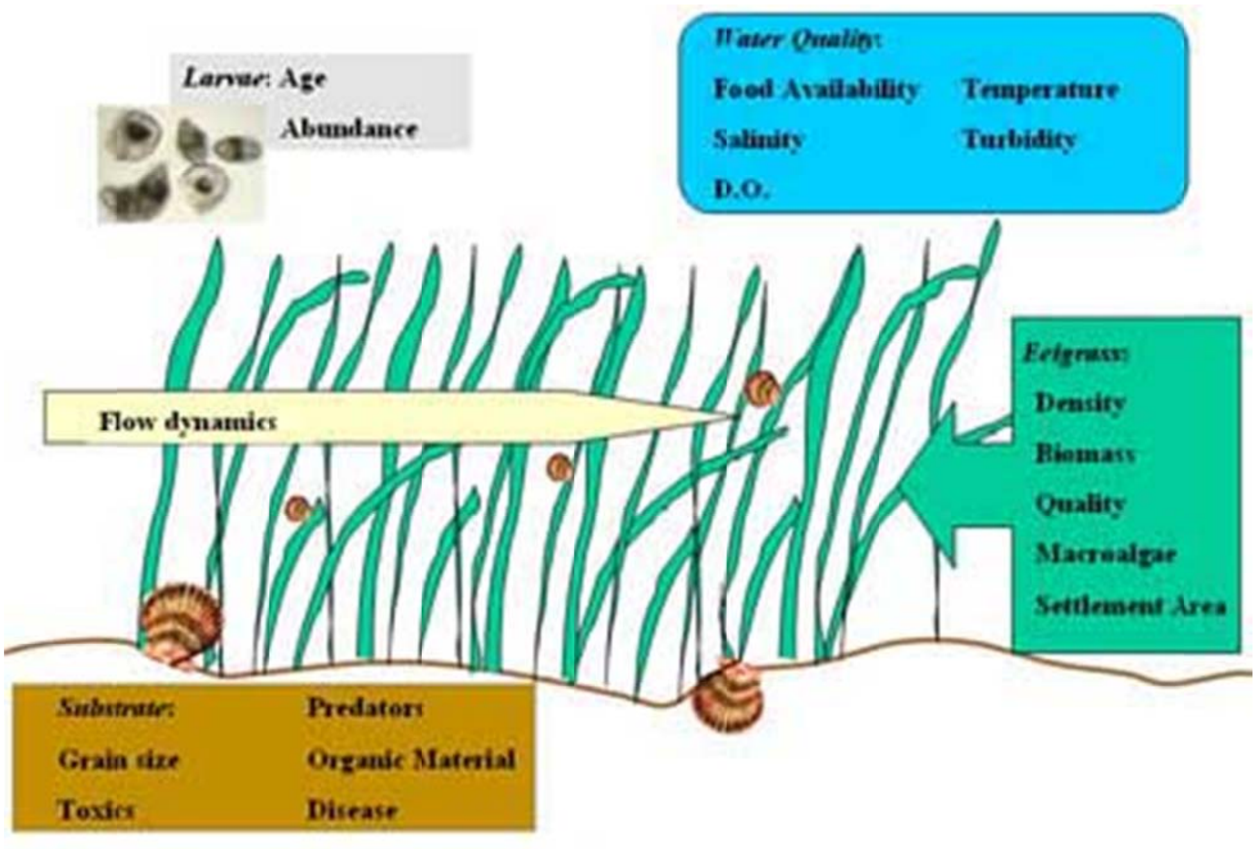


Figure 3.9. A conceptual model of the interaction of the bay scallop with its environment, used to model the role of habitat in maintaining healthy populations of scallops (USEPA - http://www.epa.gov/emfjulte/aed/html/ research/scallop/index.html).

Table 3.8. Estimates of survivorship and fecundity for the bay scallop generated by the US-EPA for inclusion in the population dynamics model (developed by the US-EPA 2014).

Stage	Survivorship	Fecundity
Larvae	0.001%	0
Juveniles on SAV	20%	0
Benthic Juveniles	20-50%	0
Adults (Year 1)	10-20%	$12.6 – 18.6 \times 10^6$
Adults (Year 2)	0%	$6.9 – 10.2 \times 10^6$

330.5. Blue Mussel (*Mytilus edulis*)

(Newell 1989, DFO 2003, Morse & Rice 2010)

Other common names: sea mussel, common mussel

Table 3.9. Environmental conditions reported for the blue mussel (Mytilus edulis).

TEMPERATURE Culture Stage	Overall Range (°C)	Optimal Range (°C)
Spawning	> 10	14.0
Larval rearing	5 - 20	16 - 22
Juvenile to Adult	0 - 29	5 - 20
SALINITY Culture Stage	Overall Range (ppt)	Optimal Range (ppt)
Larval rearing	5 - 34	25 - 33
Juvenile to Adult	0 - 34	30 - 33
DISSOLVED OXYGEN Culture Stage	Critical Levels (mg/L)	
Larval growth		
Juvenile to Adult	>0.1	
pH Culture Stage	Overall Range	Optimal Range
Larval growth		7.8 - 8.3
TURBIDITY Culture Stage	Critical level (mg/L)	
Larval growth	> 250	
WATER FLOW Culture Stage	Optimal flow (cm/s)	
Juvenile to Adult	> 10	
SUBSTRATE	Stable, hard surface	

1. *Range*

   Commonly found throughout the northern hemisphere in polar and temperate waters. In North America, it ranges from Labrador, Canada to Cape Hatteras, North Carolina. A related subspecies, *Mytilus edulis platensis*, which may be a separate species (*Mytilus chiensis*), can be found in the southern hemisphere.

2. *Morphology and Identification*

   The blue mussel is an elongated triangular-shaped bivalve where the umbonal beak forms one of the angles in the triangle and the ventral margin forms the other two. It can achieve heights of 7 – 10 cm. The shell is covered by a shiny black-blue outer layer (periostracum) with fine concentric growth lines.

3. *Habitat*

   As an epifaunal bivalve, the mussel lives attached to any form of intertidal or submerged hard substrate using a well-developed byssus thread system. They often congregate into large assemblages with mussel attaching to mussel. Some mussel beds have been reported to be more than a meter in depth. Mussels have the capacity to make and break byssus threads and can move readily if they need to reposition themselves to improve their growth environment. Mussels are both euryhaline (able to tolerate a wide range of salinities) and eurythermal (able to tolerate a wide range of temperatures), allowing them to survive in a wide variety of estuarine and bayside locations along the Atlantic coastline.

4. *Fisheries*

   The blue mussel supports a very small commercial fishery in Rhode Island where it is harvested for bait and for food by bullrake or mechanical dredge. The recreational harvest of mussels for human consumption in RI is probably a much larger demand on the resource over commercial harvest but no data are available on this effort. Recently, efforts have initiated to commercially farm the blue mussel in Narragansett Bay, using continuous rope culture hanging from surface longlines.

5. *Population Dynamics*

   Mussel density and size class distribution are affected by a variety of environmental variables (Figure 3.9). Having a high level of fecundity, blue mussel spat can set in very high densities on appropriate substrate. Initial spat settlement in the range of 20 to 200 mussels-cm^{-2} has been observed although initial mortality rates can be very high and decreasing as the mussel grows in size. Standing density on a mussel bed has been reported to be 20,000 to 100,000 mussels-cm^{-2} (Dar *et al.* 2013) In culture on hanging ropes, mussel density stabilizes to 500 to 600 individuals per meter of rope as they approach a 50-60 mm harvest size.

6. *Growth Characteristics*

   Figure 3.9 represents factors that influence the structure (density and size class) of a blue mussel population. However, the size class distribution is dependent on the growth rate of the individual mussels such that many of the same factors are the most influential in controlling the growth of the blue mussel. In considering this, under optimal conditions a mussel can grow to 7.6cm (3 inches) in height in 2 years while if any of these factors are suboptimal then the time interval to achieve that size can be extended to up to 20 years.

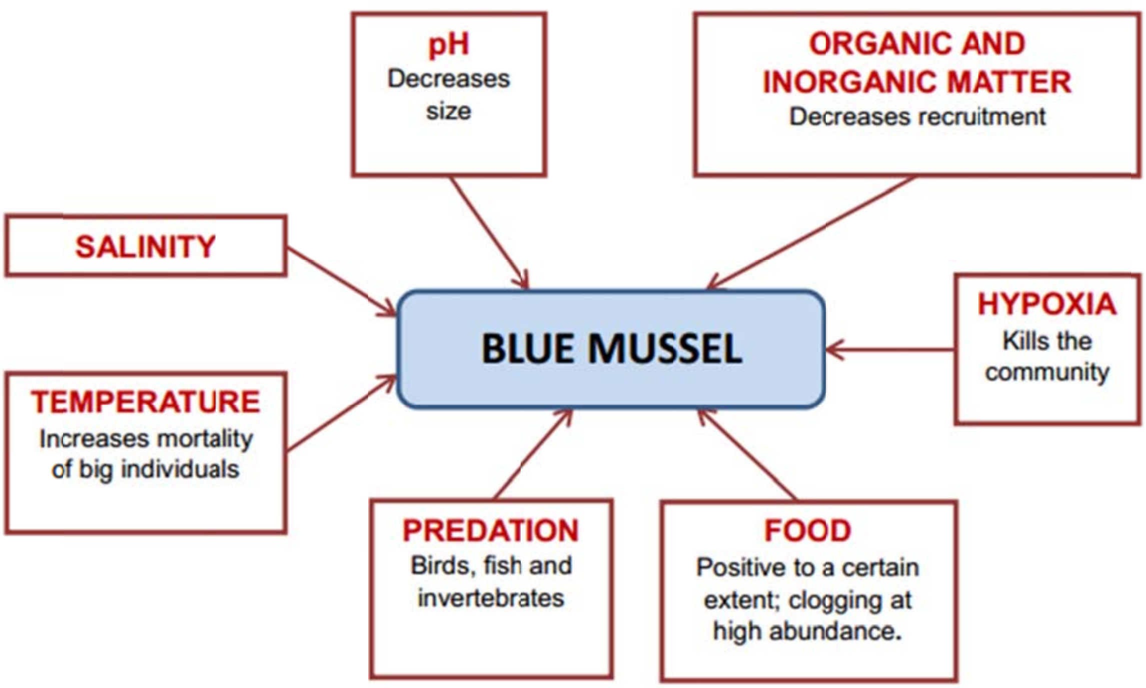


Figure 3.10. Factors influencing blue mussel population structure (from Dar et al. 2013).

7. *Ecology*

   a. Feeding Habits: As is true of many of the bivalve mollusks, the blue mussel is a suspension feeder. The feed by filtering phytoplankton particles from the water column through the sieving action of the gill filaments and associated mucous. Recent work suggests that the mussel feeds at a continuous rate when chlorophyll levels are between ~0.5 and ~6 µg Chl-α l^{-1} (Riisgard 2011).

b. Parasites and Disease: While there are a number of pathologies that affect the blue mussel (Table 3.10), relatively few studies have been reported addressing mussel diseases in the Rhode Island area. Current work at the Aquatic Animal Diagnostic Laboratory at Roger Williams University (funded by Rhode Island Sea Grant) is investigating the health status of blue mussels in the Narragansett Bay area.

c. One parasite that may be an important factor in structuring Narragansett Bay mussel populations is the digenetic trematode, Proctoeces maculates (Sunila et al. 2004). It is routinely observed in local mussels and trematodes similar to this species have been implicated in castrating blue mussels as they invade the gonadal tissue (Newell 1989).

d. Predation: Predation on the blue mussel is high and originates from a number of predators, including lobsters and crabs, whelks and drilling snails, sea stars, fish and birds. Generally, predation pressure decreases as the individual mussel grows in size and shell strength. As a mussel approaches 4-5 cm in length, it is only susceptible to the largest and most aggressive predators.

Table 3.10. A survey of diseases reported for the blue mussel by the FAO (FAO 2004-2014).

DISEASE	AGENT	TYPE	SYNDROME	MEASURES
Parasitic infection	*Marteilia maurini*	Protozoan	Potentially lethal; haemocyte infiltration of digestive gland (connective tissue and epithelia); extensive destruction of the digestive gland in heavy infections	No curative measure; prevention & site selection; monitoring mussel transfer
Viral disease	Picornaviridae-like virus	Virus	Heavy mortalities	
Vibriosis	Vibrios	Bacteria	Not specified	
Rickettsiosis	*Rickettsia*-like organisms; *Chlamydia*-like organisms	Bacteria	Microcolonies in the epithelial cells of the gills and digestive gland	No curative measure; prevention & site selection
Various parasitic infections	*Steinhausia mytilovum*	Micro-sporidian	Infects cytoplasm of mature mussel ova; incites a strong haemocyte infiltration response	No curative measure; prevention & site selection; monitoring mussel transfer
	Cliona	Sponge	Penetrates the periostracum forming holes in the outer surface and a tunnel network throughout the shell	None
	Prosorhynchus sp.	Bucephalid trematode	Mantles show abnormal colouration (patchy yellow-white) in heavily infected individuals; castration; weakness; gaping	None
	Polydora ciliata	Polychaete annelid	Burrows & blisters; mortalities; reduced condition index; loss of market quality	None
Pea crab parasites	*Pinnotheres pisum*	Crustacean	Reduces market value	No curative measure; decrease stocking density
Red 'worm' diseases	*Mytilicola intestinalis*; *Mytilicola orientalis*	Copepods	Usually commensal but may retard growth	

330.6. Razor Clam (*Ensis directus/Ensis americanus*)

(Kenchington 1998, Leavitt 2010)

Other common names: Atlantic or American jackknife clam, razorfish

TEMPERATURE **Culture Stage**	Overall Range (°C)	Optimal Range (°C)
Juvenile to Adult	3 - 30	6 - 23
SALINITY **Culture Stage**	Overall Range (ppt)	Optimal Range (ppt)
Juvenile to Adult	13 - 35	28 - 32
DISSOLVED OXYGEN **Culture Stage**	Critical levels (mg/L)	
Juvenile to Adult	>3.0	
pH **Culture Stage**	Overall Range	Optimal Range
Larval growth		
TURBIDITY **Culture Stage**	Critical level (mg/L)	
Juvenile to Adult	200	
WATER FLOW **Culture Stage**	Optimal flow (cm/s)	
Juvenile to Adult		
SUBSTRATE	fine sand with little silt	

Figure 3.11. Environmental conditions reported for the razor clam (Ensis directus). (Note: Relatively little information is available on preferred or adequate habitat for the razor clam.)

1. *Range*

Commonly found along the North American shore of the Atlantic Ocean from Labrador to South Carolina. In 1978/79, it was introduced into the Elbe estuary in Germany where it has rapidly spread and now ranges from Spain to Norway and the west coast of Sweden and across the English Channel to the United Kingdom.

2. *Morphology and Identification*

The razor clam is easily recognized in Rhode Island waters as the shell shape is long and narrow (the length being 5-8 times the width of the shell) with a slight arc to the length. The only other species that approaches this configuration is the stout razor clam (*Tagelus plebius*) but it does not achieve the adult length of up to 25 cm (10 inches) that is observed in the razor clam *E. directus*. The shell is relatively thin and fragile and is covered with a plastic-like tan to brown cuticle (periostracum) that is somewhat hydrophobic and sheds wet sediment readily. A distinguishing characteristic of the razor clam is the large muscular foot that is often observed extending out from the anterior part of the shell in this highly active and mobile bivalve.

3. *Habitat*

Razor clams prefer silt-free sand environments, generally indicating an area with good water flow; however, they have been observed in mud and gravel. They are normally located in the low intertidal to subtidal areas and, most likely, occur out into deep waters, as divers in Narragansett Bay have retrieved them at a depth of 6m (20 feet) or more and there is one report of a razor clam retrieved at 31 m (101 feet) depth in an Army Corp of Engineers Monitoring Report (Charles & Tufts 1997) while Christian *et al.* (2010) report them occurring in waters up to 35 m deep. A similar species in Ireland (*Ensis siliqua*) is routinely harvested at depths exceeding 14 m (46 feet) (Clark & Tully 2011).

4. *Fisheries*

The harvest of razor clams has traditionally been a small intermittent fishery supplying a very limited market. During the past 10 years, the market for razor clams has dramatically increased such that harvesters can receive $2.00 to $6.00 per pound for the product. Traditionally, the harvest has been by hand using a conventional four-tined clam rake or by hydraulic excavation in the intertidal areas during low tide. More recently, local harvesters have used a "salting" technique to extract the clam from the sediment where granular salt is dropped or a saturated salt solution is sprayed in the burrow of the clam resulting in the mobile animal evacuating the burrow (Krzyzewski & Carey 2005).

5. *Population Dynamics*

The bulk of the information that is currently available on razor clams has resulted from intensive studies performed on the species along the Wadden and North Seas in Europe, where the clam was introduced around 1978. It was feared the clam would out-compete native shellfish species as it established itself in the region. While it has generally been accepted that the introduction will have little adverse effect on native bivalve populations, researchers are now considering commercial uses of the species as the global market demand increases (Freudendahl & Nielson 2005).

E. directus has been reported to initially recruit at exceedingly high levels, for example 2,000 individuals/m^2 in an established population in Chesapeake Bay (Maurer *et al.* 1974) and up to 30,000 individuals/m^2 along the French coast, a location where they were recently introduced (Luczak *et al.* 1993). However, razor clams are highly mobile and will routinely redistribute themselves via swimming, crawling and byssal-drifting until they select an appropriate habitat (Armonies 1992). Between redistribution and overwinter mortality, those initial densities can drop to less than 4% of the original density (Beukema 1995), with intertidal survival on the order of 0% at mean tide level (MTL: 80 cm above low tide level (LTL), <10% between MTL and LTL, and >30% at sites exposed during spring tides only (Beukema 1995). Armonies (1999) reported large-scale mass mortalities of razor clams of varying sizes (from 1 year-old to 4 year-old populations) off the island of Sylt in Denmark that may have been disease related although no pathology was reported in the study.

Mortality rates are very high for post-set razor clams and remains relatively high into the second and third years of growth. Dannheim and Rumohr (2012) estimated the mortality rate of the population during years 1 and 2 post-set to be in the range of 74-85% per year (7% per month) with the highest level of mortality occurring in the March to May time interval.

6. *Growth Characteristics*

Razor clams grow rapidly (up to 12-13 mm per month) where the fastest growth is observed after their first year post-set (Figure 3.11; Dannheim and Rumohr 2012). They can approach their adult length (up to a maximum of 254 mm) within 4-5 years post-set (Figure 3.13).

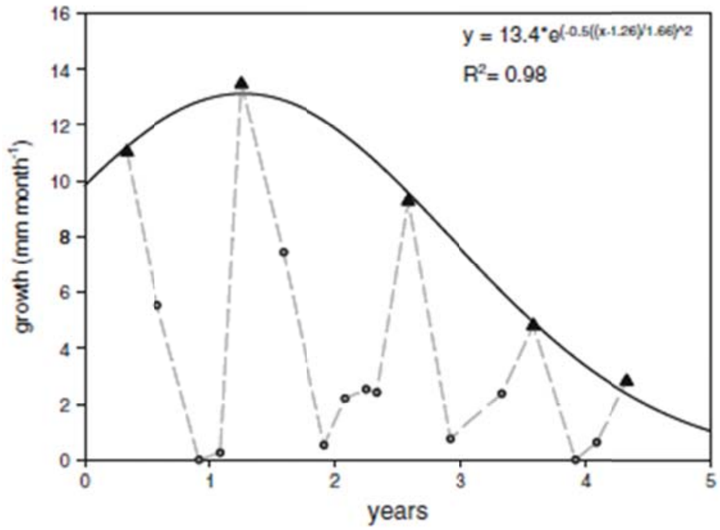


Figure 3.12. Growth rate of razor clams along the inner German Bight as a function of age where the grey circles indicate seasonal changes in growth while the black triangles indicate the maximum growth rate in the summer (from Dannheim and Rumohr 2012).

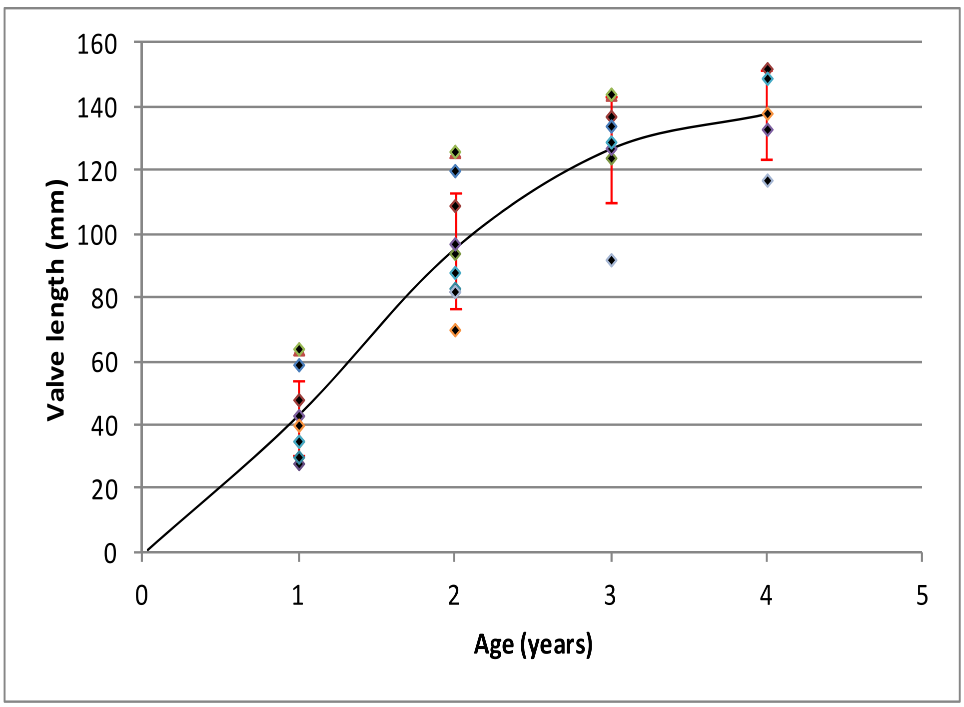


Figure 3.13. The average (± standard deviation in red) growth of razor clams reported from a compilation of European studies (modified from Dannheim and Rumohr 2012).

7. *Ecology*

   a. Feeding Habits: The razor clam is a filter feeder, pumping phytoplankton-laden seawater through their gills and removing the food particles, similar to most other bivalves. Their normal posture when feeding is to reside at the sediment surface, often protruding slightly above the surface (Figure 3.13), to allow the short siphons access to open water.

   b. Parasites and Disease: Mass mortalities have been routinely observed in the European razor clam populations (Dannheim and Rumohr 2012) however researchers have not provided a reasonable explanation as to their occurrence. No surveys have been conducted on disease status of natural populations of razor clams in the northeastern U.S. region so little is known as to their current susceptibility to disease and parasites. It has been reported that non-native E. directus in the North Sea region have a high prevalence of parasites routinely found in native bivalves in the vicinity (Krakau et al. 2006).

c. Predation: With their relatively light-weight and fragile shell, razor clams are attacked by a large array of predators. Primarily, they are preyed on by crabs, Cerebratulus nemerteans, carnivorous gastropods and birds. The one advantage the razor clam has in avoiding predation is their capacity for rapid movement both in substrate and above the substrate. Winter and Hosoi (2011) reports that the razor clam can dig quickly (~1 $cm\text{-}s^{-1}$) and deeply (up to 70 cm depth) when disturbed and have been observed avoiding moon snail predation by digging through sediment following the arch of their shell resulting in them backing up out of the substrate meters from the point of initiation of their digging (Schnieder 1982). In addition, they can leap on the sediment surface and swim in a manner similar to the bay scallop (Drew 1907). All of these behaviors are used routinely to avoid predation on the flats.

Figure 3.14. A razor clam, flanked by two infaunal anemones, feeding at the surface by extending its valves into the water column to a small degree (source: http://www.diverosa.com/Nederland/Zeelandbrug/ZLB-050713%20Amerikaanse%20zwaardschede,%20Ensis%20americanus.html).

330.7. Channeled Whelk (*Busycotypus canaliculatus*)

(Magalhaes 1948, Angel 2012)

Other common names: Smooth conch

Environmental conditions for the knobbed whelk (*Busycotypicus canaliculatus*): there is not enough information to construct a table of environmental conditions associated with the biology of the channeled whelk.

1. *Range*

This whelk species ranges from Cape Cod to central Florida (in the St. Augustine to Cape Canaveral region).

2. *Morphology and Identification*

One of two large predatory whelks in Rhode Island waters, the channeled whelk easily can be differentiated from its relative, the knobbed whelk (*Busycon carica*), by morphology of the shell. The channeled whelk is generally smaller (maximum length of 17.78 cm and average length of 15.25 cm and width at its widest part of 6.62 cm in Massachusetts (Gould 1841). As is true of both whelk species, the males are normally smaller than females of the same age. Channelled whelks have a thinner shell and the siphonal area of the shell is narrower and more distinctly differentiated from the main portion of the shell than that observed in the knobbed whelk. There is a markedly hirsute periostracum layer over the exterior of the shell and the animal is a light tan or beige color.

3. *Habitat*

The channel whelks free ranges over a wide variety of habitat types as it searches out prey. It is regularly observed in sand and sand-mud habitats and is often completely buried in the sediment. Alternatively, it can be found on mussel or oyster beds, gliding over the surface seeking out its next meal. This mobile species has been reported to be capable of moving at a maximum rate of 24.9 cm per second (85-90 mm animal at 21-23^{o}C; Shaw 1960. In moving, the channel whelk is more active during periods of low light and appears to move mostly at night during the summer months. It also seems to be more active later in the cold season as it is less sensitive to low temperatures than the knobbed whelk.

4. *Fisheries*

While this species and the knobbed whelk were originally fished to remove them from the population to protect other mollusk resources from predation, the fishery developed about 100 years ago as a food resource. More recently, the value of whelks has been increasing (from $1.67 per pound in 1967 (Davis and Sisson 1988 to $2.07 per pound in 2012 (Angel 2012) as lobster fishing in the region has been falling off, resulting in an increased fishery on the whelks over the past 5 years. Channelled whelks trap more readily than knobbed whelks, e.g. in a pot fishery survey in Narragansett Bay by Angel (2012), 98% of the trapped whelks were channeled whelks. This may reflect differences in feeding behaviors where channelled whelk can be scavengers and would be attracted to the bait in the trap, compared to knobbed whelks, which may be more predatory and less apt to approach a baited trap.

The whelk fishery in Rhode Island is primarily a baited pot fishery although whelks are routinely captured in dredge and trawl efforts as by-catch and sometimes as a directed fishery in more southern states. The fishery runs from May to December, with the bulk of the effort occurring during the fall season. Regulations governing the whelk fishery are currently under review as more biological information is gathered on the productivity of the populations in the region.

5. *Population Dynamics*

Reproduction in the whelks is very different than other mollusks. Rather than broadcast spawning with free-swimming larvae, the whelks undertake internal fertilization with the larval stages contained in an egg-case manufactured by the female. Length at reproductive maturity, where 90% of the population are reproductively active, is ~ 150 mm for females and 130 mm for males. There is currently an on-going debate as to whether the whelks are protandric hermaphrodites (male first then switching to female) or dioecious (male and female as separate individuals), as some researchers report the changing of the morphology of the sex organs as the individual grows (Kraueter and Castagna 1989, Peemohler *et al.* 2013). The egg case for the smooth whelk is distinguished by the shape of the capsules, which are a series of pouches that can contain up to 80-100 individual larvae. The channeled whelk capsules are arranged like pages of a book along a central backbone and each capsule is formed of two broad sheets of material joined at the edge as a sharp merging of the two sides (Figure 3.15). Eggs are laid during the summer and fall and it takes about 8 days for a female to deposit a full string of eggs, producing about 12-14 capsules a day with egg production occurring uninterrupted until completion. The egg capsules develop over the winter and hatch, with juvenile whelks being released, in March through May.

Figure 3.15. The egg capsule of the channel whelk (source: http://matthewwills.com/2011/05/17/whelk-egg-cases/).

Measuring the density and standing stock of a mobile animal is difficult to do accurately. In a heavily fished area in Narragansett Bay, the density of channel whelks was estimated at ~10 individuals 1,000m^{-2} (Sisson 1972). A follow up study using a trap-based survey method suggested a density of 11.5 to 17.4 individuals per m^2. Davis and Sisson (1988) estimated that a single trap can draw in channelled whelks from a range of 3,300 m^2 in area surrounding the pot and based this on knowledge of the distance that a whelk can travel over a 12-hour period. Overall, *B. canaliculatus* is 5-6 times more common in local waters than the knobbed whelk (Summer *et al.* 1911).

6. *Growth Characteristics*

Whelks, in general, are very slow growing animals where it can take up to 8 – 10 years to reach reproductive maturity. In tagging studies, growth was noted to be very irregular and, in many cases, no growth at all (or even negative growth) was recorded over intervals of hundreds of days during the regular growing season (spring through fall) (Castagna and Kraeuter 1994). It was speculated that the repair of shell damage resulting from feeding activities may account for a diversion of energy from overall growth to shell repair thus stopping overall growth from occurring (Castagna and Kraeuter 1994).

Aging of whelks can be achieved by counting annual growth rings on the hard operculum associated with the base of the foot. This is easier for channeled whelks due to the thinner nature of the operculum, allowing visual inspection of the growth rings with a light box or microscope. Plotting length at age for Narragansett Bay channelled whelks, Angel (2012) demonstrated the slow growth rate of our local stocks and also allowed us to differentiate the growth rates of the larger females form the smaller males (e.g. Figure 3.16).

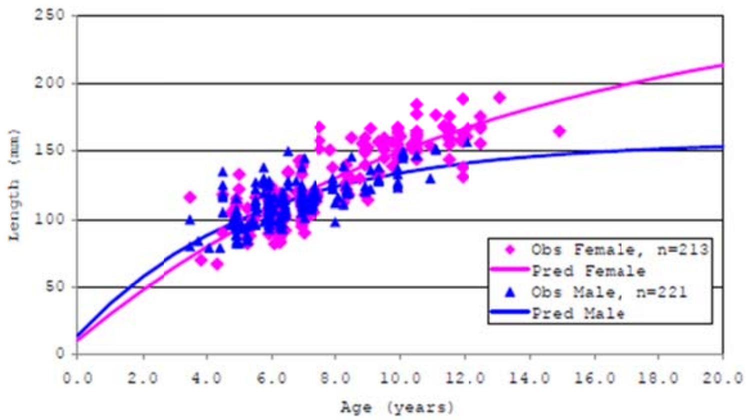


Figure 3.16. Narragansett Bay channeled whelk length at age with sexes separated (Angel 2012).

7. *Ecology*

   a. Feeding Habits: As noted above the channelled whelk is an active predator and scavenger. The preferred food for the channelled whelk are bivalve mollusks, which they can attack and consume readily using their shell and proboscis. The smooth whelk is not as aggressive in attacking prey as the knobbed whelk, in that it does not seem to use the hammering technique to attack tightly closed bivalves during feeding. Channelled whelks are highly capable of detecting food in their environment as they have a well-developed smell/taste facility that allows them to detect the presence of the bivalve in the vicinity and they can home in on its location readily.

   b. Parasites and Disease: Nothing is currently known on the pathology of whelks.

   c. Predation: The primary predators on whelks are crabs and birds. Large crabs can chip away at the shell margins to gain access to the soft tissue inside while gulls have been observed to lift and drop whelks on hard surfaces to crack the shell open. The primary tool that the whelks use for predator avoidance is the capacity to dig in and bury in soft sediment.

330.8. Knobbed Whelk (*Busycon carica*)

(Magalhaes 1948, Castagna & Kraeuter 1994, Angel 2012)

Other common names: None

Environmental conditions for the knobbed whelk (*Busycon carica*): there is not enough information to construct a table of environmental conditions associated with the biology of the knobbed whelk.

1. *Range*

   This whelk species ranges from Cape Cod to central Florida (in the St. Augustine to Cape Canaveral region).

2. *Morphology and Identification*

   Knobbed whelks can be differentiated from the related smooth whelk by inspection of the shell morphology. The knobbed whelk shell is characterized by having a shoulder whorl that is accentuated by spines projecting off the whorl. The spines are highly variable in number and length but are always present on the knobbed whelk, even as small juveniles where the spines are more like knobs projecting from the whorl.

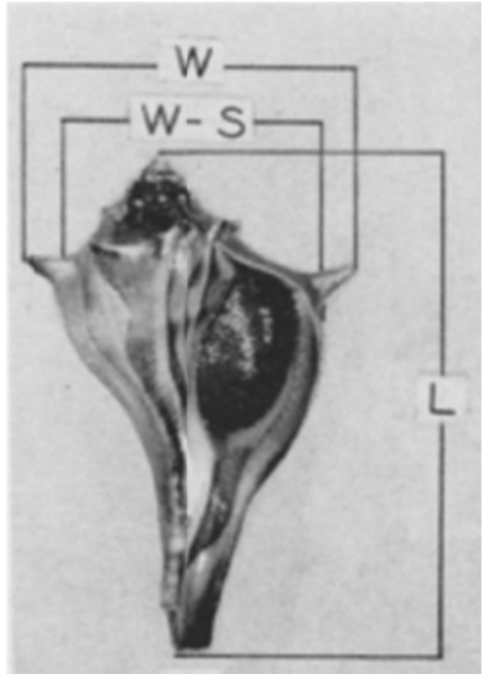


Figure 3.17. Normal measurement taken to describe the size of whelks. L is length, W is width with spines and W-S is width without spines (Magalhaes 1941).

Knobbed whelks are generally larger than smooth whelks with the largest size of knobbed whelks reported as 22 cm in length and 11 cm in width (Pratt 1935) (see Figure 3.17 to differentiate size measurement protocols). As with smooth whelks, the males of the knobbed whelk are generally smaller than females. The shell is grey in color and there is no obvious periostracum present.

3. *Habitat*

Whelks are generally found in shallow waters, up to depths of 46 m (150 feet), and are considered estuarine species as they are more commonly found in the shallow coastal waters. They are active at all times of the day and night, depending on the season and water temperatures and seem to have a higher tolerance to high water temperatures than the channeled whelk. As does the channeled whelk, the knobbed whelk ranges over a variety of habitat types as it ranges for prey. They are reported to be able to move about 15 to 40 m per day, with an average distance of 18 m per day. It is most commonly found in sand or sandy mud where it commonly buries itself in the sediment while seeking infaunal bivalves (clams that live in sediment) or avoiding predators.

4. *Fisheries*

Because the knobbed whelk is reported to not trap well, this species is primarily fished with trawling or dredging outside of Rhode Island waters. Along with the channeled whelk, knobbed whelks are being fished more heavily in Rhode Island in recent years, as the landed value increases and the lobster trap fishery declines.

5. *Population Dynamics*

Knobbed whelks also participate in internal fertilization between males and females and extrude their eggs in capsules for protection. Copulation was observed in New Jersey in May-June, egg cases were laid in mid-August to November and the capsule released juvenile whelks in mid-March through early May. The knobbed whelk egg capsule is different from the channeled whelk in that the knobbed whelk capsule has a band of material joining the two flat sides of the capsule resulting in a squared flat outer edge (Figure 3.18).

Figure 3.18. The egg capsule of the knobbed whelk (source: http://matthewwills.com/2011/05/17/whelk-egg-cases/).

6. *Growth Characteristics*

As was observed for the channeled whelk, growth in the knobbed whelk is periodic and irregular. Fastest growth is observed in the smallest individuals, e.g. lab reared whelks grew from 4 – 36.5 mm in the first year but it took them 10 years to grow to 144 mm and 14 years to get to 168.6 years (Figure 3.19). The bulk of their annual growth occurs during the interval of May to October, when water temperature is the warmest and food is plentiful. However, it is not uncommon to observe knobbed whelk that demonstrate negative growth over a measured time interval due to damage to the siphonal beak resulting from predatory activities. Based on observation by Angel (2012) the size at which 90% of the female population in sexually mature is ~150 mm and for the males it is 90-100 mm. Castagna and Kraeuter (1994) didn't observe viable egg cases generated by their captive population in the laboratory until 14 years of age.

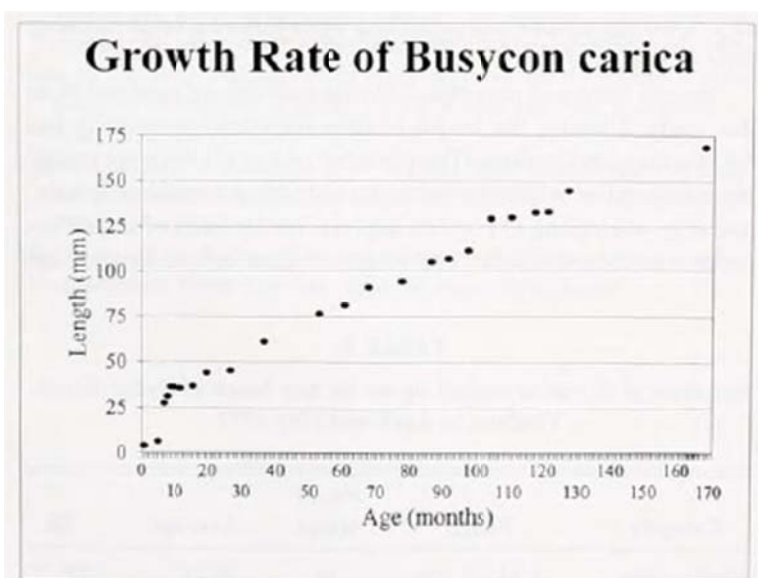


Figure 3.19. Growth of B. carica in the laboratory (Castagna and Kraeuter 1994).

7. *Ecology*

   a. Feeding Habits – Knobbed whelks prefer bivalve mollusks as their food and aggressively attack them. It is reported that the knobbed whelk uses the common tactic for opening bivalves by inserting their siphonal beak into a gaping pair of valves. However, they are also reported to undertake a hammering action, attempting to break away portions of the prey's shell by forceful blows with their beak area. It is reported that they can open a medium sized quahog in about 12 minutes with this technique. Castagna and Kraeuter (1994) report that the quahog is the preferred prey for the knobbed whelk and they can consume about 1 clam per week (Carriker 1951).

   b. Parasites and Disease – Nothing is currently known on the pathology of whelks.

   c. Predation – The primary predators on whelks are crabs and birds. Large crabs can chip away at the shell margins to gain access to the soft tissue inside while gulls have been observed to lift and drop whelks on hard surfaces to crack the shell open. The primary tool that the whelks use for predator avoidance is the capacity to dig in and bury in soft sediment.

Section 340. Issues and Recommendations

1. Through the stakeholder scoping sessions, many issues were identified that could be associated with our breadth of knowledge (or lack of knowledge) regarding the biology of the shellfish species included in this SMP. The following information articulates a brief description of the issue of concern followed by a background section that summarizes the current state of knowledge with respect to the specific issue identified. Based on our current state of knowledge, recommendations are suggested to address the issue that provides a pathway to improve on the management of Rhode Island's shellfish resources.

2. ISSUE: There is a need to improve overall shellfish management strategies.

   Fisheries management is a dynamic undertaking that is constantly being refined as more information on the biological, ecological, economic and social characteristics of the variety of shellfish resources included within this shellfish management plan become available. Establishing an overall goal and identifying what strategies will be used to achieve the goal(s) specified are an important consideration in Rhode Island shellfish management. Specific comments recorded from SMP stakeholder sessions included:

   - What are the objectives of shellfish management in Rhode Island?
   - What scale are we operating on? Are we managing for stock structure? Managing for harvest?
   - The need to manage the coastal ponds and the bay separately.
   - How do we manage the bay? By what criteria? For example manage by sediment type/substrate/structure, hydrodynamics, salinity/depth, genetics/adaptation to the environment, disease prevalence, and/or rainfall/contaminant risk.

   a. *Background* - Based on the RI-DEM 2014 Management Plan for the Shellfish Fishery Sector (RIDEM 2013), the goal of the sector management plan "is consistent with the objectives of the Rhode Island quahaug management plan (Ganz et al. 1999)" in that "Rhode Island will have a healthy bay quahaug resource and a fishery management regime which provides for sustainable harvest, cooperative management by stakeholders, and appropriate opportunities for fishery participation." To meet this goal, the Sector Management Plan lists the following objectives: 1) Maintain fishing mortality rates and brood stock abundance at levels that minimize the risk of stock depletion and recruitment failure; 2) Conserve, enhance, and rebuild quahaug resources in Narragansett Bay and the coastal ponds with appropriate management strategies including transplanting, area closures, establishment of spawner sanctuaries, and daily possession limits based upon sustainability; 3) Maintain existing social and cultural characteristics of the fishery wherever possible; 4) Provide for cooperative management with industry and efficient operation, consistent with biological objectives; 5) Provide for adaptive management that is responsive to unanticipated short term events or circumstances via establishment of shellfish management areas; and 6) Provide for a simple, uniform, and enforceable set of regulations.

While RI-DEM Marine Fisheries authorities address managing many of the shellfish resources in the state, it is unfortunate that the Sector Management Plan goals and objectives recognize only one of the many shellfish species that are routinely harvested in Rhode Island waters. As pointed out in the RI Coastal Ponds SAMP (RI-CRMC 1999), "the difficulties of managing a multiple-species, free and common recreational fishery, where all state residents have an equal right to harvest a publicly owned resource, are particularly challenging in the salt ponds. The small size of the ponds, their high productivity, and their accessibility make them particularly vulnerable to misuse and over-exploitation. These difficulties are heightened by the great concern for the condition of fishery stocks by local residents and the thousands of recreationists who come regularly from all over the state, as well as Massachusetts and Connecticut, to fish and shellfish in the salt ponds (Smith and McConnell 1979)." Given the unique attributes of the coastal ponds in Rhode Island, as are effectively described in the RI Coastal Ponds SAMP (RI-CRMC 1999), management of the shellfish resources in the multitude of coastal environments found within the borders of the state requires an appropriately scaled approach that is adaptable to the uniqueness of each water body.

b. *Management and Research Recommendations* – (1) Expand the goals and objectives of the shellfish sector management plan to include all commercially harvested shellfish species in Rhode Island. (2) Develop an ecosystem-based shellfish management plan that addresses the unique characteristics of each of RI's significant water bodies rather than a one size fits all approach. (3) To set scale and specificity of Rhode Island's shellfish management efforts, it is necessary to expand our knowledge of the population structure, larval distribution, site characteristics, and other important environmental and biological factors associated with each of the shellfish species harvested in the state.

3. ISSUE: There is a need to better understand the relationship between habitat, resource density, population composition and larval production in shellfish.

With overall reproductive effort of most shellfish species directly related to environmental conditions and with most shellfish having a reproductive strategy relying on external fertilization, the composition and distribution of the shellfish population and its interaction with the natural environment plays a critical role in determining the ability of the resource to sustain itself under increasing fishing pressure. Specific comments recorded from SMP stakeholder sessions included:

- Continue the work of Rice *et al*. in evaluating reproductive condition of quahogs in the field relative to the population density and fishing intensity.
- Management needs to recognize size composition of population and manage the specific areas accordingly. For example: to prevent senescent populations.
- Estimate minimum viable population size

a. *Background*: Reproductive effort in shellfish leading to the release of eggs and sperm results in external fertilization and the development of free-swimming larvae. Many factors affect fertilized egg production, for example, broodstock fecundity (the number of eggs that an individual may release during spawning), and are frequently classified as either intrinsic or extrinsic. Intrinsic factors are those that are regulated by the biology and physiology of the species; for example egg production is dependent on the size of the individual female producing the eggs, where larger individuals produce more eggs (Bricelj and Malouf, 1981) Therefore, the size distribution of individuals within a population will influence the amount of eggs being released during any given spawning event.

b. Extrinsic factors affecting reproductive effort in shellfish are those conditions external to the organism that can influence fecundity and/or fertilization success. Recent literature suggests that there are a number of environmental factors that can influence larval production. For example, recent work by Michael Rice and co-workers at URI has investigated the role that density and fishing pressure may play in the reproductive condition of quahogs in Narragansett Bay. Initial studies of quahogs in fished versus prohibited areas of Greenwich Bay suggested a stunting of the growth of clams from the non-fished areas due to higher stock densities in the non-fished areas (up to 194 individuals/m2 - Rice et al. 1989). Smaller quahogs lead to fewer eggs being produced. Upon closer investigation of quahogs from fished and non-fished areas, Rice's team reported that quahogs in non-fished areas were reproductively impaired, based on measurements of condition and gonadal indices (Marroquin-Mora and Rice 2008). While the decrease in reproductive condition could be attributed to a number of environmental factors, including decreased water quality, low dissolved oxygen, and degraded sediment composition, the authors speculated that density may be an overriding factor in influencing the reproductive effort within any specific metapopulation (Marroquin-Mora and Rice 2008). Further studies are currently underway to better understand the role that population density and fishing pressure may play in reproductive effort in quahogs (Griffin et al. 2014).

c. In addition to affecting growth rates and reproductive condition where high densities may impair these factors, the other end of the density spectrum is also important. In order to have successful fertilization of eggs with sperm, the density of individuals releasing gametes during a spawning event is also critical to the success of the reproductive effort. Given the potential for eggs and sperm to be swept away in prevailing currents prior to them chancing to meet, the amount of gametes in the water column is dependent on both the density and the orientation of adult populations. The minimum ratio of sperm to egg in externally fertilized gametes was calculated to be approximately 103 sperm cells per egg, translating to an optimal male to female ratio of approximately 1:1 (Luckenbach et al. 2014). In the field, an estimate of how this translates into a minimum population size to ensure effective recruitment has been reported as 0.75 individuals/m2 for quahogs in Great South Bay (Long Island, NY) (Kraeuter et al. 2005). For oysters, the Chesapeake Bay program has established a population density of 15 oysters/m2 as a minimum restoration threshold (CBP 2011). Tettelbach et al. (2010) reported a calculated fertilization rate of 62.4% in a natural bay scallop population with a density of 0.1.m2, using a model developed by Metaxas et al. (2002) and suggested that a population density of 1-2 individuals/m2 was enough to sustain a population (Tettelbach et al. 2009).

d. In Rhode Island, the only species that we have enough data on to relate overall population density to the minimum population density is the quahog. Lazar et al. (1995) reported a mean density of 5.4 quahogs/m2 in Greenwich Bay while Henry compiled data on quahog density over numerous intervals, provided in Table 3-X (Henry and Nixon 2008). With the exception of Wickford Harbor, the standing population density of quahogs is considerably higher than that needed to sustain the productivity of the Bay.

e. *Management and Research Recommendations* – (1) As we better understand the role of closed areas in shellfish stock structure and distribution, this knowledge must be factored into the overall management process. (2) Generate baseline information on closed area population dynamics, stock assessments should be conducted in Prohibited Areas. (3) If the current stock structure in Prohibited Areas proves to reduce the growth and larval output of shellfish populations then it is recommended that relays/transplants of quahogs out of high density areas (in Prohibited/Restricted waters) be conducted to reduce overall stock density. (4) Find a creative way to fund relays/transplants, should they be necessary to improve overall shellfish productivity in Rhode Island waters. One option could be a surcharge on harvested products that support a shellfish management program. (5) Continue to explore the role of closed areas in quahog stock structure and larval supply and distribution. Consider how management may be altered to accommodate this new information. (6) Explore the relationship between primary productivity and the productivity of the harvested resource for use as a management tool. 7) Develop better estimates of minimum viable population size for all commercial shellfish species.

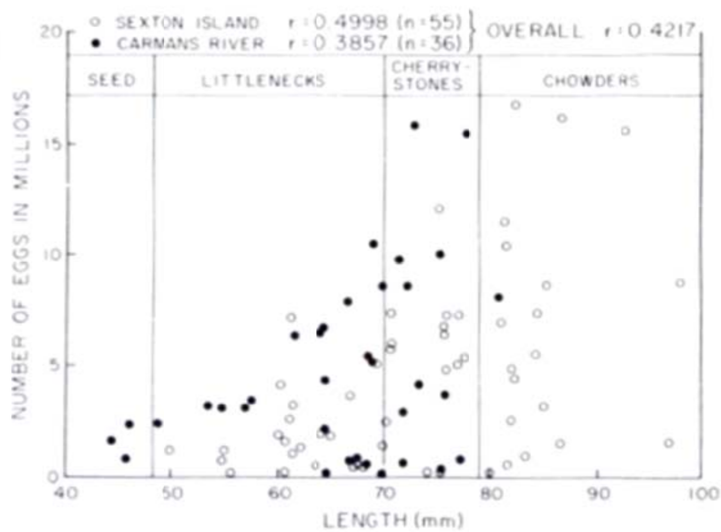


Figure 3.20. The relationship between fecundity per female quahog and shell length in millimeters (Bricelj and Malouf 1981).

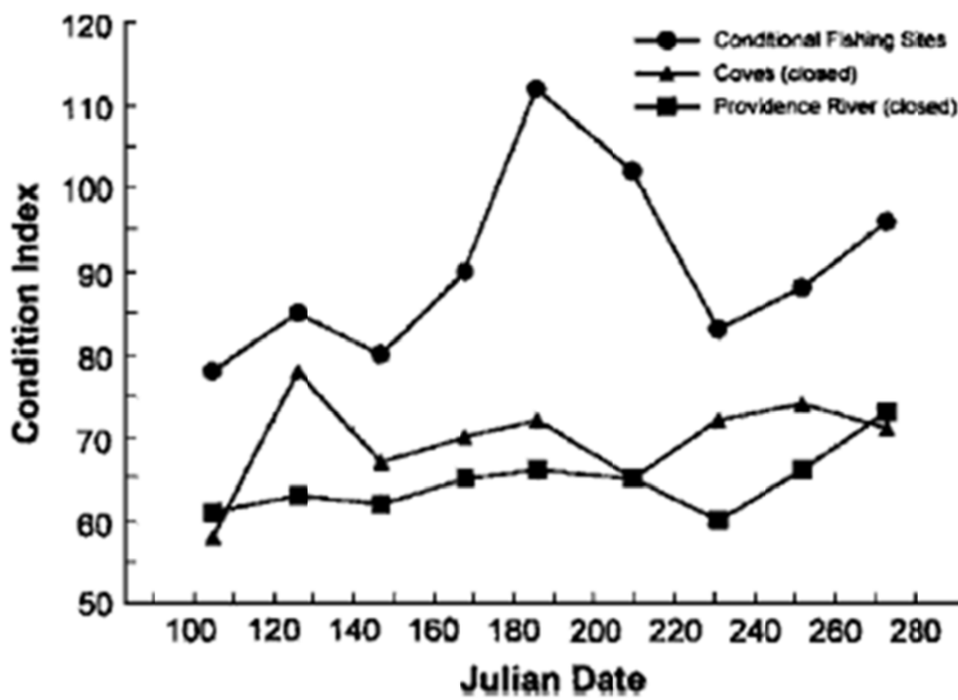


Figure 3.21. Annual condition index of quahogs from three sites in Narragansett Bay grouped according to fishing pressure (from Marroquin-Mora and Rice 2008).

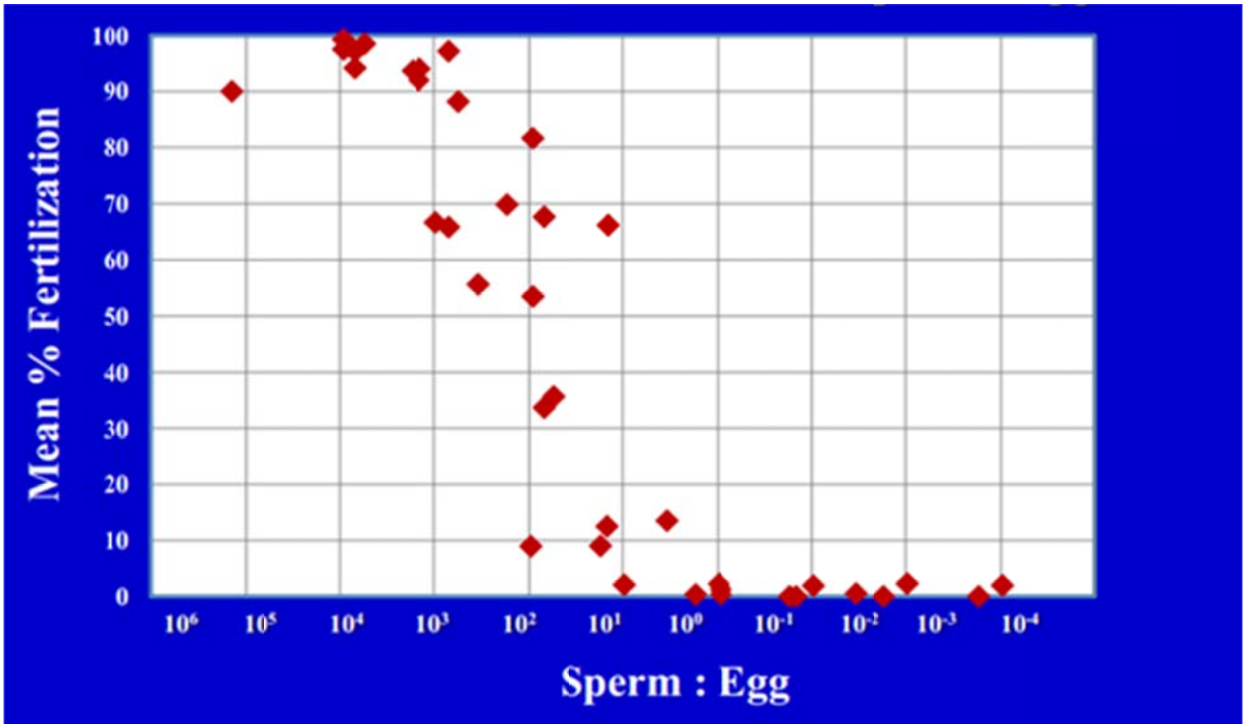


Figure 3.22. Percent fertilization as a function of sperm:egg ratios (Luckenbach et al. 2014).

Table 3.11. Average density of quahogs sampled by the Rhode Island Department of Environmental Management (from Henry and Nixon 2008).

Site	*k* value	Density (individuals m^{-2})		
		Open[a]	Closed[b]	Average
Providence River Estuary and Upper Bay				
Providence River	0.23	–	5.70	5.70
Conimicut Point	0.19	3.66	–	3.66
Ohio Ledge	0.11	1.55	–	1.55
West Passage				
Greenwich Bay	0.16	2.14	5.42	3.78
Upper West Passage	0.24	2.91	–	2.91
Wickford Harbor	0.16	0.68	0.73	0.71
East Passage				
Bristol Harbor	0.20	1.22	2.37	1.79

Density data from Murphy and Erkan (2006)
[a] Average density of sites open to shellfishing, 1997 to 2005
[b] Average density of sites closed to shellfishing, 1997 to 2005

4. ISSUE: There is a need to better understand shellfish size variability and economic return.

   A harvested quahog is a unique commodity; in that, it is marketed as four different products based on the overall size of the animal. In differentiating between littlenecks, top necks, cherrystones and chowders (Fig 3-X and Table 3-X), the value of a quahog changes with the size of the animal, where it's worth decreases as it gets larger (see Chapter 6). This is also true for other shellfish species. Therefore, the size structure of a managed population of shellfish can be an important factor in the commercial value of the resource. Specific comments recorded from SMP stakeholder sessions included:

   - Manage different areas differently. Specifically, areas with size classes that have little/no value.

   a. *Background* - Generally, the size of the individual shellfish resource dictates the commercial value of the product, although the variability in landed value is unique to each species. For example, as mentioned above, the quahog's value consistently decreases as it grows larger (Chapter 6). In other cases, such as the soft shell clam and the oyster, the value reaches a peak at some specific size category and decreases as the individual exceeds that optimum size. Usually the price difference is dictated by the consumer's preference for consuming the individual in the shell (raw or cooked) versus a shucked product, where the shucked product is generally the larger sized individuals and commonly has lower value. Lastly, some species, for example the bay scallop and the slipper shell, increase in value as the product gets larger. Due to the variability of economic value relative to the size of the shellfish species, it may be beneficial to manage each shellfish resource to optimize specific size classes leading to maximizing the commercial value of the product.

   b. However, this will require a heightened awareness of the size class distribution of the shellfish stocks coupled with an understanding of the growth rate of the species in question. Size frequency distribution of some shellfish stocks are routinely measured and compiled by RI-DEM Marine Fisheries. For example, size class is monitored in quahogs and soft shell clams (Figure 3-X) and more recently in whelks harvested from RI waters. Knowing the size class distribution allows a manager to monitor many population characteristics, such as fecundity, spawning biomass, recruitment into the fishery, etc.

   c. Managing a stock to optimize the commercial value not only requires an understanding of the size distribution of the stock but also an awareness of the growth rate of various cohorts in the population. Shellfish growth is primarily dictated by the environmental conditions that the individual shellfish experiences. Factors such as water temperature, food availability, sediment characteristics and density all play a role in governing the growth rate of an individual. A recent analysis suggests that the pattern of growth of Narragansett Bay quahogs has changed over the past 50 years, dictated by changes in the bay affecting many of the environmental parameters listed above (Henry & Nixon 2008).They reported that the growth rate of quahogs had declined as juveniles but accelerated as adults in the more recent time interval (1980-1990 setting years) compared to an earlier time interval (1960-1970 setting years) (Figure 3-X from Henry and Nixon 2008) The authors went on to speculate that the changes were due to shifts in the occurrence and composition of summer/winter phytoplankton blooms and/or changes in predator activity in the bay. Unfortunately, in-depth recognition and analyses of other shellfish species' growth characteristics has not been covered in as much detail as the quahog. Recent work has started to investigate basic biological characteristics of the whelk fishery in Rhode Island but more detailed investigation of other commercial species are required.

   d. As described in Chapter 5, the current mandate is that RI-DEM Marine Fisheries focus solely on the management of Rhode Island's shellfish resources in terms of biological sustainability with no mention of managing for optimization of the economics of the harvest. Although any regulatory change in RI requires that an assessment of the economic impact of the proposed change be completed, it appears that, for shellfish fisheries related changes, the analysis is mostly a boilerplate addition to the regulatory change. While RI-DEM Marine Fisheries routinely consults with the Shellfish Advisory Panel to the Marine Fisheries Council concerning winter area opening schedule arrangements to minimize the potential economic impact of increasing supply with diminishing demand, this is conducted on an informal basis with little background information to support decisions recommended.

e. *Management and Research Recommendations* – (1) Consider the size class composition and potential growth rate of shellfish resources as a component to the areal management of harvest within RI waters. (2) Change the state mandate to include economic considerations in the management of shellfish resources. Set harvest area openings to optimize stock stability first and economic return second. (3) Expand our knowledge of the size class composition and growth rates of shellfish resources in local waters. (4) Develop relevant information on the economics of shellfish harvesting in Rhode Island, including seasonal cycling of the market value of shellfish harvested and sensitivity of shellfish market values to changes in supply over the seasonal cycle.

Figure 3.23. A representation of the size differences of quahogs as marketed in Rhode Island. (Photo credit – Jeff Mercer RI-DEM)

Table 3.12. The average valve lengths for the various market sizes of quahogs (from MacKenzie et al. 2005).

	1910's[1]	Mid 1990's[2]	Late 1990's[3]
Littleneck	1 1/2–2 1/4	1 7/8–2	1 7/8–2
Topneck		2–2 3/8	2–2 3/8
Cherrystone	2 1/4–3	2 1/2–3 1/8	2 3/8–3 3/4
Medium	3–3 3/4		
Chowder	>3 3/4	>3 1/8	>3 3/4

[1] Data from Belding, 1912.
[2] Data from Hadley et al., 1997.
[3] Data from New Jersey dealers.

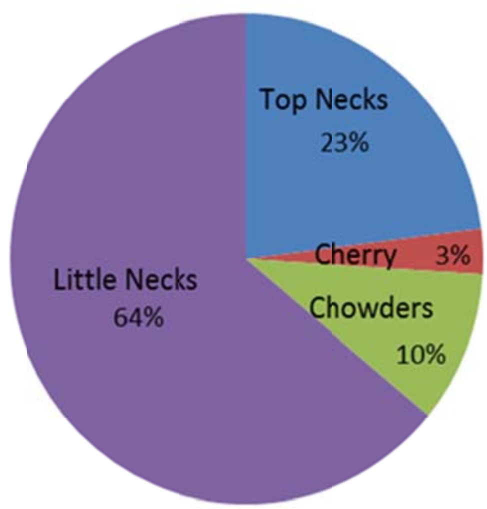


Figure 3.24. A breakdown of the 2013 quahog landings in Rhode Island, separated by the common differentiation of quahogs of various sizes (RIDEM 2014).

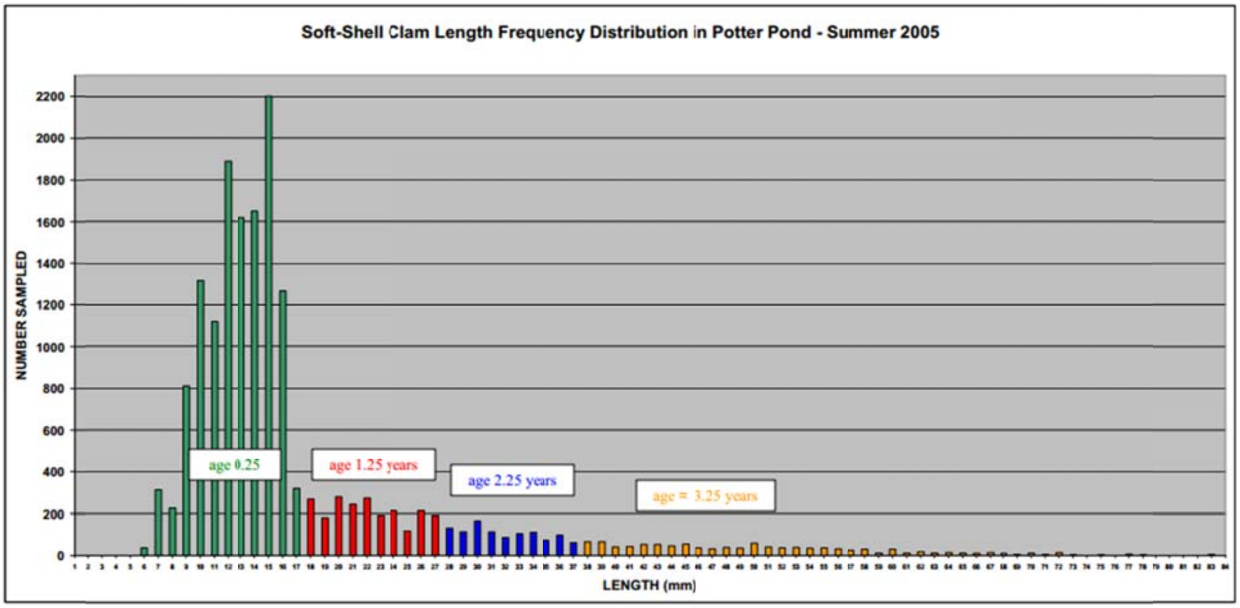


Figure 3.25. Size frequency distribution of soft shell clams sampled in Potter's Pond in 2005 (Erkan & Gibson 2005).

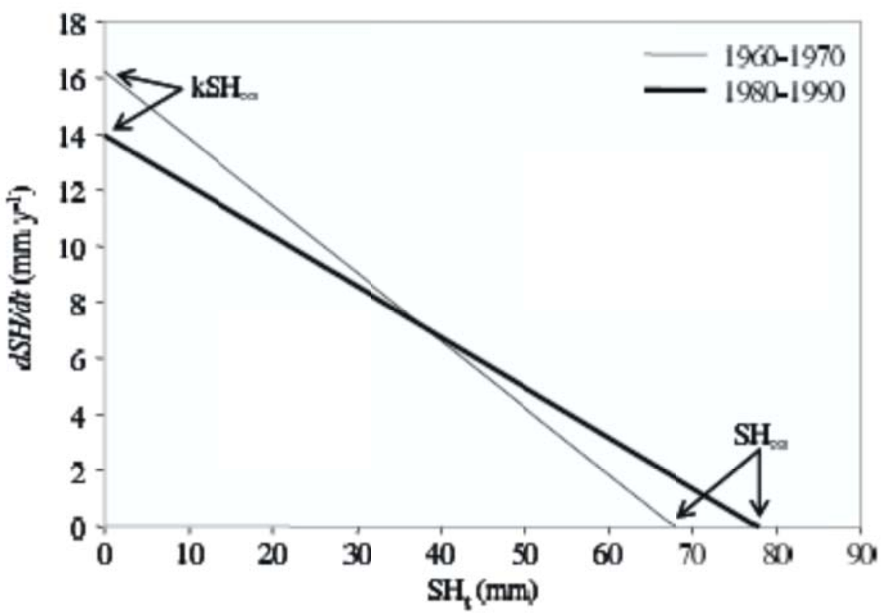


Figure 3.26. Differences in average annual growth rate (mm/yr) of Narragansett Bay quahogs sampled at two different time intervals (Henry & Nixon 2008).

5. ISSUE: There is a need to improve our knowledge of the spatial distribution of shellfish in the state (stock assessment).

   The first stage in the proper management of an exploited natural shellfish resource is to define the fishery, which involves not only identifying the fishery characteristics (fishery dependent data; such as harvest method, expended effort, landings, etc.) but also collecting unbiased (fishery independent) estimates of the resource, including the distribution and population structure of the fished resource (Hogarth et al. 2005). In Rhode Island, of the twelve species of shellfish that have been identified in this SMP, only one (the quahog Mercenaria mercenaria) is being routinely sampled as a component to the management of the fishery. Programs to monitor the soft shell clam and the two whelk species recently have been implemented although they are new and the long-term continuation of these programs is not guaranteed. Therefore, the bulk of the discussion on stock assessment will focus on the quahog stock assessment program. Specific comments recorded from SMP stakeholder sessions included:

   - If fishermen report from small areas, this could give us enough resolution to manage,
   - Involve fishermen more in stock assessment process to improve transparency,
   - Conduct shellfish stock assessment at a reasonable scalar level,
   - DEM hydraulic dredge used for stock assessment has not been calibrated in recent times,
   - Treat different areas differently; e.g. areas with size classes that have little/no value,
   - Address trends but not “point in time” numbers => define approach.

   a. *Background* - Based on information contained in the Rhode Island Quahog Management Plan (RI-QMP - Ganz et al. 1999), prior to 1994, stock surveys of quahogs in Narragansett Bay were conducted as a sporadic series of assessments with no continuity to the data collection. A partial listing of published quahog stock survey information is included in Table 3.13.

   b. Starting with a preliminary sampling in 1993 in Greenwich Bay and followed by an expansion to the entire Bay in 1994, RI-DEM has conducted an annual quahog stock survey with only minor interruptions since that time. In 2006, DEM changed the sampling protocol from a bay-wide sampling to a more focused strata-based sampling thereby allowing more samples to be collected within a specific area in any given year. The current strata designations are include in Figure 3-X.

   c. Standing quahog stock is sampled using a hydraulic dredge towed by the R/V Inspector Clambeaux, a 29 foot vessel). Details on the hydraulic dredge currently used and the sampling protocol employed are included in the RI-QMP (Ganz et al. 1999). According to Ganz et al. (1999), the hydraulic dredge has been calibrated on two different occasions where its sampling efficiency was measured on multiple substrates and at varying depths of deployment. The dredge efficiency on various bottom types is included in Table 3-X. However, the last evaluation of dredge efficiency was completed in 1995 (Ganz et al. 1995).

   d. In addition to evaluating quahog stock density using a hydraulic dredge, recent work has demonstrated that an alternative to the dredge for quahog stock surveys could be the commercial bullraker (Leavitt et al. 2014). A protocol has been developed and a preliminary calibration of the bullraker as a sampling strategy has been reported, where the bullrake provides an equivalent estimate of quahog density as is provided by the hydraulic dredge (Leavitt et al. 2014). The advantage to using a bullraker to assess standing stock is that they are more capable of sensing and adapting their fishing method to accommodate differences in substrate type, leading to a consistent catch efficiency of better than 90% on all sediment types evaluated to date (Leavitt et al. 2014).

   e. RI-DEM Marine Fisheries annually publishes the Sector Management Plan for the fisheries of Rhode Island, including a document specific to shellfish management. The most recent publication addresses the shellfish sector management for 2014 and is openly available on the Internet (RIDEM 2013). The bulk of this annual plan includes reporting averages in commercial landings and catch per unit effort and the location of dredge surveys accomplished in the previous year. However, little information is provided as to how these data and the annual stock survey data are utilized in the overall management plan and how these data are employed in formulating both a short- and long-term management strategy.

f. *Management and Research Recommendations* – (1) Develop a formal external peer review process to evaluate the stock assessment programs used to manage all shellfish commercially harvested in Rhode Island. The frequency of review should be every 2 years for quahogs and every 3-4 years for other shellfish.(2) Continue efforts to improve on the stock survey process. Develop a regular re-calibration schedule for the hydraulic dredge and further refine operations and evaluate the hydraulic dredge under a variety of sampling conditions, e.g. substrate types, depths, towing speeds, pump conditions, etc. Explore the use of video assessment to calibrate the sampling gear. (3) Consider other sampling methods that may be easier, cheaper, more reliable or effective. Continue the effort to employ a quahog research fleet for stock surveys. Identify a level for their involvement, e.g. shallow areas where dredge can't go, i.e. the coves (to start). Explore other uses of a wild harvester research fleet, e.g. environmental assessment. Find a mechanism to fund the fleet's involvement in assessment. (4) Improve communication between management agencies and users such that everyone is familiar with the use of data for management purposes. Better communicate assessment methods and data used to make management decisions. Release data to the public to add transparency to the management process, e.g. a) summarize and release fishery dependent data (SAFIS) in a timely manner and b) release fishery independent data (stock surveys, etc.) annually. Expand the level of detail provided in the annual Shellfish Sector Management Plan and improve the notification and distribution of the document. (5) Encourage continued refinement of the management process, including coordination between fishermen and regulators. (6) Continue developing techniques to involve commercial fishermen as collaborators in data collection required for improved management. (7) Explore better and/or more efficient methods for stock assessment for all of the shellfish resources routinely harvested in Rhode Island waters.

Table 3.13. A partial listing of published quahog stock surveys for specific areas in Narragansett Bay.

Author	Date	Area surveyed
Tiller	(1950)	Greenwich Cove
Pratt	(1953)	Narragansett Bay (to correlate quahog distribution with sediment types)
Stringer	(1955)	Greenwich Bay
Stickney and Stringer	(1957)	Greenwich Bay
Stringer	(1959)	Narragansett Bay (to correlate quahog distribution with sediment types)
Canario and Kovach	(1965a)	East Passage, Narragansett Bay
Canario and Kovach	(1965b)	Providence River
Saila *et al.*	(1967)	analyzed data from Canario and Kovach (1965b)
Kovach	(1968)	Wickford Harbor
Kovach *et al.*	(1968)	West Passage
Gray	(1969)	West Passage
Russell	(1972)	Reported on dredge sampling strategies
Sisson	(1976)	upper Narragansett Bay and Providence River
Ganz and Sisson	(1977)	Quonsett-Davisville area
Pratt	(1988)	Narragansett Bay
Rice *et al.*	(1989)	investigated effect of fishing pressure on Narragansett Bay stocks
Pratt *et al.*	(1992)	Narragansett Bay
Rice	(1992)	compiled existing studies 1946-1992
Lazar *et al.*	(1994)	Greenwich Bay
Gibson	(1999)	Narragansett Bay-wide assessment

Table 3.14. A summary of the efficiency of the hydraulic dredge routinely used for RI-DEM quahog stock surveys in Narragansett Bay (Ganz et al. 1999).

Sediment Type	Dredge Efficiency
Soft	66%
Shell	65%
Hard	64%
Sand	50%

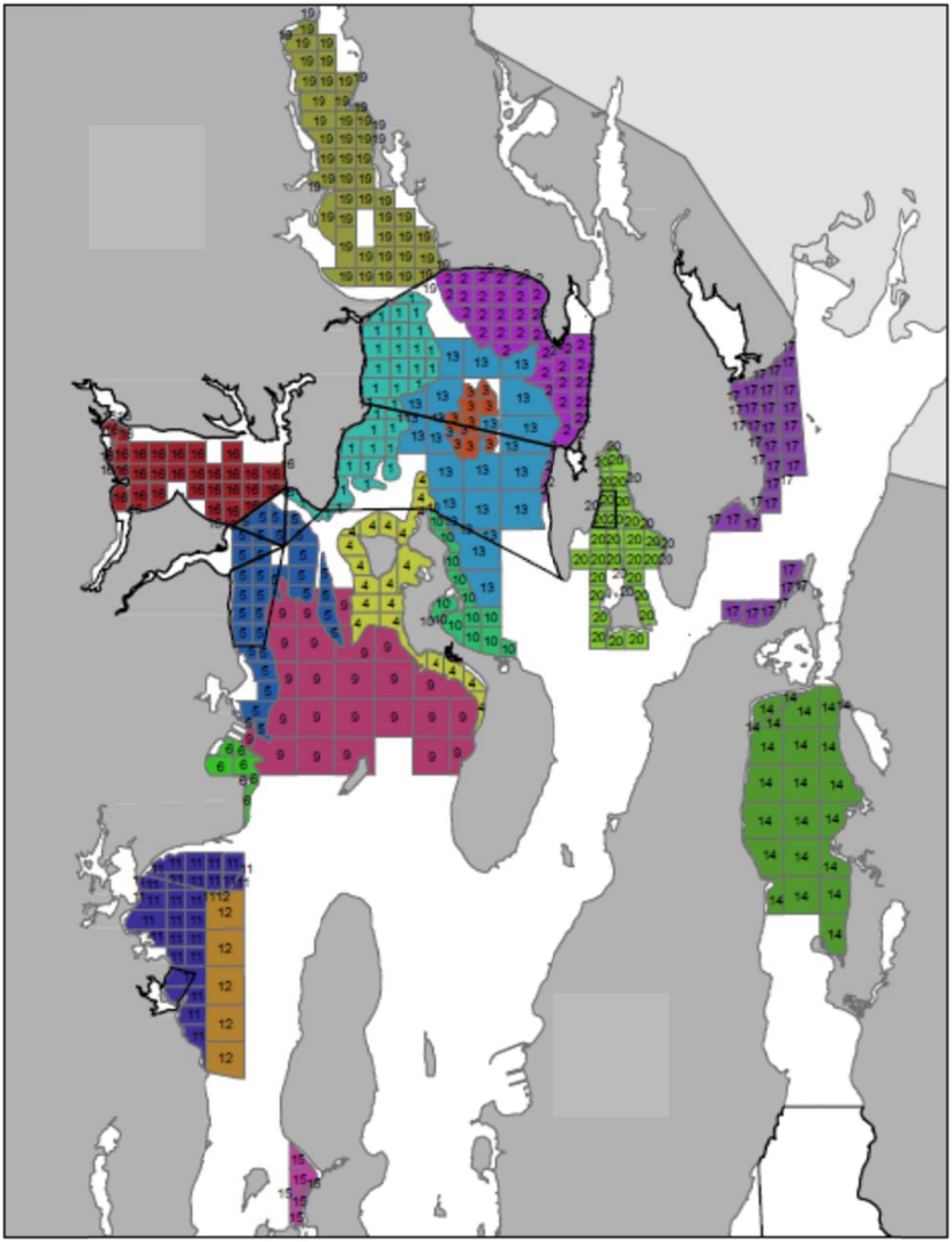


Figure 3.27. A map showing the sampling strata employed by RI-DEM for quahog stock surveys.

6. ISSUE: There are concerns about using wild stock for aquaculture (seed collection & utilization).

   A common practice for shellfish aquaculture is to rely on natural spatfall to provide the seed resources required for on-growing on the farm. However, collecting wild spat may impinge on resource availability as the wild spat grows and recruits into the fishery. Specific comments recorded from SMP stakeholder sessions included:

   - Concerns about using wild stock for aquaculture (seed collection & utilization)
   - Minimum size for aquaculture

   a. *Background* - The supply of shellfish larvae observed at any given time in the environment is dependent on the density of the reproductive adults in the vicinity coupled with an array of environmental factors, including food supply to condition the adults and support the pelagic larvae, water temperature to stimulate spawning and maintain appropriate larval metabolism, hydrodynamic forces that distribute the larvae throughout the water body, and many other parameters (Marshall et al. 2009). In general, the presence of shellfish larvae in the water column is a seasonal phenomenon, where spawning events are synchronized to facilitate fertilization and, most often, stimulated by changing water temperature (Loosanoff & Davis 1964), resulting in a large abundance of larvae in the water column during the late spring and early summer in Rhode Island waters (Table 3-1; e.g. quahog: Rice & Goncalo 1995, Butet 1997).

   b. Provided that there is enough broodstock in the system to generate the eggs and sperm required for larval production, larval supply is generally not considered to be a limiting factor in post-settlement recruitment of benthic invertebrates with pelagic larval stages (i.e. all of the species relevant to the SMP except for the whelks) (Olafsson et al. 1994). Kraeuter et al. (2005) suggested that the density of adult quahogs required to sustain the population in Great South Bay (Long Island, NY) was on the order of 0.75 individuals per m2, a stock density that is generally exceeded throughout Narragansett Bay (RI-DEM 2013).

   c. Although there is little data regarding critical spawning densities with other bivalve species, it is generally thought that the limitations to recruitment into the shellfish fisheries are dictated primarily by post-settlement processes rather than pre-settlement processes (Olafsson et al. 1994). However pre-settlement mortality is often reported as being substantial relative to the final density of larvae competent to settle, e.g. Butet (1997) estimated quahog larval densities decreased by 80-99% over the pelagic larval interval in Narragansett Bay and Lutz & Kennish (1992) estimated blue mussel larval survival to metamorphosis to be 1%.

   d. Recent work attempting to model the occurrence and distribution of larvae in Narragansett Bay suggests that while there are areas where larvae may become concentrated, depending on their point of origination, they are often distributed throughout the Bay due to hydrodynamic forcing (Fig 3.27; Leavitt et al. 2014; J. Mercer, pers. comm.) With adequate larval supply followed by hydrodynamic dispersal of larvae throughout the Bay, the practice of spat collection, where competent larvae are induced to settle through offering attractive habitat that protects the new recruits from normal risks (i.e. predation), is not considered a significant stress on wild fishery stocks to warrant limitation.

   e. *Management and Research Recommendations* – (1) Allow spat collection devices to be deployed to supply aquaculture operations but restrict the effort to pre-settlement larval collection only. Do not allow collection of post-settlement juveniles for any activity unless sanctioned as a management strategy by RI-DEM Marine Fisheries. (2) Expand our knowledge about pre- and post-settlement dynamics in structuring recruitment into the shellfish fishery, especially developing more information on all of the species listed under this SMP.

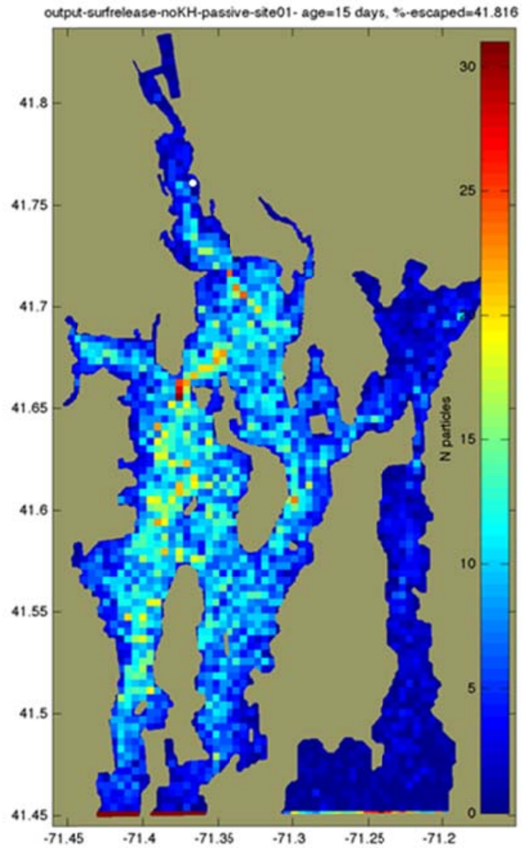


Figure 3.28. A model projection of the distribution of pelagic larvae released from the Providence River (white dot) and swimming in the water column for 15 days (Leavitt et al. 2014).

7. ISSUE: There is a need to manage to optimize post-set survival of shellfish.

   Bivalve mollusks utilize an R-type reproductive strategy (many off-spring with little maternal care), where the multitude of larvae are released to accommodate an exceedingly high rate of removal from the population. While larval supply is generally not considered a limitation (Olaffson et al. 1994), post-set mortality represents the greatest potential loss from the population, as molluscs exemplify a Type III survival curve, with a decreasing mortality rate as the animal grows larger (Figure 3-X) (Hunt and Scheibling 1997). Many factors contribute to post-set mortality, including habitat conditions, predation, disease, and hypoxia, and these will be considered in the following sections. One of the first considerations in managing post-set conditions is to address habitat quality for post-set shellfish species. Adequate habitat can provide shelter, protection from predation, improved growing conditions and numerous other advantages for the growing individual. Specific comments recorded from SMP stakeholder sessions included:

   - Substrate enhancement - Cultching for oysters; Raking grounds to enhance settlement - clams

   a. *Background* - Appropriate habitat is a significant factor in the recruitment of many shellfish species and there is a high degree of specificity in terms of which species prefer what habitat characteristics. For example, bay scallops prefer to settle initially onto dense beds of filamentous aquatic plants (eelgrass, Zostera marina or codium, Codium tomentosoides) (Carroll et al. 2010); mussels on fibrous algae-based material overlaying a hard substrate (Bayne 1964) and oysters on hard substrate with a high CaCO3 content (Crisp 1967). Numerous studies have been focused on sediment structure preferences for recruitment of the various clam species (e.g. quahog, Bachelet et al. 1992; soft shell clam, Morse and Hunt 2013; razor clam, Flanagan 2013), although more recent work suggests that sediment chemistry may play a significant role in larval settlement and survival (Green et al. 2013).

b. The role that the settlement habitat plays in recruitment success is often associated with predator avoidance, where the substrate affords some advantage to the post-set shellfish over active predators in the area (Grabowski 2004). Bay scallops achieve a higher level of survival when the early post-set can elevate off the bottom by byssing onto the blades of eelgrass or the thalli of Codium, thereby placing themselves out of reach of benthic predators (Carroll et al. 2010). Quahogs have higher survival when they set within a complex sediment structure consisting of larger gravel or shell hash interspersed in the sediment (Kraeuter et al. 2003). Oysters experience a higher rate of survival when setting in complex assemblages that are more difficult for crabs and other predators to handle rather than as single oysters (MacKenzie 1970, Krantz and Chamberlain 1978). Therefore, having the appropriate habitat structure for the various species of shellfish is an important consideration when managing shellfish.

c. For many infaunal clam species, another factor that may play a significant role in habitat selection and post-set survival is acidification of the interstitial waters of the sediment. High organic loading of sediments, often the result of highly eutrophic estuaries, leads to enhanced microbial degradation resulting in a condition of undersaturation of calcium in sediment porewaters (Figure 3-X, Green et al. 2004). One demonstrated impact of this calcium undersaturation condition is "death by dissolution" of newly recruited bivalve larvae (Green et al. 2009). More recent work suggests that infaunal bivalve larvae demonstrate a selective behavior when setting and avoid those substrates that have an undersaturated status (Green et al. 2012) thereby potentially delaying settlement and increasing the vulnerability of the larvae to predation and/or transport out of the estuary.

d. Habitat manipulation has become one means to positively affect population structure of bivalves. For example cultching of the sediment surface (deploying seasoned bivalve shell material to the estuary floor) is a commonly accepted means to enhance oyster settlement (Luckenbach et al. 1999) and has been practiced locally for hundreds of years (Visel 1982). Another strategy that has been advocated for many years is to disturb sediment by raking or dredging to enhance subsequent bivalve settlement. Although little hard scientific data are available to demonstrate a relationship between substrate disturbance and larval recruitment, it has long been argued that sediment disturbance is beneficial (Mercaldo-Allen and Goldberg 2011). Given the recent evidence that sediment chemistry may be important to promote shellfish recruitment (Green et al. 2012), disturbance may positively change that chemistry. However, more studies are needed to determine if a relationship exists between sediment disturbance and recruitment.

e. It should be noted that conducting field studies on larval bivalve recruitment is especially problematic, given the small size of the newly settled spat (200-500 µm) and the difficulty in identifying larval stages to species. If one couples the difficulty in monitoring spat with the myriad array of factors potentially impacting larval settlement, growth and survival in the wild, it presents an extremely difficult system to monitor and to study the factors influencing post-set production.

f. *Management and Research Recommendations* – (1) Continue to use shellfish nursery systems to enhance post-set survival of small shellfish. Explore implementing habitat manipulation strategies to enhance shellfish recruitment and survival, e.g. shell cultching to enhance oyster recruitment. (2) Continue to investigate the role of post-set mortality on structuring shellfish populations. (3) Develop research to address whether habitat manipulation is a viable means to promote shellfish populations in the state - Does working a shellfish area aerate the ground and provide a more favorable environment for recruitment? Are there other means to affect sediment biogeochemistry to enhance shellfish settlement and survival?

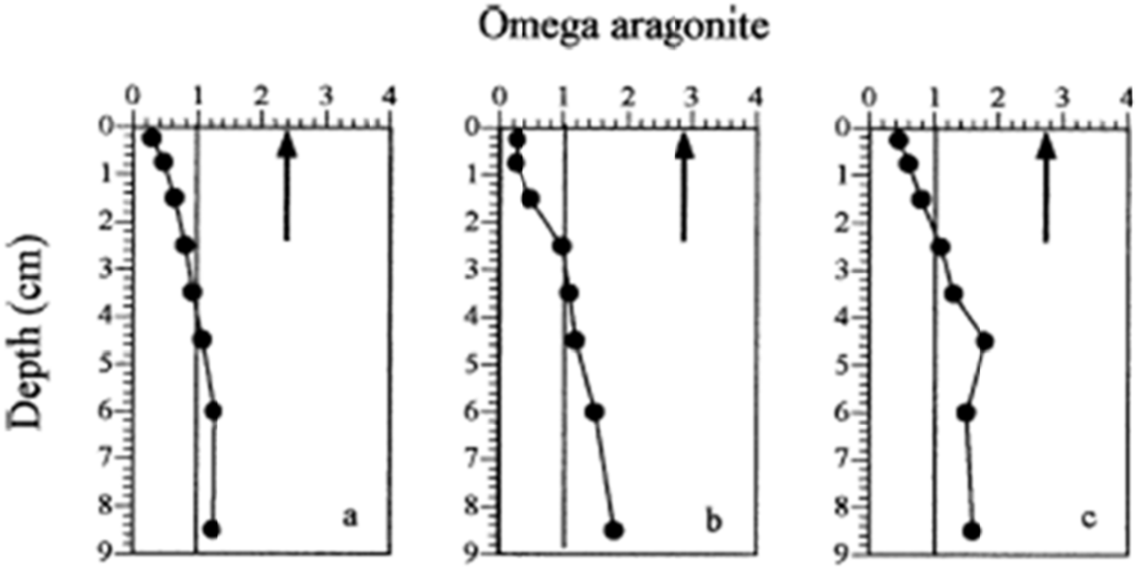


Figure 3.29. Sediment saturation state in three coastal estuaries sampled during late spring/early summer (a) Casco Bay (ME), (b) Barnstable Harbor (MA), (c) Long Island Sound (CT).

All show marked undersaturation from the sediment-water interface to depths of 2-3 cm. Maximum undersaturation occurs adjacent to the interface in each case. Overlying water saturation states is shown by the dark arrow and is supersaturated in each case. (from Green et al. 2004).

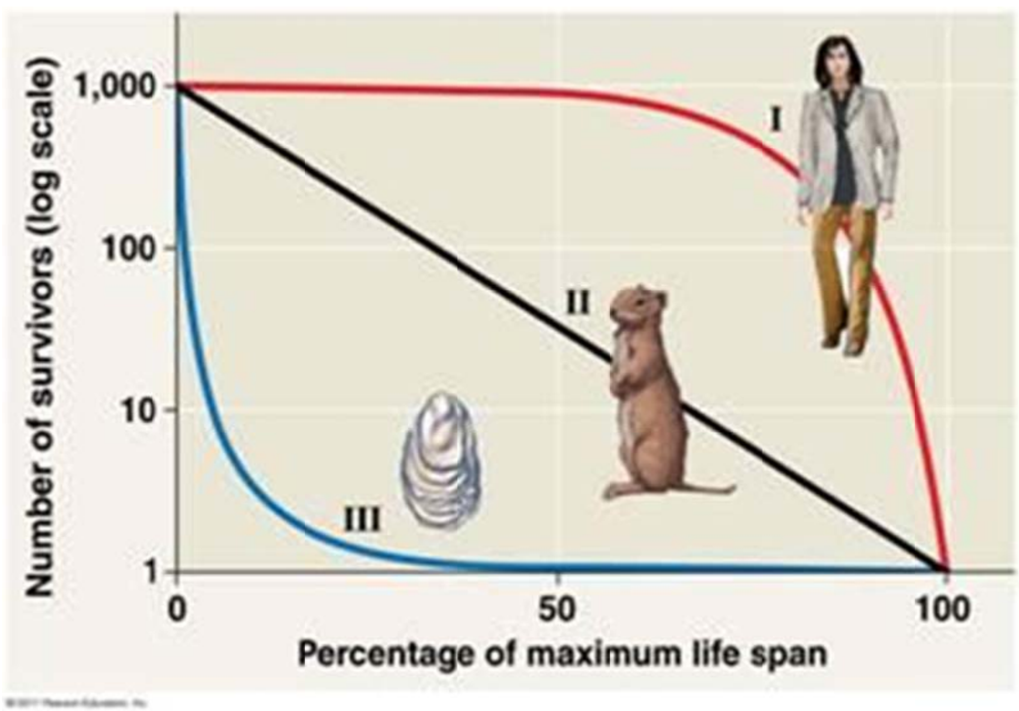


Figure 3.30. Survivorship curves for various organisms where shellfish generally follow a Type III pattern.

8. ISSUE: There is a need to better understand the role of natural mortality in structuring populations – predation.

Removal of individuals from a population can be due, among other things, to transport out of the system, competition and predation (Hunt and Scheibling 1997), although it is commonly thought that predation is one of the most important drivers of shellfish population structure and productivity (Van der Heide et al. 2014). Specific comments recorded from SMP stakeholder sessions included:

- Predation – what is its role in natural mortality at various life stages?
- Can we use predator control to increase clam numbers?
- Predator management – is abundance of sea stars or spider crabs (after lobster decline) affecting shellfish abundance?
- How does whelk fishery/management affect other shellfish species? Is whelk fishing reducing predation on quahogs, i.e. indirect predator control? What are the ramifications of an increased whelk harvest size limit on predation pressure to quahogs?

a. *Background* - A comprehensive list of the major predators of shellfish in the region is available from the Woods Hole Sea Grant Program (http://www.whoi.edu/fileserver.do?id=74621&pt=2&p=88899) or through the Northeast Regional Aquaculture Center (USDA) (Flimlin and Beal 1993; https://agresearch.umd.edu/sites/default/files/_docs/180-1993%20Shellfish%20Predators.pdf). Predators affecting Rhode Island shellfish are listed in Table 7.3.

b. The impact of predators can be direct, resulting in the death and removal of the individual from the population or it can be indirect, resulting from the presence of a predator reducing the productivity of the individual. Direct impacts are commonly studied and relatively good information is available characterizing mortality due to predation for a variety of shellfish species. For example, Bricelj (2002) summarized the current state of knowledge concerning predators on quahogs and the maximum size threshold above which success at preying on the clam decreases (Figure 3-X). In general, a length of 25 mm represents a size threshold where predation pressure on the quahog is greatly reduced (Bricelj et al. 2013). Similar information is available for oysters (White and Wilson 1996), bay scallops (Leavitt and Karney 2005), soft shell clams (Baker and Mann 1991), blue mussel (Newell 1989), and the knobbed whelk (Kozlowski 2012).

c. Indirect impacts from predation are much more subtle but may have significant effects on the productivity of the shellfish species as well. For example, many infaunal clams will bury deeper into the substrate in the presence of predators (quahog - Doering 1982, soft shell clam - Flynn and Smee 2010). Other shellfish may increase shell thickness in the presence of predators (oysters - Robinson et al. 2014) or strengthen their connection with heavier byssal threads to reduce the risk of removal from their attachment place (blue mussel - Cote 1995). In all cases, the response of the shellfish to the presence of the predator resulted in an increased energetic cost to the mollusk. The end result, while not a direct mortality, involves the reduction of the growth rate of the shellfish, as was demonstrated by Nakaoka (2000) where quahogs grew less when exposed to the chemical cue of a nearby whelk, even when the whelk was blocked from contacting the clam.

d. Regardless of the nature or extent of the impact, predators are a negative factor in the productivity of shellfish. Historically, shellfish resource users undertook predator control programs parallel to their managing the shellfish. Many methods have been developed to control predators on shellfish grounds, including mechanical removal (e.g. starfish mops, Figure 3-X, Anonymous 1946), trapping and removal (Walton 1997), physical barriers (Leavitt and Burt 2000), and chemical control (Loosanof 1960). While many of these methods have either been outlawed (i.e. chemical eradication) or proven effective for reducing predation pressure only on small localized plots, i.e. aquaculture or enhancement sites, none seem to be practical or effective for large-scale control of predators. One potential means to reduce specific predator impacts is through developing a specialized fishery for the predator species (e.g. Gomes 1991), although unforeseen results may confound this management strategy. For example, an intensifying fishery on coastal sharks has reduced predation pressure on cownose rays leading to increasing predation pressure on the bay scallop along the mid-Atlantic region (Myers et al. 2007). The recent surge in whelk fishing intensity in Narragansett Bay may prove to be beneficial to reducing predation pressure on shellfish populations in the Bay.

e. Predator control may be an appropriate tool under some management circumstances. For example, Malinowski and Whitlatch (1988) recommend protecting juvenile stages of a shellfish resource as that effort will have substantially more benefit to sustaining populations than an equivalent effort to protect adults of the same population. Their recommendation has been validated by recent work in enhancing quahog populations using cultured quahog juveniles where juvenile survival was increased when protected under predator exclusion netting or following intensive trapping of crabs that was undertaken just prior to the planting of the seed (Walton et al. 2001, Rivara et al. 2004). Under circumstances where juvenile shellfish are in high abundance or are being planted during a restoration or enhancement activity, there may be significant benefit to providing short-term localized predator reduction activities as a component to managing that situation.

f. *Management and Research Recommendations* – (1) Monitor the variability in predator populations and integrate that information into the management process. RI needs a nimble management system that can respond quickly to changes in predation pressure as the population's change. (2) Consider implementing a state-wide predator control program for selected predators, based on best available science. (3) Develop creative ways to exploit predators that provide an economic incentive to remove (composting, bounty, and new product development). (4) Encourage the continued development of a whelk fishing effort in Narragansett Bay. (5) Look at unexploited populations to better understand the role that predation may play in structuring the population of shellfish. Use Providence River and/or other closed areas for studies. (6) Continue to investigate the role of early post-set mortality on structuring shellfish populations.

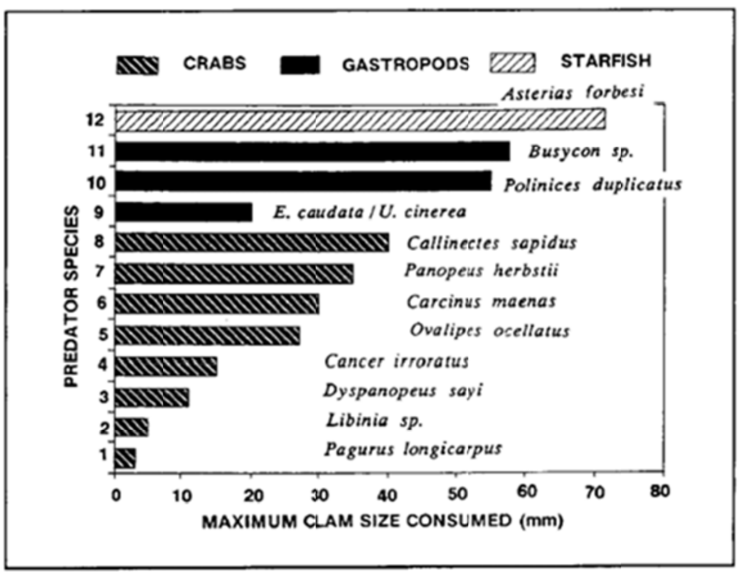


Figure 3.31. A survey of predators of the quahog and the maximum length of clam that each predator can successfully attack and consume (from Bricelj 2002).

Figure 3.32. "Mopping for Starfish", a WPA mural painted by Alexander Rummler and located in the Norwalk (CT) City Hall.

9. ISSUE: There is a need to better understand the role of natural mortality in structuring populations – disease.

   There are numerous diseases of shellfish that are recognized as having significant impacts on our local species. While many are often associated with shellfish culture activities, most of the diseases are not limited to aquaculture situations but can infect shellfish wherever they occur. Specific comments recorded from SMP stakeholder sessions included:

   - Shellfish diseases are impacting local stocks.
   - Recognize current efforts in breeding shellfish for disease resistance.

   a. *Background* - A listing of the diseases that have been detected in shellfish from Rhode Island and may cause significant problems are included in Table 7-2.While we have information on the prevalence and severity of some of these diseases, primarily those affecting oysters and quahogs, there are many disease situations that are insufficiently studied or unrecognized in natural populations of shellfish. For example, recent work funded by RI Sea Grant has started to look at potential disease situations in the blue mussel as they become more popular as a cultured species in the region and Narragansett Bay may become a source of mussel seed for various culture activities in the region.

   b. Starting in 1994 (Andamari et al. 1996), Rhode Island has intermittently supported a shellfish disease monitoring program for oysters and, to a lesser degree, quahogs, over the past 15 years. Using shellfish pathology resources at the University of Rhode Island (the Research Laboratory of Marta Gomez-Chiarri) and Roger Williams University (the Aquatic Animal Diagnostic Laboratory of Roxanna Smolowitz), this program has been partially supported by the Rhode Island Aquaculture Initiative, the RI Department of Environmental Management Fish and Wildlife Division and a NOAA Monitoring Award to RWU.

   c. Management of shellfish diseases is dependent almost entirely on prevention as there are no commonly available and approved methods to treat a diseased animal. To that end, all shellfish being moved into the state or moved across specified regions within the state are required to have a health inspection certificate generated by a qualified animal health laboratory. The health certification is one of the methods used to control disease transport and prevention by the RI CRMC, in consultation with the RI Biosecurity Board. Other efforts to protect RI shellfish include the development of disease tolerant oyster lines that are selectively bred in commercial hatcheries for use on oyster farms. These have also been integrated into some of the oyster restoration programs currently underway in the state. While they do not eradicate the risk of the disease, they produce an oyster that is more tolerant of the disease and has the capability to live longer after being infected with the predominant pathogenic parasites and/or bacteria.

d. *Management and Research Recommendations* – (1) Clarify oversight of shellfish movements to include all aspects of handling shellfish, including restoration and enhancement. (2) Reaffirm current oversight of shellfish movement and management for potential risks by the Biosecurity Board. To manage inter- and intra-state transport of shellfish. Support the advisory capacity of the Biosecurity Board to include all agencies managing shellfish resources in the state. (3) Support a state-wide shellfish disease monitoring program. Shift the cost to the state for disease monitoring rather than task farmers and fishers with this responsibility (or share cost between state and industry). (4) Encourage the use of disease resistant/tolerant shellfish lines for aquaculture. Need to maintain genetic diversity when selecting for disease resistance. Need to maintain local genetic characteristics while breeding for resistance to achieve optimal effect. RI in the middle between southern lines selected for MSX/dermo and northern lines selected for JOD. (5) Develop quicker and lower cost methods to detect common shellfish diseases. (6) Continue to work to improve genetics-based disease resistance/tolerance for farmed oysters grown in RI. (7) Need to explore the ramifications of climate change on shellfish disease processes for state waters.

10. ISSUE: There is a need to better understand the role of natural mortality in structuring populations – hypoxia.

Narragansett Bay experiences episodic hypoxic (low oxygen) events at specific locations throughout the upper bay (Saarman et al. 2008) as well as in some of the coastal ponds. The solubility of oxygen in water is primarily dependent on temperature and salinity, where increasing temperature or salinity leads to decreasing dissolved oxygen in the water. Low oxygen is a stress on living aquatic animals and if extended over time can lead to reduced productivity and death. Specific comments recorded from SMP stakeholder sessions included:

- Hypernutrification at sediment surface leading to localized hypoxia.
- Filtration as a tool to counter eutrophic conditions.
- Does hypoxia/anoxia affect predator populations as well as the shellfish resource?

a. *Background* - Low dissolved oxygen conditions in Narragansett Bay are the result of high organic loading to the bay sediment surface, generated by eutrophic conditions in the water column (Saarman et al. 2008). Specific areas of the Bay regularly undergo suboxic (2.9 – 4.7 mg O2/L) to hypoxic (1.2 – 2.9 mg O2/L, EPA 2000) conditions in the summer, during weak neap tides, and can last for periods of up to weeks (Codiga et al. 2009), due primarily to stratification of the water column with low mixing energy (Figure 3 – X, Deacutis 2008 and Figure 3-X, Melrose et al. 2007). Hypoxic events have led to large-scale mortality of many of the aquatic species caught within the sphere of hypoxia, e.g. the Greenwich Bay fish kill of 2003 (RIDEM 2003).

b. Many adult bivalve mollusks have a relatively high level of tolerance to hypoxia (Hochachka 1980), with the quahog (Grizzle et al. 2001) and blue mussel (Bayne et al. 1976) capable of surviving for extended periods of time (days to weeks) under low oxygen conditions. Because of their high level of tolerance, these species are less affected by hypoxic conditions than other species that do not have the capacity to deal with low oxygen. In some instances, this may impart an advantage to the more tolerant shellfish species in that the predators on shellfish are less tolerant of hypoxia and either leave the area with low oxygen or are killed by it resulting in less predation pressure on small shellfish remaining in or recruiting into the hypoxic area (Altieri 2006, Codiga et al. 2009).

c. Although most adult shellfish are relatively tolerant of low dissolved oxygen, larval and early juvenile shellfish are much more susceptible to hypoxia. The plot represented in Figure 3-X is a summary of the persistent low dissolved oxygen exposure criteria developed by the EPA to predict impacts on larval marine organisms (USEPA 2000). The threshold for significant impact on marine larvae is higher than that for juvenile or adult survival and is much higher than the levels observed for some areas in Narragansett Bay (Deacutis 2008). While low oxygen may be a means to enhance the survival of juvenile shellfish due to predator reductions, the same low dissolved oxygen may cause severe larval recruitment limitations because of the sensitivity of the larvae to hypoxia.

d. Monitoring and predicting low dissolved oxygen events is currently underway with a combined effort between the Narragansett Bay Commission and the Kincaid lab at the Graduate School of Oceanography at URI. Recent modeling has investigated the hydrodynamics of Narragansett Bay with an eye to understanding the distribution and frequency of hypoxic events in the Bay and what environmental conditions lead to those events (e.g. Bergondo et al. 2003, Balt 2012, 2014). Hopefully, these efforts will lead to an ability to predict hypoxic events and assist in developing a means to counter the damage done by hypoxia.

e. *Management and Research Recommendations* – (1) Continue monitoring the Bay for developing hypoxia events, including mapping of critical areas. (2) Work to decrease nutrient loading in the Bay to reduce the potential for hypoxic events to occur. (3) Apply our knowledge of hypoxia to influence management decisions that may be impacted by hypoxic events, e.g. shellfish sanctuary siting. (4) Continue studies of hypoxia in the Bay, including modeling of Bay-wide hydrodynamics and measuring the factors influencing hypoxic events. (5) Research on the real impact of hypoxia on shellfish resources. Do we know what impact hypoxia has on the various shellfish stages? (6) Encourage the continued research on the role of shellfish in mitigating eutrophication in coastal waters (research). (7) Does hypoxia/anoxia affect predator populations as well as resource?

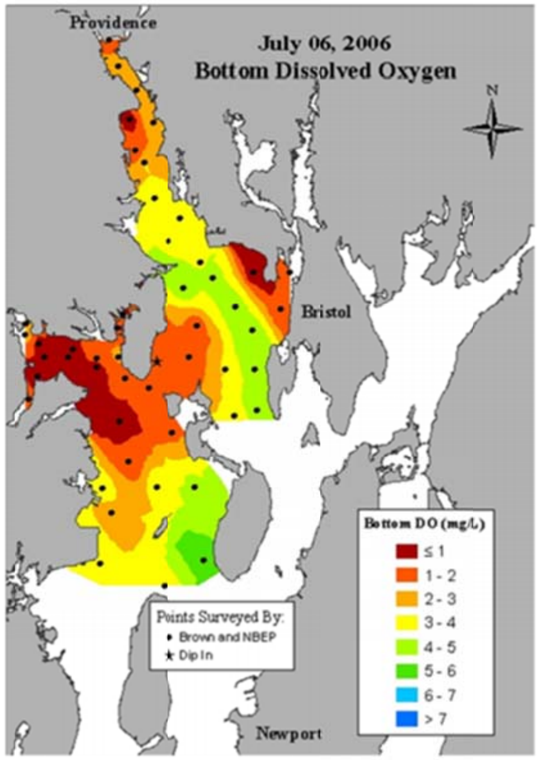


Figure 3.33. An example of the distribution of hypoxic bottom water in Narragansett Bay in July 2006 (from Prell et al. 2011).

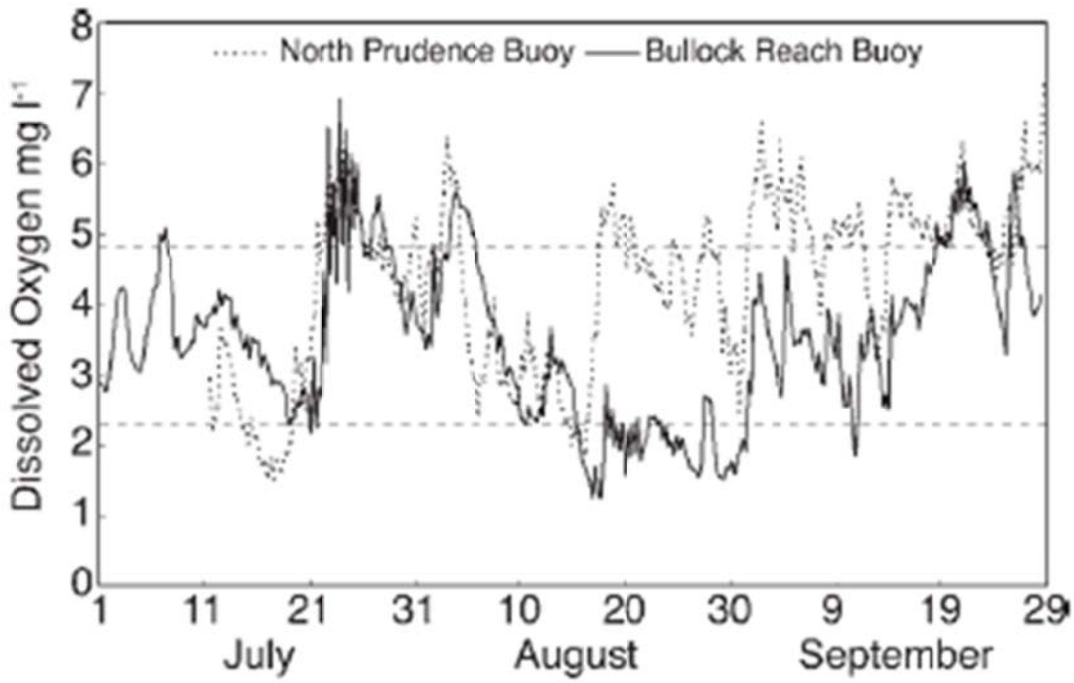


Figure 3.34. Bottom oxygen data from the North Providence and Bullock Reach monitoring buoys averaged over 6 hours (from Melrose et al. 2007).

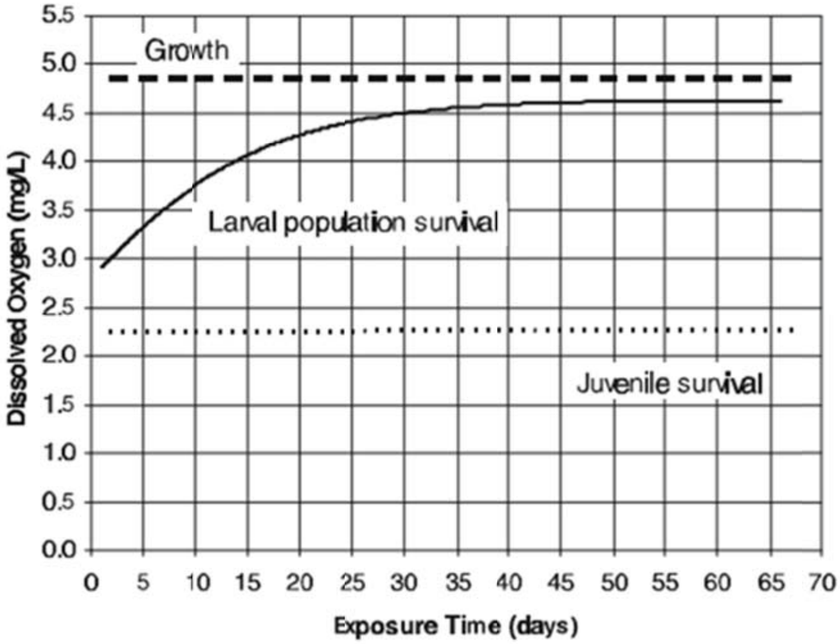


Figure 3.35. Plot of the final criteria for saltwater animals continuously exposed to low dissolved oxygen. The upper dashed line is the continuous concentration threshold for growth. The lower dotted line is the minimum concentration threshold for juvenile and adult survival. The curve between the two thresholds is the recruitment curve derived from a compilation of the 5 most sensitive species in the ecosystem (from USEPA 2000).

11. ISSUE: With regard to restoration/enhancement, there is a need to better manage spawner sanctuaries and broodstock enhancement.

    Providing an adequate supply of larvae/juveniles to replenish fished populations is a critical component to any fisheries management scenario. In addition to natural recruitment, one strategy that has been in use for a number of years is the protection and enhancement of broodstock in the form of spawning sanctuaries and/or broodstock enhancement. A second strategy that has been applied is to enhance the stock of juvenile shellfish by protecting them during their highly vulnerable larval and post-set stages and releasing them as they become more adept at surviving in the wild. Are these strategies something that can be used in Rhode Island? Specific comments recorded from SMP stakeholder sessions included:

    - Can we manage the stocks to compensate for post-set mortality? How many larvae do we need to maintain a population?
    - Can't rely on natural recruitment; manage like running a farm.
    - Placement of sanctuaries - Identify spawner sanctuaries based on environmental characteristics.
    - Hydrodynamics – part of siting spawner sanctuaries. Incorporation of hydrodynamic information in management
    - Sparse science concerning spawner sanctuaries and broodstock enhancement? Understand broodstock characteristics necessary to maintain stocks. Identify spawner sanctuaries based on environmental characteristics - Hydrodynamics – part of siting spawner sanctuaries; Incorporation of hydrodynamic information in management - Effectiveness of spawning sanctuaries?

    a. *Background* - There have been numerous successes at enhancing or restoring depleted shellfish populations through stock relaying and developing protective spawner sanctuaries. Many of these strategies have been attempted in Rhode Island over the years (Rice et al. 2000). An explanation of each of these activities is presented below.

b. Stock relaying (or transplanting) is an enhancement/restoration strategy that has long been utilized in the region. The harvest of adult shellfish from an area of high density, often behind water quality closure lines, to areas of low or no density is routinely practiced in most, if not all, of the New England states. As described in the National Shellfish Sanitation Protocols (NSSP 2013), "Relaying is the practice of harvesting shellstock from polluted growing areas and placing them in unpolluted bodies of water for a sufficient time for the shellstock to reduce contaminating microorganisms and chemical contaminants to safe levels." Rhode Island first conducted a shellfish relay in 1954 and has intermittently continued relays since that time (Rice et al. 2000). Initially, relays were undertaken to take quahogs from behind closure lines and make them available to local harvesters following an interval where they cleansed their body of harmful bacteria (Rice et al. 2000). The timing of natural cleansing is variable, depending on the temperature, salinity, dissolved oxygen content and turbidity/suspended particulates, with the time interval starting at 14 days and growing longer as environmental conditions become more adverse (NSSP 2013).

c. Setting aside areas protected from harvesting as reservoirs of reproducing individuals is another means to enhance populations of shellfish resources. Commonly referred to as "spawner sanctuaries", the concept is to protect a critical density of adult organisms to allow for the resident adults to condition and reproduce effectively thereby supplying large amounts of developing larvae to the pool of individuals in the ecosystem. Under some circumstances of low adult populations, spawner-recruit limitations warrant the institution of areas set aside for enhancing larval production to supply populations in specific areas (Peterson 2002, Kraeuter et al. 2005). Animals in shellfish spawner sanctuaries have been demonstrated to reproduce normally (Doall et al. 2008) although documenting their rate of success is extremely problematic given the degree of difficulty in monitoring larval spatfall and, furthermore, determining the origination of the spat.

d. More recently these two strategies have been combined, where relaying has been used to populate areas that are set aside from harvesting in closed systems, such as coastal ponds or enclosed waterways (Kassner & Malouf 1982, Peterson et al. 1996). In Rhode Island, a quahog transplant area off Warwick Neck was established as a spawner sanctuary and was stocked with adult quahogs retrieved from inner Greenwich Bay (Figure 3-X). Relaying has been proven to be an effective quahog enhancement tool for conditioning fecund adults and producing larvae for numerous reproductive seasons following the transplant (Doall et al. 2008). However Kassner and Malouf (1982) suggest that the overall efficacy of spawner relays may be insignificant on a bay-wide basis. They do suggest that this strategy may be effective for small-scale and well-placed situations.

e. In addition to dedicated spawner sanctuaries that have been intentionally set aside for protecting a spawning population, it has been suggested that shellfish located behind water quality closure lines are de facto spawner sanctuaries. Because those Prohibited areas are often noted for supporting exceedingly high densities of adult shellfish, they may be a significant source of larvae to the bay. For example, Saila et al. (1967) estimated the standing stock of quahogs in the Providence River (17.5 km2) to be 400-425x106 individuals. Using the quahog as an example, shellfish are considered to be r-strategists in that they have high fecundity and mature at an early age (Eversole 2001). Furthermore, egg production increases with increasing animal size (Bricelj & Malouf 1980). Therefore, it is logical to assume that areas with high densities of large clams, i.e. closed areas, will release considerably higher numbers of eggs and sperm, i.e. greater larval production. It is this rationale that has fostered the development of non-fished "spawner sanctuaries" as a management strategy to protect larval supply, a strategy that is being used by RIDEM for management (Rice et al. 2000, Rice 2006). Marroquin-Mora & Rice (2008) demonstrated that in non-fished areas in upper Narragansett Bay (e.g. Greenwich, Warwick and Apponaug Coves and Providence River) with higher densities of larger quahogs than fished areas (e.g. Conditional Areas A & B), the gonadal development and overall condition lags behind those of fished areas, leading the authors to conclude that "areas long-closed to shellfishing in Narragansett Bay are NOT serving as spawner sanctuaries or serving as a major source of spillover larvae" possibly due to over-crowding. While this study could have profound implications for developing a management strategy for upper Narragansett Bay, the authors conclude that more research and baseline information are required to confirm these preliminary observations.

f. Another means to manage spawner sanctuaries is to confine adult individuals in close proximity. This is often attempted using epifaunal species, such as oysters or bay scallops. Using aquaculture technology for confinement (Leavitt and Burt 200X), candidate species can be concentrated in cages or pens where their density can be optimized to ensure effective reproduction without the threat of individuals competing for food or space resources. With adequate knowledge, the reproductive effort can be optimized to produce the largest number of larvae and, because of the portability of the confinement system, the artificial sanctuaries can be placed at strategic positions in the target water bodies with little extra effort. One example of this technique is observed with the bay scallop spawner sanctuaries maintained by Save the Bay in Point Judith and Ninigret Ponds. In this example, cultured juvenile bay scallops are confined in plastic mesh bags housed in a wire mesh cage system. With this configuration, STB has been placing 5,000 to 15,000 reproductive bay scallops in the ponds to enhance the natural bay scallop production in those areas.

g. Provided that spawner sanctuaries and/or closed areas are sources of larvae available to repopulate areas of the bay, one strategy for evaluating spawner sanctuaries may be the application of hydrodynamic modeling to the dispersion of shellfish larvae originating from areas of high quahog densities. Research is currently underway (supported by RI Sea Grant), building on work by Jeff Mercer (URI/DEM) and Leavitt et al. (2014) to apply a bay-wide hydrodynamic model (Regional Ocean Model System – ROMS) adapted for Narragansett Bay by C. Kincaid and D. Ullman (URI/GSO) to investigate the potential trajectories of larval dispersion following release from specific points representing source areas for shellfish larvae. One model run depicting the distribution of larvae (particles) 10 days following release from the Providence River is included in Figure 3-X (from Leavitt et al. 2014). Studies such as this may be an important factor in predicting spatfall from varying source areas and for assisting in locating spawner sanctuaries should this strategy be adopted for more areas in Rhode Island waters.

h. *Management and Research Recommendations* – (1) Develop effective tools & guidelines for shellfish restoration/enhancement. (2) Support shellfish restoration/enhancement where proven effective. (3) Utilize current information when considering site locations for spawner sanctuaries. (4) Expand information gathering on the efficacy of shellfish restoration/enhancement programs – i.e. continue to monitor and evaluate. (5) Determine the impact of shellfish population densities on reproductive potential of the population. (6) Continue to investigate the effectiveness of spawner sanctuaries, in terms of their capacity to produce larvae and their efficacy in distributing larval shellfish to appropriate target areas.

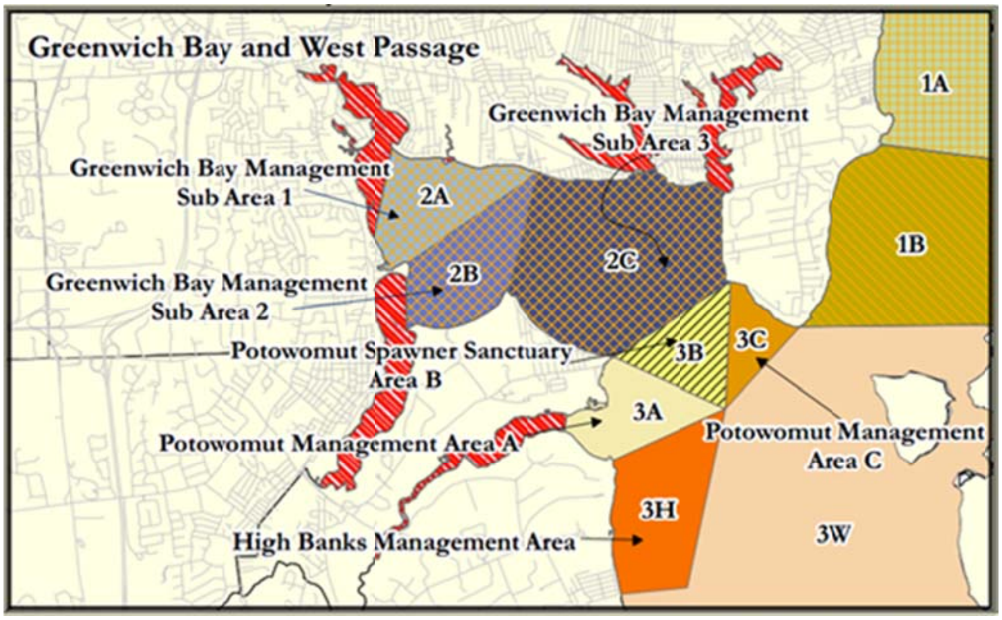


Figure 3.36. Greenwich Bay Management Area designations, including the Potowomut Spawner Sanctuary (3B).

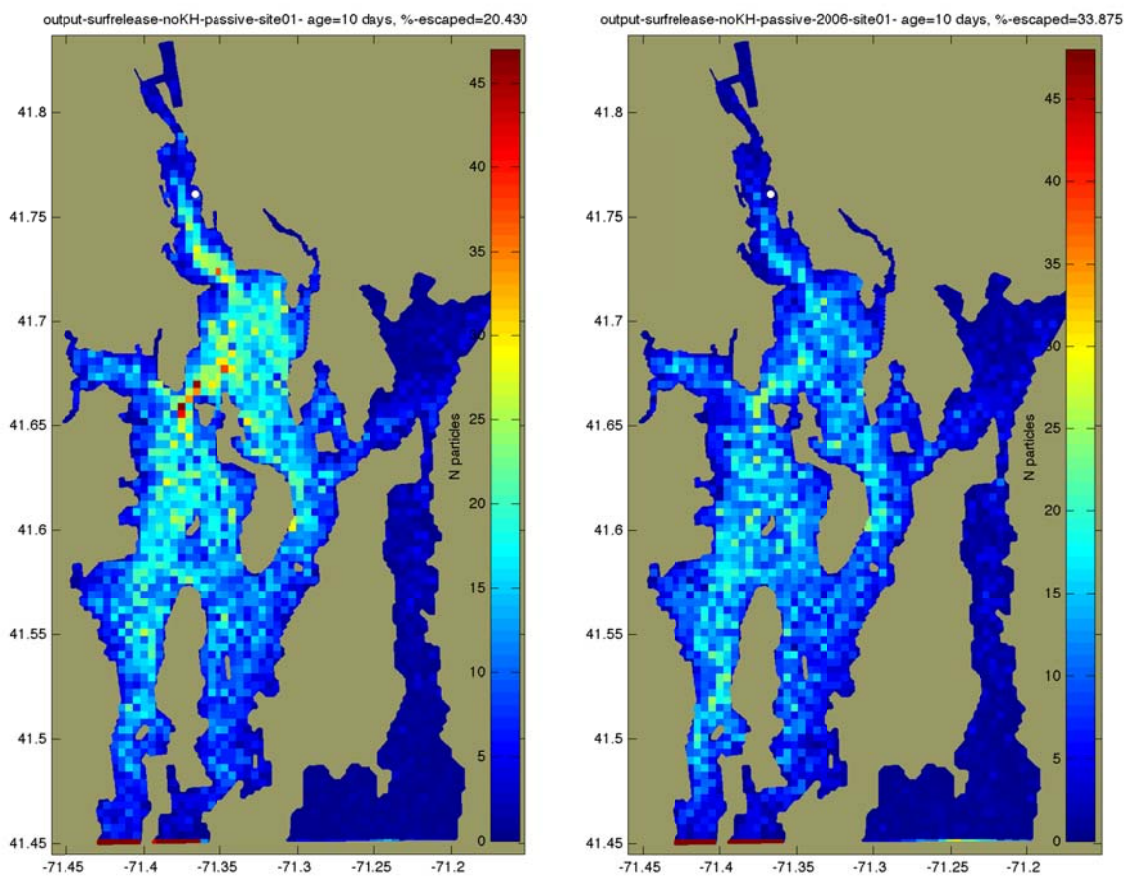


Figure 3.37. Number of particles as a function of position within the Bay 10 days after release from the Providence River site for 2006 (left) and 2007 (right). The white dot indicates the release location (from Leavitt et al. 2014).

12. ISSUE: With regard to restoration/enhancement, there is a need to better understand seeding areas.

A third strategy for restoring or enhancing shellfish resources is to apply aquaculture technology to the early development stages of the shellfish and releasing the juveniles to the wild as they achieve a size threshold that reduces the risk of mortality due to predation or other environmental stresses. Specific comments recorded from SMP stakeholder sessions included:

- Define what species to restore and to what levels
- Can't rely on natural recruitment, manage like running a farm.
- Restoration population targets? - Natural density ranges? Viable population density?
- What is effective restoration? What are the numbers?

a. *Background* - Currently, there are numerous efforts in Rhode Island to restore or enhance shellfish populations by way of seeding juveniles into an area. Primarily focused on oyster and quahog enhancement, numerous governmental and non-governmental organizations have been rearing and planting shellfish in RI waters since the 1990's. The motivation behind these activities ranges from restoring areas with oysters to take advantage of the environmental services offered by the oyster to planting seed quahogs in areas destined for commercial harvest.

b. Seed oysters are routinely produced as "spat on shell" seed using remote set technology, where competent larvae are exposed to conditioned cultch and allowed to set on the material in complex assemblages of individuals (Jones & Jones 1988). Using this technology, the seed oysters are nursery cultured in floating tray systems for the first growing season to allow the individual oyster to gain a size of greater than 25 mm in length. The combination of larger seed size and complex arrays of individuals results in a higher chance for the young oysters to survive when planted in the wild, as cultchless oysters have a high susceptibility to predation pressure (Krantz & Chamberlin 1978). This strategy for producing seed oysters for restoration has been used in Rhode Island since 2006 when the Oyster Gardening for Restoration and Enhancement (OGRE) Program was initiated at Roger Williams University. Since that time, the spat on shell program has been greatly expanded through actions by commercial oyster growers and non-governmental organizations, such as the Nature Conservancy, with support primarily from the Natural Resources Conservation Service of the USDA through their Environmental Quality Incentive Program (EQIP). This combination of programs has supported the installation of XX oyster restoration sites throughout Narragansett Bay and the coastal ponds.

c. Since the installation of the RI oyster restoration areas, limited monitoring has occurred to assess the efficacy of these programs. With funding from the NOAA Fisheries Habitat Conservation Program, Roger Williams University has been tracking the dynamics of oyster restoration areas generated by the North Cape Oil Spill Remediation Program and the RWU OGRE Program. As part of this project, a manual for monitoring oyster areas to assess their status was generated (Griffin et al. 2012). Based on this work, oyster seeding programs in Rhode Island appear to require maintenance seeding annually to sustain the populations (Griffin et al. 2014). Otherwise, the population density drops rapidly and loses its capacity to provide significant environmental services on a timescale of about 6 years from planting (Griffin et al. 2014).

d. The Rhode Island Shellfishermen's Association (RISA), in collaboration with RI-DEM and Roger Williams University, has been maintaining a quahog shellfish nursery since 2003 for the purpose of enhancing standing stock of quahogs in commercial and recreational fishing areas (Griffin et al. 2014). Utilizing a floating upweller system (FLUPSY) maintained originally in Apponaug and later in Warwick Cove, the fishermen have annually planted between 500,000 and 2 million 15 mm quahog seed into areas of Greenwich Bay, Green River and the High Banks area of North Kingstown as well as along the Escape Road in Point Judith Pond (Galilee, RI). Monitoring of the success rate of this program has not been critically evaluated although anecdotal observations suggest that the success rate (survival to harvest) may be on the order of 25 to 30%, based on the frequency of occurrence of naturally marked notata quahogs planted in the Green River area by the RISA effort in 2004 (Leavitt, personal observation).

e. Recently, a careful evaluation of a similar quahog enhancement program was conducted at multiple sites on Long Island (NY) (Rivara et al. 2005). The researchers planted seed quahogs from their nursery system at various times of the summer (June, August and October) and then carefully monitored the survival, growth and condition of the planted quahogs. They concluded: "Without protection from predators, relatively small clams planted in spring and summer will experience much higher mortality than those planted in the fall. Towns and companies growing hard clams would do best to protect clams until the first winter either by bottom nets or containerization of the seed. This could constitute a shift away from hatchery/nursery work towards field preparation/predator reduction at planting sites. An alternative that could increase survival would be identifying sites with low predator abundances and planting on those sites." (Rivara et al. 2005).

f. Currently, there is no organized planning underway to evaluate and oversee shellfish restoration and enhancement in Rhode Island. The projects that have been initiated to date have either been independent actions of various special-interest groups or remediation for environmental insults, such as the North Cape Oil Spill or the Allen's Harbor Remediation Fund. Monitoring of current and future efforts are essential for the evaluation of restoration/enhancement activities and are necessary to guide and adapt programs to be cost-effective and beneficial.

g. Restoration/enhancement programs can provide other services to the resource management activities of the state that also need to be considered. The benefits of educating shoreline landowners and other citizens of the state as to the services of shellfish in the environment, the importance of protecting coastal water quality and the advantages to having a strong shellfish management process should not be underestimated. Using the RI-OGRE Program as an example, over 100 coastal landowners are continuously being educated as to the benefits of healthy shellfish stocks in RI waters. In addition, the OGRE Coordinator visits a large number of school programs each year to teach classes on the benefits of healthy shellfish resources in our waters. Expanding the environmental awareness and guiding RI citizens to become familiar with common shellfish propagation practices is a positive outcome that is very difficult to evaluate, yet is critical to generating continued support for protecting and promoting our shellfish resources.

h. *Management and Research Recommendations* – (1) Shellfish restoration/enhancement in RI needs to be carefully evaluated to gauge the effectiveness and long-term sustainability of these programs. Need to demonstrate success (at some level) from a biological perspective. (2) If deemed to be worthwhile, then provisions need to be made in RI shellfish management to encourage the continued efforts in shellfish restoration/enhancement. (3) Clear guidelines and a defined management protocol needs to be developed to oversee restoration/enhancement efforts in RI. Must include an evaluation process. (4) Need to include site monitoring as a component to any restoration effort (including disease monitoring). (5) Should appoint an overseer to process and manage restoration projects, similar to CRMC aquaculture coordinator. Needs to deal with: Biosecurity (seed movement, disease testing), Siting, and Permitting. (6) Develop a regulatory mechanism by which shellfish can be placed in areas needing mitigation (i.e. Prohibited waters) to assist in reducing the impacts of excess nutrients. (7) Expand educational activities associated with shellfish restoration/enhancement to promote these activities and the environmental benefits generated. (8) A careful evaluation of the efficacy of restoration/enhancement activities is necessary to warrant any further development in these programs. Including an economic analysis of the cost/benefit of the program. (9) Develop procedures to enhance the effectiveness of shellfish restoration/enhancement programs, including: Handling and planting strategies to minimize predation and other losses, and improved siting criteria.

13. ISSUE: There is a need to better understand and maintain genetic diversity of shellfish stocks.

A knowledge of the overall genetic structure of shellfish populations and the role that artificial breeding of these species may play in changing that genetic structure have been on the minds of scientists, farmers and managers for many years (e.g. Wilkins 1975). Advances in gene measurement and our understanding of genetic diversity have dramatically improved in recent years and could lead to increased application of genetic information to management decision-making. Specific comments recorded from SMP stakeholder sessions included:

- Understand metapopulation structure of shellfish in bay and ponds
- Need to maintain natural genetic variability
- Understand broodstock characteristics necessary to maintain stocks

a. *Background* - Improving techniques for characterizing the genetic composition of bivalve mollusks has led to a better understanding of bivalve population genetics (Dragomir-Cosmin and Savini 2011). Improving technology coupled with an increasing appreciation of the role of genetic diversity in a species' environmental resiliency suggests that knowledge of genetic diversity may become a more important factor in managing shellfish resources. This is especially true when considering the artificial propagation of shellfish for restoration and/or enhancement projects (Falk et al. 2001) or when trying to predict the population consequences of global climate change (Pauls et al. 2013).

b. Recent work on bivalve genetic diversity has focused primarily on two commercially important species, the quahog and the eastern oyster (Figure 3-X), and has been driven both by the need to preserve the natural genetic variation of each species during restoration and enhancement activities and to improve the phenotypic characteristics of these species for farming. Because both activities are dependent on the hatchery production of seed, much of the recent work has focused on comparing diversity between wild and cultured populations and on identifying appropriate genetic markers that help to identify the overall genetic composition of an individual or family line or to allow for breeding selection to highlight specific phenotypic characteristics, such as fast growth or disease tolerance.

c. Natural genetic variability is regarded as being relatively high in bivalve mollusks (NRC 2010) and has been reported for the oyster (Hirschfeld 1999, Varney and Gaffney 2006, Richard 2006, Medley 2010, Vercaemer et al. 2010) and the quahog (Dillon and Manzi 1992, Baker et al. 2004). In comparisons between wild and hatchery produced lines of bivalves, the general observation is that genetic diversity (specifically heterozygosity) is high and is not significantly reduced by hatchery breeding although here is drop-out of some rare alleles within the population (Virenhoeck et al. 1990, Yu and Guo 2005, Dillon and Manzi 1987). This observation may be confounded by an observed decrease in heterozygosity of quahogs as one moves north (or south) from the Carolinas (Baker et al. 2008).

d. Selective breeding, a common practice for improving the performance of farmed animals, has been applied to oysters (Frank-Lawale et al. 2014) and quahogs (Camara et al. 2006) destined for aquaculture production. One of the consequences of selective breeding is an erosion of genetic diversity, resulting from genetic drift and reduced effective population size (Gaffney 2006). Therefore, it is important for hatcheries to maintain appropriate effective population sizes (Frank-Lawale et al. 2014) and to consider outcrossing (Camara et al. 2006) as a part of their breeding program.

e. It is also important that hatcheries address specific goals with their breeding program. For example, the objectives of producing seed for a shellfish farm is different than those for a restoration program. A farmer wants a fast growing, probably inbred, individual that will perform well under their growing conditions while a restoration manager wants an outbred product that has natural genetic diversity with possibly some disease resistance bred into the line. While the two end-products may not be mutually exclusive, attention must be paid to the genetics of the species to ensure that the best result is achieved in both efforts.

f. *Management and Research Recommendations* – (1) As information becomes more available, address stock-based management if necessary. (2) Continue to use native broodstock where possible when undertaking a shellfish restoration/enhancement program. Need to maintain enough genetic variability to allow for adaptation. (3) Continue studies addressing population genetics of shellfish species in the state. Understand the genetic diversity of local shellfish stocks. Study metapopulation structure in the bay and the coastal ponds. Estimate minimum viable population size for local waters to monitor impact from restoration/enhancement activities. (4) Continue to work to improve genetics-based disease resistance/tolerance and other positive attributes for farmed shellfish grown in RI. (5) Investigate the contribution of aquaculture stocks to wild population

Figure 3.38. Karyotypes of the quahog (A, Zhi-Hua 2008) and eastern oyster (B, Rodriguez-Romero 1977).

14. ISSUE: Better understand pest species.

In addition to predators, shellfish are impacted by a variety of other pest species. Some of these are native but a large number of pests have been introduced via a variety of mechanisms. Regardless of their source, these pests can affect the productivity, availability and marketability of local shellfish. Specific comments recorded from SMP stakeholder sessions included:

- What about pea crabs & other pest species?
- Boring sponge? Is it an invasive?
- Are invasive species influencing natural mortality or affecting shellfish in other ways?

a. *Background* - A number of organisms can be found in association with local shellfish that may interfere with the ability of the shellfish to function normally. A good descriptor of many of these pests is included in a bulletin of pests put out by Woods Hole Sea Grant (http://www.whoi.edu/fileserver.do?id=74620 &pt= 2&p=88899). In some cases, the pest interferes directly with the organism while, in other cases, there is an indirect effect where the pest associates with some aspect of the shellfish habitat in a negative way.

b. Examples of native pests that directly impact local shellfish include pea crabs (Tumidotheres maculata), boring sponge (Cliona spp.) and mud blister worms (Polydora spp.) These pests can either affect the soft tissue of the shellfish, as is observed with the pea crab (Stauber 1945, Haven 1958, Seed 1969) or compromise the shell by burrowing into it as a refuge, as is observed in the boring sponge (Leidy 1889, Carver 2010) or the blister worm (Blake and Evans 1973, Kent 1981).

c. Indirect effects of pest species on RI shellfish are primarily associated with biofouling, either directly on the individual or covering structures associated with the shellfish, often associated with aquaculture operations. The presence of fouling organisms may result in reduced water flow and food flux available to the individual, competition for available food or space resources, and/or physical obstruction of normal activities of the shellfish (Fitridge et al. 2012).

d. Unfortunately, many of the fouling pests that impact shellfish production are introductions from exotic sources. Through many transfer vectors, organisms such as a variety of colonial tunicates (Didemnum vexillum, Botrylloides violaceus, and Botrytus scholosseri), solitary tunicates (Styela clava, Ciona intestinalis, and Molgula manhattenensis), and macroalgal species (e.g. Grateloupia turuturu and Codium fragile), as well as predators, such as crabs (Carcinus maenas), have been introduced into Rhode Island waters. A review of the impacts of invasive species to Rhode Island resources was developed recently for the RI Aquaculture Working Group (Leavitt 2008).

e. The consequences of introduction of these species can be substantial (Table 3-X), from direct predation mortality to competition for space and food resources but the tools to manage the introduction of exotics are somewhat limited to those practices that prevent the initial introduction of the organism to local waters (Ruesink et al. 1995, Mack et al. 2000). RI recently adopted an Aquatic Invasive Species Management Plan that "outlines a five-year plan intended to for aquatic invasive species management in Rhode Island with the goal of implementing a coordinated approach to minimizing the economic, environmental and social impacts of AIS on the marine and freshwater ecosystems and resources of Rhode Island" (CRMC 2007).

f. *Management and Research Recommendations* – (1) Rhode Island should continue participation in the region-wide Northeast ANS Panel, to ensure that regulations and management of ANS introductions are uniform throughout the region and that all states are in compliance with whatever strategies are in place. (2) Develop an extensive educational campaign to prevent accidental introductions. (3) Support the Biosecurity Board's oversight of inter- and intra-state shellfish movement. Include invasive pests in criteria for managing shellfish transport intra- and inter-state. (4) Rhode Island should utilize the guidelines provided by the ICES Code of Practice on the Introductions and Transfers of Marine Organisms 2004 if intentional introductions are proposed in the state. (5) Encourage more research on husbandry strategies or management practices to reduce impact of pest species. (6) Understand the primary vectors for introductions of exotic species into RI.

Table 3.15. A list of potential impacts from aquatic invasive species (from McNally 2006).

Impacts of Aquatic Invasive Species		
Ecological Impacts	***Economic Impacts***	***Human Health Impacts***

- Competition with native species for food and space[1,2]
- Predation upon native species[1,2]
- Habitat alterations[1,2,3]
- Extinction of rare and endangered species (locally or entirely)[3]
- Parasitism[1]
- Introduction of new pathogens[1]
- Genetic changes[1]
- Species shifts/loss of biodiversity[1,3]
- Displacement of native species[2]
- Food web alterations[2]
- Alteration of environmental conditions/ecosystems[2]
- Degradation of water quality[3]
	- Clearing/removal costs for clogged piping[1]
	  - Industrial water users
	  - Municipal water systems
	  - Nuclear power plants
	- Damage to levees/dams[1]
	- Lost revenues from impacted commercial and recreational fishing[1]
	- Replacement and repair of docks and shoreline structures from introduced marine wood-borers[1,3]
	- Interference with recreational activities/water sports (navigation, boating, swimming)[1,3,4]
	- Costs of studying invasive species and proposed methods to control them[1]
	- Diminished property values[3]
	- Increased threats to public health/safety[3]
		- Cholera risk[1]
		- Paralytic shellfish poisoning[1]
		- Harmful algal blooms[1]
		- Spread of human pathogens[3]
		- Aquaculture pathogens

Source of Information: [1] Ribb and Deacutis (2002); [2] Raaymakers (2002); [3] Massachusetts Office of Coastal Zone Management (2002); [4]Lovell and Stone (2005).

15. ISSUE: There is a need to better understand environmental change that may affect shellfish.

Local environmental conditions represent a dynamic milieu that currently are experiencing a relatively rapid rate of change, lead by an upward swing of atmospheric levels of greenhouse gases, primarily carbon dioxide (Mellilo et al. 2014). The end result of changing conditions is dramatic changes in environmental parameters such as climate (temperature and weather patterns) and aquatic conditions (sea level rise and acidification), which may bring about significant changes to Rhode Island shellfish populations. Specific comments recorded from SMP stakeholder sessions included:

- How is climate-based ocean acidification occurring, etc. - Consider buffering capacity
- Other climate change issues to be considered - Environmental warming; severe weather may affect salinity, pathogen transport & bay closures, sediment, flushing & retention time (low or high flow), and water chemistry (hypoxia)
- Changes in the ranges of organisms
- Enhance predators – blue crab?

a. *Backgorund* - Climate change driven by atmospheric increases of greenhouse gases, primarily carbon dioxide, is resulting in many environmental changes that will influence shellfish populations in Rhode Island (Figure 3-X). Relevant consequences of climate change include air and water temperature increases affecting temporal patterns of phytoplankton population dynamics and fish assemblage patterns, changes in precipitation, sea level rise, and bay acidification (Smith et al. 2010). The consequences of these changes with respect to shellfish populations are many fold.

b. Increasing temperature directly influences the physiological processes of ectothermic species such as mollusks (e.g. quahog - Rice and Pechenik 1992, oyster – Shumway and Koehn 1982). Higher metabolism stimulates faster growth over a longer seasonal period and requires more food. Changing temperatures also affect normal cycles in marine creatures, such as inducing reproductive development and spawning on a different annual cycle than the population previously demonstrated (Burford et al. 2014). In addition, higher temperatures contribute to range extensions or retractions of marine animals that are at the edge of their normal distribution (Collie et al. 2008) some of which may be detrimental to shellfish populations, i.e. increased activity of shellfish predators (REF) or expansion of shellfish disease severity/prevalence (REF). When environmental changes, such as temperature, occur over an extended period encompassing many generations of individuals, the animal has some capacity to adapt to the change (Byrne 2011) or adjust their range to accommodate the changes (Saupe et al. 2014).

c. The second climate related change that is thought to result in a significant impact on shellfish is ocean acidification, as a consequence of increasing gaseous CO2 dissolving in seawater (Harley et al. 2006). Currently, the concept of ocean acidification as a phenomenon affecting shellfish is the result of a mix of environmental processes that need to be teased apart. There are three different acidification issues currently being discussed with respect to climate change and the coastal environment. They are:

- Ocean acidification, in its simplest form, is the result of increasing anthropogenic CO2 in the atmosphere being dissolved in the ocean and reducing the pH of the seawater (REF). In the long-term, this may be a problem for shellfish in the state.
- A different acidification issue is currently happening in the northwest section of the U.S., where "old-deep" water from the Pacific is being upwelled along the coastline of Oregon and Washington, resulting in low pH water originating from deep in the ocean impacting shellfish production in the region (REF). This phenomenon is highly unlikely to be a factor with respect to shellfish in Rhode Island and will not be discussed in this document.
- The third acidification issue is associated with the hypernutrification of our estuarine systems resulting in localized acidification, driven primarily by the decomposition of particulate organic matter that is being generated under the eutrophic conditions (Wallace et al. 2013). This

phenomenon is potentially important now in Narragansett Bay and the coastal ponds and will be discussed in the section addressing coastal pollution, below.

d. Many researchers have demonstrated a deleterious effect of ocean acidification on shellfish (Talmage and Gobler 2009, Miller et al. 2009, Ries et al. 2009), primarily during the larval stage when the shell formation is comprised of amorphous calcium carbonate rather than aragonite crystals as are found in older larvae and juveniles (Weiss et al. 2002). Larval shellfish respond to elevated dissolved CO2 levels in seawater with slower growth, smaller size and malformed calcified shells when exposed to levels of seawater pH equivalent to those projected to occur approximately 100 years from now (Talmage and Gobler 2009, Miller et al. 2009, Ries et al. 2009). However, it should be noted that estuarine shellfish species routinely experience large fluctuations in pH of their environment due to the unique water mixing properties where the upland freshwater meets the oceanic seawater (REF) and may be more capable of dealing with long-term acidification than more oceanic species, which have evolved in a more stable chemical environment in the open ocean (REF). Many authors have demonstrated effects due to ocean acidification but the ramifications of these effects in terms of the future of shellfish survival and productivity are poorly understood (Harley et al. 2006).

e. *Management and Recommendations* – (1) Continue to monitor changes in RI climate and waters and the biotic changes associated with these environmental changes.Continue the phytoplankton monitoring, finfish trawl survey and shellfish stock assessment survey currently operating in RI. (2) Produce more information on the impact of anthropogenically-driven climate change as it relates to management issues.

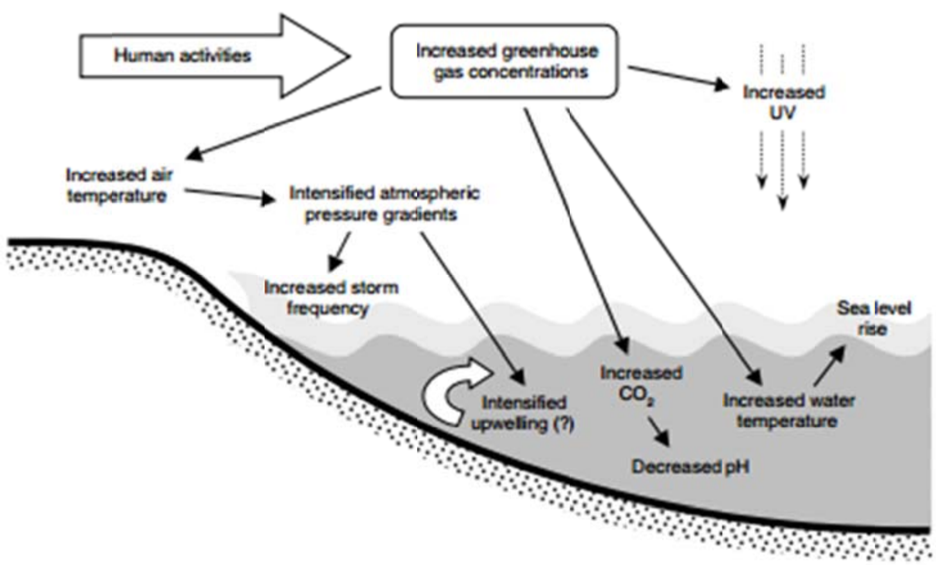


Figure 3.39. Abiotic changes in the marine environment as a result of human activities (Harley et al. 2006).

16. ISSUE: There is a need to better understand the affects of environmental pollution on shellfish populations.

In addition to global insults in water quality derived from human activity, such as ocean acidification, local changes in environmental quality are equally, if not more, important in affecting local shellfish resources. Contaminants from industry, sewage and other upland sources introduced into our local waterways can render shellfish unfit through a range of impacts from unsuitable for human consumption to direct mortality of the mollusk. Specific comments recorded from SMP stakeholder sessions included:

- Seed from upwellers in prohibited waters may be contaminated by environmental pollutants

- Run-off problems
- Restoration of shellfish in contaminated/prohibited areas
- Coastal eutrophication

a. *Background* - Shellfish have long been utilized as a sentinel species for monitoring of environmental contaminants in our coastal waters. Programs such as Mussel Watch, administered by the NOAA Status and Trends Program, utilize blue mussel and eastern oyster samples to assess the overall environmental status of specific marine locations in the U.S. (Kimbrough et al. 2008). Shellfish are used for this purpose due to the fact that they are sedentary and are processing large volumes of seawater as they filter for feeding and respiration. In addition to the soluble contaminants that can be absorbed directly by the shellfish tissue (e.g. many metals), particles filtered out during feeding can contain adsorbed hydrophobic contaminants (e.g. organic compounds) thereby allowing shellfish the capacity to integrate environmental conditions over the entire duration of their exposure with little capacity to transform those contaminants into other products (Kimbrough et al. 2008).

b. Current RI sites sampled during Mussel Watch are Dyer Island, Patience Island, Dutch Island and Block Island. A quick survey of contaminant history of Rhode Island sites reported by Mussel Watch (2005-2005 data) compared to the national average suggests that RI sites have medium levels of arsenic and lead with arsenic, copper and zinc levels trending down and medium to high levels of butyltins, dieldrins, and PAHs with butyltins, dieldrins, chlordanes and DDTs trending down (Kimbrough et al. 2008). No sites were reported to have increasing levels of any monitored contaminants.

c. In addition to Mussel Watch, more inclusive surveys of contaminants in RI waters have been conducted, including Hartman et al. 2004a, Hartman et al. 2004b, Taylor et al. 2012, Piraino and Taylor 2009, Latimer and Quinn 1998, Nixon 1995, Santschi et al. 1980, Katz et al. 2013, Calabretta and Oviatt 2008, and many more. In summary, contaminants in Narragansett Bay originated from the industrial and residential centers located around Providence and Fall River in the upper reaches of the bay. As one moves down the bay, one experiences a decreasing contaminant gradient to relatively low levels in the lower bay (Calabretta and Oviatt 2008, Kutcher 2012).

d. In addition to uptake of environmental contaminants, another piece of the puzzle is how quickly will shellfish depurate those same contaminants once the individual has been removed to clean waters? Regardless of whether the contaminants are chemical (metals or organics) or biological (coliform bacteria and potential human pathogens), understanding the depuration dynamics is an important part of managing shellfish. It has application in relaying shellfish from Conditional or Prohibited waters (i.e. closed to shellfish harvest due to human health risks) and in using Prohibited waters for the nursery culture of shellfish seed.

e. The conditions for depuration of bacterial contaminants from shellfish is relatively well understood and the mechanics have been clearly defined in documents such as the NSSP Model Ordinance (NSSP 2013) and manuals such as that published by the FAO or the WHO (Lee et al. 2008, 2010). Clearing viral contaminants are more problematic in terms of depuration as the uptake in a population is more variable (Seraichekas et al. 1968) and the depuration interval is longer (Muniain-Mujika et al. 2002). The same is true for inorganic contaminants, in that the uptake kinetics varies considerably among contaminant types as does the capacity of the individual organism to clear their tissue of those contaminants (REF). The timeline for depuration of chemical contaminants can be significantly longer that those observed fro biological contaminants, e.g. depuration half-lives of most trace metals in the eastern oyster were on the order of 90 to 120 days (Okazaki and Panietz 1981) as compared to 2 to 5 days for bacteria or viruses (Lee et al. 2008, Muniain-Mujika et al. 2002).

f. One contaminant that requires special discussion is anthropogenic nutrient discharges into the bay and the coastal ponds. Hypernutrification from upland sources is the primary contributor to eutrophication of Rhode Island waters leading a great variety of negative consequences. The most discussed consequence of eutrophic waters is the potential for developing hypoxia/anoxia in areas subjected to stratification in the water column leading to stress and mortality in many living resources in local waters. Hypoxia/anoxia problems are discussed under a separate heading with this chapter.

g. An often overlooked consequence of eutrophication is the acidification of estuarine and coastal waters as a result of microbial degradation of high loadings of organic matter derived from eutrophic conditions (Wallace et al. 2014). The end result is both hypoxia and an increase in acidity (lowering of the pH), sometimes down to levels of <7.5 (Wallace et al. 2014). That level of pH drop leads to a reduced capacity of larval shellfish to deposit CaCO3 into shell and may result in malformed larvae and possibly death (Talmage and Gobler 2009).

h. In addition to a reduction of pH in the water column, Green et al. (2004, 2009) have demonstrated that microbial degradation of organic matter, derived from eutrophic conditions in estuaries, can dramatically reduce the level of pH in the substrate. Termed “death by dissolution”, as larval shellfish undergo metamorphosis and settle onto low pH sediment, the acidity results in very high levels of mortality. Besides direct mortality, recent work suggests that low pH of the sediment acts as a deterrent to larval shellfish selecting a specific site for settlement and metamorphosis (Green et al. 2012).

i. Current work at the Environmental Protection Agency’s Atlantic Ecology Division (in Narragansett, RI), researchers are adapting a food web mass balance model (EcoPath) to interpret nutrient loadings in Narragansett Bay and how future changes in nutrient levels may affect shellfish populations (M. Chintala, pers. comm.) Following a similar but opposite logic, current research efforts also have been addressing the role that shellfish may play in mitigating eutrophic conditions in estuaries. Driven by local discussions on methods to mitigate excess nitrogen in estuaries, numerous studies have been addressing the ecological services provided by oysters and other shellfish under natural, aquaculture or restoration situations (Rose et al. 2014, Ostroumov 2005, Reitsma et al. 2014 and others). Results so far have been very supportive for utilizing shellfish as a tool to mitigate hypernutrification of local waters; however, they are not the entire solution and should be used in concert with other efforts to reduce nutrient inputs at their origination (Cerco and Noel 2007).

j. *Management and Research Recommendations* – (1) Educate all parties as to the risks associated with shellfish growing in contaminated areas. Know the history and source of shellfish purchased for consumption. When harvesting shellfish, post-harvest handling is a critical step in ensuring the safety of the product for consumption. (2) Continue to monitor shellfish for human health risks and manage those resources as recommended by the NSSP Model Ordinance. (3) Explore the role of shellfish in remediation of nutrient inputs in local waters and utilize this strategy as a component to nitrogen management strategies throughout the state, if appropriate. (4) Continue to encourage research on contaminant dynamics in RI shellfish. Investigate the contaminant uptake and depuration kinetics of juvenile shellfish held in Prohibited waters during early stages of their life cycle. (5) Encourage further studies on the potential role of shellfish in nutrient management in local waters.Evaluate the impact of shellfish deposits as sources of organic loading to sediment, i.e. benthic-pelagic coupling.

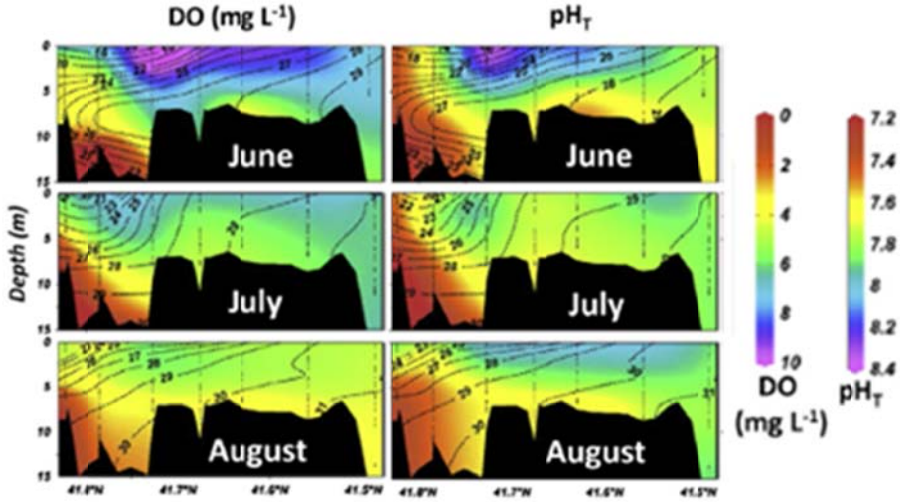


Figure 3.40. Multiple vertical section plots of dissolve oxygen and pH with salinity contour lines during the summer of 2013 in Narragansett Bay. Vertical lines denote CTD drops. Depth is 0-15 m (from Wallace et al. 2014).

17. ISSUE: There is a need to better understand ecological and biological carrying capacity.

    In its simplest form, the carrying capacity represents the maximum number of individuals or activities an environment can support for a long period of time. The question of carrying capacity arises as the waters of Rhode Island are more and more in demand for a variety of uses, from recreational sailing to food production. Specific comments recorded from SMP stakeholder sessions included:

    - Ecological impacts from Aquaculture
    - Biological carrying capacity

    a. *Background* – While the question of carrying capacity can be applied to a number of activities on the water, it has most recently been asked with respect to the development of shellfish farms in the state. As the density of farms increases throughout RI waters, especially in the coastal ponds, one often hears asked, "How much is too much?" The answer to that question is dependent on the context from which the question arose. Carrying capacity or "How much is too much?" needs to be further defined in order to extract an answer from our knowledge and experience. McKindsey (2006) separates the concept of carrying capacity into four distinct categories: 1) physical carrying capacity, 2) production carrying capacity, 3) ecological carrying capacity, and 4) social carrying capacity (Figure 3-X). The following information is based on these categories and their definitions, as provided by McKindsey (2006).

    b. Physical carrying capacity describes the space available that is suitable for the activity and can be described and measured based on the environmental requirements of the organism in question. In the case of shellfish farming, the physical carrying capacity can be bounded by our knowledge of the environmental limits to growth of the cultured species coupled with the ability of the farm technology being used to hold those animals within areas of suitable environmental conditions. These data are mostly available and can be compiled and analyzed using a straight-forward approach.

    c. Production carrying capacity measures the capacity of the local environment to support the production (growth) of the species being considered. In the case of shellfish farming, production is dependent on the primary productivity and the dynamics of carbon or energy flow in the area that is available to the filter-feeding shellfish. As above, these data exist for estimating resources available to the growing shellfish (e.g. Nixon et al. 1995, Keller 1998, Oviatt et al. 2002).

d. Ecological carrying capacity differs from production carrying capacity in that production focuses on the organism in question (i.e. farmed shellfish) while ecological addresses the productivity of the entire ecosystem and the role that expanding shellfish farms may play in the energy flow dynamics of the complete system. An important question regarding shellfish farms and carrying capacity in Rhode Island centers on this issue.

e. Over the past century, Narragansett Bay has experienced dramatic fluctuations in the extraction of shellfish resources, starting with wide-spread bottom culture of oysters in the early 1900's, followed by extensive harvest of wild quahogs during the mid- to late-century and recently supporting a combined harvest of wild quahogs and cultured oysters (Oviatt et al. 2003). In the coastal ponds, the current practices of oyster culture are expanding rapidly as is expansion of culture practices in the bay to include the blue mussel (Beutel 2014). If we couple these developments with recent improvements in our sewage handling practices leading to the potential for reduction of nutrient inputs into the bay (NBEP 2014), the question arises as to whether we are overtaxing the primary productivity of the bay or ponds, to the detriment of all species (i.e. exceeding the ecological carrying capacity)?

f. To address that question, a recent study applied a static mass-balance model (Eco-Path, Figure 3-X) to Narragansett Bay (Byron et al. 2011a) and the coastal ponds (Byron et al. 2011b) to investigate what the thresholds were for shellfish aquaculture in those water bodies before exceeding the ecological carrying capacity. Due to both systems having high energy through-put, based on primary productivity and detrital contributions, neither system is approaching exceeding their ecological carrying capacity. Based on the model, Narragansett Bay currently supported a farmed oyster biomass of 0.47 tons/km2 that could be increased to 297 tons/km2 (a 625% increase) without measurable impacts to other members of the ecosystem (Byron et al. 2011a). In Point Judith Pond, the reported farmed oyster biomass was 12 tons/km2, which could be increased to 722 tons/km2 (a 62% increase) before exceeding the ecological carrying capacity (Byron et al. 20911b). Table 3-X presents the maximum production capacity of farmed oysters for Rhode Island water bodies, based on the mass-balance model and production characteristics generated in the late 2000's (Byron 2010).

g. While shellfish farming has a long way to go to exceed the ecological carrying capacity of RI water bodies, the social carrying capacity may invoke local limits to aquaculture development long before the ecological carrying capacity is approached. Social carrying capacity is much more complex than ecological carrying capacity as it requires not only consideration of the three science-based concepts (physical, production and ecological) but it also involves socioeconomic considerations of all stakeholders associated with the resource (McKindsey 2006). Efforts are currently underway to address the concept of social carrying capacity in managing the placement and extent of shellfish farming in the state (Dalton and Thompson, A model for understanding public support for aquaculture & estimating social carrying capacities in RI waters. RI Sea Grant).

h. *Management and Research Recommendations* – (1) Increase educational efforts directed at Rhode Island citizens to allow for an informed decision-making process when managing shellfish resources.(2) Maintain open communication among all stakeholders to ensure that information is being exchanged in a constructive and informative manner. (3) Encourage the further development of Spatial Tools – EcoPath, EcoSpace, etc. and their application to RI conditions.

Figure 3.41. Categories of carrying capacity, as differentiated by McKindsey (2006).

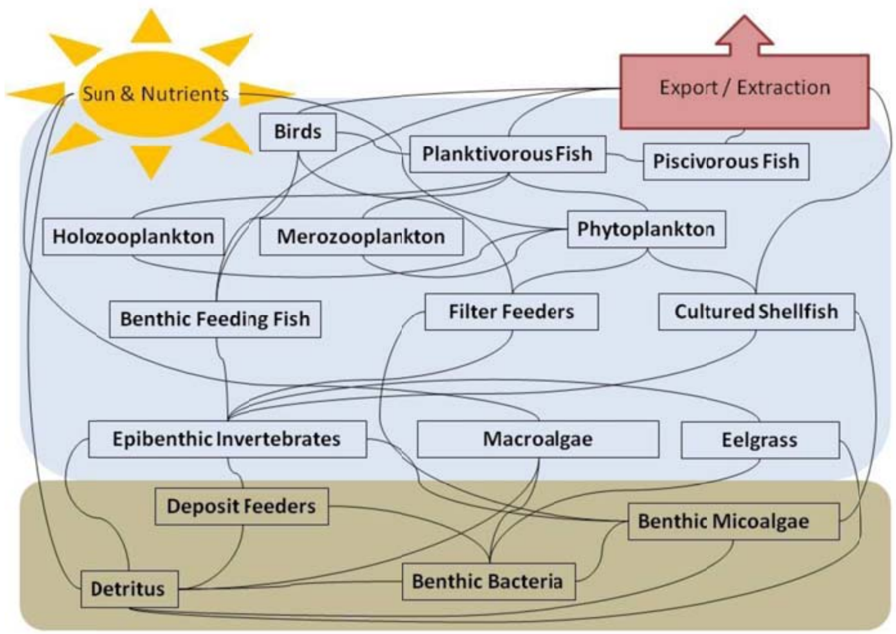


Figure 3.42. A schematic of the processes included in the EcoPath mass-balance model utilized by Byron et al. (2011a, 2001b).

Table 3.16. Potential for farmed oyster production in Rhode Island waters without exceeding the ecological carrying capacity, based on work by Byron et al. (2011a, 2011b).

Waterbody	Surface area (km^2)	Total biomass (t)	Harvest biomass (t)
Narragansett Bay	355	105,279	38,953
Point Judith Pond	6.37	4,601	1,288
Potter Pond	1.33	962	269
Ninigret Pond	6.92	5,001	1,400
Quonochontaug Pond	2.93	2,133	592
Winnipaug Pond	1.89	1,304	365

Table 3-X: Potential for farmed oyster production in Rhode Island waters without exceeding the ecological carrying capacity, based on work by Byron *et al.* (2011a, 2011b).

Section 350. References (Chapter 3)

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CHAPTER 4. Wild Harvest and Aquaculture

By Jeff Mercer, RIDEM; Monique LaFrance, GSO/URI; Azure Dee Cygler, CRC/URI

Section 400. Introduction

1. The purpose of this chapter is to summarize the current status of shellfish harvesting within Rhode Island state waters, including commercial and recreational shellfishing and aquaculture, and to highlight the economic, social, cultural, and historic trends of these activities to Rhode Island.

2. This chapter focuses on the current status of shellfish harvesting and aquaculture activities based on the best available, existing data and information from the past decade. Available historic information is also included, as appropriate, to provide context and underscore the longstanding economic and cultural importance of these activities to Rhode Island.

3. Commercial and recreational wild shellfishing are among the oldest and most widespread human activities of Narragansett Bay and Rhode Island's coastal ponds. The commercial shellfishing industry provides jobs to fishermen and supports associated businesses, and product is sold locally and exported throughout the United States and overseas. Recreational fishing is a popular and traditional pastime, with participation from both Rhode Island residents and out of state tourists that provide families with healthy, local food, and is a unique element of the region's recreation and tourism economy. Shellfishing also has a significant cultural component in that the activity enhances Rhode Island's connection to the sea and New England's rich maritime history.

4. Shellfishermen and residents alike hold a strong affinity for upholding their rights as assured in the RI Constitution in all manners of resource management. Rhode Island residents firmly embrace the notion of a "Free and Common" fishery, guaranteed to them through the State Constitution and predicated by the King Charles Charter of 1663, which states that the government: *"… shall not, in any manner, hinder any of our loving subjects, whatsoever, from using and exercising the trade of fishing upon the coast of New England, in America; but that they, and every or any of them, shall have full and free power and liberty to continue and use the trade of fishing upon the said coast, in any of the seas thereunto adjoining, or any arms of the seas, or salt water, rivers and creeks, where they have been accustomed to fish"* (King Charles Charter).

5. The Rhode Island Constitution further elaborates the rights of its citizens to access the fishery resources of the state: *"The people shall continue to enjoy and freely exercise all the rights of fishery, and the privileges of the shore, to which they have been heretofore entitled under the charter and usages of this state, including but not limited to fishing from the shore, the gathering of seaweed, leaving the shore to swim in the sea and passage along the shore; and they shall be secure in their rights to the use and enjoyment of the natural resources of the state with due regard for the preservation of their values"* (RI Constitution, Section 17).

6. Aquaculture in Rhode Island and throughout the United States has grown intensively over the last decade. It is one of the few growth industries in Rhode Island, exhibiting a strong increase in the number of farms, employees, and production values every year since the mid-1990's. Aquaculture is not new to Rhode Island, however, having been a significant industry in the 1800's through mid-1900's with over 21,000 acres leased to multiple oyster aquaculture companies between 1911-1912 (Rice, 2006). After a decline due to multiple factors, it is now on a steady rise again (see *Rhode Island's Shellfish Heritage: An Ecological History*, at www.rismp.org for more information on the historical oyster industry in the state).

7. There is currently an ever-increasing demand for fresh, local seafood harvested in a sustainable manner. As some of our natural resources have diminished over time, aquaculture is a means to address food production demands; the amount of shellfish that can be produced in an aquaculture setting exceeds that which can be harvested from naturally occurring populations in the environment without causing natural population declines.

8. The aquaculture industry in the state, comprised of small business farmers, provide seafood not just to Rhode Island, but also to consumers throughout the United States and Canada. The cultivated products, often formally brand named after well-known local areas (e.g. Ninigret, Matunuck, East Beach, Rome Point, Point Judith), also bring nationwide recognition to Rhode Island.
9. Water quality is a major factor impacting all shellfish activities (i.e. commercial & recreational harvest, aquaculture, and restoration and enhancement). In the interest of human health, DEM Office of Water Resources (OWR) conducts water quality sampling to monitor water quality and pollution levels. Based on the data, DEM OWR classifies shellfish grounds and establishes closures in areas of poor water quality to help prevent illnesses that may result from consuming shellfish harvested or grown in such areas. Such areas are designated as prohibited and closed to shellfishing and the harvest or cultivation of shellfish within these areas is not permitted (Refer to Appendix 4.1 for DEM 2014 classification of open/closed waters due to pollution or visit http://www.dem.ri.gov/maps/mapfile/shellfsh.pdf). Only those waters classified as SA or SA{b} and determined by DEM to be meeting all NSSP requirements of approved, seasonally approved or conditionally approved status are open to the wild harvest or cultivation of shellfish for direct human consumption. Currently, 87.5 sq. miles of RI marine waters are approved, 21.6 sq. miles are conditionally approved and 11.2 sq. miles are prohibited due to pollution. Shellfishing is also prohibited in closed safety zones in the vicinity of wastewater treatment facility outfalls (accounting for 10.8 sq miles) and coves where insufficient data are available to assess their sanitary condition making up 1.59 sq miles. For more information on the DEM OWR water quality program and procedures, review their Standard Operating Procedures (last updated in 2008) at: http://www.dem.ri.gov/pubs/sops/shellgro.pdf.
10. Due to declining water quality related to unacceptable bacteria levels, there has been substantial loss of areas available for recreational shellfish harvesting. These tidal rivers, smaller embayments and shallow areas include iconic areas previously favored by recreational shellfishers such as Palmer River, Barrington River, Potowomut River, Narrow River, Pawcatuck River, Green Hill Pond and Dutch Harbor.

Section 410. Shellfish Issues Identified by Stakeholders

1. Throughout the SMP process, the SMP team met with stakeholders to identify issues and concerns they had regarding all aspects of shellfish, including but not limited to environmental, management, marketing, capacity building, and decision making. The following are issues highlighting the major themes from stakeholders concerning wild harvest shellfish, aquaculture, and/or restoration & enhancement (the full list of issues identified can be found in Appendix 2.2). Stakeholders identified a need for:
   a. The improvement of shellfish management through increased sharing of information and coordination between shellfish management agencies, between the shellfish industries and agencies, and between user groups of the resource.
   b. Further understanding the myriad of uses on the Bay and coastal salt ponds, collecting data on use activities, and developing tools to help minimize possible use conflicts on the water.
   c. The identification of the role economic valuation plays in shellfish management, including collecting economic information on recreational harvest activities in the state, and discussing avenues for direct marketing opportunities for shellfish businesses.
   d. A better understanding of the biological processes of our shellfish resources, including understanding shellfish stocks in more detail and conducting more collaborative research on stock issues.
   e. Increased understanding of ecosystem-wide interactions with shellfish management, including enhancing and expanding shellfish restoration efforts, and the possibility of permitting restoration for water quality enhancement purposes.

f. Open discussions to identify and minimize various risks to shellfish resources and to mitigate those risks, including consideration of public health risks associated with shellfish, and educating the public at large about safety and risks regarding consumption of shellfish.

g. The examination and determination of the effectiveness of existing policy and investigate alternative strategies for improved management, such as enhancement and funding for Enforcement efforts, re-examining the utility and effectiveness of Management Areas, and discussing the possible permitting of certain shellfish culture and restoration activities in prohibited waters.

h. Discussions and actions for identifying and securing additional resources (i.e. funding, man power) to support management decision-making and research relating to shellfish.

i. Increased opportunities for recreational shellfishing primarily by improving water quality in our embayments and other shallow tidal waters.

Section 420. Shellfish Species Considered in the SMP

1. For the purposes of the SMP, only select bivalves and select gastropods are considered in deliberating management recommendations (Table 4.1). The criteria used for selecting the species to be included in the SMP were: 1) The species is commercially and/or recreationally harvested or cultivated in state waters; and 2) There are no current federal management plans in place.

Table 4.1. List of shellfish species commonly pursued in Rhode Island and considered within the SMP.

Common name(s)	Scientific name	Commercially Harvested	Recreationally Harvested	Aquaculture	Restoration
Quahog (Quahaug, hard clam, hard shelled clam)	*Mercenaria mercenaria*	X	X	X	X
Soft-shell clam (steamers, softshells, longnecks)	*Mya arenaria*	X	X	X	
Channeled Whelk (conch)	*Busycotypus canaliculatus*	X			
Knobbed Whelk (conch)	*Busycon carica*	X			
American Razor clam, Atlantic Jack Knife	*Ensis americanus, Ensis directus*	X	X		
Eastern Oyster	*Crassostrea virginica*	X	X	X	X
Blue mussel	*Mytilus edulis*	X	X	X	
Bay scallop	*Argopecten irradians*	X	X	X	X

Common name(s)	Scientific name	Commercially Harvested	Recreationally Harvested	Aquaculture	Restoration
Periwinkle	*Littorina littorea*		X		

Table 4.1. Species considered in the SMP. Note: Federally managed species, such as ocean quahog, sea scallop, and surf clam are not included in the SMP. The European Flat oyster was introduced to RI in the 1800's and is found periodically in the salt ponds. However, though attempts have been made, this species has not been successfully grown or harvested in recent years so is not listed in the table or discussed in the chapter.

2. The following provides a brief description of the general characteristics (size, shape, color) of the species listed in Table 4.1. In addition, harvesting regulations (limits, minimum size, and season) are provided in Tables 4.2 and 4.3, also below. See Appendix 4.2 for illustrations of the shellfish species (by Brandon Fuller, 2014). More information on these species can be found in Chapters 2 and 3.

   a. *Quahog* – Quahogs (also referred to as 'quahaugs' in DEM shellfish regulations) are a popular species harvested by commercial and recreational diggers alike, and are also cultivated by aquaculturists. There are four market categories for quahogs, each varying in size and price. From smallest to largest, these categories are: little necks, top necks, cherry stones, and chowders. Two varieties of quahog exist, which differ only in color, and are native to Rhode Island waters: alba and notata. The alba variety is the most common, having a white shell, whereas the notata quahog has a reddish-brown pattern on the shell and is found in 1-2% of the wild population. The difference is a natural occurrence due to a single locus genetic variation.

   b. *Soft-shell clam* – Commonly referred to as "steamers," these white clams have a thinner, softer shell than quahogs. They are harvested both commercially and recreationally. Along the shore, soft-shell clams can often be spotted on sand flats due to the hole left in the sand from their protruding siphons and will often squirt water through there holes when you step on the sand next to them.

   c. *Channeled whelk and knobbed whelk* – While two separate species, the channeled and knobbed whelk are often grouped together, and are most of referred to as "conchs" or "snails" by commercial fishermen. Both species have spiral shells; the knobbed whelk typically has strong, blunt knobs around the top whorls or spirals. The shell of the channeled whelk is generally smooth and more pear-shaped. The wide, deep channel between the whorls gives the channeled whelk its name. Both species can tuck their muscular foot into their shell and close it with the hard part of the foot called the operculum, which acts like a door to the shell and provides protection to the soft flesh within the shell. Whelks are popular among the commercial fishery, but are less targeted by recreational shellfish harvesters.

   d. *American razor clam, Atlantic jack knife* – Often referred to interchangeably, these are two different species, each found in sand or muddy bottoms along the shore. Razor clams have a streamlined, long shell with a strong, muscular "foot," allowing the clam to burrow very quickly, as well as swim, if needed. Jack knife clams can be given similar descriptions but are often more blunt and shorter than razor clams. The clams are primarily harvested recreationally, though to a lesser degree compared to quahogs and soft-shell clams and there is a very limited commercial fishery. The aquaculture industry has also begun to take an interest in cultivating razor clams and in developing effective growing techniques.

   e. *Eastern oyster* – Oysters create reefs and beds, thereby creating habitat, and thus are considered foundational species. Oyster habitat is considered one of the most degraded estuarine habitats in the world. The oyster is a coveted species by growers and harvesters alike in Rhode Island. The shell is often white in color, has ridges and is very strong and difficult to open without proper tools. The oyster is, by far, the most cultivated species by the State's aquaculture industry, comprising over 98% of all aquaculture. In general, there is comparatively little effort to harvest wild oysters recreationally or commercially due to low natural abundance and wild harvest only being permitted in the colder months.

f. *Blue mussel* – Blue mussels or "edible mussels" are harvested commercially and recreationally throughout Rhode Island, and are grown on several aquaculture lease sites. Shaped like a rounded triangle, they are black to brown in color on the outside with a shiny violet interior when opened. They grow most often in clumps and attach to rocks, pilings, and other hard structures using their strong bissel threads.

g. *Bay scallop* – Bay scallops are small in size (up to three inches in diameter) with an exterior shell color that ranges widely from grey to yellow to red. They are often purple near the hinge and have corrugated shells that are nearly perfectly circular. Along the edge, or mantle, there are 30-40 bright blue eyes, allowing the scallop to detect movement and shadows in the water. Bay scallops grow quickly and generally live for two years, rarely surviving past three years of age. They are able to swim, rapidly closing their valves to expel water and push them through the water column. The species is popular among commercial and recreational harvesters during the open season. There has been considerable interest in growing the species in the aquaculture industry but economically effective cultivation methods have yet to be developed.

h. *Periwinkle* – These small, edible sea snails are black in color, wide and oval with a sharp point. Periwinkles rarely grow bigger than 2 inches in height. While there is no commercial fishery for these species, they are recreationally harvested off rocks and other structure along the intertidal zone. Periwinkles are an introduced species (i.e. not native to Rhode Island), but have been present for many years.

Table 4.2. Harvest limits for species considered in the SMP, including commercial and recreational harvesting within and outside of designated Shellfish Management Areas (SMAs).

Species	Harvest Limits (person/day) Within Shellfish Management Area			Harvest Limits (person/day) Outside of Shellfish Management Area		
	Commercial	Recreational RI Resident	Recreational Non-Resident	Commercial	Recreational RI Resident	Recreational Non-Resident
Quahog	3 bushels*	1 peck	1/2 peck	12 bushels	1/2 bushel	1 peck
Soft-shell clam	3 bushels	1 peck	1/2 peck	12 bushels	1/2 bushel	1 peck
American razor clam, Atlantic jack knife	None	None	None	None	None	None
Whelk	35 bushels & 300 pots	1/2 bushel & 5 pots	Prohibited	35 bushels & 300 pots	1/2 bushel & 5 pots	Prohibited
Eastern oyster	3 bushels*	1 peck	1/2 peck	3 bushels	1/2 bushel	1 peck
Blue mussel	3 bushels*	1 peck	1/2 peck	None	1/2 bushel	1 peck
Bay scallop	3 bushels	1 bushel	Prohibited	3 bushels	1 bushel	Prohibited
Periwinkle	None	None	None	None	None	None
*12 bushels within Conimicut Point Shellfish Management Area						

Table 4.3. Harvest size and season regulations for species considered within the SMP.

Species	Harvest Size	Harvest Season
Quahog	1" hinge width	Year round
Soft-shell clam	2" longest axis	Year round
Americal razor clam, Atlantic jack knife	None	Year round
Whelk	2-7/8" diameter or 5-1/8" length	Year round
Eastern oyster	3" longest axis	Sept 15 – May 15
Blue mussel	None	Year round
Bay scallop	Must have raised at least one annual growth ring	Nov – Dec
Periwinkle	None	Year round

Section 430. Water Quality Monitoring and Management

1. The RIDEM Office of Water Resources (OWR) is the lead department within DEM that establishes shellfish harvesting classifications for all estuarine waters and conducts water quality monitoring to determine whether designated shellfishing areas are safe for harvest. The OWR, in partnership with the RI Department of Health (DOH) is the state Control Authority and implements the RI Water Pollution Control Act and the Federal Clean Waters Act.
   a. There are two estuarine water classifications that affect shellfish in the state. Class SA waters are designated for shellfish harvesting for the purposes of direct human consumption. These areas also allow for primary and secondary contact recreational activities, as well as fish and wildlife habitat protection. Class SB waters are also designated for primary and secondary contact recreation and fish and wildlife habitat protection, but additionally allow for shellfish harvesting for the purposes of controlled relay and depuration.
   b. OWR and its water quality-monitoring program assure compliance with the USFDA's National Shellfish Sanitation Program (NSSP). In order to participate in interstate shellfish commerce, states agree to follow and be in compliance with the NSSP/ISSP Guide for the Control of Molluscan Shellfish (2013, found at: http://www.fda.gov/Food/GuidanceRegulation/FederalStateFoodPrograms/ucm2006754.htm)) with several key program areas including: 1) Growing area classification, 2) Laboratory procedures, 3) Control/patrol of growing areas, 4) Storage, transportation and processing, and 5) Shellfish aquaculture.
   c. In accordance with the NSSP Model Ordinance, the OWR conducts annual reviews of water quality. Approximately 95 percent of Rhode Island's coastal waters, including RI and Block Island Sounds, are designated for shellfishing uses. The RIDEM Shellfish Growing Area Monitoring Program responsibilitiesinclude the following elements:
      i) Collects and maintains an extensive water quality dataset of fecal coliform levels used as an indicator of pathogens.
      ii) Conducts routine sanitary shoreline surveys of all approved shellfish growing areas as well as routine bio-toxin monitoring. These surveys identify actual and potential pollution sources that may adversely impact the sanitary condition of approved waters and are conducted every twelve years with sources revisited every year or three years as necessary..
      iii) Creates "conditional area" management plans

iv) Supplies legal descriptions of all classified waters including supporting maps.

v) Administers emergency shellfish closings that may result from severe weather events due to flooding and associated wastewater overflows or malfunctions. These events require follow up sampling and acceptable bacteria results for the impacted area to reopen.

vi) Reviews aquaculture farm applications.

vii) Oversees vessel and no-discharge zones and pump out facilities monitoring.

d. The monitoring effort through OWR ensures shellfish are harvested from waters with acceptable water quality, to ensure the dual goals of public health and safety and maintaining a viable shellfish industry. The program collects samples from 18 shellfish growing areas, including offshore waters, and analyzes them for fecal bacteria. The growing areas include all of Narragansett Bay, its shellfish harboring tributaries, all of the south shore coastal salt ponds, Little Narragansett Bay, Block Island, and offshore waters. The frequency of sampling varies with the classification of the growing area with all approved and conditionally approved areas sampled for fecal coliform and harmful algal blooms 6-12 times per year. There are 18 fixed stations with 4 (Narrow River GA7-2) – 27 (East Passage GA-6) stations sampled in each growing area, over 2,000 samples collected annually.

e. The ISSC/NSSP also mandates that harvesting is prohibited within marinas, near discharge areas from waterwater treatment facilities, in waters impacted by actual or potential sources of poisonous or deleterious substances, in waters where pollution impacts are not predictable, and in response to emergencies and extreme rainfall events. In these extreme events where raw sewage from a WWTF or large community sewer is released and effects approved waters, the surrounding shellfishing area must be closed for a minimum of 7 days and provided that the shellfish meats are sampled and meet acceptable levels of male-specific bacteriophage levels.

f. Conditional Areas are closed for seven days at minimum when affected by severe rainfall events or combined sewer overflows based on the Model Ordinance directive, which ensures that "sufficient time has elapsed to allow the shellstock to reduce pathogens that might be present to acceptable levels." (Model Ordinance, Chapter IV, 03 C.2(c)(iii)). Both RI and MA use two days as the acceptable time period for shellfish to purify themselves of potential bacteria contamination after the surrounding waters have returned to approved bacteria levels.

g. While the measures in place through the OWR to ensure acceptable water quality for harvest, often restrict harvest, there have been efforts to allow harvesters the maximum opportunities while at the same time following safe protocols to protect public health. For example, in 2011 as a result of implementation of Phase one of the Narragansett Bay Commission CSO Abatement Project and extensive sampling results, the rainfall closure criteria for Area A was increased from 0.5" to 0.8" and Area B from 1.0" to 1.5". In addition, new sampling stations have been added to the OWR protocol to evaluate potential feasibility of a higher rainfall closure criteria or the reduction of area "B" that closes on a 1.5" rainfall. Completion of the Phase II of the Narragansett Bay Commission Abatement Project in 2015 may also offer potential changes to the existing closure criteria.

Section 440. Commercial Shellfish Industry

1. Commercial shellfishing within Narragansett Bay and the coastal ponds has a longstanding history in Rhode Island. The commercial shellfishing industry also benefits the economy by providing jobs to fishermen and supporting associated businesses, with product sold locally within state, shipped throughout the US, and exported overseas.

2. The commercial shellfishing "Fleet" in Rhode Island is largely characterized by independent owner/operators who typically work without crewmembers on small boats that are generally 20-24 feet in overall length. Most shellfishermen work within Narragansett Bay, not far from their

homeport. Many lobster fishermen have diversified due to declining catches, many turning to the whelk fishery.

3. Shellfishermen in Rhode Island can be generally categorized as "West Bay" or "East Bay" fishermen, denoting the general area of Narragansett Bay they are from. The "West Bay" fishermen typically have a homeport around Greenwich Bay and the West Passage, whereas the East Bay fishermen primarily call areas around Mount Hope Bay, Bristol, and Warren home. A limited number of fishermen also target shellfish in the coastal salt ponds, particularly Point Judith Pond.

4. With regard to industry involvement in management processes, the Rhode Island Shellfishermen's Association (RISA), primarily comprised of fishermen from the West Bay, has historically been the most active group. RISA members have also been the main industry representation on the Rhode Island Marine Fisheries Council Shellfish Advisory Panel. However, the formation of a Whelk Fishermen's Association was underway at the time of writing.

Table 4.4. 2013 landings and ex-vessel value of commercially harvested species (courtesy of RI DEM).

Species	Landings	Ex-vessel value
Quahog	7,642,1047lbs.	$4,714,8755
Whelk	595,326 lbs.	$1,295,294
Oyster	188,119 lbs.	$73,699
Soft-shell clam	45,780 lbs.	$112,795

5. Commercial fishermen harvest a diverse variety of species within Rhode Island waters (refer to Table 4.1). The most important species include quahogs, whelks, and, at times, soft-shell clams. Historically, bay scallops and oysters were also important commercially harvested species but their current low natural abundance limits commercial harvest. Refer to Tables 4.2 and 4.3 for descriptions and associated harvesting regulations for each species.

6. The quahog, Rhode Island's official state shell, is the most economically important resource harvested from Narragansett Bay. They are, by far, the most important commercially harvested shellfish species by amount landed and total value (Table 4.4). In 2013, approximately 7.647.68 million pounds of quahogs were harvested with and ex-vessel value of $4.715.12 million. In comparison, whelk landings were about 811% of quahog landings by poundage but about 2732% by value as they have a higher price per pound. Oyster landings were 2.41% of quahog landings by poundage and 1.6% by value and soft shell clams were 0.65% by poundage and 2.4% by value. Both were approximately worth 1.6% the value of quahogs. Due to the importance of quahogs, this section will focus more intently on this species while also addressing the other commercially harvested species. Rhode Island's commercial shellfishing industry relies mostly on un-mechanized tools to harvest the resource in an efficient, yet sustainable manner. Shellfish harvesters are permitted to use a variety of hand-operated tools, such as rakes, forks, hoes, and tongs, though, the majority of shellfishermen use bullrakes. The choice is based on location and bottom characteristics of the harvest site, time of year, as well as personal preference and skill level. Below is a brief description of commercial shellfishing equipment and techniques, as well as associated harvesting regulations, where applicable.

   a. *Rakes* – Rakes can vary in size and style, but all involve a wire basket at the end of an adjustable length pole (stale). The basket has steel tines, or "teeth," at the end and the rake is pulled along the bottom to collect quahogs. Rakes are typically used from work skiffs in waters depths that are generally between 15-30 feet and down to as deep as 45 feet. Common rakes include the Bull Rake ("square back"), Suitcase Pocketbook Rake, Virginia Harvester Rake, and Soft-Shell Box Style Clam Rake. Regulations require rake tines be spaced 1" apart and any reinforcement cannot result in forming a rectangle less than 1" x 2.5" (to reduce the amount of undersized quahogs removed from the water). If power hauling equipment is used to lift the rake to the surface (the only time power equipment can be used) then the bullrake cannot be more than 31.5" in width and the basket cannot be greater than 12" in depth. The teeth length on power hauled rakes can be no more than 4.5".

b. *Forks* – Forks are similar to those used in gardening, having short handles with four or five tines at the end. These tools are usually utilized while digging quahogs from the shore.

c. *Dry-digging rake* – Generally a four-tined potato fork rake bent at an 80 degree angle and mounted on a short 18-inch wooden handle. Dry-digging is conducted along the shoreline during the low tide with the shellfish harvester bent over and "clawing" through the mud flats, picking out legal-sized quahogs or steamers.

d. *Tongs* – Tongs are scissor-like double levers with a wooden handle and metal basket cut in half and attached to each lever. Tongs are used to harvest quahogs. The longest tong length is about 20 feet, making them most effective for use in shallow water. While once a popular tool, tongs are less utilized in the industry today. Regulations require tong teeth be spaced 1" apart and any reinforcement cannot result in forming a rectangle less than 1" x 2.5".

e. *Diving* – Free-diving and scuba, involves using the diver's hands to dig for quahogs by fanning away sediment. Scuba diving is permitted within Narragansett Bay, but is prohibited while digging from shore. In addition, as of 2001, scuba diving is no longer permitted within Green Hill Pond, Quonochontaug, Ninigret, and Potter Ponds (which also is prohibited to shellfishing due to water quality issues). Bags used to hold quahogs while diving are required to have bar spacing of at least 1" and the mesh on the bags must be at least 2" when measured while stretched. Those wishing to dive with surface-supplied air as opposed to scuba are allowed to do so.

f. *Pots* – Whelk pots are small, wooden or wire mesh pots, used to target knobbed or channeled whelks. Horseshoe crabs are the preferred bait for pots. For commercial and recreational harvest, 300 pots and five pots are permitted, respectively.

g. *Dip nets* – Dip nets are simply mesh nets at the end of a long pole and are most often used to harvest bay scallops and are the only permitted gear for harvesting bay scallops within shellfish spawner sanctuaries. Dip netting is only allowed from a boat for safety reasons related to cold winter water temperatures and to protect the seed scallops from being trampled by harvesters.

h. *Dredge* – Dredges come in many sizes and modifications but are generally wide metal devices that are towed in back of a boat to harvest species off the bottom. Dredges and other mechanical harvest methods may not be used to harvest bay quahogs, soft shell clams, and oysters. Hydraulic dredges (with certain gear restrictions, trip limits, and minimum size) are used to harvest surf clams and ocean quahogs within state waters; they are not used to harvest mussels. Permits are required to use a mussel dredge and only a small number of shellfishermen currently use this method of harvesting. Dredging for bay scallops is permitted in the month of December. A total of 6 small dredges with a maximum width of 28" each may be towed behind a boat for the harvest of bay scallops, provided all by catch is returned to the water.

7. *Licenses* – There are a number of commercial licenses available that allow for the harvesting and selling of shellfish to dealers in Rhode Island. The license categories are the Multi-purpose license (MPURP), Principal Effort License (PEL), Commercial Fishing License (CFL), Student Shellfishing License (STUD), and Over 65 (O65) shellfishing license (**Error! Reference source not found.**). Licenses can be bought and sold along with a vessel and gear as part of the sale of a business if certain requirements are met. *License structure* – There are a number of commercial licenses available that allow for the harvesting and selling of shellfish to dealers in Rhode Island. The license categories are the Multi-purpose license (MPURP), Principal Effort License (PEL), Commercial Fishing License (CFL), Student Shellfishing License (STUD), and Over 65 (O65) shellfishing license (**Error! Reference source not found.**). Licenses can be bought and sold along with a vessel and gear as part of the sale of a business.

Table 4.5. Total number of licenses by each license category in 2013 including the percentage of active licenses, average number of days fished by each license, and the average number of quahogs harvested per day by each license category (courtesy RI DEM).

License Type	Total Licenses	Active	% Active	Avg # of Days Fished	Avg # Quahogs / Day
PEL	376	182	48%	71	1148
MPURP	829	202	24%	63	1236
CFL	165	84	51%	39	995
Student	48	19	40%	15	516
Over 65	268	26	10%	20	843

8. *Dealers and catch reporting* – There are a total of 22 dealers in Rhode Island that reported buying quahogs from harvesters in 2012. Of these, the top three dealers account for 50 % of the landings.

   The shellfish sector is the only group of fishermen who are exempt from the state requirement to maintain a log book. Therefore, dealer reporting is the only source of information on the fishery. Since 2007, landings have been captured in the Atlantic Coastal Cooperative Statistics Program (ACCSP) Standard Atlantic Fisheries Information System (SAFIS) through dealer reports. Much of the data used and the industry trends discussed in this chapter come from dealer reporting information.

9. *Shellfish Tagging Areas* – Dealers are required to report the Shellfish Tagging Area from which shellfish were harvested. There are 19 tagging areas within Rhode Island waters when including all the sub-areas. The Sakonnet River has two sub-areas, Mt Hope Bay (2), Greenwich Bay (3), Upper Bay (4), the East Passage (6), and the West Passage (2). Prior to 2007, landings data on a yearly basis for all of Rhode Island is available from the NMFS (back to 1945 for some species).

10. *Shellfish Management Areas* – A number of the Tagging Areas are designated as Shellfish Management Areas. These are specific areas (15 total) defined in DEM statute throughout Narragansett Bay and the coastal salt ponds (Figure 4.1) that . These areas are designated either for conservation or shellfish stock rebuilding, or can be utilized for designated shellfishing related purposes. These areas have reduced harvest limits (see Table 4.2) and some have limited access times.

11. *Winter Harvest Schedule* – A number of the SMAs permit harvesting only in the winter season. The Winter Harvest Schedule is determined annually through the Council and SAP process, no later than November of each year. The schedule identifies specific dates and times for a select number of designated Shellfish Management Areas to be opened for harvest throughout the year (Table 4.6. Winter harvest schedule for 2013 - 2014). These selected areas are: Greenwich Bay Areas 1 and 2, Bristol, Bissel Cove/Fox Island, Mill Gut, High Banks and Potowomut Area C. The identified areas are closed to commercial harvest between May and November each year, and are opened from December through April (unless impacted by water quality closures during this time frame). These restrictions apply only to commercial harvesters, not recreational. These selected areas are known to typically exhibit relatively high shellfish densities and have reasonably safe winter access. As such, designating winter harvest schedules for these areas provides safe fishing grounds during the winter months that have not had the resource depleted during the summer months helping sustain the business of those fishermen who harvest year round.

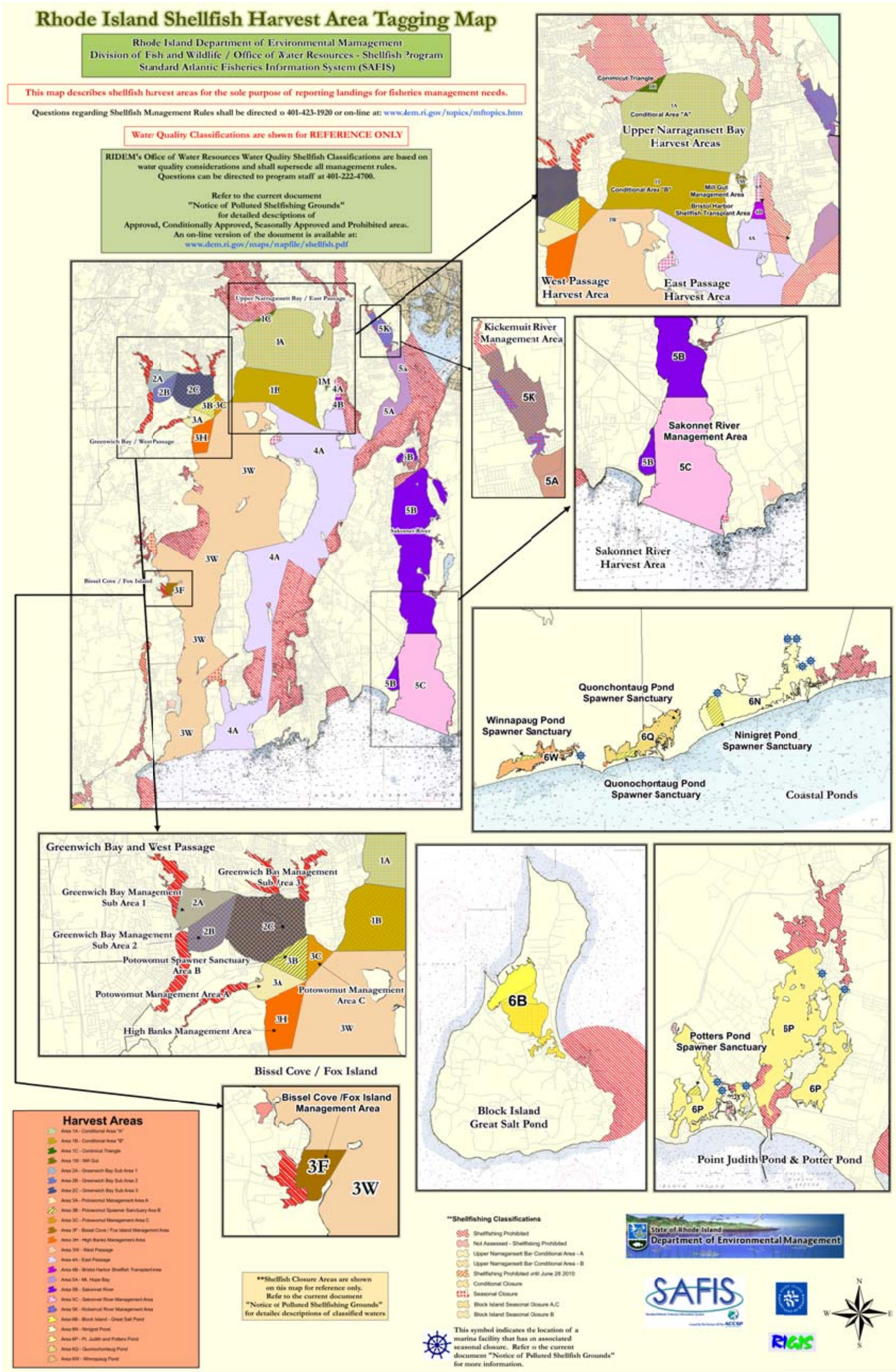


Figure 4.1. Narragansett Bay Tagging Areas. Each of the Coastal Ponds and Block Island has its own tagging area identifier, as well. Map found at: http://www.dem.ri.gov/programs/bnatres/fishwild/pdf/tagmap.pdf.

Table 4.6. Winter harvest schedule for 2013-2014.

	Dec	Jan	Feb	March	April
GB Sub Area 1 & 2	CLOSED OWR	8-12 Jan 2 and starting Jan 6, 8-12 MWF	8-12 MWF	8-12 MWF	8-12 MWF
Bristol	CLOSED	8-12 MWF beginning Jan 3	Open	Open	Open
Bissel/Fox	Opens 2nds Wed*	Open*	Open*	Open*	Open*
Mill Gut	Opens 2nd Wed	Open*	Open	Open	Open
High Banks & Pot C	Open Year Round	Open Year Round	Open Year Round	Open Year Round	Open Year Round

12. *Trends and Current Status*

a. *Quahog Fishery* – Historical perspective

The quahog fishery has gone through periods of ups and downs often associated with the types of gear used to harvest and changes in areas open to fishing. The high point in landings occurred in 1955 when 12,307 metric tons (27.13 million lbs) were landed (Figure 4.3). At this point in time, quahogs were being harvested in the shallows primarily by tongers and in deeper waters by dredge boats. The use of dredges depleted the resource quickly and was unsustainable. Catches began to drop off and the use of dredges decreased as the deep-water populations had declined. There was an incremental process of limiting the use of dredges to certain areas before finally banning them entirely in 1969. After this period, quahoggers were limited to the shallow waters until the adoption of bullrakes with extendable aluminum stales in the early 70’s opened up new, deeper grounds with a large exploitable biomass to the fishermen. A second peak in landings occurred in the mid-1980’s after portions of the upper bay that were previously closed to harvest were opened to shellfishing on a conditional basis. The landings again peaked in 1985 with a total of 11,464 metric tons of shellfish being landed.

In the mid-1980’s dealers began to use rolling sorters to buy small quahogs, little necks, top necks, and cherrystones by the piece instead of by the pound. The use of sorters to grade the catch resulted in the definition of a legally harvestable quahog was adjusted from 1.5” in length to 1” width. This adjustment fundamentally changed the strategy of the fishery and put the focus on the smallest quahogs, which had the highest value, rather than targeting all size classes to maximize poundage. It also meant that less biomass had to be removed from the water on a daily basis to make the same daily pay. An increasing number of fishermen began to enter the fishery beginning around 1975 as changes in the economic environment made the fishery more attractive to potential fishermen. In the early 80’s, there was a boom in the number of participants and the fishing effort was at an all-time high. After a decade of increasing catches, the landings began to plummet before bottoming out in 2009 at 1,775 metric tons. Since landings have remained at modest levels with a slight increae in recent years up to 3,466 metric tons in 2013.

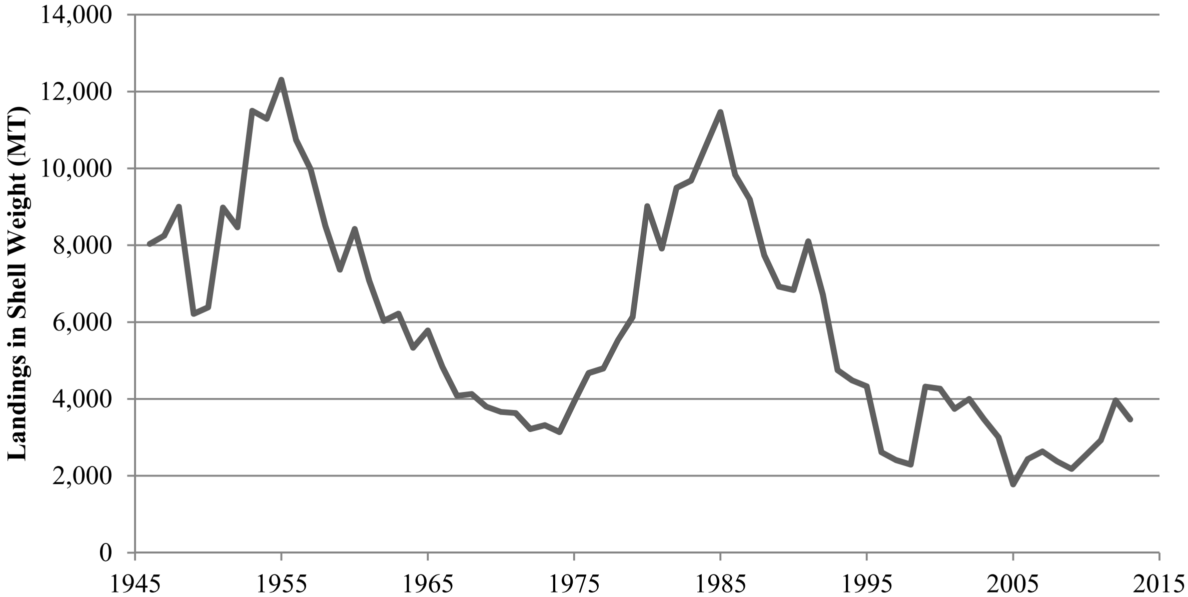


Figure 4.2. Historical landings for quahogs in Rhode Island from 1946-2013. Landings are shown in metric tons of shell weight. (source: NMFS)

b. *Quahog Fishery* – Present Day

In 2013, the total landings of quahogs were 3,466 metric tons, or 7.6 million pounds. This number equates to just over 34 million individual quahogs harvested from the waters of the state by commercial fishermen (Table 4.7). Of this total, 65% of the quahogs landed were littlenecks that had an average ex-vessel price of $0.15 per piece. Top necks made up 23% of the catch with a per piece average of $0.10 per piece. Chowder clams made up the next largest portion of the landings accounting for 10% of landings. Shellfishermen are typically paid for Chowders by the pound, instead of by the piece, but the average weight of a Chowder can be used to estimate that the average price paid per Chowder to be $0.11 per piece. Cherrystones make up only 2% of the total landings and are sometimes bought by the pound and sometimes by the piece. The average price paid per Cherrystone is estimated to be $0.08 per piece.

The Upper Bay (Conditional Areas A, B & C) accounted for 54% of the catch in 2013 (refer to Table 4.7). The West Passage accounts for another 23% of landings, primarily coming from the areas of the west passage north of Jamestown. The East passage accounted for 15% of landings. Greenwich Bay makes up an additional 6.2%, a relatively low percentage of landings copmpared to recent years. The eastern portion of Greenwich Bay is open year round on a conditional basis, but the western side is managed as a winter fishery and in 2013 is only open to fishing on Monday, Wednesday and Friday until 12 pm from January through the end of April. Furthermore, in recent years the western portion of Greenwich Bay has been closed for the month of December due to pollution concerns. The remaining 3% of landings are distributed amongst Mt Hope Bay, the Sakonnet River, the coastal ponds, and other management areas.

Catch and effort in the quahog fishery can be separated out by license groups. Of MPURP license holders, 24% (202 fishers) reported landing quahogs in 2013 (Figure 4.4). The average number of days fished for quahogs by active MPURP holders was 63 days with an average daily catch of 1,236 individual quahogs. Of the 376 PEL licenses with quahog endorsements, 48% (182) reported quahog landings in 2012. This group fished on average 71 days of the year and landed an average of 1,148 quahogs per day. The activity of the CFL license holders was about the same, with 51% (84) of the 165 license holders reporting quahog landings in 2013. However, these fishermen expressed less effort, fishing on average 39 days and landing 995 quahogs on average each day. Of Student license holders, 40% (19) of the 48 licensees reported landing in 2013, with an average of 15 days fished and 516 quahogs per day. Only 10% (26) of the 268 free Over 65 licenses reported landings in 2013 and the average number of days fished and daily catch were low at 20 and 843, respectively.

Of the total 513 fishermen that reported landing quahogs in 2013, the level of effort varied dramatically (Figure 4.4). For instance, 120 fishermen reported landings on 5 or fewer days, 57 of which were MPURP license holders. An additional 112 reported landings on fewer than 25 days. Using 100+ days as an approximate definition of a full-time quahogger, there are currently123 fishermen who meet this criterion. The average age of those fishing for quahogs exceeds that of the national average of the workforce.

There are very few young people entering the fishery; as of 2012 there were only 93 active fishermen under the age of 40, and only 19 of this age group fished 100+ days during the year (Figure 4.5). This trend may be the result of the recent licensing reform, which now makes it more difficult to enter the fishery and restricts newly licensed harvesters to a low daily catch limit for the first two years.

From the 1960’s through the early 2000’s the number of licenses issued and the national unemployment rate tended to mirror one another (Figure 4.6). The quahog fishery was a relatively easy and profitable fishery to enter into when work on land was hard to come by. Typically, the initial investment to enter the fishery was rather small – a rake and typically a small boat were the only gear needed. With the licensing reform of 2003, this relationship appears to decouple as unemployment rates climbed to a 30 year high and licenses continued to fall, likely due to the exit to entry ratio strategy in place since 2003.

Table 4.7. Quahog landings by market category and area by poundage for 2013.

Shellfish Tagging Areas	Number landed by Market Size				Total *(lbs)*
	Littleneck	Top Neck	Cherry	Chowder	
Unknown	24,281	10,639	891	8,482	44,293
RI 1A - Conditional Area A	6,205,888	2,260,822	92,451	1,182,676	9,741,837
RI 1B,C - Conditional Area B & C	5,946,040	1,986,166	177,584	599,610	8,709,400
RI 2 - Greenwich Bay	1,674,587	386,948	24,577	47,569	2,133,680
RI 3A,C,F,H - Management Areas	103,559	38,096	14,772	5,235	161,662
RI 3W - West Passage	4,977,544	1,723,105	417,133	687,156	7,804,937
RI 4A,B - East Passage	2,905,519	1,314,105	65,436	769,877	5,054,936
RI 5A,K - Mount Hope Bay	37,153	20,710	0	15,016	72,879
RI 5B - Sakonnet River	58,231	34,835		44,570	137,636
RI 6B,N,P,Q,W - Coastal Ponds & BI	426,107	52,182	5,881	23,372	507,542
Grand Total	22,358,909	7,827,608	798,723	3,383,563	34,368,803

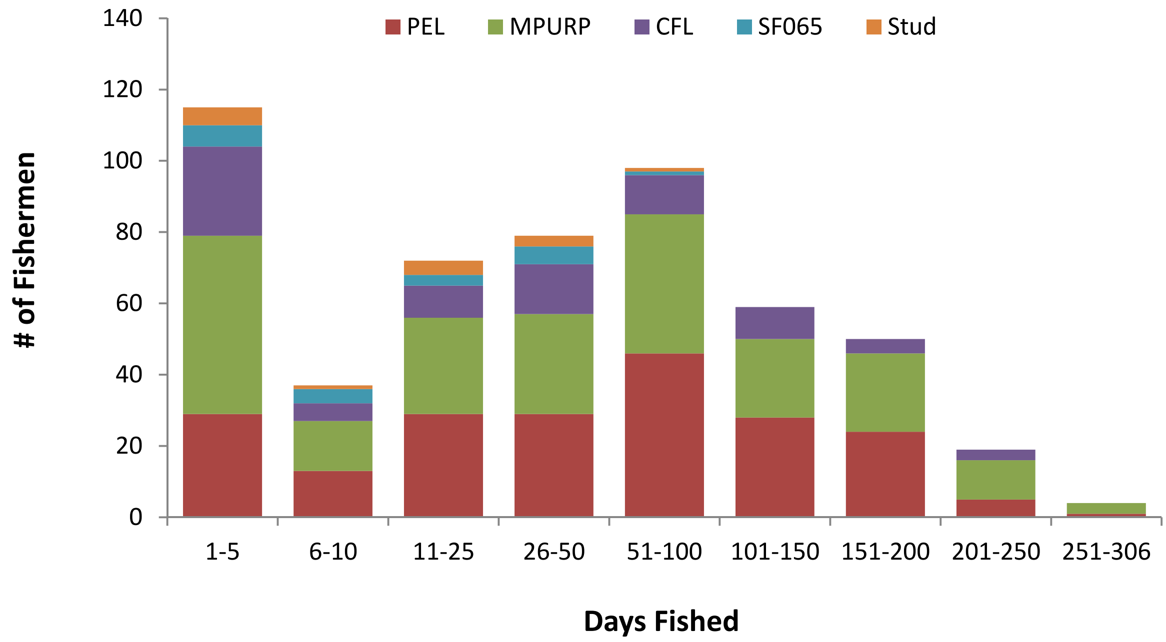


Figure 4.3. The number of fishermen versus the number of days fished grouped by license category.

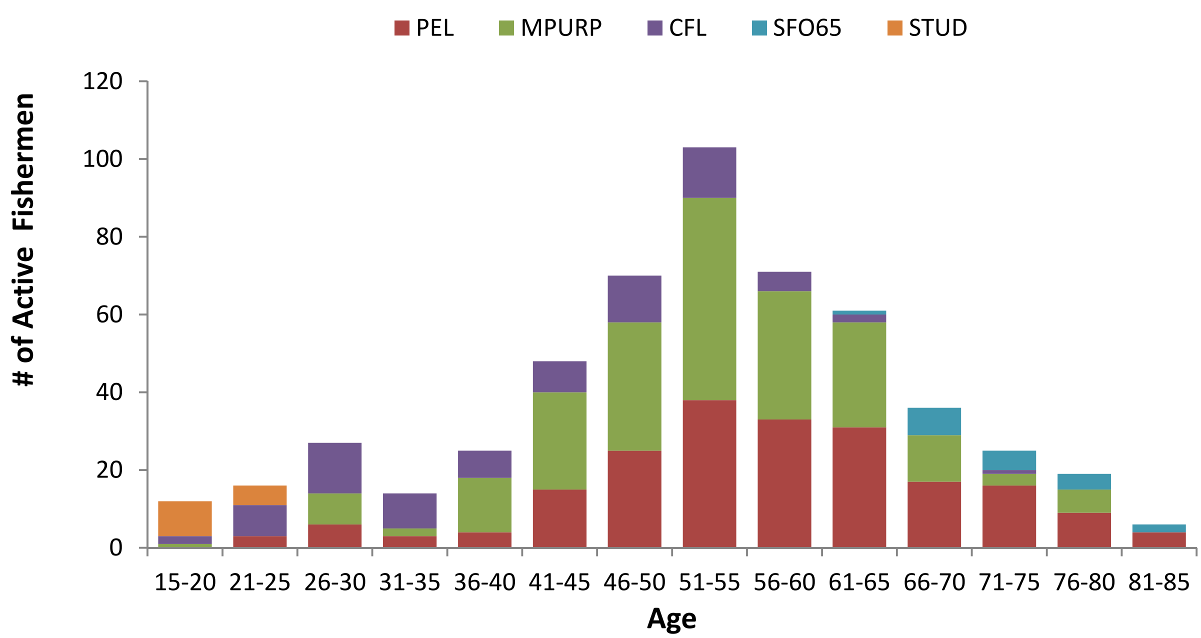


Figure 4.4. Age and number of active shellfishermen for each license category.

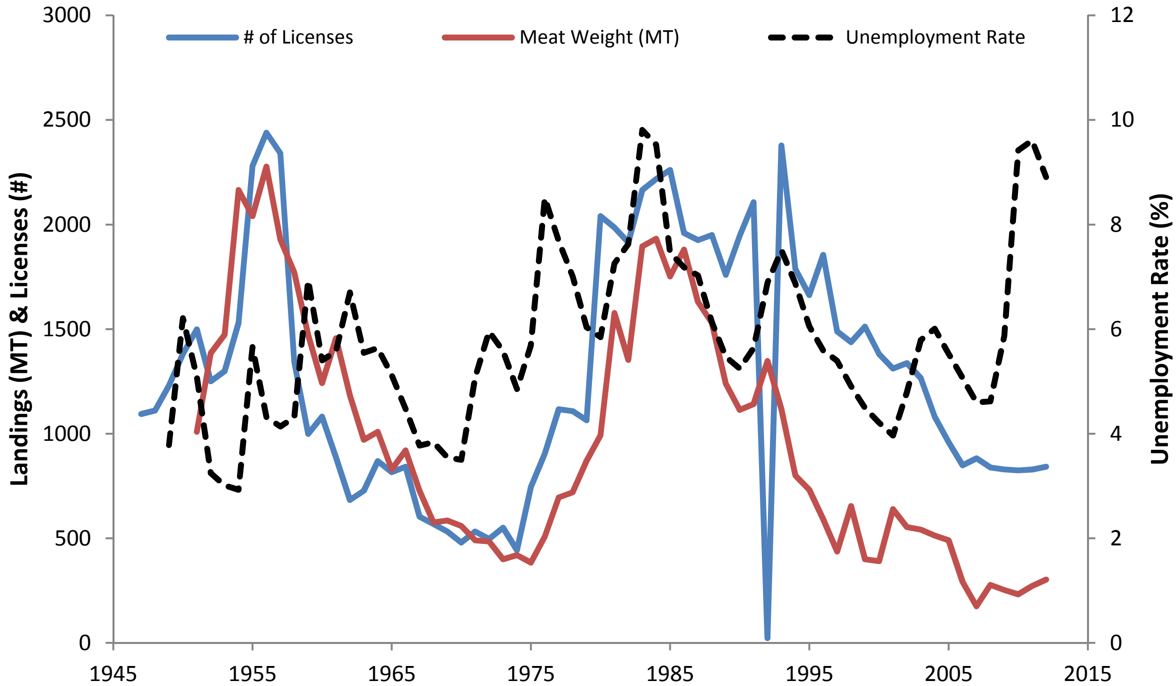


Figure 4.5. Number of licenses with the ability to harvest quahogs, landings in metric tons of meat weight and the national unemployment rate.

c. Soft-shell Clam Fishery

Soft-shell clam resources are distributed in the inter-tidal to sub-tidal zones of Narragansett Bay and within the coastal ponds. The most extensive populations in recent years have been located in the Upper Narragansett Bay, particularly in the Conimicut Point area (Table 4.9). The soft-shell clam fishery in Rhode Island can be characterized by boom-bust cycles (Figure 4.10). The average yearly landings between 1945 and 2012 are 151 metric tons, with a low of 2.3 metric tons in 1958 and a high of 1,330 metric tons in 1949. In comparison, the average quahog landings over the same time period was 5,885 metric tons, therefore, soft-shell clam landings equate to approximately 2.5% of the quahog landings over the last 70 years. Despite relatively low landings, the soft-shell clam fishery can be an important commercial fishery in "boom" years that supplements the income of fishermen who primarily target other species.

From 2003-2010, soft-shell clam landings were relatively high, exceeding 200 metric tons a year (See Figure 4.10). During this time period, improvements in water quality due to the Narragansett Bay Commission's combined sewer overflow (CSO) project resulted in a substantial reduction in the number of rainfall-induced closures in Conditionally Closed Areas "A" and "B," and opening of new areas, such as the new soft-shell clam grounds in the Conimicut Point Area known as the "Conimicut triangle". These areas have good habitat for soft-shell clams and account for a large portion of the landings (refer to Figure 4.12).

The Conimicut triangle area opened on June 13th, 2010. The number of fishermen reporting landings increased from three on June 12th to 40 on June 13th and peaked at 68 unique harvesters on June 29th (Figure 4.12). The daily catch limit of 12 bushels was not changed resulting in the biomass being depleted by extensive derby fishing to 5% of its former abundance. The minimum size was increased from 1 ½" to 2" on August 5th, 2010 through emergency regulation. In April 2011, this size increase became permanent and the Conimicut Management Area was established with a three bushel daily limit for soft shell clams.

By 2012, the soft-shell clam resources had been severely depleted; landings statewide in 2012 totaled less than 6% of the average landings from 2008-2010. Over harvesting through derby fishing and mass mortality of undersized, thin-shelled discarded soft-shell clams are the likely result of this dramatic decrease.

Table 4.8. Soft-shell clam landings by year and area in pounds (lbs).

Shellfish Tagging Areas	2008	2009	2010	2011	2012	% Δ '10-'12
Unknown	8,820	46,169	7,922	183	1,134	-85.7%
RI 1A - Conditional Area A	519,762	351,635	138,754	66,576	2,371	-98.3%
RI 1B,C - Conditional Area B & C	-	-	498,901	46,476	192	-100.0%
RI 2 - Greenwich Bay	5,704	4,182	70	358	286	308.6%
RI 3 - West Passage	151,825	72,660	36,227	16,745	10,377	-71.4%
RI 4 - East Passage	4,856	5,636	2,692	19,400	377	-86.0%
RI 5 - Sakonnet & Mount Hope	860	1,930	427	394	97	-77.3%
RI 6 - Coastal Ponds	22,333	12,421	13,602	33,619	27,053	98.9%
Grand Total	**714,160**	**494,633**	**698,595**	**183,751**	**41,887**	**-94.0%**

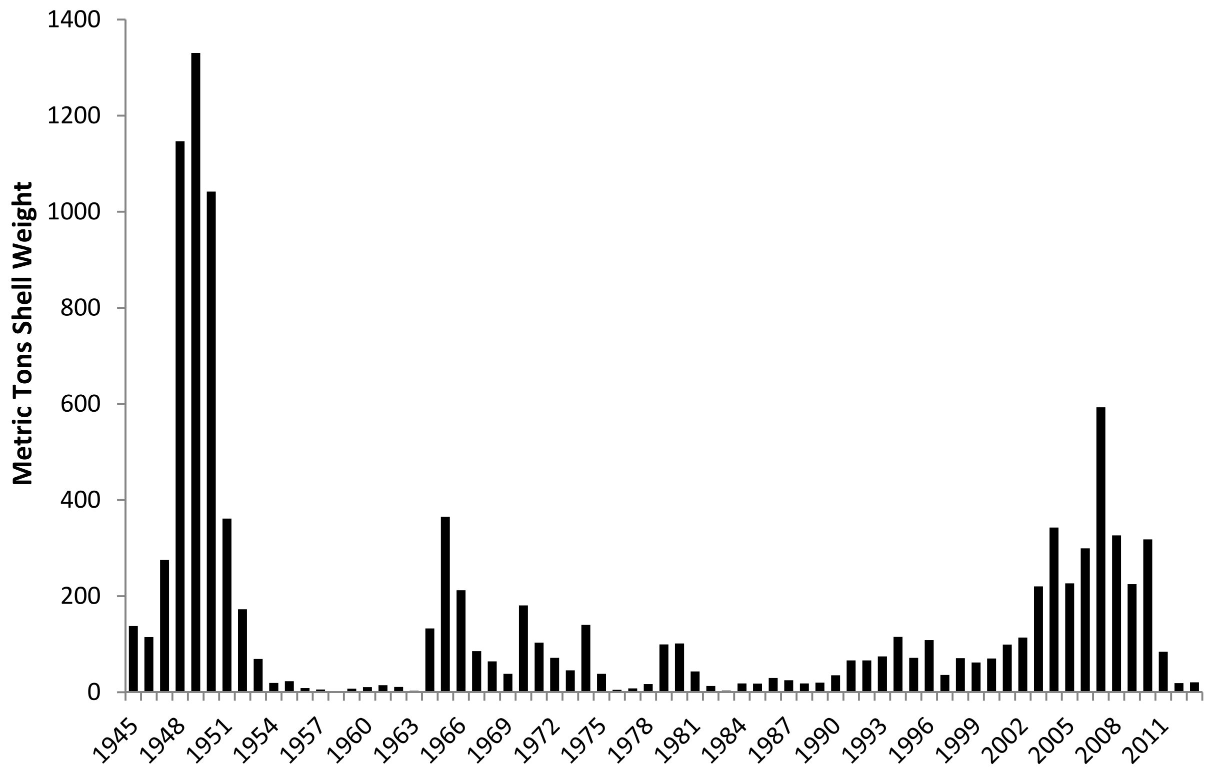


Figure 4.6. Soft-shell clam landings from 1945-2013 in metric tons of shell weight.

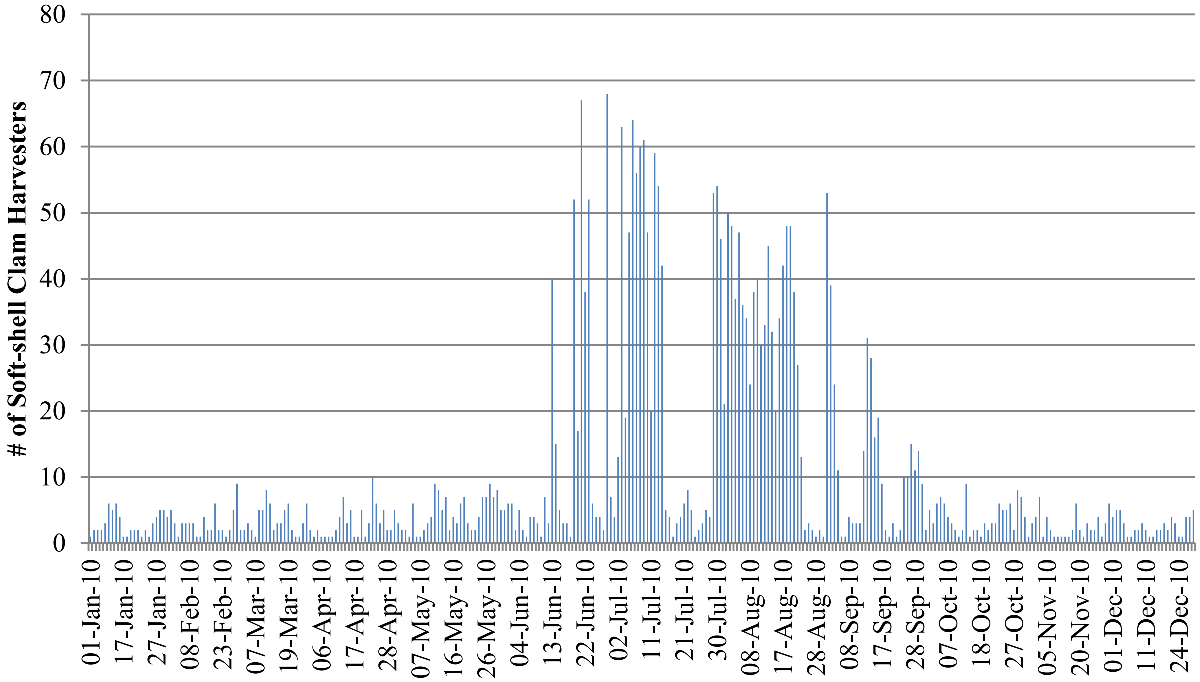


Figure 4.7. Soft-shell clam landings state-wide in 2010. The Conimicut Triangle area opened on June 13th. Gaps during the summer are due to closures of the Upper Narragansett Bay by DEM OWR due to rainfall events.

d. Whelk

A commercial fishery for whelks has existed in Rhode Island for many years; however, until September 2009 it was not regulated or the subject of a stock assessment. In 2009 a 2.5” minimum shell width or 4.5” minimum shell length minimum sizes were implemented.

Channeled and knobbed whelk resources are distributed from inter-tidal to sub-tidal zones of Narragansett Bay and Mount Hope Bay, with abundance generally increasing moving from south to north, except in northernmost areas of Narragansett Bay where the fresh water influence of the Providence River causes physiological stress. Both whelk species are also typically more abundant in water depths of less than 60 feet and more so in water depths of less than 30 feet. The whelk fishery is active from May to early December with maximum catch rates occurring in the spring and fall (Wood 1979), typically during the months of June and November. The period of May-December accounts for an average of 98.6% of total annual RI whelk landings (Figure 4.13) (ACCSP 2013). The channeled whelk is taken with baited traps while the knobbed whelk does not trap well but can be taken by trawl.

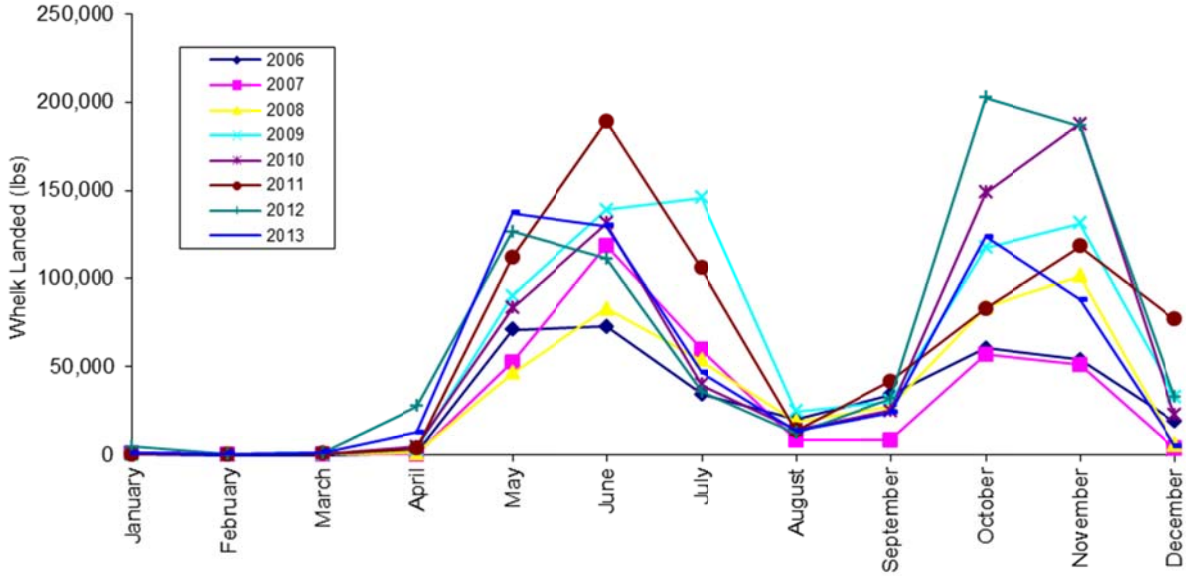


Figure 4.8. 2006-2013 Rhode Island commercial whelk landings by month.

A commercial fishery for whelks has existed in Rhode Island for many years. Whelks have been harvested over the past 125 years as a means to control predation on the more economically-important clam and oyster populations (Shaw 1960, Walker 1988), as a food-source bycatch, and economic supplement in southern New England lobster and finfish fisheries (DeKay 1843, Davis and Sisson 1978).

Over the past 35 years a directed fishery has emerged as the economic viability of predominantly overseas market for whelks has increased. During more recent years (2006-2012), fishing effort directed on the RI whelk fishery resource has increased substantially in terms of both reported whelk landings (110%) and numbers of fishers reporting whelk landings (80%) (Figures 4.14 and 4.15), as severe declines in the southern New England commercial lobster fishery and dramatic increases in ex-vessel prices for whelks (182%) have resulted in shifts in fishing effort. A decreasing trend in both reported whelk landings and numbers of fishers reporting whelk landings began in 2013.

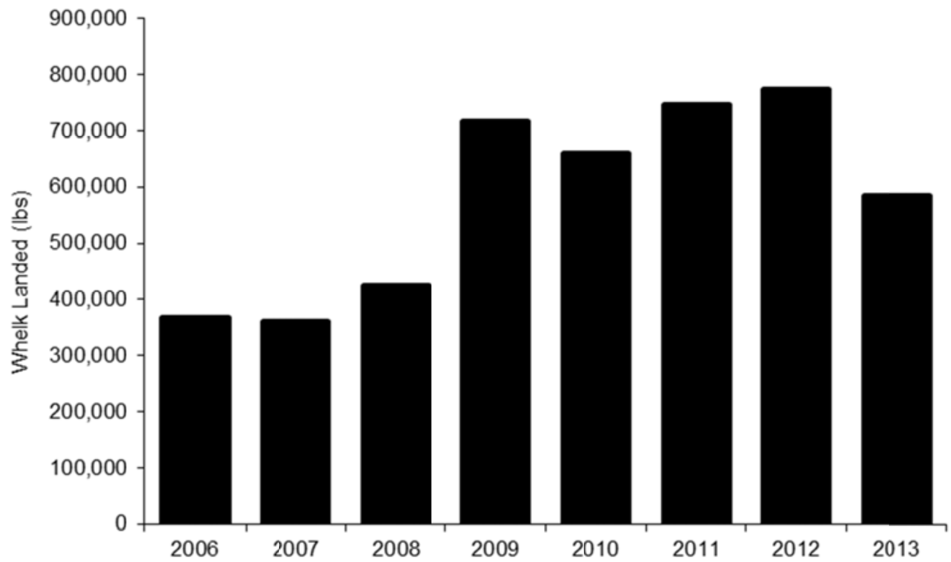


Figure 4.9. 2006-2013 Annual RI Commercial Whelk Landings (species combined).

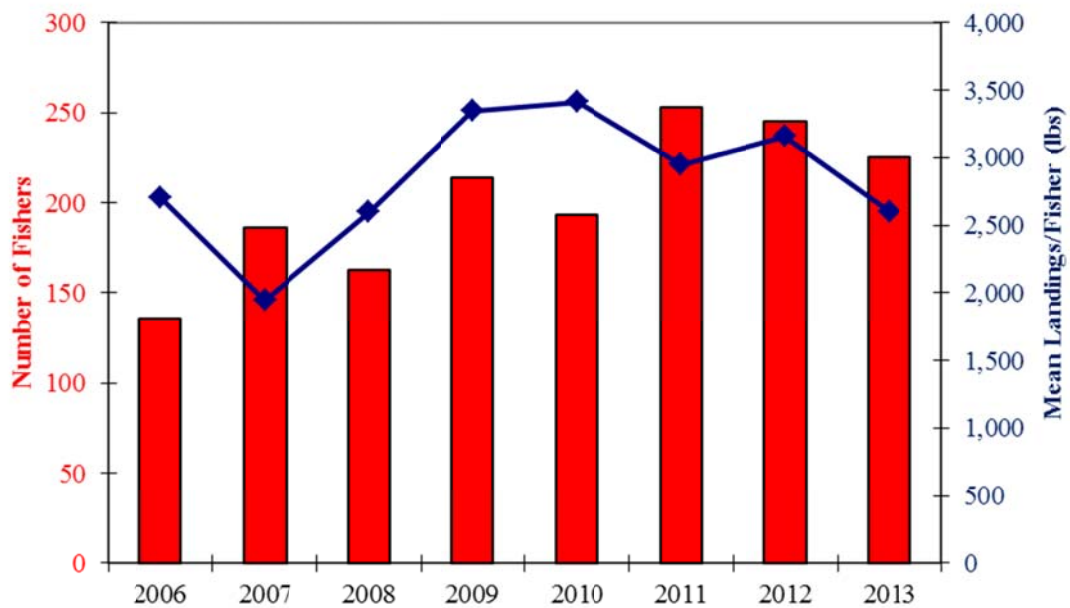


Figure 4.10. 2006-2013 Number of fishers reporting whelk landings and mean landings per fisher.

According to NMFS statistics, RI whelk landings were 90,390 pounds of meat weight in 1950 and increased over time to a peak of 348,327 pounds of meat weight in 1986. After several years of high landings, the fishery declined rapidly from 1994-2003, when reported landings were less than 22,000 pounds. From 2006-2013, commercial whelk landings averaged 579,288 pounds and are almost exclusively (96%) channeled whelk. A sharp increase in whelk landings occurred from 2008 to 2009, with years 2006-2008 averaging 384,489 pounds annually and years 2009-2012 averaging 723,986 pounds annually. A sharp decrease in landings occurred from 2012 to 2013, dropping nearly 189,000 pounds.

Ex-vessel value of whelks from 1950 to 1976 was steady at about $1.25 per pound of meat. It then increased sharply from $1.27 to $3.24 from 1976 to 1983. From 2004 to 2008, value has fluctuated around $3.00 per pound (NMFS).

Section 450. Recreational Shellfishing

1. Recreational shellfishing is a traditional pastime and valued cultural component to the Rhode Island way of life. The activity attracts a wide variety of local residents and tourists of all ages, cultures, and backgrounds. Unlike the commercial harvest industry, there is no formal organization exists to represent or advocate for this group, including on issues related to management. The exception is a sole representative on the Shellfish Advisory Panel to the Marine Fishery Council (MFC), which advocates on behalf of recreational users. Shellfish also provide a relatively easily accessible seafood and protein source with little investment in gear. Some harvesters do not use any tools, preferring to dig in the mud with their hands and toes. The most popular recreational clamming spots tend to be those with easy public access to the shore and available parking.
2. Rhode Island residents do not require a shellfish license, though non-residents do. Any person is permitted to harvest quahogs, soft-shell clams, razor clams, oysters, blue mussels, and periwinkles from approved and conditionally approved waters. Whelks and bay scallops can only be harvested by Rhode Island residents. Harvesters must follow minimum size requirements set forth by regulation. Refer to Table 4.3 for descriptions and associated harvesting regulations for each species.
3. The equipment used to harvest clams recreationally varies widely. The following are descriptions of commonly used tools and techniques, as well as associated regulations (if applicable). A few tools e.g.bull rakes, whelk pots) used in recreational harvesting are regulated by the state. To ensure only proper size shellfish are kept, a gauge or other measuring device should be used during harvesting.
    a. *Clam rakes* – Recreational harvesters use a variety of rakes for digging quahogs that range in overall size and the size, number and length of tines. Some rakes have a basket attached to confine captured clams. Small bull rakes, similar to those used in commercial harvesting, are sometimes utilized.
    b. *Clam Forks* – Forks are smaller versions of rakes, having shorter handles and fewer tines. Characteristics are wide-ranging in terms of tine shape (flat or round) and length, shoulder width, and handle length.
    c. *Household garden tools* – Many recreational harvesters utilized everyday items to fish for clams, including hand trowels, hoes, and pitch forks).
    d. *Hands and feet* – Commonly, harvesters capture clams (such as quahogs, razor clams, and soft-shell clams) and scallops simply using their hands or feet as they walk along the shore at low tide, wade in the water, or snorkel. For clamming, feet or hands are used to dig into the sediment to locate and collect clams. For harvesting sedentary species, such as mussels, oysters, and periwinkles, people often walk along the shoreline and collect shellfish attached to stable structure, including rocky outcrops and docks.
    e. *Dip nets* – Dip nets look similar to large, hardy butterfly nets and are most often used to harvest bay scallops and are the only permitted gear for harvesting bay scallops within shellfish spawner sanctuaries and the first month of the open scallop season.
    f. *Pots* – Whelks are not commonly harvested by recreational fishers, though pots are small, wooden or wire mesh pots, about 2 ft x 2 ft long used to target knobbed or channeled whelks. Horseshoe crabs are the preferred bait for pots. A maximum of five pots is permitted for recreational harvesters that are residents of Rhode Island.
4. The popularity of shellfishing is widely recognized by the state, and can be witnessed on a summer low tide by visiting Point Judith Pond, Potter's Cove, or other accessible recreational digging spots. The majority of recreational harvesting activity takes place within the summer months, though

harvesting does occur year-round. The location of popular recreational clamming spots is largely dictated by approved or conditionally approved status, accessibility to the shore, parking, and tides. Please visit the CRMC Public Access Guide for more information: http://www.crmc.ri.gov/publicaccess/ri_access_guide.pdf. Unfortunately, opportunities to enjoy this popular activity have been in steady decline over the past several decades due to unacceptable levels of bacteria.

5. Aside from this general understanding, however, harvest trends, overall contribution to the economy, and the impact to the shellfish resource by recreational harvesters is largely unknown and is not easily quantifiable. This knowledge gap exists for several reasons, outlined below:
   a. Rhode Island residents are not required to have a shellfish license, making it challenging to determine the number of shellfishers, both spatially and temporally. In addition, licenses from non-residents are not tracked in a database, which would allow for some trends to be discerned. Furthermore, there is no documented information on harvester demographics to gain an understanding of who is harvesting what and where.
   b. Though there are harvest limits in place, recreational shellfishers are not required to report their catch to state agencies. As a result, there is a lack of information on the species and volume of shellfish that is extracted from recreational use.
   c. The benefit from non-direct purchases as a result of recreational shellfishing is poorly understood. Such purchases may include tools (rakes, gauges, snorkels, etc.), storage containers (baskets, coolers, etc.), and logistical needs (food, lodging, gas, etc.).
6. *Harvest size and catch regulations* – Many species open to recreational harvest have associated minimum size and harvest limits. Refer to Table 4.2 for specific harvest restrictions.
7. *Licensing* – Rhode Island residents are allowed to harvest by hand without purchasing a license or reporting their catch. Non-residents must purchase a license (for a fee of $11 for a 14-day license or $200 for the year).
8. *Harvestable areas* – Recreational harvesters must follow the same pollution closures for safe harvest locations specified by the RI DEM Office of Water Resources. Information on areas opened and closed to shellfishing can be found by visitng http://www.dem.ri.gov/maps/mapfile/shellfsh.pdf. Harvesting is permitted only during daylight hours.
9. *Block Island* – Block Island has been granted permission by DEM to protect and regulate wild harvest shellfishing on the Island (RIGL § 20-3-7). As a result, Block Island has a unique management strategy for recreational harvesting, with regulations implemented by the Block Island Shellfish Commission. Great Salt Pond (New Harbor) is the most important shellfish location on the island and is divided into ten management areas. Annual stocking is conducted (soft-shell clams, quahogs, bay scallops) for a "put and take" recreational shellfishery, where fee-based licenses are required for Rhode Island and out of state residents. The Commission also conducts a water testing program through the New Shoreham Harbors Department, DEM, and the Commission.
10. Every harvester, Rhode Island resident or otherwise, must purchase a shellfish license from the Harbormaster's office and the fee ranges between $1 and $60 depending on the age of the applicant. While shellfishing, every harvester must carry their license and must follow these rules: 1.) No harvesting permitted from designated closed areas; 2.) No harvesting permitted from barrier grasses or eel grass beds; 3.) Harvesting at night is prohibited; 4.) Use of SCUBA is prohibited; and 5.) Shellfish must meet the minimum size requirement.

Section 460. Aquaculture Industry

1. Aquaculture is defined as "the cultivation, rearing, or propagation of aquatic plants or animals under either natural or artificial conditions" (RIGL § 20-10-2) and is formally recognized by the state and federally as agriculture.

2. Aquaculture has exhibited a strong increase in the number of farms, employees, and production values every year since the mid-1990's. The aquaculture industry in the state, comprised of local, small business farmers provide quality seafood, not just to Rhode Island, but also to consumers throughout the United States and Canada. The cultivated products are often named after well-known local areas (e.g. Ninigret, Matunuck, East Beach, Rome Point, Point Judith). In addition to human interests in and benefits of shellfish aquaculture, some research indicates that the practice is environmentally beneficial (See Chapter 2 for more details regarding the ecosytstem services provided through aquaculture). Shellfish provide ecosystem services that contribute to environmental restoration, including providing habitat structure and improving local water quality. Many shellfish species feed by filtering the water for food particles, a process that results in increased water quality. In the peak summer months, oysters can filter significant volumes of surrounding sea water (See Chapter 3). Consequently, the combined effort of organisms, such as those on an aquaculture lease may result in water quality benefits to an area. The Ocean State Aquaculture Association (OSAA) is the only formally established and recognized Rhode Island industry association. Regionally, there is the East Coast Shellfish Growers Association (ECSGA). Both are well-respected associations that are industry advocates and promoters, often involved in management and other processes to better the industry, and work with state and federal agencies to improve management strategies. In Rhode Island, the most cultivated species is the eastern oyster, comprising over 98% of all aquaculture. Other species grown and harvested include the quahog and the blue mussel. The soft-shell clam (steamer) has been cultivated at one lease site since 2013, but harvest has not yet commenced. Though not currently grown in the state, there has been increasing interest in cultivation of razor clams.

3. Aquaculture activities must adhere to the same water quality based closures and prohibitions as wild harvesters. Cultivation sites may only operate in approved waters. During emergency situations where areas of aquaculture activities are presently permitted, and water quality closure must be instituted, growers may seek permission to plant seed, perform certain maintenance and / or gear retrieval activities under closed conditions by notifying the state's aquaculture coordinator prior to entering the permitted lease.

4. All cultivation sites require the proper environment to support shellfish growth, including sufficient water flow, food availability, and temperature. The site should also exhibit minimal risks, such as that from predators, excessive fouling, and disease potential.

5. There are a variety of general techniques and equipment used in the aquaculture industry today, which many farmers modify to best suit their needs. A brief overview of different cultivation equipment and methods is provided below.

   a. *Bottom culture* – Bottom culture involves distributing, or planting, seed on the seafloor. The technique is commonly used in the cultivation of sedentary species (e.g. oyster and quahog). This technique requires very little maintenance or gear, and, therefore, can be very cost effective. Bottom culture also has the advantage of having little to no visual impacts and user conflicts on an area, making the method less controversial. One challenge is site selection; because the farmer is relying completely on the environment to support the growth of the shellfish, choosing the right site is essential, particularly with regard to sediment type and predatory risks. For oysters, planting usually occurs when the animals reach 1.5" in size (when they are less vulnerable to predation) and are planted at densities of 8-15 organisms per square foot. The density at which quahogs are planted depends on the size of the organisms and the cultivation strategy employed. In general, seed quahogs can be planted at densities up to 1,000 organisms/ft2. However, density at the time of harvest is typically around 75 organisms/ft2. Some strategies involve planting seed

(8-10 mm) at high densities, then digging up the quahogs and replanting them at lower densities partway through the growout cycle. Other strategies include planting quahogs (seed or larger) at the harvest density to avoid replanting. Nets are placed over quahog seeding sites for predator protection. Once grown, the shellfish are then harvested manually with a bullrake or tongs, gathered by a diverBottom cage and bags – This technique is widely used in the aquaculture industry for the cultivation of oysters, and to a lesser degree, scallops. Cages are wire structures that are secured to the seafloor. The cages often have six slots (2x3; two columns by three rows), though cage configuration is variable (e.g. 2x2, 2x4, 3x3). Each slot houses a sturdy plastic mesh bag, within which oysters are kept. The mesh size of the bags varies with the size of the oysters; as oysters grow, the mesh size increases. The mesh bags are used to allow adequate water flow over the oysters, offering a continuous food supply and waste removal system. When culling and harvesting the oysters, the entire cage is often hauled out of the water.

b. *Bottom rack and bags* – Similar to the cage and bag technique, rack and bags are commonly utilized in the industry for oysters and, to a lesser degree, scallops. For this technique, a continuous rack system is secured along a portion of the seafloor some distance above the seafloor, often 6"-12". The rack structure could take the form of two parallel strips PVC pipe or rebar spaced about 30" apart with numerous rows of racks laid throughout the cultivation site. The bags are then placed on top of and attached to the racks. To access the oysters, bags are removed from the racks, which remain in secured to the seafloor.

c. *Floating cages and bags* – Floating systems are a relatively new technology in the aquaculture industry and mostly used to grow oysters and, to a lesser degree, scallops. For this approach, cages with inserted bags (as described above) are attached to floating devices, commonly pontoons. The pontoons are filled with air, allowing them to float. In this configuration, the cages can be placed in the water (oyster growing position) or flipped so that the cages sit above the water (drying position to reduce fouling). The pontoons can also be filled with water to sink the equipment if needed, such as for overwintering or for protection from storms. These structures are usually have six slots (two columns by three rows; 2x3) and the most common is the OysterGro™ system. Though floating systems tend to work exceptionally well for promoting oyster growth at a fast rate and minimizing fouling, perhaps the greatest challenge with this technology is gaining public acceptance – overcoming user conflicts and visual impacts. As floating systems, the gear is very visible from the water surface and can impede other uses. As floating systems, the gear is very visible from the water surface and can impede other uses.

d. *Long line* – This technology is used in Rhode Island for growing oysters and blue mussels. This approach involves suspending lines in the water column, from which shellfish are attached. The long lines are secured on one end by an anchor on the seafloor while the other end is maintained in the water column by a float. The lines in Rhode Island start about six feet from the surface, but, could be placed at the surface or at any depth in the water column. For long lines that are near the surface, the lines can be loosed to raise or lower the cages as necessary to promote growth (in water) or to control fouling (out of water). Or, to achieve the same effect in an automated fashion, surface long lines can be set so that the cages are exposed at low tide and submerged at high tide.

e. *Upweller systems* – Upweller systems are used to rear young shellfish seedlings, and are valuable in that they accelerate seed growth and offer protection from predation during early life development. Upwellers commonly house quahogs and oysters, but also soft-shell clams and scallops. Such systems provide a continuous flow of water, and therefore food supply, to the seedlings. Systems take various forms, ranging from passive (e.g. attached to a structure, such as a dock, with water movement from tidal action) to active (e.g. set up on a platform and run by electricity or solar power to pump water throughout the system).

6. *Trends and current status* **–** While this chapter focuses on aquaculture and industry trends over recent years, it should be noted that aquaculture has a long and rich history in Rhode Island, as described in "A brief history of oyster aquaculture in Rhode Island" by Dr. Michael A. Rice (http://seagrant.gso.uri.edu/41N/vol4no2/12_rice.pdf), *Rhode Island's Shellfish Heritage: An*

Ecological History written by Sarah Schumann, and "The Fisheries of Rhode Island" by Howard A. Clarke.

a. *Farms and employment* – Aquaculture takes place both in Narragansett Bay and the coastal ponds (Table 4.11). The industry has grown every year since 1996; at the close of 2013, 52 farms were active in the state (for a map of aquaculture lease sites, visit: http://www.northeastoceandata.org/maps/aquaculture/), an increase from 43 farms in 2011 and from 9 farms in 1996. Of these 52 farms, there are 32 unique leases. The farms employ 127 people on a year round or seasonal basis (Table 4.10). The total area of submerged land leased by CRMC for aquaculture activity at these 52 farms was 176.55 acres. Narragansett Bay and Block Island waters contain 94.85 acres, just over half of the total leased acreage (53.7%). The remaining 81.7 acres exist within the Coastal Ponds (Point Judith, Ninigret, Potters, Winnapaug, and Quonochontaug) (CRMC, 2013).

b. *Production* – The increasing demand for oysters and for local, sustainable seafood has allowed the aquaculture industry to flourish over the last decade. In 2013, 6,398,979 oysters were cultivated and sold in Rhode Island, a 48.7% increase from 2012 (Figure 4.16). However, quahog and mussel production showed a decrease from the previous year (38,500 quahogs in 2013 versus 81,425 in 2012, and 6,250 pounds of mussels in 2013 versus 11,000 pounds in 2012).

c. *Value* – Aquaculture has contributed significantly to the local economy. The farm gate value of these aquaculture products was $4,204,656, a value that has increased every year and is a significant increase from just the year previous (the 2012 value was $2.8 million) (Figure 4.17). The farm gate value represents the wholesale price of shellfish, which is how the majority of shellfish product is sold. However, many farmers are also dealers, which allow him/her to sell product directly (to restaurants, at farmers markets, etc.) at retail price. Consequently, the economic contribution of aquaculture to the state is likely underestimated.

d. *Distribution of product* – Rhode Island cultured product is sold throughout the United States and Canada. In fact, there are only two states not part of the industry's market. Rhode Island oysters are very popular throughout New York City, including Grand Central Oyster Bar, Boston, and Washington DC. Oysters from the Ocean State Shellfish Cooperative have been promoted on a national level by Wholefoods in Chicago.

e. *Restoration participation* – In addition to growing shellfish for consumption, a number of aquaculturists participate in restoration projects, including the Environmental Quality Incentives Program (EQIP) operated by the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS). These types of activities also contribute to the economy and livelihoods of local aquaculturists. Since the EQIP program began, over $3.4M was awarded to participating growers (NRCS 2014).

Table 4.9. Aquaculture farm employment statistics showing an increase in total numbers each year (CRMC, 2013).

Year	Full Time Year Round	Full Time Seasonal	Part Time Year Round	Part Time Seasonal	Total
2006	17	8	17	15	**57**
2007	14	2	28	17	**61**
2008	12	1	25	24	**62**
2009	14	3	25	20	**62**

Year	Full Time Year Round	Full Time Seasonal	Part Time Year Round	Part Time Seasonal	Total
2010	17	4	30	28	**79**
2011	23	3	26	32	**84**
2012	32	9	32	32	**105**
2013	35	13	37	42	**127**

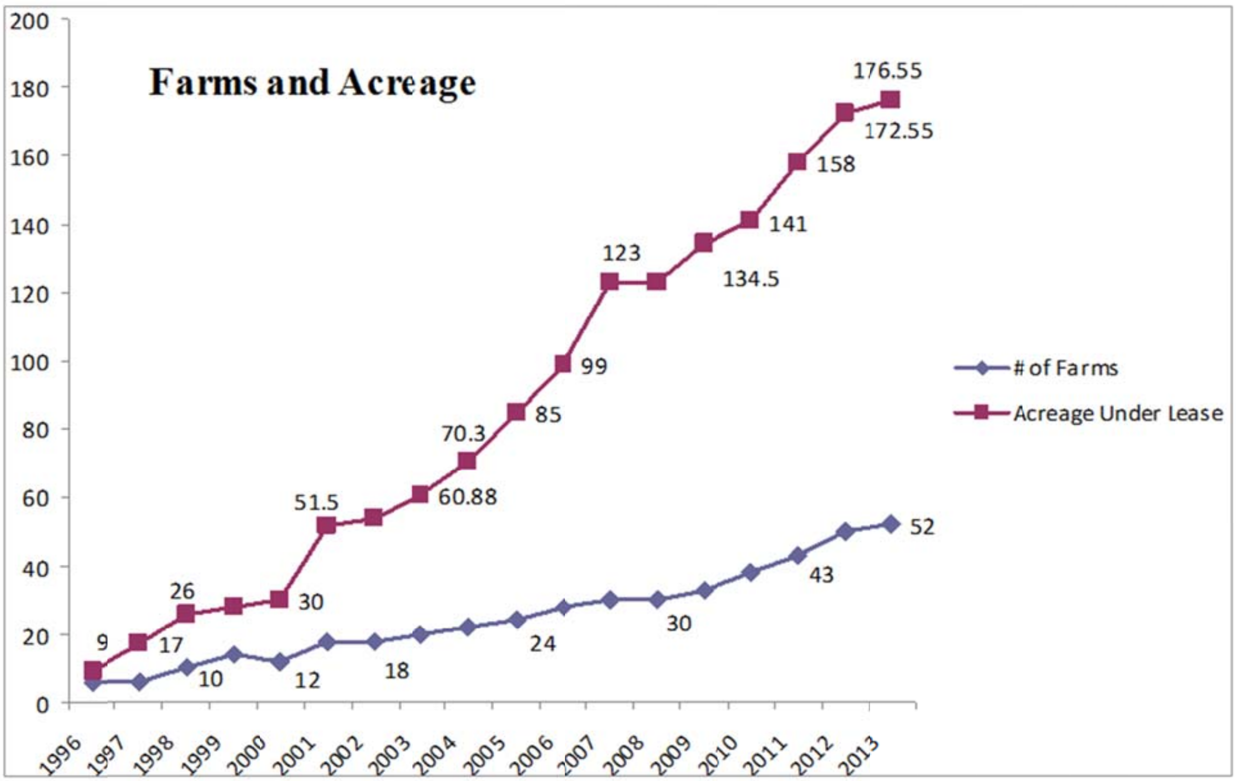


Figure 4.11. Total number of aquaculture farms and acreage under lease in Rhode Island from 1996 to 2013 (CRMC, 2013).

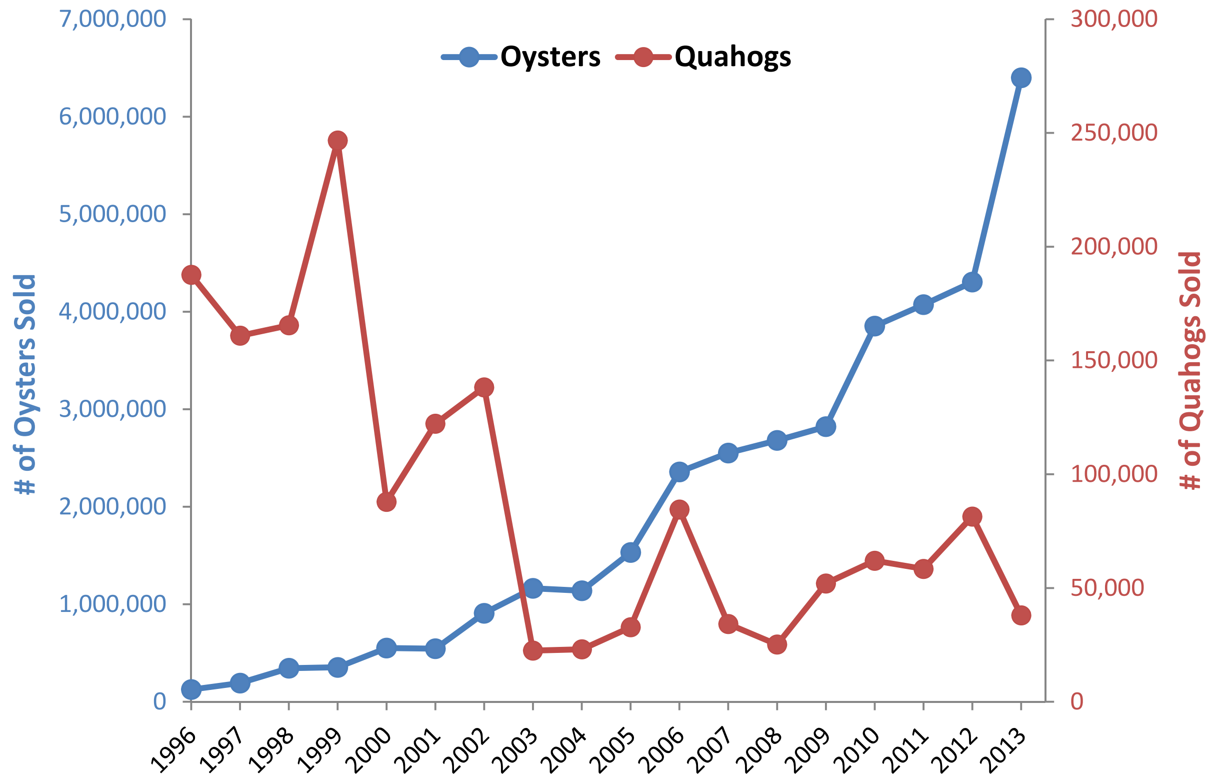


Figure 4.12. Aquaculture production of oysters and quahogs in Rhode Island (CRMC, 2013). Note the different scales on the vertical axes.

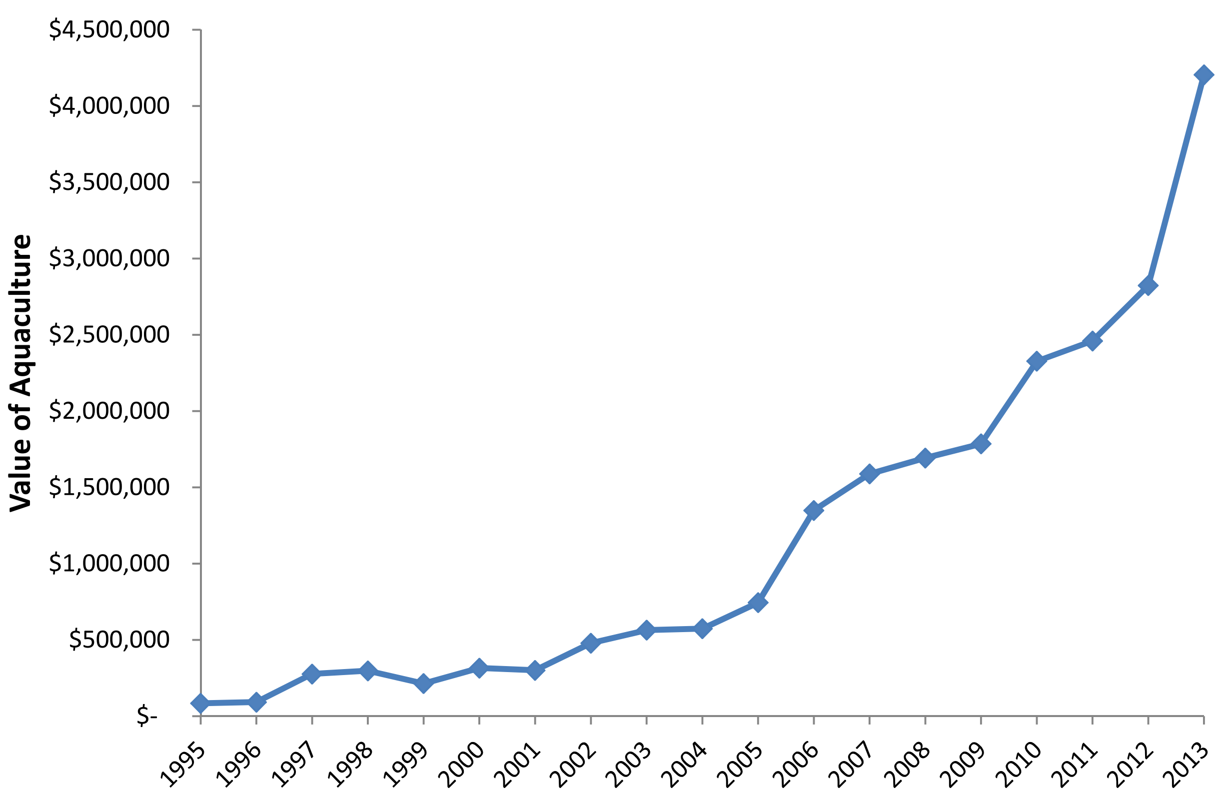


Figure 4.13. Total value of aquaculture (shellfish grown for consumption) in Rhode Island from 1995 to 2013 (CRMC, 2013).

Section 470. Recommendations

1. The Technical Advisory Committee (TAC) for this chapter has generated a comprehensive list of recommendations based on the extensive list of issues identified by stakeholders throughout the SMP process (Appendix 2.2). These recommendations can be found in Chapter 11. The TAC coordinators and lead chapter writers were: Monique LaFrance, GSO; Jeff Mercer, DEM; and Azure Cygler, CRC. The TAC for this chapter had eight members:

   Jim Arnoux, Ocean State Aquaculture Association
   Art Ganz, Salt Pond's Coalition
   Paul Kennedy, Shellfish Advisory Panel
   Bryan DeAngelis, TNC
   Katie Eagan, Commercial Shellfisherman
   Mike McGiveney, Rhode Island Shellfishermen's Association
   Robert Rheault, East Coast Shellfish Grower's Association
   Robbie Hudson, Save the Bay

   Decisions to include any recommendation put forth by the TAC was made by consensus then discussed through the SMP Coordinating Team. Alongside each recommendation listed below is a brief rationale to provide context for that recommendation and explain its need.

2. The list of recommendations (Chapter 11) represent the initial steps to identify actions necessary to improve the way the shellfish resource and associated activities are managed in Rhode Island for the benefit of all. As such, every stakeholder group – including management agencies, industry, civic and environmental organization, and citizens – is responsible for accomplishing the listed recommendations. The recommendations do not discuss logistical items (i.e. funding, lead person/group); these items will be addressed in the SMP implementation plan and research agenda that will follow the SMP document.

3. While the recommendations are all considered important and can benefit the shellfish resources/industry in many ways, it is important to note that the state agencies will need to prioritize these recommendations due to strained resources. In addition, 2015 will mark changes in administration due to the 2014 elections, and will bring new, unforeseen priorities for which we cannot plan in advance. Therefore, while it is the hope and intention of the SMP that these recommendations will be implemented, it is likely that challenges such as funding sources, shifting government leadership, etc. will lead to prioritization of these recommendations.

CHAPTER 5. Shellfish Resource Assessment and Management

By Jeff Mercer, RIDEM

Section 500. Introduction

1. Only select bivalves and gastropods are considered within this chapter (see Table 1.1). The criteria used for selecting the species to be included were: 1) The species is commercially and/or recreationally harvested or cultivated in state waters; and 2) There are no current federal management plans in place. The second criterion eliminates species such as ocean quahogs, sea scallops, and surf clams from being considered in the SMP (although it is recognized these species can be found and periodically harvested in state waters). Furthermore, while lobsters and crab are often considered a shellfish, they are crustaceans with vastly different life histories compared to molluscs, and there are considerable federal and state management efforts underway for this species already.
2. The purpose of this chapter is to summarize the current status of the shellfish resource; describe the structure in place to manage this resource; and outline recommendations for improving management, where necessary, and within the context of other existing and future uses.
3. This chapter includes information on the current stock status of the mentioned shellfish resource based upon the best available existing data and information. Available fisheries dependent and independent information from the past decade are used to establish current status and trends.
4. Aquaculture in Rhode Island and throughout the United States has grown intensively over the last decade. It is one of the few growth industries in Rhode Island, exhibiting a strong increase in the number of farms, employees, and production values every year since the mid-1990's. Aquaculture is not new to Rhode Island, having been a significant industry in the 1800's through mid-1900's with over 21,000 acres leased to multiple oyster aquaculture companies between 1911-1912 (Rice, 2006). After a decline due to multiple factors, it is now on a steady rise again.
5. The terms shellfish "restoration" and "enhancement" are often used interchangeably, however, there are differences between the primary goals of the two activities. Restoration, in its multiple forms, centers on re-building shellfish habitats and populations, typically for the myriad of non-harvest ecological, economic and social benefits that shellfish habitats provide to people. Shellfish enhancement differs from restoration in that the primary goal is to support sustainable fisheries, both commercial and recreational. Efforts commonly focus on transplanting quahogs from one area to another or growing shellfish in nursery systems and relocating them to selected areas for harvest.
6. Water quality is a determining factor driving the management of all shellfish activities. In the interest of human health, DEM Office of Water Resources (OWR) conducts water quality sampling to monitor water quality and pollution levels. Based on the data, DEM OWR classifies shellfish grounds and establishes closures in areas of poor water quality to help prevent illnesses that may result from consuming shellfish harvested or grown in such areas. Such areas are designated as prohibited and closed to shellfishing and the harvest or cultivation of shellfish within these areas is not permitted (Refer to Appendix 4.1 for DEM 2014 classification of open/closed waters due to pollution or visit http://www.dem.ri.gov/maps/mapfile/shellfsh.pdf).

Section 510. General Management Structure

1. Rhode Island residents firmly embrace the notion of a "Free and Common" fishery, guaranteed to them through the State Constitution. The Rhode Island Constitution states: "The people shall continue to enjoy and freely exercise all the rights of fishery, and the privileges of the shore, to which they have been heretofore entitled under the charter and usages of this state, including but not limited to fishing from the shore, the gathering of seaweed, leaving the shore to swim in the sea and passage along the shore; and they shall be secure in their rights to the use and enjoyment of the natural resources of the state with due regard for the preservation of their values" (RI Constitution, Article 1, Section 17).

2. The RI Constitution places limits on the ability to "freely exercise all the rights of fishery" by stating that general assembly has the obligation to manage to preserve and protect the natural resources and environment of the state. Sections 17 of the RI Constitution continues "*it shall be the duty of the general assembly to provide for the conservation of the air, land, water, plant, animal, mineral and other natural resources of the state, and to adopt all means necessary and proper by law to protect the natural environment of the people of the state by providing adequate resource planning for the control and regulation of the use of the natural resources of the state and for the preservation, regeneration and restoration of the natural environment of the state*".
3. Shellfish management in Rhode Island is accomplished through the legislature and multiple state agencies and industry advisory boards and, in some instances, in collaboration with federal, primarily in regards to food safety.

510.1. Regulatory Agencies

1. There are a variety of state and federal entities and regulatory bodies currently managing wild harvest activities in Rhode Island. The primary federal agency is the U.S. Food and Drug Administration (FDA) who regulates the interstate shipping of shellfish and food safety. On the state level, the Rhode Island Department of Environmental Management (DEM), the Rhode Island Coastal Resources Management Council (CRMC), and the Rhode Island Department of Health (DOH) all oversee the management of shellfish in different, but often coordinated manners.
2. RI DEM – Preserves the quality of Rhode Island's environment, maintaining the health and safety of its residents, and protecting the natural systems upon which life depends. Section 20-1-2 of the Rhode Island General Laws "vests in the director of the department of environmental management authority and responsibility over the fish and wildlife of the state and over the fish, lobsters, shellfish, and other biological resources of marine waters of the state."
    a. Division of Fish and Wildlife – Protects, restores, and manages the fish and wildlife resources of the state. The Division is responsible for setting seasons, size limits, methods of taking, and daily limits for the harvest of all wildlife as well as all recreational and commercial fisheries in the state. In particular, the Marine Fisheries Section conducts research and monitors marine species to support the effective management of finfish and shellfish of commercial and recreational importance.
    b. Office of Water Resources – Implements the RI Water Pollution Control Act and the Federal Clean Waters Act. They establish shellfish harvesting classifications for all estuarine waters and conducts water quality monitoring to determine whether designated shellfishing areas are safe for harvest.
    c. Division of Agriculture – Works to sustain, promote and enhance Rhode Island's agricultural viability today and for generations to come. They are actively involved with the oversight of the aquaculture industry and efforts to ensure safety and increase marketing opportunities for locally harvested seafood.
    d. Division of Law Enforcement – Protects the States natural resources and ensures compliance with all environmental conservation laws through law enforcement and education, while constantly maintaining the health and safety of the public.
3. CRMC – Established by RI General Law Section 46-23, and administered by a council who are appointed representatives of the public and state and local government, and a staff of professional engineers, biologists, environmental scientists, and marine resources specialists, they have a primary responsibility for the preservation, protection, development and where possible the restoration of the coastal areas of the state via the implementation of its integrated and comprehensive coastal management plans and the issuance of permits for work within the coastal zone of the state. As such, CRMC coordinates the permitting and leasing of lands for aquaculture within state waters and is involved in some aspects of shellfish restoration activities.

4. DOH – Prevent diseases and protects and promotes the health and safety of the people of Rhode Island by coordinating public health activities across the state. The Office of Food Protection administers the Shellfish Inspection Program that protects the health of consumers by regulating the processing and distribution of molluscan shellfish in accordance with the National Shellfish Sanitation Program.
5. Rhode Island Marine Fisheries Council (Council) – The Council is a statutory body formed in 2003 that provides management guidance to DEM on relevant topics and species. Explicitly stated, the relationship between the Council and DEM is: "The director, in exercising authority under this title for the planning, management, and regulation of marine fisheries, shall request and consider in the record as applicable the advice of the marine fisheries council, and in the adoption of management plans and regulations affecting licensing for marine fisheries, the director shall provide a written response to the advice of the marine fisheries council." (Title 20, RI General Laws). The Council is comprised of eight private citizen members and a chairperson from DEM. The citizen members must include three members of the commercial fishing industry, three members from the recreational or sport fishing industry, and two members with appropriate management or marine biology experience. Council members are appointed and serve a term of four years and are not compensated, except for travel expenses.
6. RIMFC (Council) Advisory Panels – The Council has been given the authority to appoint relevant recreational and commercial fishermen, dealers, and other interested parties to various fishery-related Advisory Panels. With regard to shellfish, there exists a Shellfish Advisory Panel (SAP) and an Ad Hoc Whelk Advisory Committee. Members of the Panels and committees follow one-year term limits and offer species-specific guidance (although they have no formal authority) to the Council, which then offers formal recommendations to the DEM Director.
   a. Shellfish Advisory Panel (SAP) – The SAP is composed of a minimum of six and a maximum of fifteen panel members and decisions are made by vote. Currently the SAP is made up of 7 commercial bullrakers, 1 diver, 1 representative for East Bay fishers, 1 recreational harvest rep, 1 aquaculturist, and 1 shellfish dealer. SAP meetings are held as needed to address necessary pending policy adjustments and review proposed aquaculture lease applications. In an effort to streamline the aquaculture review process, the SAP recommendations become the formal Council recommendations to DEM if there are no objections from any Council members or the aquaculture applicant.
7. Administrative Procedures Act (APA) – All shellfish management decisions must conform to the RI Administrative Procedures Act (APA; Administrative Procedures Act, United States Code, Title 5). In summary, the Act is a statute that governs the way in which federal and state agencies propose and set regulations. For DEM, this requires that proposed regulation be posted for public notice and go through a public hearing process before a decision is ultimately rendered. Exceptions to the APA requirement are allowed in consideration of issues pertaining to designated Shellfish Management Areas. In such instances, DEM does not need to adhere to the APA; rather, the Council can make a direct recommendation to the DEM Director, who may make modifications to regulations for these areas, without following the public hearing process.

510.2. Industry Organizations

1. There are a number of shellfish industry organizations that are industry advocates and promoters, often involved in management and other processes to better the industry, and work with state and federal agencies to improve management strategies. The Rhode Island Shellfishermen's Association (RISA), primarily comprised of fishermen from the West Bay, has historically been the most active group. RISA members have also been the main industry representation on the Rhode Island Marine Fisheries Council Shellfish Advisory Panel. The formation of a Whelk Fishermen's Association was underway at the time of writing (2014) and is largely composed of East Bay members. The Ocean State Aquaculture Association (OSAA) is the only formally established Rhode Island aquaculture

industry association but the regional East Coast Shellfish Growers Association (ECSGA) is active in Rhode Island.

510.3. Block Island

1. Block Island has a different management structure for shellfish than mainland Rhode Island (RIGL § 20-3-7). The Block Island Commission, rather than DEM, administers shellfish programs for Great Salt Pond (New Harbor) under Rhode Island General Law 20-3-2, the Charter of the Town of New Shoreham, and the 1996 Charge to the Shellfish Commission from the Town of New Shoreham. There are seven members serving on the Commission who report to the Town Council. Each year, there are twenty commercial harvest licensees issued, nineteen are available to Block Island residents only and one is available to off-Island residents. However, most of these licenses are not used (Personal Communication, 2014). Aquaculture applications are still administered and permitted through CRMC.

Section 520. Safe Harvesting and Handling

1. The RIDEM Office of Water Resources (OWR) is the lead department within DEM that establishes shellfish harvesting classifications for all estuarine waters and conducts water quality monitoring to determine whether designated shellfishing areas are safe for harvest. The OWR's Water Quality Monitoring Program assures compliance with the USFDA's National Shellfish Sanitation Program (NSSP). In order to participate in interstate shellfish commerce, states agree to follow and be in compliance with the NSSP Guide for the Control of Molluscan Shellfish (2013, found at: http://www.fda.gov/Food/GuidanceRegulation/FederalStateFoodPrograms/ucm2006754.htm). Several key program areas of the NSSP include: 1) Growing area classification, 2) Laboratory procedures, 3) Control/patrol of growing areas, 4) Storage, transportation and processing, and 5) Shellfish aquaculture.
2. In accordance with the NSSP Model Ordinance, the OWR conducts annual reviews of water quality. The RIDEM Shellfish Growing Area Monitoring Program responsibilities include the following elements:
    a. Collect and maintain an extensive water quality dataset of fecal coliform levels used as an indicator of pathogens.
    b. Conduct routine sanitary shoreline surveys of all approved shellfish growing areas as well as routine bio-toxin monitoring. These surveys identify actual and potential pollution sources that may adversely impact the sanitary condition of approved waters and are conducted every twelve years with sources revisited every year or three years as necessary.
    c. Create "conditional area" management plans.
    d. Supply legal descriptions of all classified waters including supporting maps.
    e. Administer emergency shellfish closings that may result from severe weather events due to flooding and associated wastewater overflows or malfunctions. These events require follow up sampling and acceptable bacteria results for the impacted area to reopen.
    f. Review aquaculture farm applications.
    g. Oversee vessel and no-discharge zones (pump out facilities) monitoring.
3. There are two estuarine water classifications that affect shellfish in the state. Class SA waters are designated for shellfish harvesting for the purposes of direct human consumption. These areas also allow for primary and secondary contact recreational activities, as well as fish and wildlife habitat protection. Class SB waters are also designated for primary and secondary contact recreation and fish and wildlife habitat protection, but additionally allow for shellfish harvesting for the purposes of controlled relay and depuration.

4. Only those waters determined by DEM to meet all NSSP requirements of approved, seasonally approved or conditionally approved status are open to the wild harvest or cultivation of shellfish for direct human consumption. Currently, 87.5 sq. miles of RI marine waters are approved, 21.6 sq. miles are conditionally approved and 11.2 sq. miles are prohibited due to pollution. Shellfishing is also prohibited in closed safety zones in the vicinity of wastewater treatment facility outfalls (accounting for 10.8 sq miles) and coves where insufficient data are available to assess their sanitary condition, making up an additional 1.59 sq miles.

   Conditional Areas are closed for seven days at minimum when affected by severe rainfall events or combined sewer overflows based on the Model Ordinance directive which is to ensure that "sufficient time has elapsed to allow the shellstock to reduce pathogens that might be present to acceptable levels." (Model Ordinance, Chapter IV, 03 C.2(c)(iii)). Both RI and MA use two days as the acceptable time period for shellfish to purify themselves of potential bacteria contamination after the surrounding waters have returned to approved bacteria levels.

5. Additional requirements by the NSSP state that harvesting is prohibited within marinas, near discharge areas from waterwater treatment facilities, in waters impacted by actual or potential sources of poisonous or deleterious substances, in waters where pollution impacts are not predictable, and in response to emergencies and extreme rainfall events. In these extreme events where raw sewage from a WWTF or large community sewer is released and effects approved waters, the surrounding shellfishing area must be closed for a minimum of 7 days and provided that the shellfish meats are sampled and meet acceptable levels of male-specific bacteriophage levels.

6. The monitoring effort through OWR ensures shellfish are harvested from waters with acceptable water quality, to ensure the dual goals of public health and safety and maintaining a viable shellfish industry. The program collects samples from 18 shellfish growing areas, including offshore waters, and analyzes them for fecal bacteria. The growing areas include all of Narragansett Bay, its shellfish harboring tributaries, all of the south shore coastal salt ponds, Little Narragansett Bay, Block Island, and offshore waters. The frequency of sampling varies with the classification of the growing area with all approved and conditionally approved areas sampled for fecal coliform and harmful algal blooms 6-12 times per year. There are 18 fixed stations with 4 (Narrow River GA7-2) – 27 (East Passage GA-6) stations sampled in each growing area, over 2,000 samples collected annually.

7. While the measures in place through the OWR to ensure acceptable water quality for harvest, often restrict harvest, there have been efforts to allow harvesters the maximum opportunities while at the same time following safe protocols to protect public health. For example, in 2011 as a result of implementation of Phase one of the Narragansett Bay Commission CSO Abatement Project and extensive sampling results, the rainfall closure criteria for Area A was increased from 0.5" to 0.8" and Area B from 1.0" to 1.5". In addition, new sampling stations have been added to the OWR protocol to evaluate potential feasibility of a higher rainfall closure criteria or the reduction of area "B" that closes on an 1.5" rainfall. Completion of the Phase II of the Narragansett Bay Commission Abatement Project in 2015 may also offer potential changes to the existing closure criteria.

8. Although not a tool developed specifically for shellfish resource management (e.g. the only consideration is water quality), the prohibition of shellfishing in an area can have a dramatic impact on the resource and distribution of biomass throughout the bay. In addition, restoration and enhancement activities are generally not permitted within closed waters. Therefore water quality and its designation impacts on shellfish activities are an important overarching consideration when designing and/or re-thinking management strategies in the state.

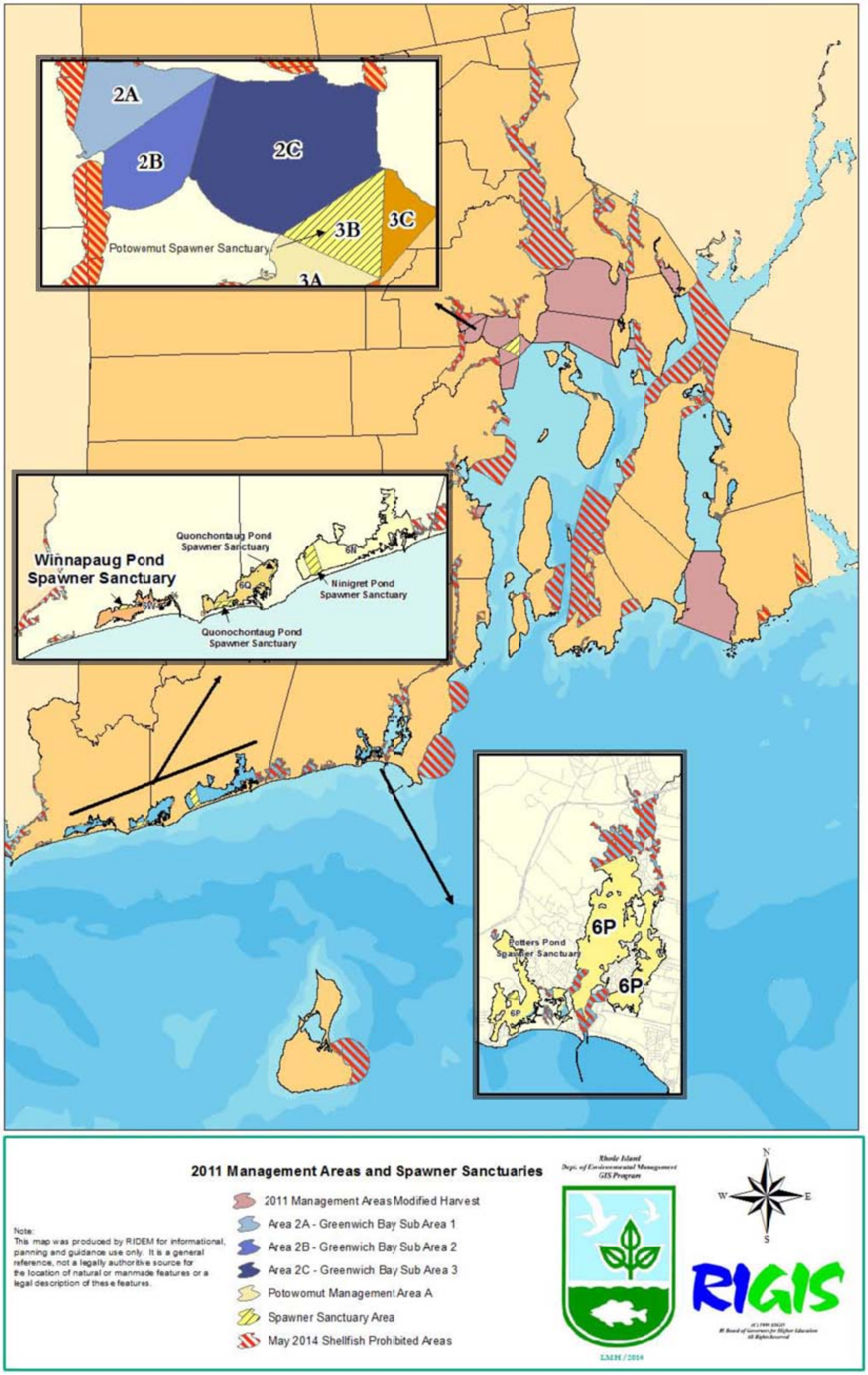


Figure 5.1. DEM OWR map of shellfish management areas and spawner sanctuaries.

Section 530. Wild Harvest Management

1. RI DEM Management Philosophy – The marine fishery resources belonging to, allocated to, and of interest to Rhode Island need to be preserved and protected, at healthy, sustainable levels because of their ecological value, and because they are renewable natural resources that provide food, recreation, income, employment, and other economic, social, and cultural benefits.
2. RI DEM Management Goals – 1) Maintain the health of the State's marine ecosystem; 2) In accordance with sustainable harvest levels, manage harvest in ways that make full and effective use of available harvest opportunities, while minimizing discards, ecological impacts, habitat degradation, and other wasteful practices at the same time balance the interests of different user groups and stakeholders. There are specific goals for each of these stakeholders:
   a. Recreational Harvesters- Provide fair, open, and equitable access and harvest opportunities with certain preferences to residents of the State.
   b. Commercial Industry- 1) Maintain an economically strong viable and diverse industry; 2) Support the business interest of fishermen and economic interest of the industry; 3) Support safe fishing operations; 4) Support enhanced marketing opportunities.
   c. Prospective Fishermen- Provide meaningful access opportunities without unduly impacting the interests of those currently engaged in the industry
   d. General Public- 1) Maintain the health of the State's marine ecosystem; 2) Provide a stable supply of safe, fresh, locally caught seafood
3. In each of the following subsections a specific management strategy is discussed. These strategies include 1) Licensing; 2) Gear and harvest method restrictions; 3) Minimum sizes; 4) Catch limits; 5) Area specific management, which includes a number of different strategies.

   In the discussion, management strategies, assessment tools and methods are described which help to evaluate the effectiveness of each tool. The assessment methods may include fisheries dependent data, fisheries independent survey results, and life history studies. This information can be incorporated into mathematical models or computer simulations, tools that aid managers in decision making.

530.1. Licensing

1. The main goals of the licensing are for RI DEM to protect and balance the interests of: 1) the marine fisheries resources; 2) invested fishermen who rely on commercial fishing for their livelihoods; and 3) those seeking the opportunity to fish on a commercial basis. The licensing system allows for RI DEM to administer regulatory and management programs, enforce compliance with requirements, identify and convey information to participants in the fishery, and enhance abilities of managers to collect fishery-dependent data.
2. Reform of the licensing system began in 1995 and the current licensing system has been in place since 2003. Prior to 1995, there was open access to commercial fishing licenses; any person who wanted a commercial fishing license could obtain one. Concern over the level of fishing effort sparked a legislative response that resulted in a number of license moratoriums beginning in 1995 and ending in a new licensing statute passed by the legislature in 2002 and the new program enacted in 2003.
3. *License structure* – There are a number of commercial licenses available that allow for the harvesting and selling of shellfish to dealers in Rhode Island. The license categories are the Multi-purpose license (MPURP), Principal Effort License (PEL), Commercial Fishing License (CFL), Student Shellfishing License (STUD), and Over 65 (O65) shellfishing license (Table 4.5). Licenses can be bought and sold along with a vessel and gear as part of the sale of a business if certain requirements are met.

a. The Multi-Purpose License (MPURP) is only available through a renewal process; no new MPURPs are issued in Rhode Island. A total of 1,191 of these licenses were "grandfathered" into the new system when it was enacted in 2003. A fisher holding a MPURP in Rhode Island is able to fish at full effort levels for all legally harvestable species in Rhode Island and is not required to obtain endorsements. The current cost of a MPURP license is $300. As of 2013, there were 829 licensed multi-purpose fishermen. Of these holders, 24% reported landing quahogs at least once in the year.

b. The Principal Effort License (PEL) also allows full harvest levels. The difference between a PEL and MPURP is that the holder of a PEL license must also obtain an endorsement for the species or group of species that they intend to fish. The cost of a PEL is $150, with each additional endorsement after the first costing $75. Currently, there are four endorsements related to shellfish fisheries: "quahog," "soft-shell clam," "whelk," and "other shellfish." In 2013, there were 376 quahog endorsement holders, 235 soft-shell clam, 118 whelk, and 211 shellfish other.

c. Like the PEL, those with a Commercial Fishing License (CFL) also have to obtain endorsements for species or groups of species. The cost of a CFL is $50 and each endorsement is $25. The four endorsements are the same as with a PEL (quahog, soft-shell clam, whelk, and other shellfish). All of the endorsements have full harvest levels, with the exception of the quahog endorsement; the holder of a CFL with quahog endorsement is allowed to take 3 bushels per day as opposed to the 12 bushels afforded to the MPRUP or PEL license holder. A CFL license holder with a quahog endorsement can obtain a PEL license after two years of actively fishing the CFL license. In 2013, there were 165 quahog endorsement holders, 163 soft-shell clam, 92 whelk, and 160 shellfish other.

d. The Student shellfish license (STUD) is available to full-time students under the age of 23 and allows for a 3-bushel daily limit (same as a CFL). The cost of the Student Shellfish license is $50. In 2013 there were 48 Student licenses issued.

e. The state also provides a free "Over 65" license to those who are 65 or older and wish to obtain a commercial license for the harvest of quahogs only. The Over 65 license has a 3-bushel daily limit. In 2013, 268 Over 65 licenses were issued. Some fishermen who are 65 or older maintain and pay for their MPURP or PEL licenses to afford them the opportunity to harvest a full 12-bushel limit.

4. *Entering the fishery (exit/entry ratios)* – CFLs are issued to new license holders based upon the exit/entry ratios for each endorsement. This ratio has changed over the years pursuant to the annual license renewal process where the Industry Advisory Committee meets to review exiting licensees and consider an appropriate method for distributing new licenses.

    a. In 2003, when the new system was established, three PEL Quahog endorsements had to be given up before a CFL with Quahog endorsement was issued to one prospective fishermen (3:1 exit:entry ratio). Currently, two PELs with Quahog endorsements or MPURPs must be retired before a CFL with Quahog endorsement is issued (2:1 exit:entry ration).

    b. In 2008, a "Soft-Shell Clam" endorsement became available to those who possessed a Non-Quahog endorsement in 2007. Five licenses either MPRUPs or PELs and CFLs with Soft Shell Clam endorsements, must be retired before a new CFL license with Soft Shell Clam endorsement will be issued. This exit/entry ratio has stayed the same from 2008 till present.

    c. In 2012, a new Whelk endorsement was made available to all commercial license holders. In 2013 and 2014, the Whelk endorsement was available only to those fishers who held a quahog or soft shell clam endorsement and were actively fishing.

    d. The STUD and O65 licenses are the two open license categories that allow for the harvest of quahogs to which the exit/entry ratio does not apply.

530.2. Gear Restrictions and Harvest Methods

1. The quahog fishery has gone through periods of ups and downs often associated with the types of gear used to harvest quahogs. The high point in landings occurred in 1955 when 12,307 metric tons (27.13 million lbs) were landed (Figure 5.2). At this point in time, quahogs were being harvested in the shallows primarily by tongers and in deeper waters by dredge boats. The use of dredges depleted the resource quickly and was an unsustainable practice. Catches began to drop off and the use of dredges decreased as the deep-water populations declined. An incremental process of limiting the use of dredges to certain areas began in the50's before finally being banned entirely in 1969. Section 20-6-7 of Rhode Island General Law states that: "No person shall take any oysters, bay quahaugs, or soft-shell clams from the waters of this state by dredges, rakes, or other apparatus operated by mechanical power or hauled by power boats."
2. After dredging was banned, quahoggers were limited to the shallow waters until the adoption of bullrakes with extendable aluminum stales in the early 70's opened up new, deeper fishing grounds with a large exploitable biomass to the fishermen. A resulting increase in landings began around this time as fishermen now had access to abundant quahogs in the new fishing grounds.

1. Today, Rhode Island shellfish harvesters are permitted to use a variety of hand-operated tools, such as rakes, forks, hoes, and tongs, though, the majority of commercial shellfishermen use bullrakes. Some harvest equipment has specific configurations by which they must abide to help ensure continued sustainability of the resource and fishery and to conserve the natural habitat.
   a. *Rakes* – Regulations require rake tines be spaced 1" apart and any reinforcement cannot result in forming a rectangle less than 1" x 2.5" (to reduce the amount of undersized quahogs removed from the water). If power hauling equipment is used to lift the rake to the surface (the only time power equipment can be used) then the bullrake cannot be more than 31.5" in width and the basket cannot be greater the 12" in depth. The teeth length on power hauled rakes is no more than 4.5".
   b. *Tongs* – Regulations require tong teeth be spaced 1" apart and any reinforcement cannot result in forming a rectangle less than 1" x 2.5".
   c. *Pots* – For commercial and recreational harvest, 300 pots and five pots are permitted, respectively.
   d. *Dip nets* – Dip are the only permitted gear for harvesting bay scallops within shellfish spawner sanctuaries. Dip netting is only allowed from a boat for safety reasons related to cold winter water temperatures and to protect the seed scallops from being trampled by harvesters.
   e. *Dredge* – Dredges and other mechanical harvest methods may not be used to harvest bay quahogs, soft shell clams, and oysters. Hydraulic dredges (with certain gear restrictions, trip limits, and minimum size) are used to harvest surf clams and ocean quahogs within state waters; they are not used to harvest mussels. Permits are required to use a mussel dredge and only a small number of shellfishermen currently use this technology (Pers. Comm. D. Beutel, 2014). Dredging for bay scallops is permitted in the month of December. A total of 6 small dredges with a maximum width of 28" each may be towed behind a boat for the harvest of bay scallops, provided all by catch is returned to the water.
2. *Diving* – Scuba diving is permitted within Narragansett Bay, but is prohibited while digging from shore. In addition, as of 2001, scuba diving is no longer permitted within Green Hill Pond, Quonochontaug, Ninigret, and Potter Ponds (which also is prohibited to shellfishing due to water quality issues). Bags used to hold quahogs while diving are required to have bar spacing of at least 1" and the mesh on the bags must be hung on the square and must be at least 2" when measured on the stretch. Those wishing to dive with surface-supplied air as opposed to scuba are permitted to do so.

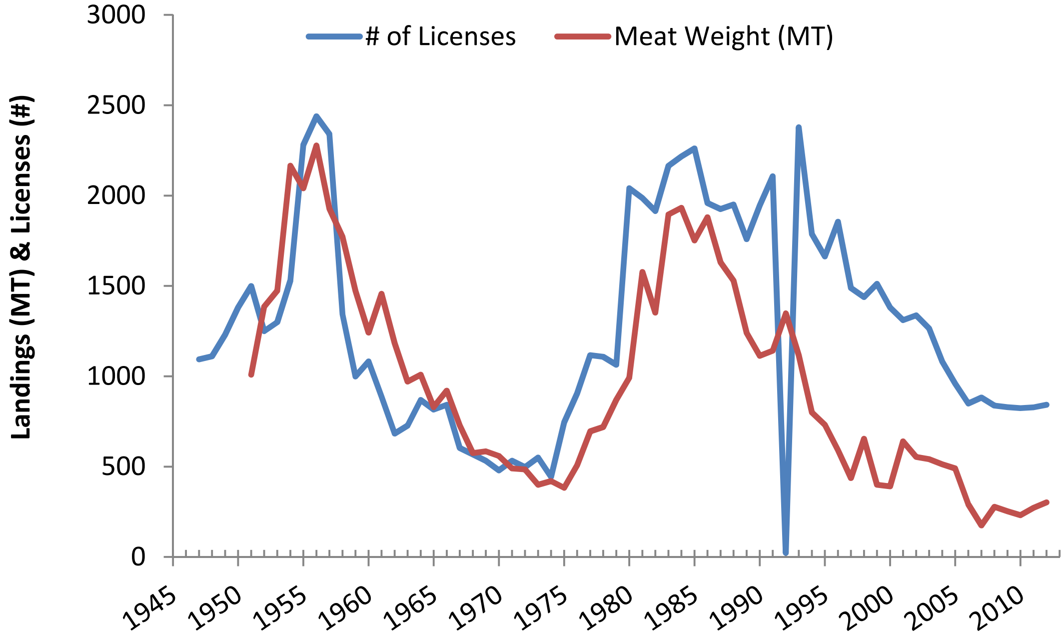


Figure 5.2. RI quahog landings in metric tons in red (NMFS) and number of licenses (RI DEM).

530.3. Minimum Sizes

1. Minimum sizes are used all over the world and are likely the most commonly used fisheries management tool. This is primarily because it is crucial to protect immature fish and shellfish and give them the opportunity to reproduce before they are captured in the fishery. If shellfish are caught before they have had the chance to reproduce there is no opportunity for them to replace themselves, which will inevitably lead to population collapse.
2. Minimum sizes of harvest for shellfish species in Rhode Island are listed in Table 5.1. Of note is that bay scallops are not managed by a minimum size. This is because the short life span and life cycle of bay scallops allow them to be managed by season instead. Nearly all scallops that are at least one year old (as evident by the growth ring) will reproduce during the summer and then may be caught in the following winter fishery. Most scallops will die of natural causes prior to reproducing again the following summer.
3. Minimum sizes are typically determined by looking at the relationship between size and proportion of the population at that size that are mature, known as a maturity ogive. Not all individuals mature at the same time due to the individual characteristics of the animal or environment which they live in therefore there is a size range at which most individuals will reach sexual maturity. Quahogs reach the size of maturity sometime in their 4th year and typically attain legally harvestable size in the 5th year, ensuring that they have the chance to reproduce at least once (Figure 5.3).

Table 5.1. 2013 harvest size and season regulations for species considered within the SMP.

Species	Harvest Size	Harvest Season
Quahog	1" hinge width	Year round
Soft-shell clam	2" longest axis	Year round
Americal razor clam, Atlantic jack knife	None	Year round
Whelk	2-7/8" diameter or 5-1/8" length	Year round
Eastern oyster	3" longest axis	Sept 15 – May 15
Blue mussel	None	Year round
Bay scallop	Must have raised at least one annual growth ring	Nov – Dec
Periwinkle	None	Year round

4. In the mid-1980's dealers began to use rolling sorters to buy small quahogs, little necks, top necks, and cherrystones by the piece instead of by the pound. As a result of the use of sorters to grade the catch, in 1987 the definition of a legally harvestable quahog was adjusted from 1.5" in length to 1" width. The dimensions of shellfish typically grow in relation to one another, in the case of quahogs, it typically takes about the same time for a quahog to grow to 1.5" as it does to grow to 1" width. Therefore the change in minimum size did not affect the number of quahogs that were being protected but rather aided the industry in making the sorting and grading more efficient.

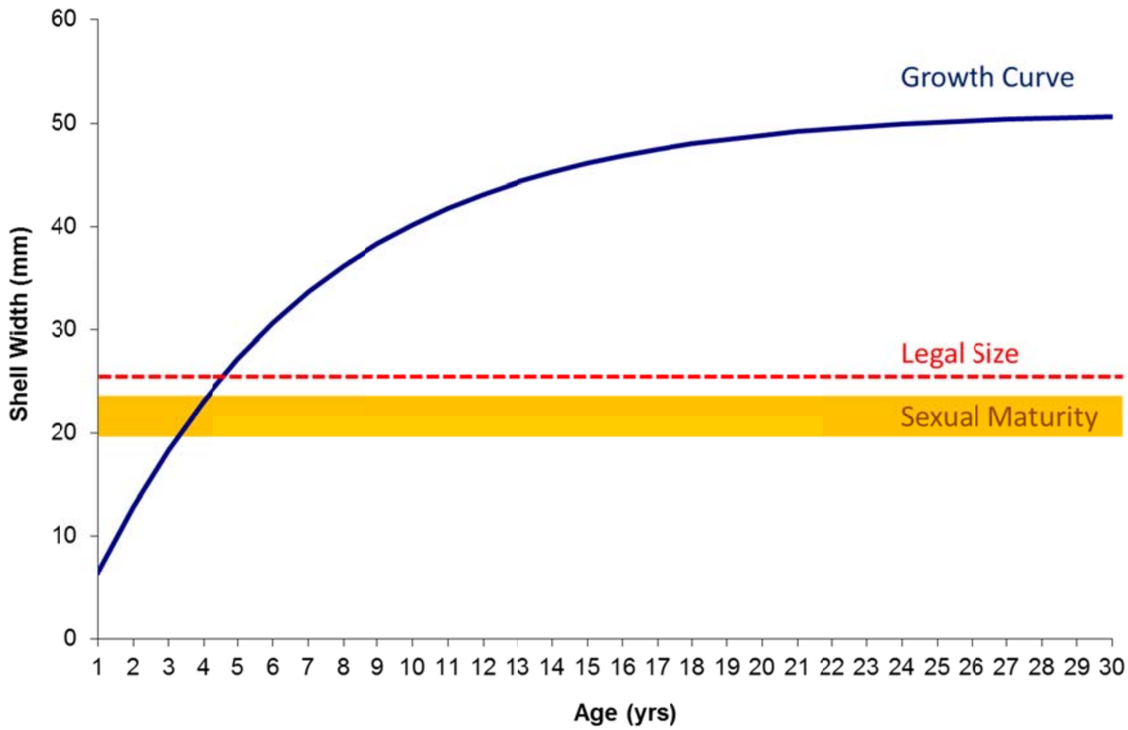
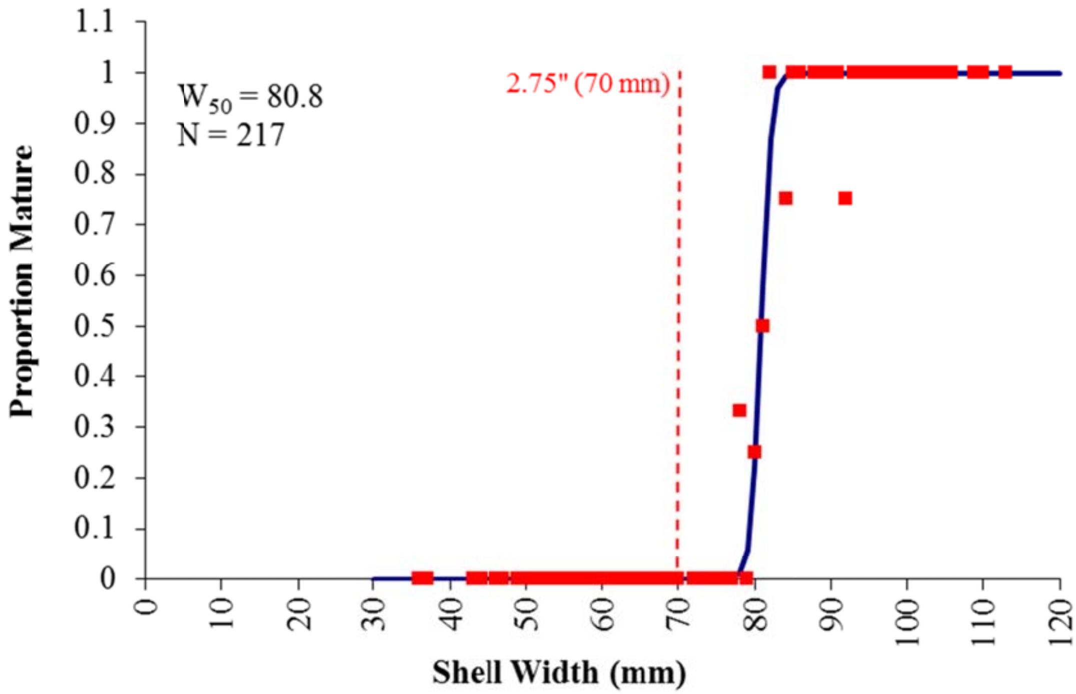


Figure 5.3. Average growth curve of the quahog with approximate size range at which individuals reach sexual maturity and the minimum legal size.

5. Recent studies conducted by RI DEM in Narragansett Bay during 2012 (Angell 2013, unpublished data) on the life history attributes of whelks, including the size and age at maturity and growth rates of individual whelks, indicate that no female channeled whelk and only approximately 25% of female knobbed whelk were mature at the 2012 established 2.75" minimum shell width (Figure 5.4 A&B).

A



B

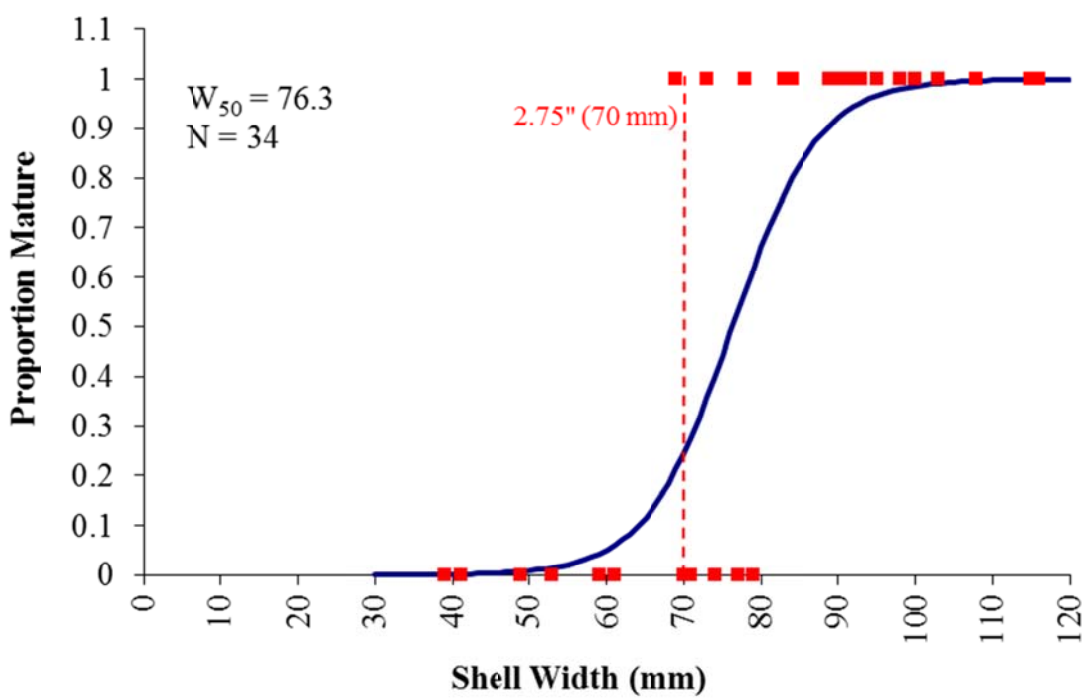


Figure 5.4. Female channeled (A) and knobbed (B) whelk size (width) at maturity. The red points indicate the actual portion of whelks mature at the given size and the blue line is a logistic curve fit to the data. W50 indicates that estimated point at which 50% of female whelks are mature. N is the number of individual whelks inspected. The 2012 minimum width size of 2.75" is indicated by the red dotted line.

6. Whelks have limiting biological traits that make them vulnerable to overfishing including a limited early dispersal stage, slow growth and late maturation, low fecundity, low genetic diversity, and a sedentary lifestyle (Hancock 1963, Berg and Olson 1988, Gendron 1992). These attributes allow for intense exploitation on local whelk aggregations and serial depletion of populations that may fail to recover (Gibson, 2010). As a result of the study completed by RI DEM, in conjunction with similar work conducted by Massachusetts Division of Marine Fisheries, the minimum width of a legally harvestable whelk was increased 1/8" in 2014 and additional 1/8" beginning in 2015 to provide a greater opportunity for female whelks to reproduce at least once before being captured in the fishery.

530.4. Harvest Limits

1. Harvest Limits are primarily established to control fishing effort and prevent overharvesting. Secondarily, daily limits are established to ensure the continued vitality of the fishery throughout the year as opposed to quickly depleting the resource in a limited amount of time through maximal daily harvest.

Table 5.2. 2013 harvest limits for species considered in the SMP, including commercial and recreational harvesting within and outside of designated Shellfish Management Areas (SMAs).

Species	Harvest Limits (person/day) Within Shellfish Management Area			Harvest Limits (person/day) Outside of Shellfish Management Area		
	Commercial	Recreational RI Resident	Recreational Non-Resident	Commercial	Recreational RI Resident	Recreational Non-Resident
Quahog	3 bushels*	1 peck	1/2 peck	12 bushels	1/2 bushel	1 peck
Soft-shell clam	3 bushels	1 peck	1/2 peck	12 bushels	1/2 bushel	1 peck
American razor clam, Atlantic jack knife	None	None	None	None	None	None
Whelk	35 bushels & 300 pots	1/2 bushel & 5 pots	Prohibited	35 bushels & 300 pots	1/2 bushel & 5 pots	Prohibited
Eastern oyster	3 bushels*	1 peck	1/2 peck	3 bushels	1/2 bushel	1 peck
Blue mussel	3 bushels*	1 peck	1/2 peck	None	1/2 bushel	1 peck
Bay scallop	3 bushels	1 bushel	Prohibited	3 bushels	1 bushel	Prohibited
Periwinkle	None	None	None	None	None	None
*12 bushels within Conimicut Point Shellfish Management Area						

2. Harvest limits, licenses, and seasons can be used in combination to limit the amount of fishing effort on a given population and maintain healthy, sustainable populations. DEM uses a Bay Wide Stock Assessment Model to evaluate the abundance of quahogs and level of fishing effort within the Bay. The size structured model takes the general form of

$$N_{ij} = \left[\left(N_{ij-1} * (1-p) * e^{-(F_{ij-1}+M)}\right)\right] + \left[\left(N_{i-1j-1} * (p) * e^{-(F_{i-1j-1}+M)}\right)\right]$$

Where:

- N = population size
- F = fishing mortality rate
- P = promotion probability
- M = natural mortality rate
- i = size class
- j = year

a. The promotion probability, or likelihood that an individual quahog grows from one market class to the next (eg. littleneck to topneck), is governed by a von Bertalanffy growth equation derived from Henry & Nixon (2008). The inputs to the model include fisheries dependent landings, a fisheries independent abundance index (see below), and a fishing effort index derived from licensing information.

b. The model indicates that the fishing effort at the height of the fishery from the mid-80's through the mid-90's far exceeded sustainable levels (Figure 5.5). This time period coincided with the opening of the Conditional Areas of the Upper Bay which had been previously closed to fishing due to pollution concerns and thus was a large reservoir of previously unexploited quahogs that were heavily fished upon causing quick reductions in local abundance. Fishing mortality rates decreased to moderate levels from 1997-2004 and the estimated population abundance remained about the same throughout this time. Since 2004, this fishing mortality rate has been below $F<0.3$ and the estimated abundance in the Bay has increased slightly. In general it appears that fishing mortality rates in excess of 0.45 lead to decreased abundance as recruitment can not keep up with fishing levels. Recruitment and fishing mortality are roughly in balance for fishing rates between 0.3 and 0.45 and modest increases in population abundance are observed for fishing rates below 0.3 suggesting recruitment rates exceed fishing mortality.

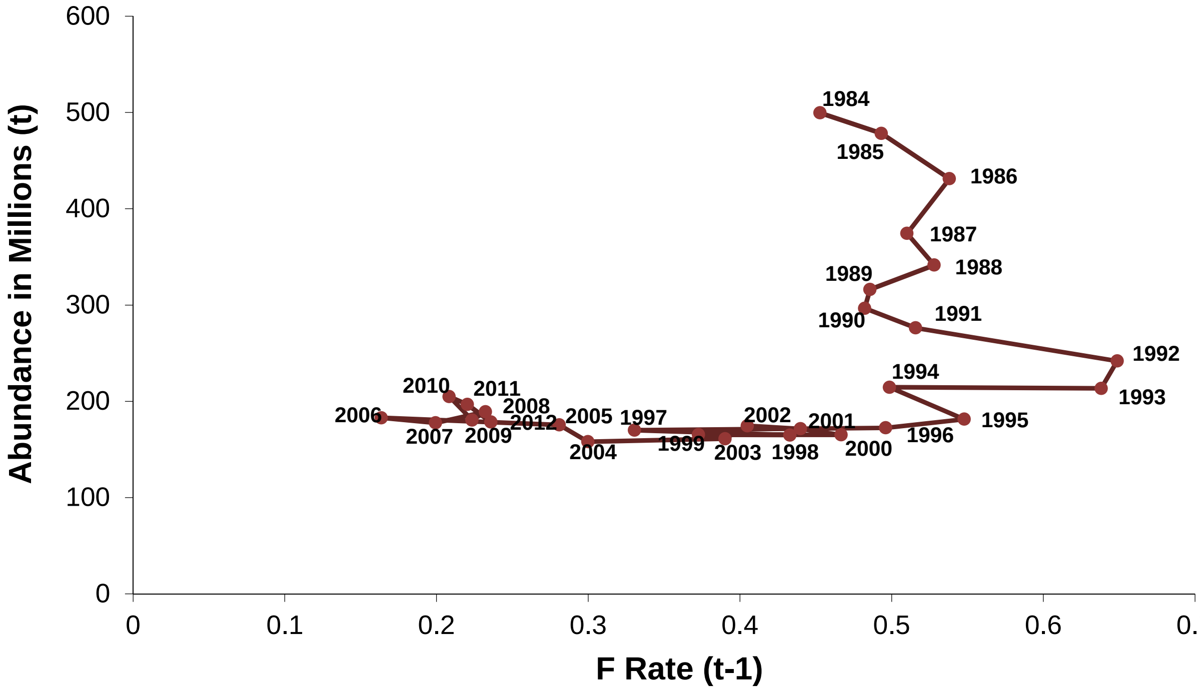


Figure 5.5. The estimated number of quahogs in Narragansett Bay versus the calculated fishing mortality rate from the previous year. Values are derived from the stock assessment model.

3. A fisheries independent survey is conducted as part of the DEM's yearly assessment of the quahog resource in Narragansett Bay. A hydraulic dredge designed to retain legal size quahogs is used to sample fished and un-fished portions of the Bay and all species, not only quahogs, are identified, measured, and recorded. While stratified random survey has been ongoing since 1993, DEM conducted an evaluation of the dredge survey design in 2006, leading to a new strategy that that increased statistical confidence in the survey results. The new, reconfigured design is intended to increase the sampling intensity in rotating designated areas in order to provide enough samples to get more precise estimates of biomass of quahogs by size class (Figure 4.8). All areas of the bay can be sampled every two years. Since 1993, DEM has conducted 2,714 number of tows and measured 30,018 individual quahogs to determine size class distributions.

4. The stock assessment model and the dredge survey data both indicate an average density of 1.5-2 quahogs per square meter in the fishable areas of the Bay in recent years.

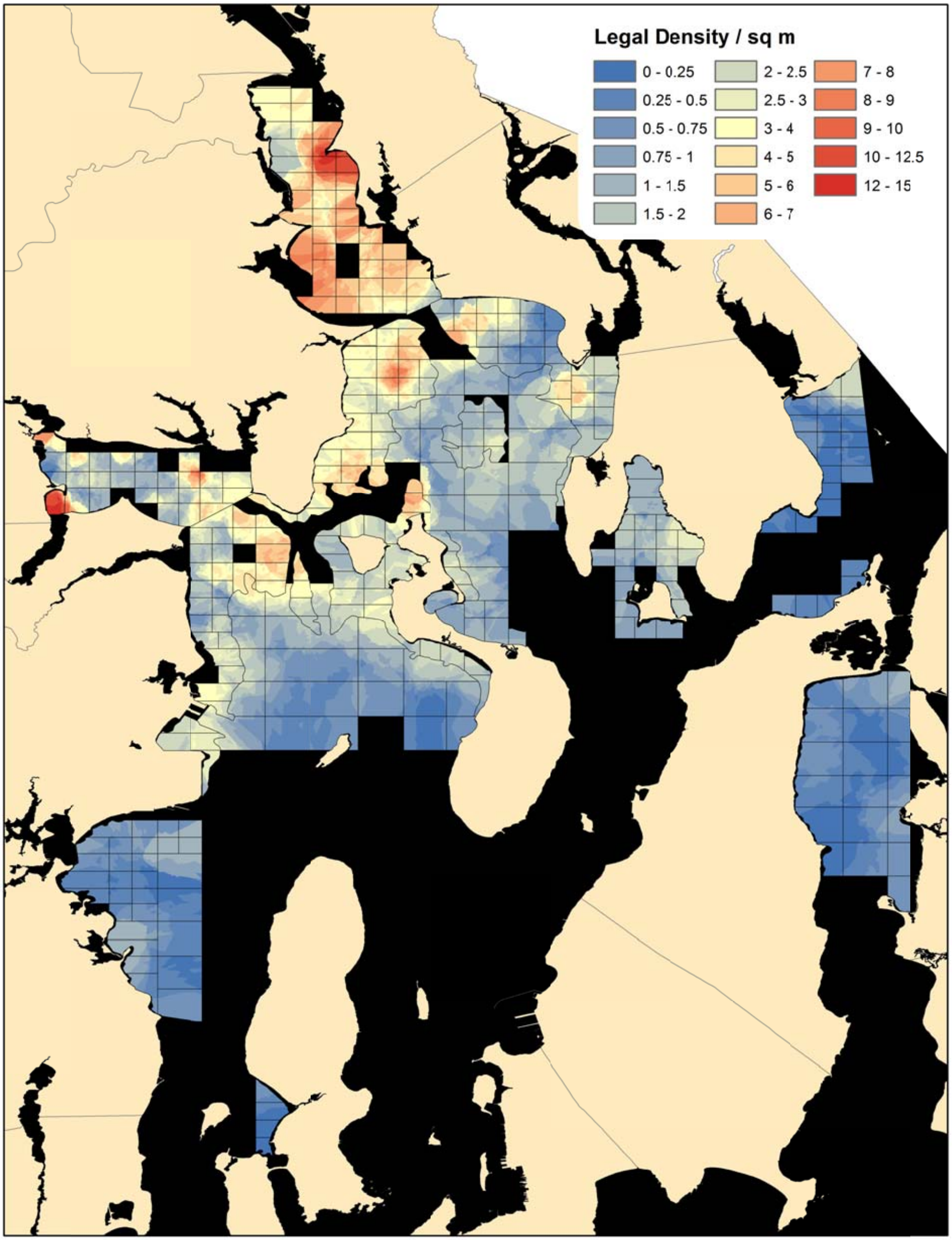


Figure 5.6. Interpolated (kriged) density of quahogs in Narragansett Bay based on RI DEM dredge surveys from 1993-2013. Interpolations were restricted to current survey strata. Density estimates for the rest of the Bay do not have high certainty.

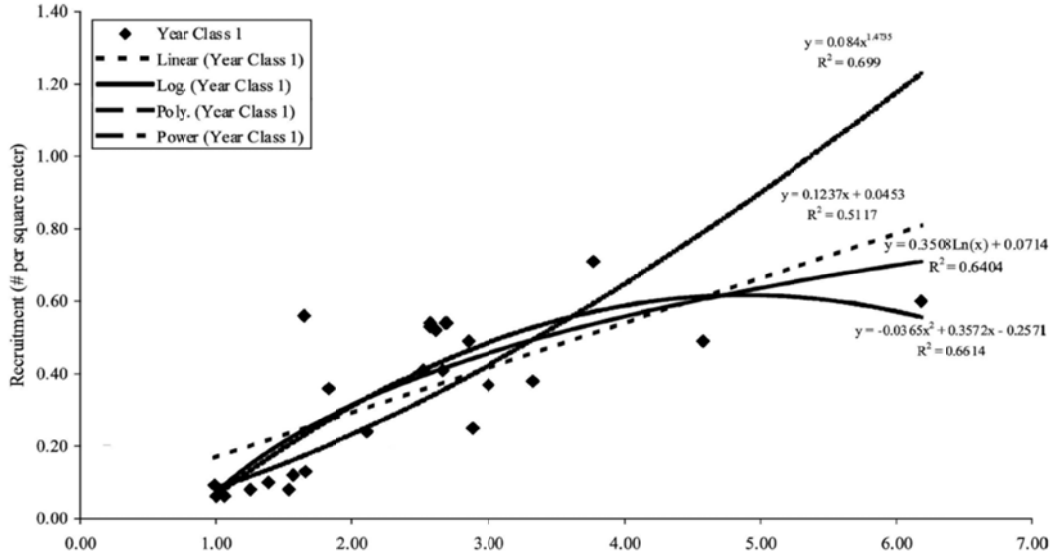


Figure 5.7. Spawning stock and recruitment relationship determined for Great South Bay, NY. The curves represent the best fit model for linear, log, 2nd order polynomial and power functions.

5. Another type of stock assessment model is utilized by RI DEM to determine the effect of fishing on whelk populations in Narragansett Bay. An initial stock assessment was performed by Gibson (2010) using a biomass dynamic model (BDM). The BDM clearly showed that whelk abundance is strongly influenced by fishing mortality rate (F). Rates above the calculated Fmsy of 0.33 resulted in low biomass and high whelk abundance when the F rate was lower than Fmsy. Based on the available data at that time, it was concluded that Fmsy=0.33 was an appropriate overfishing reference point and a fishing mortality rate target equal to 75% of Fmsy (F=0.25) would provide a buffer between the overfishing threshold. Based on this initial stock assessment, F rate was at or below this level, indicating that overfishing was not occurring. Also, biomass was estimated to be near the Bmsy reference level, so an overfished condition was not likely (Gibson 2010).
6. The whelk stock assessment was updated to include data through 2013 and resulted in re-estimation of Fmsy at a higher fishing rate of 0.40 (Figure 5.10). As with the previous stock assessment, high fishing mortality rates above this level resulted in low biomass and high whelk abundance occurs when the F is less than Fmsy. The updated target F rate equal to 75% of the Fmsy was 0.30. Over the last two years, the F rate has risen and is now estimated to be at or above the target and exceeded

Fmsy in 2012, so overfishing is likely (Figure 5.9). Biomass remains above Bmsy (Figure 5.8).

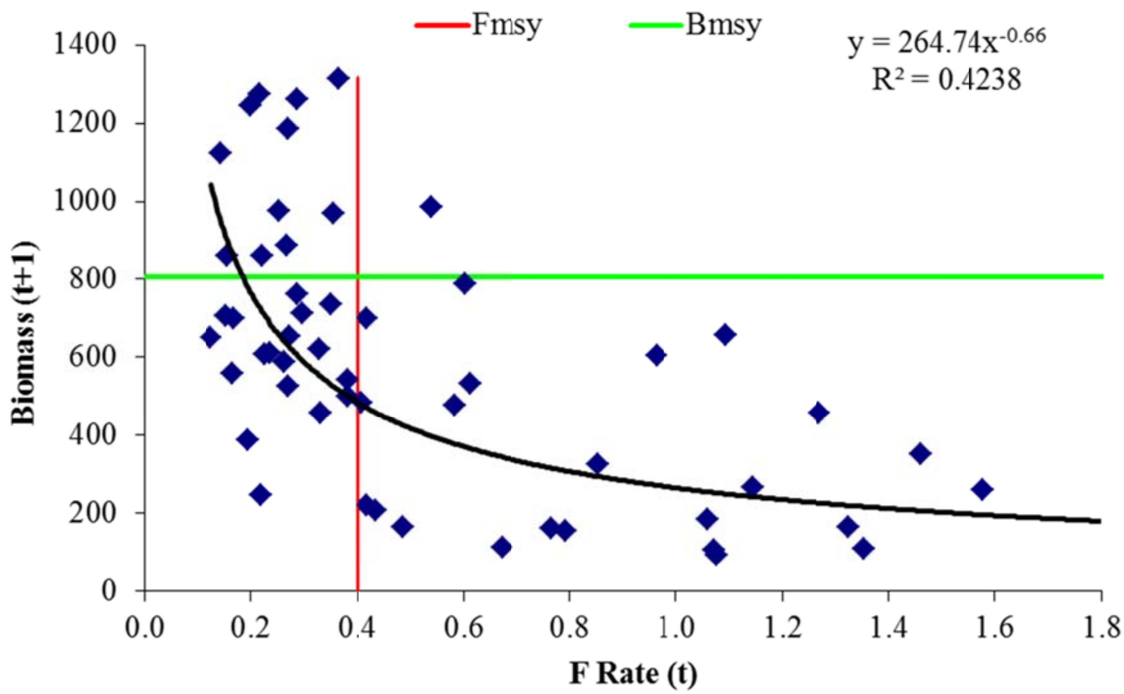


Figure 5.8. Phase Plot for fishing mortality rate and biomass the following year. Blue points are actual data back to 1959 and the black curve is the best fit model. Estimated F-rate (red) and biomass (green) at maximum sustainable yield are indicated.

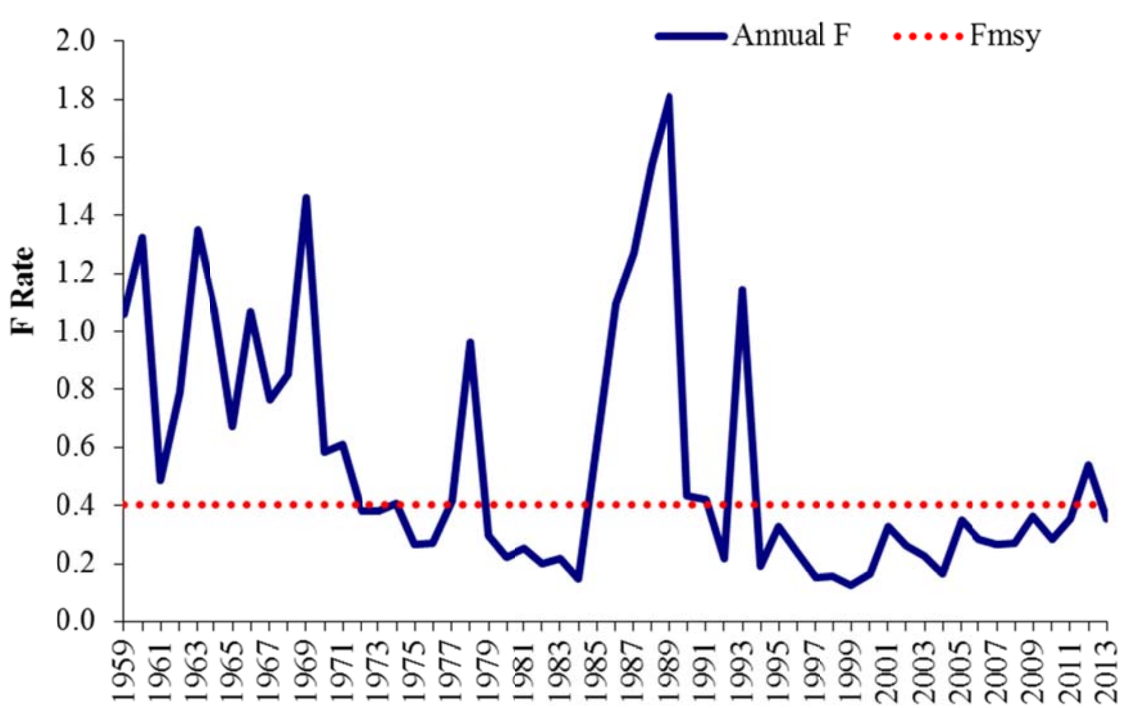


Figure 5.9. Estimated whelk fishing mortality rate compared to Fmsy.

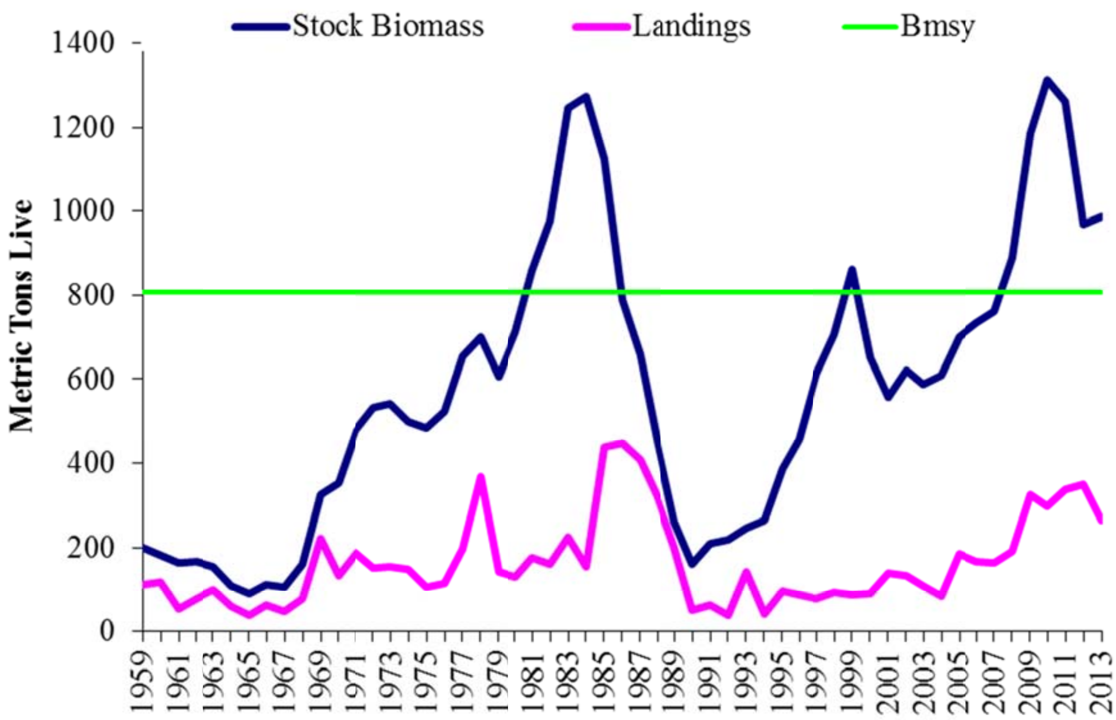


Figure 5.10. Estimated whelk abundance and landings compared to Bmsy.

530.5. Area Specific Management

1. Shellfish Management Areas are specific areas (15 total) defined in DEM statute throughout Narragansett Bay and the coastal salt ponds (Figure 5.11). These areas are designated either for conservation or shellfish stock rebuilding, or can be utilized for designated shellfishing related purposes.
   a. Specifically, Shellfish Management Areas are: "…certain portions of the shores of the public waters of the state, or land within the state covered by tidewater at either high or low tide, or portions of the free and common fisheries of the state as shellfish or marine life project management areas for the purpose of enhancing the cultivation and growth of marine species, managing the harvest of marine species, facilitating the conduct by the department of experiments in planting, cultivating, propagating, managing, and developing any and all kinds of marine life, and any other related purpose" (RIGL § 20-3-4).
   b. Harvest rules and restrictions set for these areas, following the Council and SAP process, are marked with signs and are described in regulations using landmark descriptions. Management Areas are instituted for five-year periods, after which their effectiveness is required to be evaluated by DEM.
   c. The following are designated Management Areas (refer to Figure 5.11). Full descriptions of the locations of these areas can also be found in the RI Marine Fisheries Regulationsfound at: http://www.dem.ri.gov/pubs/regs/fishwild/rimftoc.htm. It should be noted that water quality classifications supercede any management restrictions and should be determined prior to harvesting within any of these management areas.
      1) Greenwich Bay
      2) Conimicut Point
      3) Potowomut
      4) High Banks
      5) Bissel Cove/Fox Island

6) Mill Gut
7) Bristol Harbor
8) Kickemuit River
9) Jenny's Creek
10) Sakonnet River
11) Point Judith Pond
12) Potter Pond
13) Ninigret (Charlestown) Pond
14) Quonochontaug Pond
15) Winnapaug Pond

d. There are 4 management strategies that have been employed within Shellfish Management Area. These include 1) Reduced daily limits; 2) No harvest (ie spawner sanctuaries); 3) Limited Access Time; 4) Rotational Harvest.

e. All of the management areas with the exception of the Sakonnet River Management Area, have reduced harvest limits. The reduced daily limits are intended to reduce the fishing pressure on the resource within management areas. The Conimicut Triangle SMA was created in 2011 and was specifically established to manage the once-abundant soft-shell clam resources present there. The reduced limits of the Conimicut Triangle apply only to soft-shell clams.

f. Spawner sanctuaries are closed areas that serve as refuges for quahogs to build biomass in the absence of fishing pressure. There are a total of six sanctuaries: one each within Narragansett Bay, Ninigret Pond, Winnapaug Pond, Potter Pond, and two within Quonochontaug (refer to Figure 5.11). The locations of the spawner sanctuaries have been chosen by DEM to promote quahog larval distribution, and thus, the quahog population, throughout Rhode Island waters. The determination of locations of the spawner sanctuaries have been a collaborative process between industry and DEM and some were originally developed to receive transplanted quahogs from polluted waters. Often time sanctuary locations were for ease of enforcement and not to interfere with productive fishing grounds. New modeling tools and computer simulations developed by researchers throughout the state allow managers to evaluate the effectiveness of these sanctuaries at exporting larvae to other areas of the Bay that are suitable for quahog survival. Figure 5.12 shows an example of outputs from the LTRANS model (North, 2010) adapted to Narragansett Bay which show where simulated quahog larvae spawned in the Potowomut Sanctuary will end up when they are ready to settle to the bottom and begin their benthic life phase. 54% of the simulated larvae that originated in the Potowomut Sanctuary were lost to the open ocean presumably to perish. This number is realatively low compared to surrounding areas of the Bay due to a high percentage of larvae being advected into Greenwich Bay.

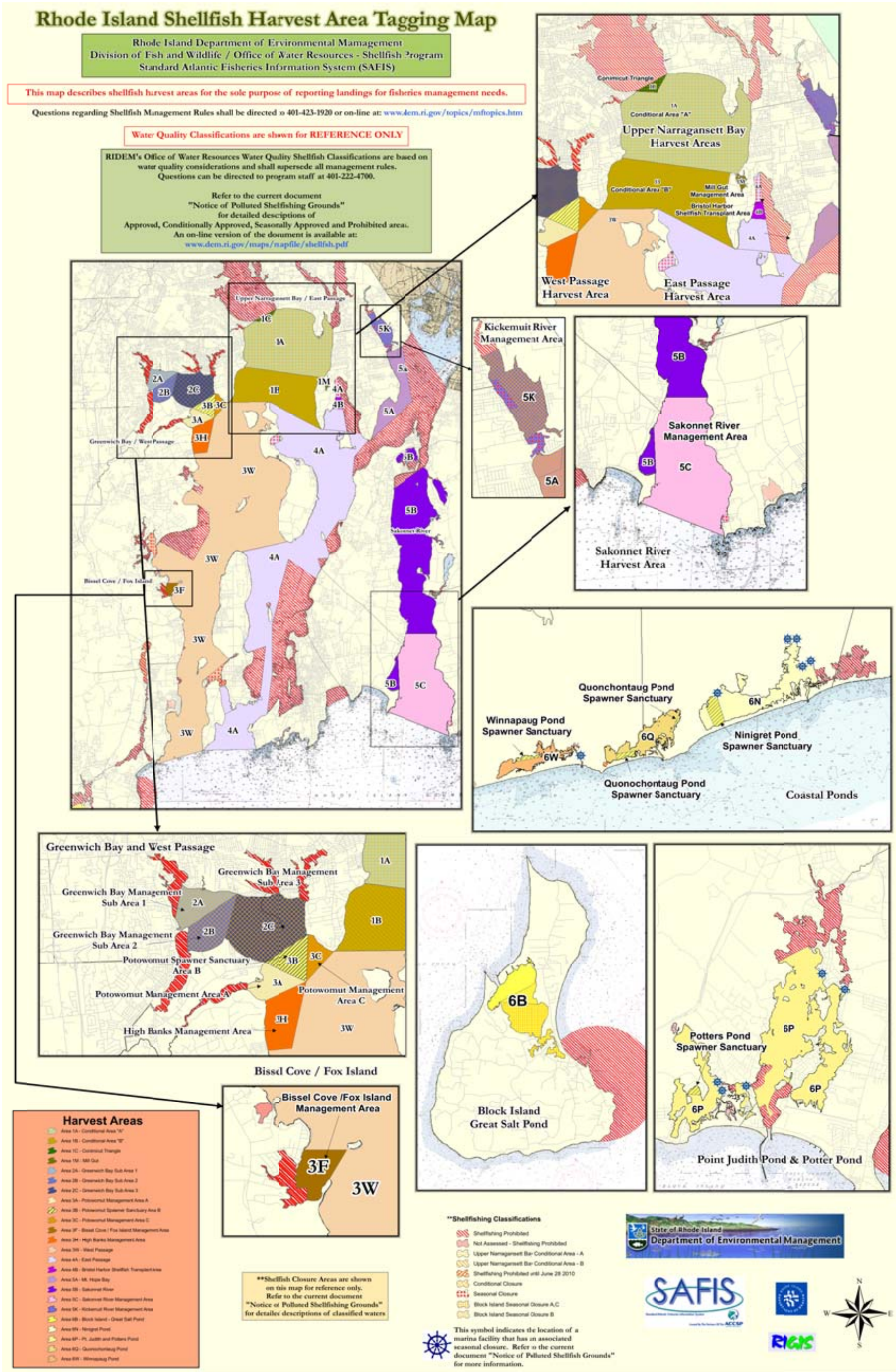


Figure 5.11. Shellfish Management Areas.
Map found at: http://www.dem.ri.gov/programs/bnatres/fishwild/pdf/tagmap.pdf.

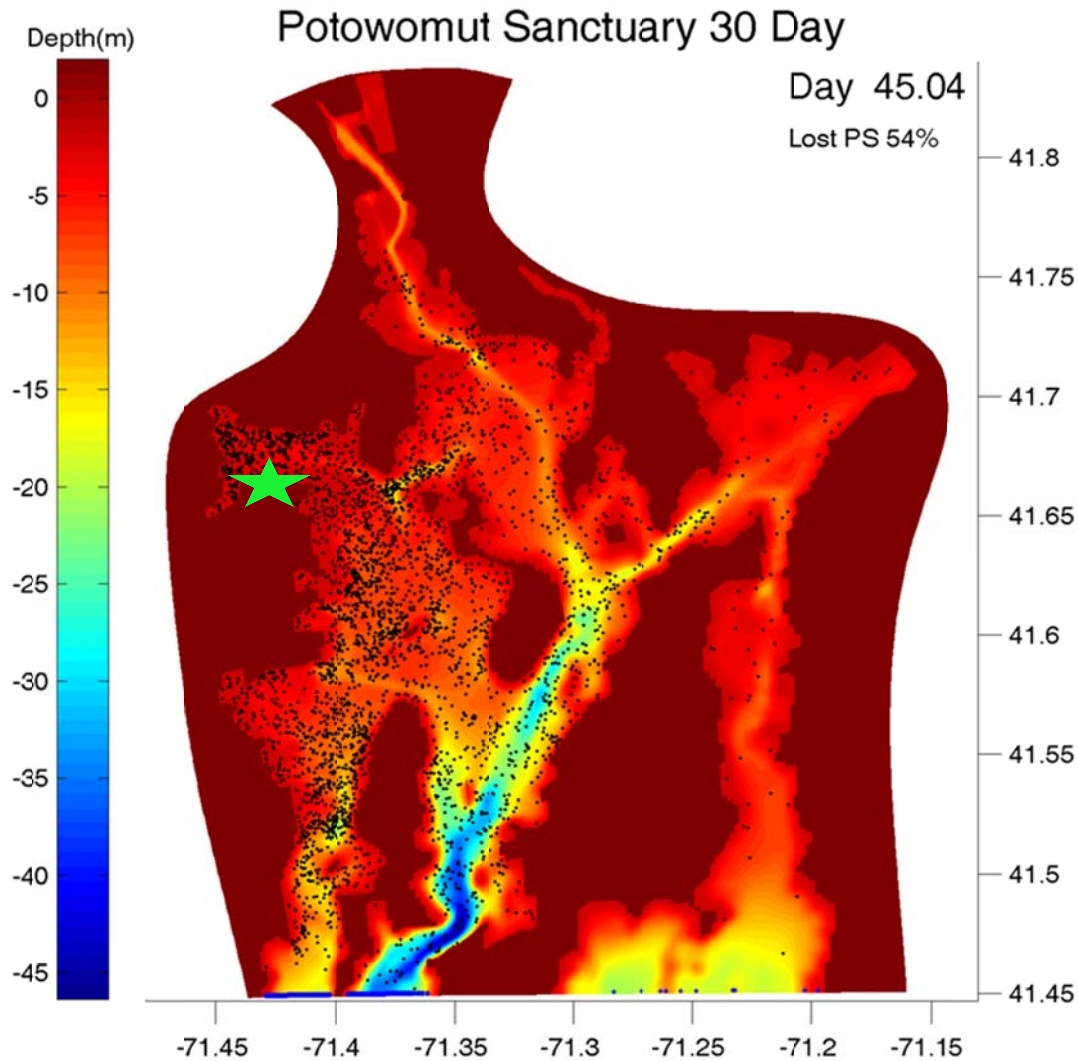


Figure 5.12. Outputs from the LTRANS model which show the settling locations of simulated larvae released randomly over a 30 day period within the Potowomut Sanctuary (green star).

2. Shellfish transplants from polluted areas to harvestable areas have occurred for over half a decade. DEM and DOH coordinate these events, during which a large amount of adult quahogs from high-density shellfish areas in polluted areas within Narragansett Bay are relocated to predetermined Shellfish Management Areas. Transplants have taken place for the dual purposes of increasing landings by stocking shellfish grounds, closed for a period to allow for depuration, which are then targeted by commercial and/or recreational harvesters or to increase reproductive potential of the transplanted stock by moving them to less dense, higher water quality spawner sanctuaries which are closed to fishing year-round.

3. *Limited Access Time* – A number of the SMAs permit harvesting only in the winter season. The Winter Harvest Schedule is determined annually by RI DEM after receiving input for the SAP and RIMFC. The schedule identifies specific dates and times for a select number of designated Shellfish Management Areas to be opened for harvest throughout the year. These selected areas are: Greenwich Bay Areas 1 and 2, Bristol, Bissel Cove/Fox Island, Mill Gut, High Banks and Potowomut Area C. Table 5.3 describes the harvest schedules for 2013-2014 for these areas. These restrictions apply only to commercial harvesting from a boat, not commercial or recreational shore digging.

Table 5.3. Winter harvest schedule for 2013-2014.

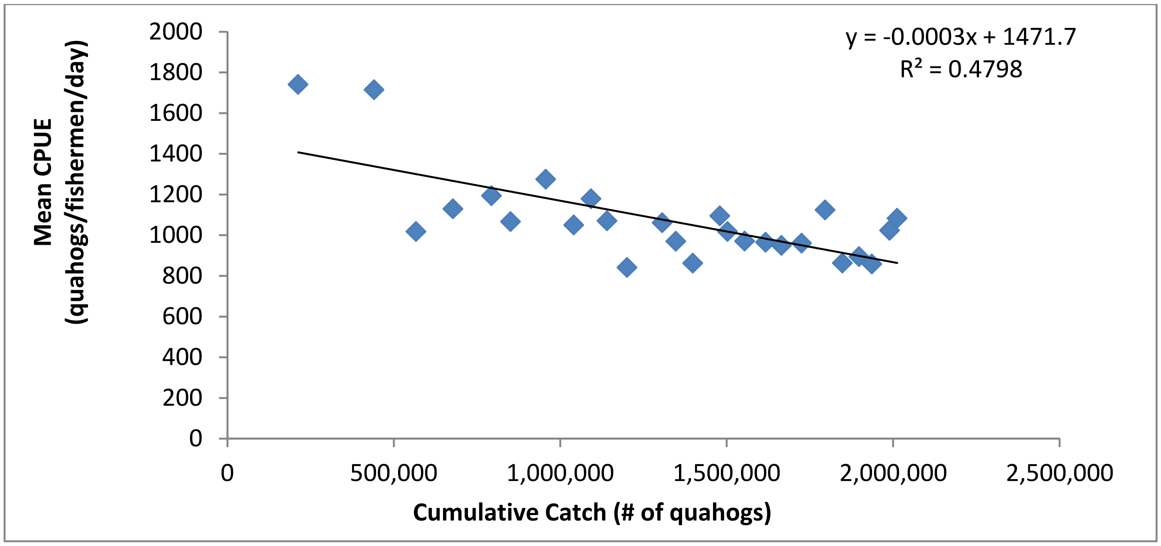
	DEC	JAN	FEB	MARCH	APRIL
GB Sub Area 1 & 2	CLOSED OWR	8-12 Jan 2 and starting Jan 6, 8-12 MWF	8-12 MWF	8-12 MWF	8-12 MWF
Bristol	CLOSED	8-12 MWF beginning Jan 3	Open	Open	Open
Bissel/Fox	Opens 2nds Wed*	Open*	Open*	Open*	Open*
Mill Gut	Opens 2nd Wed	Open*	Open	Open	Open
High Banks & Pot C	Open Year Round	Open Year Round	Open Year Round	Open Year Round	Open Year Round

a. These selected areas are known to typically exhibit relatively high shellfish densities and have reasonably safe winter access. As such, designating winter harvest schedules for these areas provides safe fishing grounds during the winter months that have not had the resource depleted during the summer months helping sustain the business of those fishermen who harvest year round.

b. The process by which DEM determines the winter harvest schedule each year is performed with industry input. This agency-industry interaction has become a common and effective process for metering the flow of quahogs to the market to keep prices steady for fishermen, while at the same time meeting DEM objectives of sustaining and monitoring the shellfish resource.

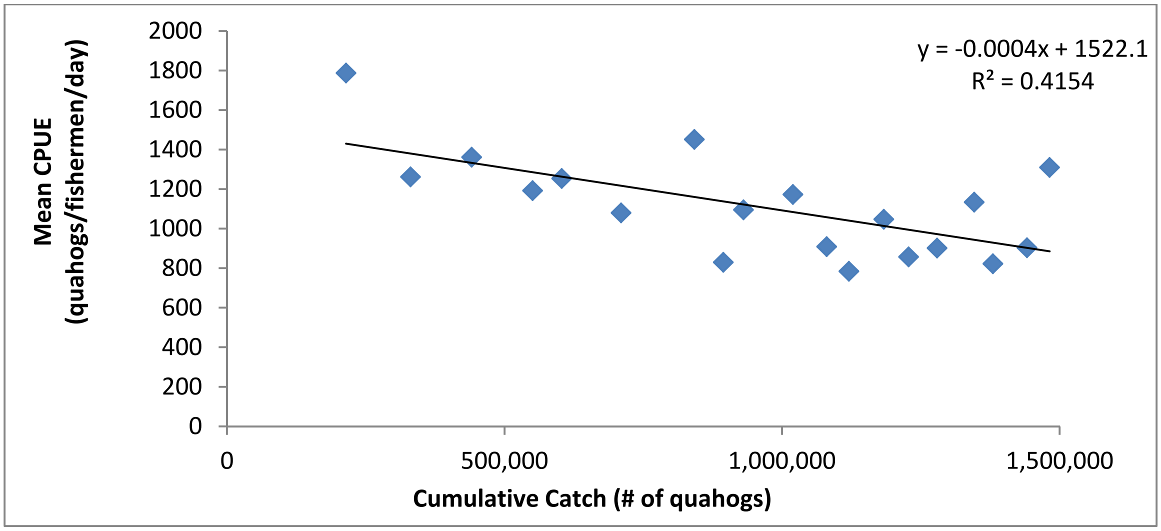
c. There is serious concern by DEM that if the harvest levels are not metered effectively, a "derby fishery" (i.e. a race to fish when areas open) will result, which could serve to saturate the market and result in negative consequences to shellfishermen and associated businesses that rely on the resource year round. process has generally achieved the dual goals of maintaining sustainable harvest levels, while simultaneously providing shellfishermen opportunity to maintain viable businesses.

A



Starting N	Catch	Exp rate	Start Density	End Density	F Rate	End N
4,872,719	2,012,279	0.412968	1.786405	1.048676	0.532677	2,860,440

B



Starting N	Catch	Exp rate	Start Density	End Density	F Rate	End N
3,544,222	1,482,124	0.41818	1.29936	0.755993	0.541595	2,062,099

Figure 5.13 (A and B). Depletion models for the western Greenwich Bay winter management areas for 2013 (A, top) and 2014 (B, bottom). Starting and ending population parameters and estimated fishing mortality rates are given for each year.

4. A similar dynamic depletion model applied to the soft-shell clam fishery to evaluate the fishing mortality rate and impact on biomass over this time period (Figure 5.14, Gibson, 2012), indicated that fishing effort and fishing mortality was very high from 2006 through 2011.
5. The high fishing rates were exacerbated when the the Conimicut triangle area, which was previously protected from fishing by its polluted status, opened on June 13th, 2010 after water quality had improved. The number of fishermen reporting landings increased from three on June 12th to 40 on June 13th and peaked at 68 unique harvesters on June 29th. The daily catch limit of 12 bushels was not changed resulting in the biomass being depleted by extensive derby fishing to 5% of its former abundance by the start of the following summer, and follow up surveys in the fall of 2011 showed even lower densities (Table 5.4). By 2012, the soft-shell clam resources had been severely depleted; landings statewide in 2012 totaled less than 6% of the average landings from 2008-2010. Over harvesting through derby fishing and mass mortality of undersized, thin-shelled discarded soft-shell clams are the likely result of this dramatic decrease.
6. As a result of the severe depletion of number of management strategies were implemented to help the stock rebound. The minimum size was increased from 1 ½” to 2” on August 5th, 2010 through emergency regulation. In April 2011, this size increase became permanent. In addition, the Conimicut Management Area was established with a reduced three bushel daily limit for soft shell clams. Unfortunately, these measures were not established prior to the severe depletion that occurred but it is hoped that they will help in the rebuilding of this population.

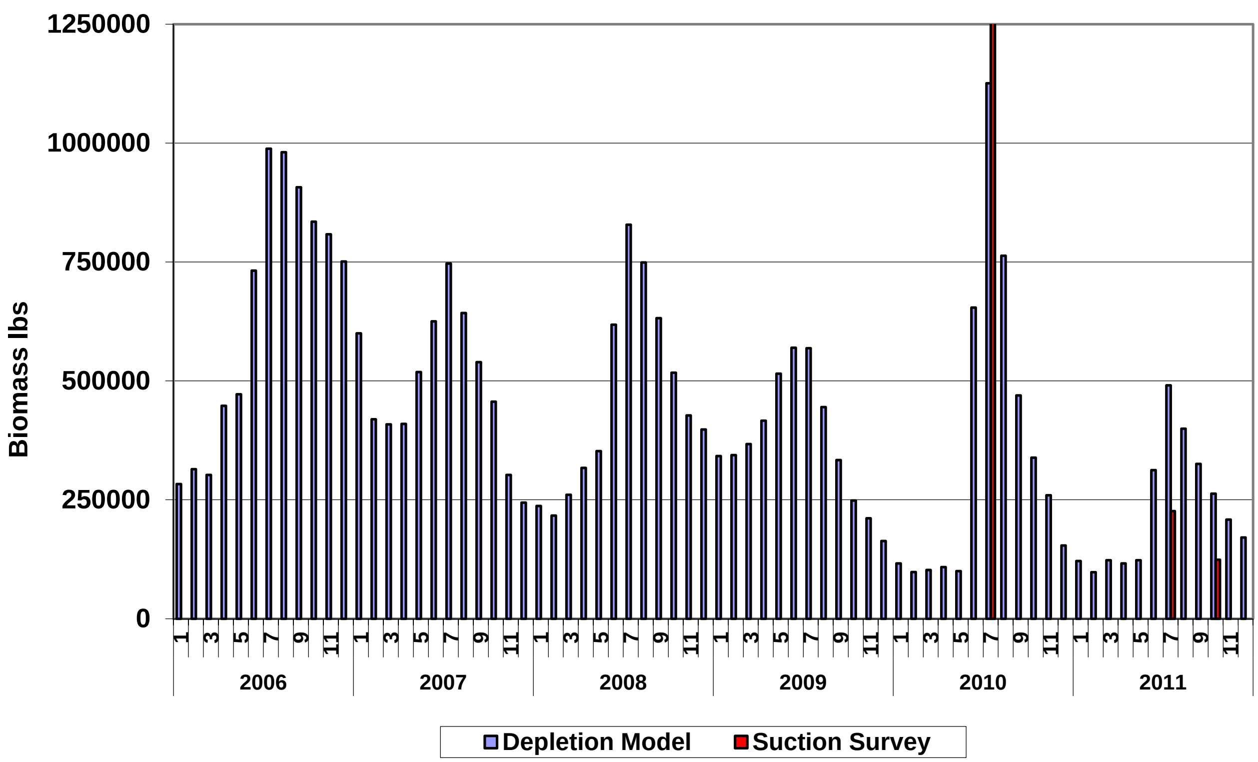


Figure 5.14 Dynamic Depletion Model Results - soft-shell clam landings and, for comparison,RI DEM suction survey (red). From Gibson, 2012.

Table 5.4. Soft-shell clam densities in the Conimicut Point Triangle based on RI DEM suction surveys before and after the area was open to fishing.

Date	Area	Mean Density (No. per m2)	SE	Acreage	Biomass (lbs)
June 2010	Open Fished	49.3	24.6	33.0	362690
	New Triangle	360.0	7.3	22.7	1820700
June 2011	Open Fished	17.0	11.3	33.0	124989
	New Triangle	20.0	4.0	22.7	101150
September 2011	Open Fished	10.0	6.0	33.0	73523
	New Triangle	10.0	6.0	22.7	50575

Section 540. Recreational Shellfishing

1. Any person is permitted to harvest quahogs, soft-shell clams, razor clams, oysters, blue mussels, and periwinkles from approved and conditionally approved waters. Whelks and bay scallops can only be harvested by Rhode Island residents. Refer to Table 5.1 for descriptions and associated harvesting regulations for each species. Rhode Island residents do not require a shellfish license, though non-residents do.
2. Aside from this general understanding, however, harvest trends, overall contribution to the economy, and the impact to the shellfish resource by recreational harvesters is largely unknown and is not easily quantifiable. This knowledge gap exists for several reasons, outlined below:
    a. Rhode Island residents are not required to have a shellfish license, making it challenging to determine the number of shellfishers, both spatially and temporally. In addition, licenses from non-residents are not tracked in a database, which would allow for some trends to be discerned. Furthermore, there is no documented information on harvester demographics to gain an understanding of who is harvesting what and where.
    b. Though there are harvest limits in place, recreational shellfishers are not required to report their catch to state agencies. As a result, there is a lack of information on the species and volume of shellfish that is extracted from recreational use.
    c. The benefit from non-direct purchases as a result of recreational shellfishing is poorly understood. Such purchases may include tools (rakes, gauges, snorkels, etc.), storage containers (baskets, coolers, etc.), and logistical needs (food, lodging, gas, etc.).
3. *Harvest size and catch regulations* – Many species open to recreational harvest have associated minimum size and harvest limits. Refer to Table 5.1 for specific harvest restrictions.
4. *Licensing* – Rhode Island residents are allowed to harvest by hand without purchasing a license or reporting their catch. Non-residents must purchase a license (for a fee of $11 for a 14-day license or $200 for the year).
5. *Harvestable areas* – Recreational harvesters must follow the same pollution closures for safe harvest locations specified by the RI DEM Office of Water Resources. Information on areas opened and closed to shellfishing can be found by visitng http://www.dem.ri.gov/maps/mapfile/shellfsh.pdf. Harvesting is permitted only during daylight hours.
6. *Block Island* – Block Island has been granted permission by DEM to protect and regulate wild harvest shellfishing on the Island (RIGL § 20-3-7). As a result, Block Island has a unique management strategy for recreational harvesting, with regulations implemented by the Block Island Shellfish Commission. Great Salt Pond (New Harbor) is the sole shellfish location on the island and is divided into ten management areas. Annual stocking is conducted (soft-shell clams, quahogs, bay scallops)

for a "put and take" recreational shellfishery, where fee-based licenses are required for Rhode Island and out of state residents. The Commission also conducts a water testing program through the New Shoreham Harbors Department, DEM, and the Commission.

7. Every harvester, Rhode Island resident or otherwise, must purchase a shellfish license from the Harbormaster's office and the fee ranges between $1 and $60 depending on the age of the applicant. While shellfishing, every harvester must carry their license and must follow these rules:
   1) No harvesting permitted from designated closed areas;
   2) No harvesting permitted from barrier grasses or eel grass beds;
   3) Harvesting at night is prohibited;
   4) Use of SCUBA is prohibited; and
   5) Shellfish must meet the minimum size requirement.

Section 550. Aquaculture

1. Aquaculture is defined as "the cultivation, rearing, or propagation of aquatic plants or animals under either natural or artificial conditions" (RIGL § 20-10-2) and is formally recognized by the state and federally as agriculture.
2. Aquaculture activities must adhere to the same water quality based closures and prohibitions as wild harvesters. Cultivation sites may only operate in approved waters. During emergency situations where areas of aquaculture activities are presently permitted, and water quality closure must be instituted, growers may seek permission to plant seed, perform certain maintenance and / or gear retrieval activities under closed conditions by notifying the state's aquaculture coordinator prior to entering the permitted lease.
3. Aquaculture is conducted on submerged lands, which are owned by the state of Rhode Island. Therefore, all aquaculture leases are granted by the state. The lead agency responsible for the permitting of leases is CRMC, in consultation with DEM.
4. CRMC's regulatory approach to aquaculture has been driven by the dual goals of protecting the public trust while at the same time encouraging a sustainable aquaculture industry that respects the traditions of the state. The CRMC recognizes the environmental benefits and economic value of aquaculture to the State of Rhode Island, and that commercial aquaculture is a viable means for supplementing the yields of marine fish and shellfish food products. As such, CRMC shall support commercial aquaculture in those locations where it can be accommodated among other uses of Rhode Island waters.

550.1. Obtaining an Aquaculture Lease

1. There are several permit types that can be obtained, each of which has specific application requirements and standards that address the variability of each permit type. Permits include:
   - Commercial intentions
   - Commercial viability evaluation
   - Research/educational purposes
   - Recreational use
   - Nursery/upweller establishment
2. While a formal application is required, the process of obtaining a lease to conduct aquaculture activities at a designated site is more of a public review process lead by CRMC, and is quite complex. The following steps describe the general process (Figure 5.15). For additional information, visit the CRMC website for additional information (http://www.crmc.ri.gov/aquaculture.html) or contact the CRMC Aquaculture Coordinator.

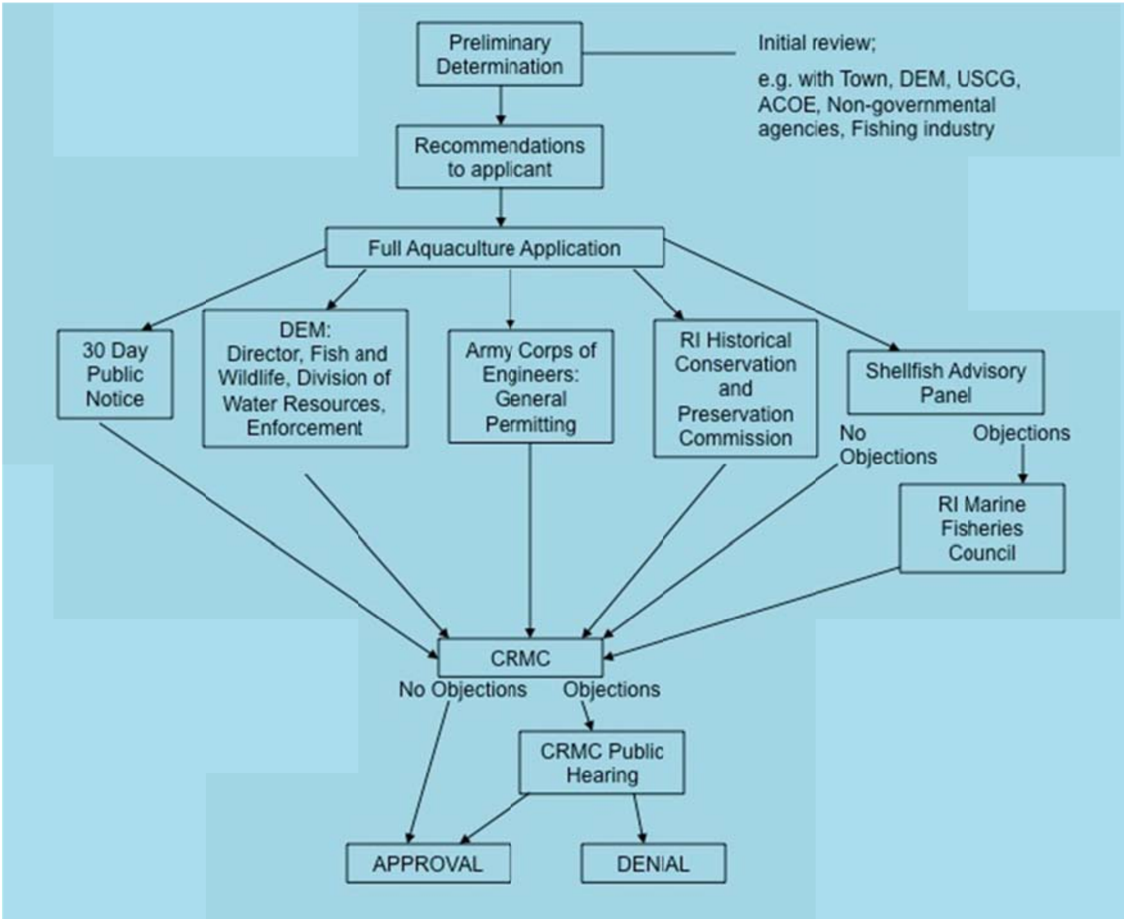


Figure 5.15. Flow chart demonstrating steps to obtaining an aquaculture lease permit through CRMC.

a. Step 1. Suitable Site Selection:

The applicant should (though is not required) to meet with the CRMC Aquaculture Coordinator to discuss his/her proposal plans and review the application process. The applicant should be prepared to discuss his/her proposed lease site location, lease site suitability, cultivation methods, and other intentions. The Aquaculture coordinator can offer advice for completing the initial lease application. The applicant may also want to consider making personal contact with local officials, fishing interests, and/or other relevant individuals and groups to gain insights and determine potential conflicts prior to submitting the initial application.

In general, there are restrictions on where aquaculture leases can be permitted. Areas that support the wild harvest of shellfish (i.e. contain high densities of quahogs or soft-shell clams), contain eelgrass, or are within designated navigational channels/areas are not suitable lease sites. In addition, leases will not be granted in areas designated as closed waters by DEM Division of Water Quality. The only exception to this would be the permitting of nurseries and upwellers – such systems are currently in place at commercial marinas in prohibited waters and at residential docks in approved waters. For those within closed waters, seed cannot exceed a maximum size of 32 mm for oysters and 20 mm for quahogs to ensure the shellfish is safe for consumption at the time it reaches harvestable size.

b. Step 2. Submitting an Initial Application:

There are several components to the lease application, as outlined below.

i) Application package - Four copies of the application must be submitted, along with a $25 application fee to CRMC.

ii) Location Map – The location and size of the proposed lease site must be accurately delineated in geographical space on a NOAA chart, aerial photograph, ortho-photograph, or something of the like. A scale bar, north arrow, and the coordinates of the proposed site must be shown on the map. Google Earth is commonly used to accomplish this requirement.

iii) Photographs – Of proposed lease site and adjacent area in each cardinal direction.

iv) Site Plan – Both a plan-view diagram and cross-section view diagram of the how the proposed lease site will be operated must be provided. The diagrams must be presented according to scale and should show proposed gear layout (i.e. bottom culture, racks, cages, bags, netting, etc.), site boundary lines, site corners labeled with coordinates, and distance from proposed site to nearest shoreline. In addition, the diagrams should include applicant's name, date, scale bar, north arrow, and water depth contours at mean low tide. The mean high tide and mean low tide water elevations must also be indicated on the cross-section view diagram.

v) Gear Diagrams – Detailed drawing or images showing the dimensions of the proposed gear (racks, cages, bags, nets, etc.) must be provided. The diagrams should also depict the depth of water covering the gear at mean low tide for the shallowest portion of the site.

vi) Operations Plan – This plan describes the applicant's intentions and outlines the type of facility, size and location of proposed site, species to be cultivated, gear type and methodology to be used, practices and procedures for handling and harvesting shellfish and maintaining records, and identifies potential buyer(s) of product. The CRMC Aquaculture Coordinator will provide a recommended format for developing the Operations Plan.

vii) Site Access and Public Use – The proposal must demonstrate the intended site location is compatible with public access and other existing uses of the area and nearby area, including navigation, recreational activities, and fishing. The applicant must also considerate of visual impacts the lease operation may cause to the nearby area.

viii) Section 300.1B Requirements – These requirements focus on demonstrating there a need for the proposed activity, and that activity will not result in (1.) adverse impacts to the environment; (2.) unreasonable interference with public access and use; and (3.) significant adverse scenic impacts.

c. Step 3. Preliminary Determination (PD) Meeting:

Once the initial application is submitted to CRMC, a Preliminary Determination (PD) meeting is scheduled. The PD is a staff-level stakeholder-based meeting to provide and initial review of the proposal and solicit input from state, federal, and local officials, NGOs, commercial and recreational fishing industry representatives, as well as the general public. The overall goal of the PD is to provide advice and suggestions to the applicant and to identify potential issues or conflicts with existing regulation and uses. The PD process has shown to be successful in clarifying proposal concerns and challenges prior to the full application process being undertaken.

Before the PD meeting takes place, the said application is sent to all invited participants (as listed in Table 5.5). In addition, preliminary surveys of the proposed lease site are conducted independently by CRMC and DEM F&W to determine if the proposed application may have significant negative impact on the living marine resources, such as seagrass, or fishery activities in the waters and submerged lands at and adjacent to the proposed site. At the meeting, all participants are offered the opportunity to provide input on the application. After the PD, the Aquaculture Coordinator must submit a report to the applicant within 30 days that summarizes the PD meeting and offers recommendations to the applicant based on insights gained from the meeting. While the applicant is not required to adopt the recommendations, he/she is strongly encouraged to do in efforts to avoid continued concerns and conflicts over the issue(s) stated at the PD meeting.

Table 5.5. List of those involved in aquaculture lease application process.

Federal Agencies	US Army Corps of Engineers (ACOE)
	US National Marine Fisheries Service – Habitat Conservation Division (NMFS)
	US Fish and Wildlife (USFW)
	US Environmental Protection Agency (EPA)
	US Coast Guard (USCG)
State Entities	Coastal Resources Management Council (CRMC)
	Department of Environmental Management – Division of Fish and Wildlife (DEM)
	Department of Environmental Management – Office of Water Resources (DEM)
	Department of Environmental Management – Division of Law Enforcement (DEM)
	Department of Environmental Management – Office of the Director (DEM)
	Department of Health (DOH)
	Marine Fisheries Council (MFC)
	Shellfish Advisory Panel (SAP)
	Historical Preservation and Heritage Commission (HPHC)
Town Representatives (vary based on town)	Harbor Master / Harbor Commission Members
	Town Planner / Manager
	Planning Committee Members
	Conservation Commission Members
NGOs	Save the Bay (STB)
	The Nature Conservancy (TNC)
	Salt Ponds Coalition (SPC)
Industry Representatives	RI Shellfishermen's Association (RISA)
	Ocean State Aquaculture Association (OSAA)
	RI Saltwater Anglers Association (RISAA)

d. Step 4. Submitting a Full Application:

   If the applicant chooses to continue to pursue the lease site after the PD meeting, he/she must submit a full application. This primarily involves revising the initial application as suggested in the report provided by the Aquaculture Coordinator. The application should be concise, thoughtful, and comprehensive, as this is the applicant's final opportunity to review and adjust the proposal before the public review process.

e. Step 5. Public Comment Period:

f. Once the full application is received, a 30-day public comment period ensues. During this time, the full application is resent to those state, federal, and local agencies, and other entities involved in the PD meeting. The town in which the proposed lease site is located is also notified of the submittal of a full application. Any person is free to submit written comments to CRMC in support of or in opposition to the proposed lease site.

g. Step 6. Marine Fisheries Council:

   Following the public comment period, the SAP meets to review the application. The meeting gives the opportunity for the SAP to learn about the aquaculture proposal, hear preliminary comments from DEM, ask questions, and address concerns regarding the proposal. The SAP responsibility sto object or not object the proposed lease, primarily considering the proposal's impact on commercial and recreational shellfishing and fishing activity.

   The MFC has delegated the SAP with the authority to prepare recommendation(s) concerning individual lease applications and forward those recommendation(s) to the CRMC on behalf of the MFC. The SAP then is responsible for updating the MFC on reviewed applications and recommendation(s) put forth. The recommendation to CRMC comes from the chairof the MFC. The said recommendation(s) constitute the MFC recommendation(s) unless a member of the MFC notifies the DEM within ten (10) days to bring the recommendations before the full MFC for further review and consideration. The applicant may also request to be heard before the MFC to discuss the SAP recommendation(s).

h. Step 7. Obtaining Required Permits:

   Before an aquaculture lease site can proceed to the Coastal Council for a hearing, permits are required from the ACOE and DEM. These are typically obtained during the 30-day public comment period. The ACOE PGP meeting is held once a month and the application is usually reviewed in the month after being received.

   i) ACOE Permit: The CRMC Aquaculture Coordinator holds a meeting with ACOE to obtain a programmatic general permit (PGP) on behalf of the applicant. At the meeting are representatives from Federal agencies (ACOE, NMFS, EPA, USFW) and State agencies (DEM Fish and Wildlife and Water Quality Divisions). The CRMC Aquaculture Coordinator is present to give a brief review of the proposal, issues connected with the proposal and to answer any questions that might arise.

   ii) DEM Permit: DEM issues an Aquaculture License to the applicant for the possession, importation, and transportation of marine shellfish species to be used in the proposed aquaculture operation. The License permits the leaseholder to handle and harvest sub-legal shellfish and to sell their product to a licensed dealer.

i. Step 8. Coastal Council Hearing:

   If no objections are received regarding the proposed lease, CRMC can grant the lease administratively without going before the Coastal Council. If the proposal receives one or more objections, the applicant must attend a hearing during which the Council will vote to approve or deny the proposed lease.

Approximately one week prior to the proposal being reviewed at the scheduled hearing, the CRMC distributes a package to each member of the Council. The package includes the applicant's proposal, report from CRMC Aquaculture Coordinator, advisory opinions from DEM and MFC/SAP, and any comments received from the public.

The Council hearing is an open meeting and subject to the State's open meetings law, thus the meeting and agenda are advertised. Additionally, authors of any specific comments received are individually notified of the meeting to provide them with the opportunity to discuss the comments with the Council. At the hearing, the application is presented to the Council by the CRMC Aquaculture Coordinator, who is then free to ask the Aquaculture Coordinator or the applicant questions pertaining to the application. The Council then hears from, and may ask questions of, interested parties. The Council is then free to vote on the application. The Council can approve the application as presented, change the proposal if deemed necessary, or vote not to grant the application in any form. If the Council votes to not grant the proposal the applicant has a right to appeal. If the Council approves the application in any form, the public has the right to appeal. After the Council decides on the proposal,the attorney reviews the decision and writes a legal decision for the Council. Anyone can appeal the legal decision within 30 days of issuance.

j. Step 9: Issuing Aquaculture Lease:

The lease is formally established once CRMC and the applicant sign the lease agreement and it is notarized. The new leasee must also pay the designated lease fee for the remainder of the calendar year and post a performance bond with CRMC as the payee in the event of default.

550.2. Details and Conditions of Granted Aquaculture Leases

1. *Annual fees* – The annual lease fee charged to each leaseholder is $150.00 for the first acre and $100.00 per each additional acre or fraction of. The performance bond must also be kept current.
2. *Annual report* – Leaseholders must submit an annual report to the Aquaculture Coordinator to allow CRMC to have a solid understanding of the aquaculture industry in the state, primarily how the industry changes/grows/declines over time. The information provided is not publically distributed, but, rather, is used to develop the annual CRMC aquaculture report that summarizes the industry and trends over that past year.
3. *Maintaining lease* – In order to maintain the assent, the site must be actively farmed and be marked as specified by CRMC. The leaseholder cannot cultivate species or utilize gear that was not permitted (i.e. specified in the granted lease application). The Aquaculture Coordinator conducts site visits to each lease at least once per year to ensure compliance.
4. *Time Span* – Upon being granted, an aquaculture assent is valid for a period of fifteen (15) years; though, yearly renewal is necessary. After fifteen years, leases can be renewed for ten (10) year periods.
5. *Revocation* – Failure to comply with any of the terms and conditions of the lease agreement set forth by CRMC can result in revocation of the lease.
6. *Nursery and upweller systems* – Such systems must be permitted by CRMC and follow the CRMC standards and criteria. Upwellers currently are in place at commercial marinas in prohibited waters and at residential docks in approved waters. For those within closed waters, seed cannot exceed a maximum size of 32 mm for oysters and 20 mm for quahogs to ensure the shellfish is safe for consumption at the time it reaches harvestable size.
7. *Biosecurity Board* – The Biosecurity Board was formed in 2001. The board is convened by CRMC and has seven official members: The executive director of CRMC or designee; the RI sate veterinarian (DEM); a representative of the Department of Health; a representative of DEM Division of Fish and Wildlife; a representative of the RI Marine Fisheries Council; a representative of the aquaculture industry; and a representative from the URI Department of Fisheries, Animal, and

Veterinary Science (RIGL § 20-10-1.1). In practice, the board additionally includes shellfish and disease experts from Roger Williams University and environmental organizations.

a. The board works to minimize potential outbreaks and movement of aquatic diseases with a goal of maintaining a healthy aquaculture and shellfish industry. The board creates shellfish zones around RI based upon current levels of shellfish diseases. Shellfish cannot be moved between zones unless: a pathology report documents acceptable disease levels of the proposed shellfish to be moved; or the shellfish are being moved from an area known to have minimal disease to an area known to have a higher incidence of disease. Shellfish may be imported from out of state only with acceptable pathology reports. CRMC maintains the record of all pathology reports and notifies DEM Division of Fish and Wildlife and DEM Division of Law Enforcement before shipments occur.

b. The board manages the introduction of non-indigenous species and genetically modified species grown in aquaculture. Approved protocols must be in place to ensure that the species cannot escape into local waters before that it will be permitted for aquaculture (RIGL § 20-10-1.2).

c. Issues of aquaculture compliance for public health concerns are reviewed and recommendations to ensure compliance are made to appropriate state agencies.

8. *Public Access* – Given the multiple uses of our waters, CRMC recognizes there is a need for a planned approach in granting lease sites and managing the State's aquaculture industry. As such, great efforts are made during the leasing process to choose sites that are compatible with other uses and/or to minimize user-conflict concerns. For lease sites that are established, the public is permitted open access when water depth permits; i.e. the public may pass through the lease, or take part in traditional water activities such as fishing, boating, kayaking, and swimming. However, it is illegal for anyone to disturb the gear or harvest stock within a lease site. Also, no person (the leaseholder or the public) may harvest wild shellfish from the lease area. As a result, lease sites act as de-facto shellfish sanctuaries.

9. *The Coastal Pond 5% Rule* – The nature of aquaculture leases causes them to be a controversial subject at times. When a lease is granted by the state, a single individual gains the right to utilize the submerged lands and the material (i.e. shellfish, gear) within that lease is private property. This right sometimes interferes with other public uses and has created user-conflicts, despite efforts to minimize such conflicts during the leasing process. Furthermore, DEM desired a strategy for addressing the continuing growth and expansion aquaculture in Rhode Island. In response to these user concerns and planning desires, in 2009, the "5% rule" was created for the coastal ponds. The rule stated aquaculture leases should consume not more than 5% area of any of the coastal ponds in an effort to help "balance" out and be fair to the interests of the many and diverse user groups of the ponds. The consensus was reached with input from numerous stakeholders and established a sort of social carrying capacity, though recognizing studies (Byron, 2010) have shown the ecological carrying capacity is much greater. The regulation went into effect in 2009. As of 2014, this 5% cap has not been reached by any pond (Table 5.6). The 5% rule for aquaculture does not exist within Narragansett Bay, which currently occupies less than 1% of the Bay.

Table 5.6. Total acreage and percentage of each coastal pond's total area leased for aquaculture (adapted from CRMC, 2013).

Year	Winnapaug	Ninigret	Potters	Point Judith	Total acreage in Coastal Ponds
2000	5	1	0	2.5	8.5
2001	5	1	0	2.5	8.5
2002	5	1	6.9	21.5	34.4
2003	5	1	6.9	21.5	34.4
2004	5	1	6.9	38.5	51.4
2005	6	2	6.9	38.5	53.4

Year	Winnapaug	Ninigret	Potters	Point Judith	Total acreage in Coastal Ponds
2006	6	2	6.9	38.5	53.4
2007	8	4	6.9	38.5	57.4
2008	8	4	6.9	38.5	57.4
2009	8	10	6.9	38.5	63.4
2010	8	16	6.9	38.5	69.4
2011	8	16	6.9	44.25	75.15
2012	8	19.5	6.9	47.3	81.7
2013	8	19.5	6.9	47.3	81.7
	1.69%	**1.23%**	**1.91%**	**3.05%**	**Percentage of coastal pond leased**

10. *Block Island* – While Block Island has administrative control over the wild harvesting of shellfish over the Island, CRMC maintains regulatory authority for aquaculture. Therefore, aquaculture lease holders and lease sites follow the same process and management structure as occurs on mainland Rhode Island.

Section 560. Restoration and Enhancement

1. While restoration and enhancement often differ in their primary goals, technical approaches often share similarities. Efforts in Rhode Island commonly focus on increasing spawning and recruitment levels by one or all of the following: 1) Building habitat structure to promote larval settlement; 2) Establishing spawner sanctuaries to protect and enrich existing shellfish communities; and 3) Growing and releasing shellfish at selected sites to increase spawning. DEM OWR has completed water quality restoration plans for most SA waters closed to shellfishing due to pollution. Inadequate on-site wastewater treatment and polluted stormwater are common problems identified. Implementation of the water quality restoration plans primarily the responsibility of municipalities, Rhode Island Department of Transportation and private property owners.
2. Restoration and enhancement projects are typically orchestrated by non-profit organizations (e.g. TNC, STB, Salt Pond Coalition), Federal government agencies (e.g. NOAA, EPA, USDA/NRCS), and/or academic institutions (e.g. URI, RWU). All projects must be conducted in partnership and/or in consultation with DEM and, at times, CRMC. Several projects are ongoing at the time of writing, including oyster restoration efforts in the coastal salt ponds and Narragansett Bay. These efforts focus on providing substrate, e.g. cultch (large shell pieces) to encourage settlement of oysters, offering increased habitat for other marine species, as well as potentially providing future generations of oyster reefs in these areas.
3. Restoration can take many forms, though all typically share the primary goal of increasing the ecological, economic and social services provided by shellfish habitat and populations. While shellfish restoration projects can improve water quality, efforts to reduce pollution at the sources, is also vital to ensuring existing water quality is sufficient to allow the shellfish restoration projects to thrive. Restoration typically involves creating and/or building habitat in previously degraded areas, primarily to improve the quality of the environment. Efforts commonly focus on increasing spawning and recruitment levels, including by 1.) Building habitat structure to promote larval settlement; 2.) Establishing spawner sanctuaries to protect and enrich existing shellfish communities; and 3.) Growing and releasing shellfish at selected sites to increase spawning. In Rhode Island, the most commonly practiced shellfish restoration has been: a) to increase species distribution and resiliency, and provide ecological benefits for the bay scallop and quahog; and b) to restore oyster habitat for the services that complex biogenic habitats provide including water filtration, fish production, denitrification, and stabilizing shorelines.

4. The filtering capabilities of shellfish are used to help improve water quality and remove excess nitrogen. It should be noted however that as defined here "restoration" does not refer to restoration of water quality such that waters designated for shellfish harvesting but closed due to water pollution may be re-opened to harvest. Oyster habitat has been demonstrated to provide increased production of finfish over and above substrate limited areas. The shellfish also act as ecosystem engineers creating new habitat (e.g. oyster reefs) for other species and can create physical barriers to protect shorelines from storm damage and erosion. The non-harvest ecological services provided by oysters have conservatively been estimated to provide an economic value between $5500 and $99,000 per hectare per year. Research is underway to better quantify the ecological and economic services provided by oyster reefs and other shellfish habitat (Pers. Comm.,TNC, 2014).
5. Enhancement differs from restoration in that the goal is to support sustainable fisheries, both commercial and recreational. Efforts commonly focus on transplanting quahogs from one area to another, or growing shellfish in nursery systems and relocating them to selected areas.
6. Restoration and enhancement efforts may employ standard aquaculture technology to cultivate shellfish for later relocation (refer to Section 450.3 for details). The most common approach is bottom planting, though cages are also used to grow shellfish seed to suitable sizes prior to release, or for holding and protecting broodstock (parent stock) during the spawning season to increase the potential for larvae and fertilization success. In addition, for quahogs, another technique is transplanting quahogs from existing beds to another area. Particularly, from beds with high densities located in waters classified as closed by DEM into waters classified as open.

560.1. Recent and Current Restoration Efforts

1. Restoration in Rhode Island was significantly propelled as a result of the North Cape oil spill in 1996. Approximately 828, 000 gallons of heating oil was spilled into Block Island Sound when North Cape, a tank barge, struck ground off the coast of Rhode Island. In response, an extensive restoration plan was developed, with projects focusing the restoration of shellfish wet tissue biomass. Restoration of quahogs, bay scallops and oysters was conducted in various years and locations in Rhode Island from 2002 to 2008. Though funding for these restoration projects is no longer available, some of the shellfish restoration sites are still active, and some of the projects have been adopted and continued by other restoration efforts.
2. There are numerous organizations throughout the state currently undertaking restoration projects (Table 5.7). Most restoration efforts take place within spawner sanctuaries because they provide protection from fishing effort. Though restoration and enhancement projects are largely funded and implemented by non-profit organizations, all projects must partner with DEM.
   a. RI DEM: Spawner sanctuaries – Spawner sanctuaries are closed areas that serve as refuges for quahogs to build biomass in the absence of fishing pressure. The locations of the spawner sanctuaries have been chosen by DEM to promote quahog larval distribution, and thus, the quahog population, throughout Rhode Island waters. There are a total of six sanctuaries: one each within Narragansett Bay, Ninigret Pond, Winnapaug Pond, Potter Pond, and two within Quonochontaug, one of which is designated for oysters (refer to Figure 4.2). Shellfish are transplanted into these areas, offering protection from fishing, allowing them to spawn for multiple years and provide non-harvest services that shellfish provide to people such as increased habitat for finfish and crabs and increased water quality.
   b. RWU: Oyster Gardening for Restoration and Enhancement – The Oyster Gardening for Restoration and Enhancement (OGRE) Program is lead by Roger Williams University (http://rwu.edu/academics/schools-colleges/fcas/ceed/oyster-gardening). The program engages the pubic, allowing waterfront property owners to maintain an oyster nursery under his/her dock. Once large enough, the oysters are moved from the nursery to established restoration sites within Narragansett Bay, the coastal ponds, and Block Island.

c. NRCS: Environmental Quality Incentives Program – The United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Environmental Quality Incentives Program (EQIP) is another oyster restoration program (http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/eqip/). While EQIP is an agriculture program, aquaculturists are able to participate because aquaculture is considered agriculture. The goal of the oyster portion of the EQIP program is to increase spawning and recruitment levels to the degree at which the oyster population is self-sustaining. The program engages aquaculturists, who institute best management practices, in these efforts by funding them to cultivate oysters, which are then moved to established restoration sites.

d. Restoration participation – In addition to growing shellfish for consumption, a number of aquaculturists participate in restoration projects, including the Environmental Quality Incentives Program (EQIP) operated by the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) (see Section 460 for further details). These types of activities also contribute to the economy and livelihoods of local aquaculturists.

e. Save the Bay: Scallop Restoration Program – The restoration program run by Save the Bay (http://www.savebay.org/shellfish) is an extension of the North Cape project, with the goal of increasing stock population through increased spawning. The methods used are identical to those of the North Cap project, as are the site locations, with the addition of a site in Narragansett Bay. The program focuses on one location at a time; from 2007-2009, efforts focused on Narragansett Bay, followed by Point Judith Pond from 2010-2012, and Ninigret Pond from 2013 to current. Scallops are grown in cages at locations throughout Narragansett Bay and the coastal ponds, the released. The sites are monitored to measure success.

f. Save the Bay: Upweller – Save the Bay is in the process of constructing an upweller at their operation site in Fields Point, Providence. Intentions are to grow a variety of shellfish species (including quahogs, oysters, ribbed mussels, scallops) for restoration purposes. Restoration sites will be determined in collaboration with DEM, CRMC, and others. The shellfish from this effort will not be accessible for commercial or recreational harvest.

g. The Nature Conservancy (TNC) – The Nature Conservancy is the lead or a partner organization in numerous restoration efforts in Rhode Island and globally. In Rhode Island, TNC has been or is currently involved in multiple projects to restore oyster habitat in the coastal salt ponds, with a focus on increasing production of fish, crabs and other epifauna by provided by these habitats. TNC has also worked closely with RIDEM in the past to organize and monitor quahog transplants in the coastal salt ponds. TNC is also heavily engaged in improving our understanding of the value of shellfish restoration (i.e. ecosystem services) such as their work to evaluate fish and invertebrate production benefits as a result of oyster reef restoration. This research is being conducted in Ninigret Pond at TNC established oyster reef restoration sites. In addition, TNC is partnering on a project lead by the Environmental Protection Agency (EPA), also in Ninigret Pond, to estimate denitrification rates of restored oyster reefs.

Table 5.7. List and brief description of restoration projects within Rhode Island.

Program & Website	Program Lead(s)	Focus Location(s)	Species Utilized	Years Active
North Cape darrp.noaa.gov/northeast/north_cape/shellfishRestoration.html	NOAA	Coastal Ponds, Narragansett Bay	Oysters, Quahogs, Bay scallops	2002 – 2008
Scallop Restoration savebay.org/shellfish	Save the Bay	Coastal Ponds, Narragansett Bay	Bay scallops	2007 – present

Quahog Transplant	DEM	Spawner sanctuaries	Quahogs	1950's – present
Oyster Gardening for Restoration and Enhancement (OGRE) rwu.edu/academics/schools-colleges/fcas/ceed/oyster-gardening	Roger Williams University	Coastal Ponds, Narragansett Bay	Oysters	2006 – present
Environmental Quality Incentives Program (EQIP) nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/eqip/	Natural Resources Conservation Service (NRCS), USDA	Coastal Ponds, Narragansett Bay, Block Island	Oysters	Present
The Nature Conservancy (TNC) nature.org/ourinitiatives/regions/northamerica/unitedstates/rhodeisland/	The Nature Conservancy (TNC)	Coastal Salt Ponds	Oysters	Present

560.2. Recent and Current Enhancement Efforts

1. Numerous enhancement projects have taken place throughout Rhode Island, both for commercial and recreational harvesting purposes, largely to promote shellfishing in the state as a valuable source of employment, encourage ecotourism, and to enrich our cultural ties to shellfish and the ocean.
2. Upwellers – The primary source of quahog seed used in the enhancement of the recreational and commercial fisheries is the upweller located in Warwick Cove. The upweller was established in 2004 and is owned and voluntarily operated by the Rhode Island Shellfishermen's Association (RISA). A second upweller is in the process of being established in the East Bay by local fishermen with the assistance of Roger Williams University.
3. Public enhancement – Quahogs are primarily used to enhance the recreational fishery by moving the seed from the upweller to popular fishing locations throughout the state. For example, quahogs are relocated in the sand flats along the Galilee Escape Road in Narragansett, one of the State's most well known recreational shellfishing sites. Exact enhancement locations are identified in consultation with DEM. Approximately 100,000 seed are planted annually. This recent effort, led by RISA in collaboration with RWU and DEM, began in 2010 and is conducted on an annual basis, as funds permit. The primary funding source for this public enhancement effort over the past five years has been DEM, stemming from settlement money received for remediation from the Allen Harbor Superfund Site. Other funding has come from NOAA grants, the Narragansett Bay Commission, and the state of Rhode Island.
4. Commercial enhancement – Enhancement occurs by planting quahog seed from the RISA-owned upweller to areas such as Greenwich Bay or High Banks off of North Kingstown.
5. Transplants – Another method of enhancement is transplanting quahogs from one area to another. Transplant events take place yearly within Narragansett Bay and are managed and facilitated by DEM and DOH. The process involves the collection of quahogs by quahoggers using bullrakes from high-density shellfish areas in waters classified by the DEM as "prohibited" due to poor water quality. The quahogs are then transported to pre-determined Shellfish Management Areas classified as "open waters" to fishing, where they are relocated.
    a. Transplants usually occur in the Spring and newly transplanted areas are closed to fishing until December. This closure is enacted to provide an adequate depuration period (e.g. time for shellfish to purge themselves of pollutants by filter feeding and become safe for human consumption). The closure also allows time for shellfish to spawn and replenish stocks in the immediate vicinity and adjacent areas.

b. The areas to be enhanced are determined in collaboration with DEM and the industry. Enhancement receiving sites are typically those known to be productive on a commercial scale, such as the western side of Greenwich Bay, High Banks off of North Kingstown, Bristol Harbor, the vicinity of Quonset Point, Pine Hill, and Hope Island. In recent years, portions of the transplants have also been dedicated to restoration of the coastal ponds.

c. In previous years, quahoggers were compensated for their participation in transplant events through license revenue fees. In 2012, shellfishermen were paid $5.00 - $7.00 per 50 lb. bag of quahogs harvested. However, the level of funding available has been reduced and, in recent years, the process has relied on volunteers.

d. The only transplant program that has occurred in the last two years has been in Bristol Harbor. This decreased effort in transplant events is due to 1.) Funding constraints, and 2.) Recognition of the lack of understanding and scientific evidence regarding the impacts and effectiveness of such transplants on the resource. There has been increased research efforts to better understand the effect transplants have on the resource.

e. Transplants also occasionally occur as a result of dredging activities. At the time a dredging permit from CRMC is requested by a marina, a quahog density survey is conducted within the proposed dredge area. If the density is high enough, the quahogs must be transplanted to a new site, which typically involves hiring commercial shellfishermen to dig up the quahogs, then transport them to a new site, determined in collaboration with DEM and the shellfish industry. The process is overseen by DEM and costs are incurred by the marina.

560.3. Restoration and Enhancement Guidelines

1. Rhode Island does not have a clear, established set of guidelines for restoration projects to adhere to. Though some statutes are in place, such as the Narragansett Bay Oyster Restoration Act (RIGL § 20-2-45), Shellfish transplant program (RIGL § 20-2-44), Shellfish and marine life management areas (RIGL § 20-3-4), and Assent to wildlife restoration projects (RIGL § 20-9-1), their application has been inconsistent.
2. Though restoration projects are largely funded and implemented by non-profit organizations, all restoration projects must partner with DEM Department of Fish and Wildlife and other offices as appropriate. For projects involving oysters, CRMC must be included, as well. In addition, projects creating reefs, using cages or other gear, and/or requiring an upweller system need permits from CRMC and the US Army Corps of Engineers (USACOE).
3. Restoration efforts involving transplanting shellfish from one location to another must conform the standards set forth by the Biosecurity Board (refer to Section 450.5 for further details).
4. The restoration of shellfish within waters designated as “closed” by DEM is prohibited. This has been raised as an issue through the SMp stakeholder process.
5. A major priority of DEM’s management strategy is protecting public health. A concern of Office of Water Resources and Law Enforcement is that the restoration of shellfish in closed waters would increase shellfish biomass at project sites, therefore, increasing the potential for human illness through shellfish harvesting, though illegal, of these areas, by creating an “attractive nuisance”. This has been an area of conflict between restoration efforts and management, since restoration serves to increase water quality and is sometimes most appropriately sighted in areas closed because of reduced water quality.
6. The restoration program under RWU is the one exception to this stipulation, with some of the sites located within closed and un-assayed waters. RWU has partnered with DEM on these sites selections, some of which are a continuation of the North Cape restoration program sites.
7. *Cultching and/or placement of substrate* – Cultch is re-used oyster or clam shell, which is placed at designated sites to provide substrate for oyster settlement, and structural complexity to increase settlement, recruitment and survival for fish, crabs and other invertebrates that induce larval

settlement of oysters. The shell (or other substrate proposed for use) is considered fill, and therefore any projects attempting to use cultch or other substrate requires permits from CRMC and US Army Corps of Engineers.

8. *Oyster Restoration Working Group* – The working group formed in 2009 as a result of the disparities observed in oyster restoration siting and monitoring protocols. The working group was originally chaired by CRMC and currently has co-chairs from DEM Division of Fish and Wildlife and CRMC. Meetings are held on an as needed basis.
   a. The volunteer group included representation from state management agencies (DEM DFW, DEM OWR, DEM Division of Law Enforcement, CRMC), federal agencies (NRCS, EPA, NOAA Habitat Conservation Restoration Center), academic institutions (RWU, URI), industry associations (OSAA, RISA), and non-profit organizations (TNC, STB, JAM).
   b. Subcommittees were formed to address several issues: 1.) Oyster restoration monitoring protocol; 2.) Oyster restoration site location protocol; and 3.) Education and communications.
9. The monitoring and assessment of any restoration project is paramount to understanding the success of such effort. As restoration efforts began to propel following the North Cape restoration projects, it became clear that managers, restoration practitioners and interested stakeholders needed a mechanism to ensure systematic monitoring of all projects and an avenue for disseminating monitoring information. To address this issue, in April 2012, the monitoring protocol subcommittee, lead by RWU, completed the creation of the manual "RI Oyster Restoration Minimum Monitoring Metrics and Assessment Protocols." The full working group recognized the value of the document, and recommended that all restoration projects in RI follow this protocol, though it has not been formally adopted by the state. Additionally, in 2014 a national Oyster Habitat Restoration Monitoring and Assessment Handbook, led by NOAA and TNC, was published which proposes Universal Metrics for all oyster restoration projects. The basic metrics proposed by the two documents are similar.
10. The DEM Division of Fish and Wildlife, NRCS, TNC, CRMC, and RWU have continued to work on the site location protocol and the challenge of balancing human risks with environmental benefits. The siting and permitting of restoration projects has been quite informal, without an established application and review process in place, and often being heavily influenced by ease of enforcement. While protection of human health is of critical concern, other factors need to be considered in determining suitable restoration sites.
11. *Block Island* – Block Island is very different in the way the shellfish resource is managed, including restoration. Block Island is the only area that has established a fee-based recreational licensing program for both Rhode Island residents and non-residents. The fees from the licensing program return to the public – they are used to fund restoration and enhancement projects. For instance, quahogs have been purchased and planted annually for decades to support a "put and take" fishery around Block Island. In addition, beginning in 2013, soft shell clams have been planted in Cormorant Cove for recreational harvesting. Bay scallop enhancement efforts also take place, though on a much smaller scale.

CHAPTER 6. Economic Value of Shellfish

By Azure Dee Cygler, Coastal Resources Center, URI

Section 600. Introduction

1. This chapter summarizes the general nature of economic issues as they relate to shellfish, highlights what is known about the issues, and identifies information gaps. There are two separate and distinct ways to characterize economic issues relating to shellfish: economic value and economic impact. Both concepts are important, but in different ways.

    a. Economic value is a measure of net economic contribution to society, assessed by comparing benefits and costs. To the extent that RI's shellfish resources generate revenues that exceed associated costs, the resulting efficiencies constitute economic value.

    b. Economic impact is a measure of expenditures throughout the economy stemming from a given source. The impacts may be both direct, e.g., prices paid to fishermen, and indirect, e.g., fuel purchases and other ripple effects associated with harvesting, processing, and distribution operations. To the extent that RI's shellfish resources generate business output, value added, income, and jobs, the flow of associated expenditures constitutes economic impacts.

2. Generally speaking, individual industries such as fisheries impact the overall economy in three primary ways: 1) direct effects, through generation of products, value-added, and employment; 2) indirect effects, including the purchase of goods and services from other industries, stimulating additional economic activity; and 3) induced effects which include expenditures by direct and indirect employees which feed the local and regional economy. The sum of these three effects is often used as an estimate of the total economic impact.

3. Available economic data pertaining to shellfish in RI is generally limited to the direct economic impacts associated with prices paid to fishermen and farmers – aka ex-vessel value for wild-harvested shellfish and farm-gate value for farmed shellfish. Those impacts are significant, and reflect the economic importance of shellfish in RI. Additional impacts resulting from multiplier effects are known to occur, but have yet to be analyzed and quantified. As well, actual economic values associated with shellfish have not yet been assessed.

4. Characterizing the economic impact of shellfish to RI can be done by considering overall landings of all shellfish species, or just those that are grown in and harvested from RI waters – aka state-waters species. Overall shellfish landings in RI include landings of sea scallops, surf clams, and ocean quahogs, which are all generally harvested from offshore federal waters. Landings of quahogs, whelks, soft-shelled clams, oysters, bay scallops, and mussels reflect the shellfish resources that come from RI waters. An even broader assessment of the economic impact of shellfish for RI would also include data on shellfish that are landed in other states by RI vessels (e.g., sea scallops landed in Massachusetts); as well as data on shellfish imports, i.e., shellfish products that are shipped into RI for processing/distribution.

5. The overall economic importance of shellfish to RI is generally the sum of impacts from commercial shellfishing and shellfish farming, recreational shellfishing impacts, and shellfish restoration activities.

6. Economic analyses that compare values and contributions to the economy over time need to account for inflation; however, no such adjustments have been made for the information presented in this chapter.

7. Data for RI's state-based wild fisheries is collected and housed though the Atlantic Coastal Cooperative Statistics Program (ACCSP), a cooperative state-federal program that serves as the depository for state and federal collected fisheries data. Under ACCSP, a web-based data entry system, the Standard Atlantic Fisheries Information System (SAFIS) provides a means for state and

federal agencies to enter, compile, and access the fishery data they have collected. Once data is entered into SAFIS, it is made available to researchers and resource managers. SAFIS records total landings and total ex-vessel values of those landings by state, but does not track any other economic data. As an ACCSP partner, RIDEM is responsible for ensuring that all RI landings data is accurately reported. Pursuant to RIDEM regulations, all commercial fishermen are required to land at licensed dealers, and all licensed dealers are required to report to SAFIS.

8. Several software systems are available that estimate economic impacts, applying multipliers to federal data. For example, NOAA Fisheries has developed an Interactive Fisheries Economic Impacts Tool, which can be used to generate annual estimates of the economic impacts of the seafood industry, as well as annual estimates of both the expenditures and impacts of marine recreational fishing (see https://www.st.nmfs.noaa.gov/apex/f?p=160:7:9118246697717). Other generic models have been developed to examine the overall effect that a particular activity, event, or industry has on the wider economy. While economic impact models in most cases attempt to discern differences before and after certain activities or industries exist, they can also be helpful in measuring the combined inputs of that industry on the wider economy at its current state. However, the models are not able to capture every possible effect, leaving gaps in our understanding. (Hodges et al. 2002). While there have been no directed studies on the economic impacts of the shellfish industry in Rhode Island, other states have conducted similar studies, including Florida and Alaska, and may offer significant insights to RI.

Section 610. Issues Identified by Stakeholders

1. Throughout the SMP process, the SMP team met with stakeholders to identify issues and concerns they had regarding all aspects of shellfish, including but not limited to environmental issues, management, marketing, capacity building, and decision making. The following are the major themes concerning the economic value of shellfish (the full list of all issues identified by stakeholders can be found in Appendix 2.2). There is a need for:
   a. Better understanding of the role shellfish play in the Rhode Island economy.
   b. Further research to gain an increased understanding of the value of recreational shellfish harvesting in the state.
   c. More information on whether ecotourism operations hosted in coordination with shellfish harvesters and growers would add value to these businesses.
   d. A cost-benefit analysis or other tools to assist managers in further understanding closed waters, use conflicts, and overall the best use of space in the Bay and coastal salt ponds.
   e. Shellfish industries to better understand how to incorporate value-added opportunities like direct marketing, local branding, and connecting with local buyer initiatives to improve their bottom line.
   f. Discussions and actions to better consider overall economic strategies, such as a lack of resources and funding to support improved management efforts.

Section 620. Status and Trends

1. The commercial shellfish sector has a significant economic impact in RI, as evidenced by the number of people employed in the commercial industry, and the revenues generated by commercial sales. In 2013, over 500 commercial fishermen and 127 commercial shellfish farmers and farm workers, harvested and landed shellfish in RI. Revenues (ex-vessel and farm-gate values) stemming from those sales totaled $6.2 million for wild-harvested shellfish; this value, it must be noted, includes sea scallops, surf clams, and ocean quahogs. These species are not considered in the SMP as they have federal management plans associated with them already. Table 6.1 shows landings of shellfish species considered in the SMP for 2013 only and Table 6.2 shows landing values for these species over time (2007-2013) which has generally increased. Total revenues from the sale of farm-raised shellfish have also been on the rise, with a farm-gate value reaching $4.2 million in 2013.

Table 6.1. Ex-vessel values of shellfish from RI state waters in 2013. Note: There were no mussel landings in 2013, but these have been harvested commercially in years prior.

Species	Value in 2013
Soft-shelled clams	$ 112,795
Blue Mussels	$ 0
Eastern Oysters	$ 73,699
Bay Scallop	$ 563
Whelks	$ 1,295,294
Quahogs	$ 4,714,876
TOTAL	**$ 4,901,933**

Table 6.2. Ex-vessel values of shellfish from RI waters during period 2007-2013.

Year	Value	
2007	$	5,809,236
2008	$	4,669,774
2009	$	4,569,732
2010	$	5,237,106
2011	$	5,658,481
2012	$	6,935,735
2013	$	6,197,226

620.1. Commercial Wild Harvest

1. Shellfish constitute a key component of RI's overall commercial wild-harvest fishery. Ex-vessel values of shellfish from RI waters constitute about 10 percent of total ex-vessel values for all commercial species, including finfish and crustaceans, landed in RI. If the ex-vessel values of sea scallops, surf clams, and ocean quahogs are factored in, the percent contribution from shellfish jumps to about 33 percent of total ex-vessel values.
2. Quahogs are the most commercially important shellfish harvested in RI waters. Revenues from the sale of wild-harvest quahogs far exceed the revenues from other wild-harvest shellfish. In 2013, the total landings of quahogs (all market categories) harvested commercially from RI waters was 6.96 million pounds (3,158 metric tons), which equates to just over 39 million quahogs. The total value of these landings (based on ex-vessel sales) was just over $4.7 million. Of all seafood products landed in RI, quahogs are generally the 5th most important in terms of total value (based on ex-vessel sales), following sea scallops, squid, lobster, and summer flounder.
3. *Quahogs* - Quahogs generally fall into one of four market categories, based on their size. Of the total harvest of all quahogs in 2013, 64% were littlenecks that had an average ex-vessel price of $0.15 per piece. Top necks made up 23% of the catch with a per-piece average of $0.10. Chowder clams accounted for about 10% of landings. Shellfishermen are typically paid for chowders by the pound, instead of by the piece, but based on the average weight of a chowder clam, the per-piece average for chowders was about $0.11. Cherrystones constituted about 3% of the total quahog landings; they are sometimes bought by the pound and sometimes by the piece. The average price paid for cherrystones is estimated to be $0.08 per piece.
4. The prices paid to commercial shellfishermen for quahogs has varied very little over the years, remaining about the same as it was in during the height of shellfishing in the 1980's at $0.10 - $0.18 per piece. The stagnant price trend over the past seven years is shown in Table 6.3.

Table 6.3. Total value of the four market categories of quahogs between 2007 and 2013. Note: 2014 values are not included as data is incomplete.

Year	Market Category	Value	lbs	Total Pieces	Price per piece	Price per lb
2007	Little Neck	$ 2,528,114	1,673,167	14,728,040	0.17	1.51
2008	Little Neck	$ 2,207,671	1,438,766	12,664,729	0.17	1.53
2009	Little Neck	$ 1,852,651	1,201,896	10,579,677	0.18	1.54
2010	Little Neck	$ 2,214,736	1,461,564	12,865,401	0.17	1.52
2011	Little Neck	$ 2,746,806	1,996,770	17,576,553	0.16	1.38
2012	Little Neck	$ 3,702,230	2,822,014	24,840,755	0.15	1.31
2013	Little Neck	$ 3,459,150	2,540,066	22,358,909	0.15	1.36
Year	Market Category	Value	lbs	Total Pieces	Price per piece	Price per lb
2007	Top Neck	$ 660,844	1,188,142	5,177,062	0.13	0.56
2008	Top Neck	$ 626,320	1,160,688	5,057,436	0.12	0.54
2009	Top Neck	$ 572,252	1,111,745	4,844,179	0.12	0.51
2010	Top Neck	$ 620,401	1,300,618	5,667,153	0.11	0.48
2011	Top Neck	$ 702,716	1,493,739	6,508,631	0.11	0.47
2012	Top Neck	$ 911,784	2,038,176	8,880,895	0.10	0.45
2013	Top Neck	$ 838,578	1,796,445	7,827,608	0.11	0.47
Year	Market Category	Value	lbs	Total Pieces	Price per piece	Price per lb
2007	CHERRYSTONE	$ 76,709	264,519	728,986	0.11	0.29
2008	CHERRYSTONE	$ 91,942	340,591	938,631	0.10	0.27
2009	CHERRYSTONE	$ 70,848	306,100	843,579	0.08	0.23
2010	CHERRYSTONE	$ 74,016	329,418	907,841	0.08	0.22
2011	CHERRYSTONE	$ 70,322	308,389	849,888	0.08	0.23
2012	CHERRYSTONE	$ 92,259	439,210	1,210,416	0.08	0.21
2013	CHERRYSTONE	$ 56,850	289,824	798,723	0.07	0.20
Year	Market Category	Value	lbs	Total Pieces	Price per piece	Price per lb
2007	Chowder	$ 431,425	2,098,841	3,459,871	0.12	0.21
2008	Chowder	$ 342,921	1,861,531	3,068,674	0.11	0.18
2009	Chowder	$ 333,728	1,854,391	3,056,904	0.11	0.18
2010	Chowder	$ 360,792	2,104,556	3,469,293	0.10	0.17
2011	Chowder	$ 384,793	1,946,492	3,208,729	0.12	0.20
2012	Chowder	$ 419,009	2,383,574	3,929,246	0.11	0.18
2013	Chowder	$ 360,298	2,052,550	3,383,563	0.11	0.18

5. Other species of commercial importance harvested from RI waters include soft-shell clams, whelks (channeled and knobbed), oysters, bay scallops, and blue mussels (See Table 6.4).

6. *Soft-shell Clams* - In 2007, when a previously unfished portion of the Bay (Conimicut Triangle) was opened to shellfishing due to a change in water-quality classification, landings of soft-shell clams spiked to about 1.3 million pounds, with a resulting value (based on ex-vessel sales) of $1.7 million. Since then, landings of soft-shell clams have dropped dramatically and leveled off at about 10,000 pounds annually with a corresponding ex-vessel value of about $83,000 annually.

7. *Whelks* - In 2012, total ex-vessel sales of whelks in RI totaled $1.3 million, with the vast majority involving channeled whelks. A sharp increase in whelk landings in RI occurred in 2009, with years 2006-2008 averaging 397,330 pounds annually and years 2009-2013 averaging 765,561 pounds annually. From 2004 to 2008, the ex-vessel value of whelks fluctuated around $3.00 per pound, but dropped to around $2.25 in 2013.

8. *Mussels, Oysters, and Bay Scallops* - Landings of blue mussels in RI are generally modest and variable; in particularly good years, such as 2009 and 2010, annual landings range as high as $145,000 in total ex-vessel value. Oysters have generally not been landed in commercially significant amounts in recent years; but there has been a slight increase as of late, with total landings in 2013 valued at $74,000. Bay scallops remain relatively insignificant, with a total value of just $5,000 in 2012.
9. *Razor Clams* - While there is no information for other years, in 2010 the value of Atlantic razor clams was $25,555 (Industry Profile, 2011).

Table 6.4. Average landing values for all whelks, soft-shelled clams, bay scallops, blue mussels and oysters between 2007 and 2013.

Species	Average Landings per year	
All Whelks	$	977,984
Soft-Shelled Clams	$	693,811
Bay Scallops	$	876
Blue Mussels	$	48,099
Oysters	$	31,542

10. An analysis of commercial shellfish trips broken down by port (for just the year 2010) reveals that the vast majority of activity is based in Greenwich Bay, with East Greenwich Warwick accounting for about half of all trips. The other 50 percent of trips are based out of Wickford Harbor (North Kingstown), Bristol Harbor (Bristol), Warren, Portsmouth, and Point Judith (Narragansett). See Table 6.5.

Table 6.5. Number of trips by individual shellfish species by port for 2010 (From the Industry Profile, 2011).

Table 2.6: Number of Trips by Individual Shellfish Species by Port 2010

	CLAM, RAZOR, ATLANTIC	CLAM, NORTHERN QUAHOG	CLAM, SOFT	MUSSEL, BLUE	OYSTER, EASTERN	SCALLOP ,BAY	SCALLOP, SEA	
PORT	# TRIPS	# TRIPS	# TRIPS	# TRIPS	# TRIPS	# TRIPS	# TRIPS	TOTAL
Bristol		2,877	148		7			3,032
Charlestown		8	2					10
East Greenwich		5,098	325		13			5,436
Jamestown		8						8
New Shoreham							5	5
Newport		122	9				6	137
North Kingstown (local name Wickford)	10	3,338	252	139	9			3,748
Point Judith		797	174	1	6	1	94	1,073
Portsmouth		1,588	84					1,672
Rhode Island (State)							2	2
South Kingstown (Town of)		1	6					7
Warren		2,512	119				5	2,636
Warwick (RR name Apponaug)		6,955	532	38	4			7,529
Total Trips								25,295

Information provided by Daniel Costa ACCSP Coordinator Division of Fish & Wildlife RIDEM-SAFIS data (Dealer Reports)

11. As commercial shellfish products are processed and moved into the wholesale and retail markets, they generate additional revenues (e.g., businesses that process and distribute shellfish, and retail establishments that sell shellfish); however, there is no data available to quantify those amounts. Commercial shellfish activities also generate additional expenditures in the form of purchases for fuel, vessel maintenance, equipment and supplies, docking fees, and other infrastructure costs

associated with the growing, harvesting, processing, and sale of shellfish products. Again, while these expenditures are known to be significant, they have yet to be quantified. Finally, it's important to note that RI's overall seafood industry includes seafood products that are landed in other states by RI vessels, and seafood products that are shipped into RI for processing/distribution. Although data on the nature and extent of shellfish imports is lacking, one report found that the value of quahogs imported to RI was $610,000 in 2010, down from over $1.4 million in 2001 (Industry Profile, 2011).

620.2. Recreational Wild Harvest

1. The economic impacts associated with recreational harvest activities are presumed to be significant, but there is little or no data available to determine the level of significance. A license is only required for non-residents, and no survey has ever been undertaken to estimate the level of participation in the recreational shellfishing in RI. What is known, anecdotally, is that many thousands of people engage in the activity, and that the activity is coupled with a range of expenditures for such things as equipment, fuel (for cars and boats), food, and lodging. For some, recreational shellfishing may involve little more than a walk down to the shoreline, with a bucket and rake, with little or no expenditures involved. For others, the activity may be the focal point of a day trip, with modest expenditures for ice and food. And for tourists drawn to RI for, among other things, the delight of digging a bucket of clams, the activity may be associated with bookings at hotels, meals at local restaurants, shopping in local stores, and other tourist-related expenditures. To the extent that recreational harvesting provides a source of food for harvesters and their families, there is clearly an economic value, or impact, associated therewith.

620.3. Aquaculture

1. Farming shellfish (mostly oysters) has been a growing trade in Rhode Island in recent years. Since 1995, annual farm gate values have increased steadily; since 2006, they have been sky-rocketing. The 2013 farm gate value was over $4.2 million, which was almost 50 percent higher than 2012. (See Figure 6.1)

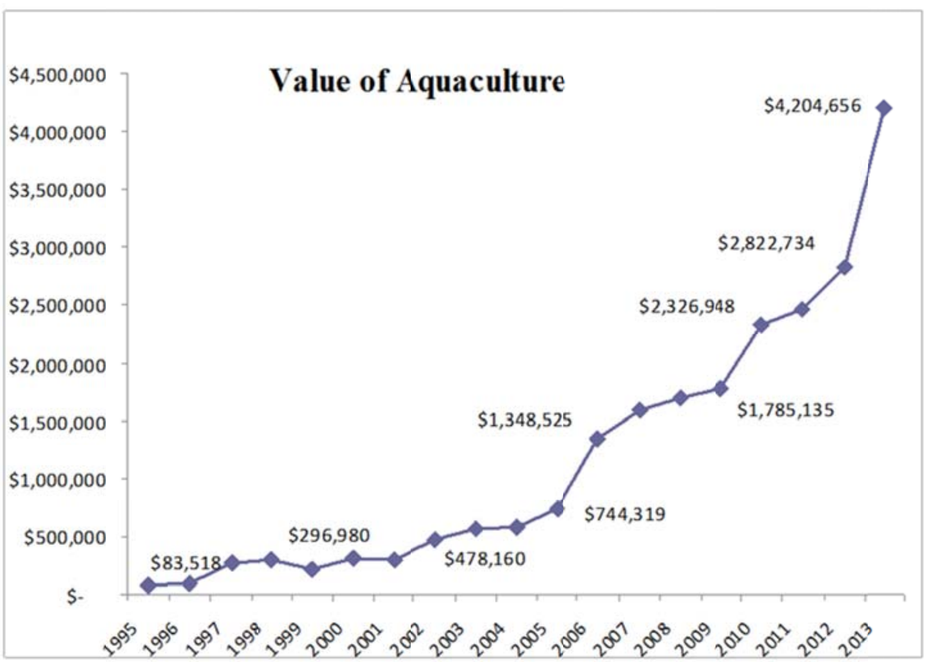


Figure 6.1. Total value of aquaculture (shellfish grown for consumption) in Rhode Island from 1995 to 2013 (CRMC, 2013)

2. While CRMC documents farm gate values, employment, and acreage, the agency does not collect information on the amount of money growers spend on gear (i.e. mesh bags, tumblers, sorters, etc.), vessel maintenance, fuel costs, or other business-related needs. Each grower does maintain a business

plan, but this is not required by DEM or CRMC on a regular basis (only when applying for a lease or by request) and does not include an expense forecast or spending plan.

3. Aquaculture products cultivated in RI are distributed throughout the U.S. and Canada, including New York City and Washington D.C. However, information on the amount of product sold and where it is distributed is not reported, and this not available. The influence of such sales on the local and wider economy is not known.

620.4. Restoration and Enhancement

1. Restoration and enhancement of shellfish resources offer many benefits, both ecologically and economically; however, information is sparse as to how to measure these contributions. Obtaining economic values for restoration activities is challenging because the contribution of these activities comes largely in the form of environmental benefits such as water quality improvement, habitat improvement, shellfish recruitment, etc. These types of benefits have different "currencies," making economic calculations difficult. It is also a challenge to determine the ripple effect of these activities, e.g., increased use of cleaner waters, increased harvests, and protection of property values from storm damage. To some extent, restoration projects also generate income for those involved in the development and maintenance of oyster reefs, with the NRCS' EQIP Program being a case in point. For example, $3.4M was paid to 18 farmers between 2002 and 2008 for the EQIP program (NRCS 2014).
2. The economic value of restoration efforts, in the form of improved water quality, renewed habitat, recreational opportunities provided, etc. are not easily quantifiable, yet are important contributions to Rhode Island. The Nature Conservancy has designed various guidelines for measuring the value of restoration in terms of habitat rebuilding, recruitment of shellfish to the established reef and other areas, water quality effects, and shoreline protection (TNC, Practitioners Guide). However, there is little assignment of monetary value to these services in the Rhode Island environment.
3. Ongoing research by Gabowski and others is looking to better understand the economic value of various ecosystem services, like oyster reef restoration. Gabowski states that quantifying various services provided to the ecosystem through restoration can aid more effective management strategies. Though focused primarily on Virginia and Maryland, the researchers were able to assign approximate values to the various ecosystem services provided by oyster reefs, including habitat status, values of finfish and crustaceans, water quality improvement, carbon burial, shoreline protection, habitat services, and landscape processes. Interestingly, the non-oyster harvest service was estimated to provide a maximum of $99,421 per hectare per year and shoreline protection offered $85,998 per hectare per year (in 2011 dollars) (Gabowski, 2012). These estimates do not include commercial harvest benefits or recreational benefits derived from the reefs, likely a significant contribution to the overall value. There are no specific estimates for Rhode Island reefs, however this work does imply there is considerable benefit to these restored areas.

Section 630. Other Economic Issues

1. There are a host of issues that relate to the economics of shellfishing. In addition to revenues, which were previously addressed in this chapter, other issues include:
   a. Access to the resource, and the size and make-up of the industry (see Chapter 4);
   b. Wages and profits; and
   c. Markets – supply, demand, competition from other products, pricing, etc.
2. There have been no significant analyses conducted on the issues noted above. Status and trends with regard to industry participation in the wild harvest fishery is reflected, to some extent, by the numbers of commercial shellfishing licenses issued by DEM and the activity levels of those license holders, both covered in Chapter 4. However, the data do not reveal details on the exact number of full-time commercial shellfishermen versus those who shellfish on a part-time basis to supplement their other

fishery-related or non-fishery-related income. What's more, the data do not reveal details on wages and profits. It thus becomes difficult to characterize the overall economic status and project economic growth opportunities in the industry.

3. One issue that has been the subject of recent analysis is the market implications associated with the opening and closure of shellfish management areas in Narragansett Bay by DEM as a component of the State's shellfish management program. This long-standing practice, which essentially involves metering the flow of product - namely quahogs - to the market, is done in response to industry's desire to avoid market gluts and maintain relatively stable pricing.

4. The Winter Harvest Schedule for the commercial wild harvest fishery is determined annually via a collaborative process involving DEM, the RI Marine Fisheries Council (Council) and the Council's Shellfish Advisory Panel (SAP). The schedule is generally set no later than November each year and identifies specific dates and times for a select number of designated Management Areas to be opened for harvest throughout the year. The SAP consists of Council-appointed representatives from the commercial and recreational shellfish sectors in the state, including dealers and other interested parties. Generally, the management areas are open periodically from December through April, and then closed from May through November.

    a. DEM administers the program by setting an appropriate extraction level for quahogs in each designated area, i.e., a total number of hours for harvesting in each area. This input control is aimed at maintaining the resource at sustainable levels. As an informal DEM policy, DEM typically adopts the industry recommendations for the harvest schedules (i.e. the days each week, and the hours each day, that the areas are open to harvest), provided that the total hours are not exceeded. DEM plans to transition its management program from an input-control approach to an output control approach, but the need to coordinate with industry on harvest schedules is likely to continue.

5. Although there has been no direct analysis of the impacts of this management approach on the market, a recently completed study took a first step in attempting to characterize and quantify the market interactions of wild harvested shellfish products in Rhode Island. Specifically, the study estimated the sensitivity of the ex-vessel prices of shellfish products (three market categories for quahog, scallop, and whelk) with respect to the quantity landed. The study found that: 1) ex-vessel prices were responsive to the quantity landed but was less than proportional; 2) the scale of sensitivity varied across products; and 3) shellfish products included in this study were all substitutes to each other, suggesting that consumers' demand (i.e., substitutive relation) is dominant than potential complementarity of goods in processing or distribution through the supply chain (See Uchida et al. 2014 unpublished in Appendix 6.2).

Section 640. Seafood Marketing

1. It has long been recognized that promoting seafood to consumers can boost consumer demand, induce a willingness to pay more, and thus increase the economic value of seafood products. As such, various federal and state seafood-marketing programs have been launched over the years, including efforts in RI which ended many years ago due largely to fits and starts in funding, but as well to the difficulty of measuring their efficacy on a broad scale. Until recently these efforts had waxed and waned, due largely to fits and starts in funding, but as well to the difficulty of measuring their efficacy on a broad scale. The market for RI seafood products has traditionally been regional, and the distribution system has typically co-mingled RI seafood products with those from other states, making it difficult to target, and gauge the effectiveness of, promotional campaigns. Lately, there has been a surge of interest in both food sourcing and local food networking which is particularly strong in Rhode Island. To an ever increasing extent, consumers want to know where their food comes from, and they want to buy locally and support a more locally-based, sustainable food system. This so-called foodie movement which has its origins in terrestrial agiculture, as applied to seafood, has given new focus to revitalized seafood marketing campaigns.

2. Another new marketing angle in RI is direct sales. Although licensed commercial shellfishermen and aquaculturists must sell their products to licensed commercial dealers (who typically serve as the "middle men"), many dealers (some of whom double as growers and harvesters) are increasingly taking advantage of direct-sales opportunities via farmers markets, cooperatives, and direct deliveries to restaurants. The angle is to achieve added value by removing the middle man and thereby increase the value of sales earned directly by the fisherman or grower -- provided the fisherman/grower is also a licensed dealer.
    a. In order to directly market shellfish, growers and fishermen must obtain a Shellfish State Shipper's License from DOH and be a certified shellfish dealer. This requires HACCP certification (see Chapter 7) and the proper infrastructure such as coolers and refrigeration trucks to ensure safe processing of shellfish products, among other requirements. These added requirements entail added costs, so those wishing to engage in direct sales need to calculate the net change in economic value associated with the endeavor to determine whether it makes economic sense to take on that role.
3. A study by Grimley and Roheim (2010) assessed the market potential for local seafood in Rhode Island, and offered a marketing framework for a local seafood initiative. The survey findings provided by the study showed that of the 200 respondents, 63.5% preferred to purchase seafood at independent seafood markets and 45.5% preferred to purchase seafood at conventional supermarkets.
4. Community Supported Fisheries (CSFs) have been developed using the Community Supported Agriculture model, allowing consumers to buy directly and regularly from the producer. There are several CSFs throughout Rhode Island, all offering various seafood products (including shellfish) that are distributed weekly, monthly, or by other arrangements, directly to the customer.
5. The RI Shellfishermen's Association, representing a large segment of the State's wild-harvest industry, and the Ocean State Aquaculture Association, representing a large segment of the State's shellfish farming industry, have long been engaged in promotional efforts aimed at increasing awareness of their industries and the seafood they produce. Both groups routinely participate in various events and activities, including annual festivals and State House events. Several years ago, the RI Shellfishermen's Association launched their own branding initiative – developing an insignia to demarcate bagged RI quahogs in the marketplace – but the funding for the initiative was short-lived and the campaign lost steam. More recently, the Association secured a grant to undertake a new promotional campaign. A video, highlighting the industry and the shellfish they produce, has been developed and will soon be airing on local television stations.

640.1. RI Seafood Marketing Collaborative and RI Seafood Brand

1. The Rhode Island Seafood Marketing Collaborative was established via legislation enacted in 2011 (RIGL Chapter 20-38). In accordance with the statute, the role of the Collaborative is to identify opportunities to promote RI seafood, for the dual purposes of strengthening the RI seafood industry and contributing to the development of a locally produced sustainable food system that capitalizes on RI's bounty. Given that the RI seafood industry encompasses thousands of small businesses – including the fishermen and growers, the working waterfronts and support industries, the wholesalers and retailers, the restaurants, and the tourism industry as a whole -- adding value to RI seafood products gives rise to a tide with broad benefits. And using marketing to better connect Rhode Islanders with locally produced, healthy, affordable seafood contributes to their well-being, economic and otherwise.
2. The nine-member Collaborative consists of representatives from five RI state agencies – the Departments of Environmental Management, Health, and Administration, the Coastal Resources Management Council, and Commerce RI – as well as the University of Rhode Island. Its ten-member Advisory Council consists of representatives from a wide range of industry sectors, including harvesters, growers, wholesalers, processors, retailers, and hospitality, as well as science and

management. The two bodies have worked together, over the past three years, to assess and prioritize issues, develop recommendations, and spearhead initiatives.

3. The Collaborative has set forth a series of steps and action items – some completed, some in process, and some yet to be initiated – in its three annual reports. Many of these items pertain to the shellfish industry, either directly or as part of a fishery-wide agenda.

4. Since its inception, one of the top priorities of the Collaborative has been to develop and adopt a "Rhode Island Seafood" brand to distinguish Rhode Island seafood in the marketplace. That was achieved in November 2013, when DEM filed regulations establishing the new "Rhode Island Seafood Logo" (Figure 6.2). The logo, which is trademarked, may be used, upon application to DEM and receipt of a Letter of Authorization, to identify and promote seafood landed in Rhode Island by commercial fishermen, as well as seafood grown in Rhode Island waters by commercial farmers. Authorized users include licensed seafood dealers, and others who obtain seafood products from dealers, following along the chain of custody. To date, several licensed seafood dealers have received authorization to use the logo, and it is starting to appear in more and more retail stores and restaurants throughout the State.

Figure 6.2. RISMC logo created in 2013-14.

5. In conjunction with the launch of the RI Seafood Logo, DEM and the Collaborative have launched a website – SeafoodRI.com – and developed a professional marketing plan, oriented around the logo and website. Funding is being pursued to implement the plan, and the campaign is expected to kick-off, in a big way, in 2015. The branding program and associated publicity hold great potential to boost the economic interests of RI's seafood industry, including the shellfishing sector. In fact, shellfish are a particularly good fit for the local marketing campaign, given how truly native they are.

6. *RI Local Agricultre and Seafood Act* – The Rhode Island Local Agriculture and Seafood Act (LASA) was established by legislation enacted in 2012. It authorizes the DEM to obtain private funding to set up a grant program for new farmers and organizations that support the growth, development, and marketing of RI's agricultural and commercial fishing sectors; to promote marketing and outreach efforts to support local agriculture and seafood products; and to coordinate with DOA and DOH to establish an Inter-Agency Food Council to address the safe production, distribution, and processing of local foods for both local and national markets. This new statute complements the work and direction of the RI Seafood Marketing Collaborative, and has already served a critical role by providing support to the development of the Collaborative's seafood marketing campaign.

   Under LASA, funding in 2014 has also been provided to the following shellfish-related projects and activities:

   - $20,000 to RI Seafood Marketing Collaborative's statewide seafood branding and marketing campaign,
   - $5,000 to Jamestown Oyster Company for materials used to increase oyster harvest,
   - $13,648 to Newport Harbor Corporation in Newport to promote increased consumption of top neck clams, a locally harvested and under-utilized sea clam,

- $7,925 to RI Shellfisherman's Association to produce three PSAs highlighting commercial shellfishing and local shellfish available to RI consumers, and
- $7,500 to the Local Catch in Narragansett to increase the presence of RI seafood at RI farmers markets, increase Community Supported Fisheries (CSFs), improve brand awareness of RI-landed seafood and launch a web-based distribution channel

Section 650. Recommendations

1. There was no Technical Advisory Committee for this chapter and thus no recommendations were formed via that structured approach. As noted, however, there were a number of issues identified by stakeholders, all of which serve as de facto recommendations. As well, there are a host of recommendations that have been developed by the RI Seafood Marketing Collaborative. Many of those recommendations address economic issues associated with the commercial shellfishing industry, either directly or as part of a broader, fishery-wide focus. As such, those recommendations are incorporated by reference into this plan.
2. Additionally, as noted throughout this chapter, there is a general dearth of data and information pertaining to the economic impact and value of shellfish in RI. It is important to target future research on assessing the economic status of the industry in its current form, and identifying opportunities for economic growth.

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CHAPTER 7. Human Health Risks Associated with Shellfish

By Robert Rheault, East Coast Shellfish Grower's Association

Section 700. Introduction

1. Shellfish have been an important source of nutritious protein since well before the colonization of America. Paleontologists believe that shellfish played role in the evolution of hominids, allowing them to develop large, energy-hungry brains (Crawford *et al.* 1999). Despite the many health benefits associated with shellfish consumption that will be discussed in this chapter, there is a history of challenging public-health issues associated with shellfish.

2. Because shellfish are filter feeders that can bio-accumulate toxins and pathogens from the waters in which they are grown, they pose unique health threats to consumers. Pathogens in shellfish tissues may reach concentrations as high as 100 times those found in growing waters. In addition, the threat of foodborne illness related to shellfish is especially high because they are one of few proteins that consumers often consume raw. Even so, less than 3 percent of foodborne illness outbreaks in the U.S. are associated with shellfish consumption, compared with 46 percent from vegetables and 22 percent from meat and poultry (Painter *et al.* 2013).

3. Sewage-related pathogens such as bacteria and enteric viruses are not the only potential shellfish contaminants. Shellfish can also accumulate heavy metals and industrial pollutants such as pesticides. The tendency of these substances to bind to particles speeds the process of uptake and accumulation by filter-feeding shellfish. In addition, phytoplankton blooms such as "red tides" can produce neurotoxins, and naturally-occurring bacteria such as *Vibrios* can cause significant illness or death. To mitigate many of the risks from eating shellfish, there are numerous regulations based upon the best available science designed to ensure that commercially-harvested shellfish are safe for consumption.

4. This chapter will describe current human health risks associated with shellfish consumption, including those threats from sewage-borne pathogens, naturally-occurring pathogens, risks from heavy metals uptake, etc. This chapter will also describe processing techniques used to minimize health risks, the process of depuration and relay, as well as precautions to take to avoid illness from consumption of shellfish as well as the health benefits inherent in eating clean shellfish.

Section 710. Issues Identified by Stakeholders

1. Throughout the SMP process, the SMP team met with stakeholders to identify issues and concerns they had regarding all aspects of shellfish, including but not limited to environmental, management, marketing, capacity building, and decision making. The following are the major themes concerning human health risks associated with shellfish. A full list of all issues identified can be found in Appendix 2.2:

    a. There is a need to better understand and manage human health concerns with respect to Vibrios and other human health risks and provide expanded consumer education regarding those risks, especially to vulnerable populations.

    b. Management of shellfish for human risks through FDA is often too rigid and DOH and DEM needs to encourage management based on protecting human health while also fostering a good business environment for shellfish industries to expand and prosper.

Section 720. Short History of Shellfish Health Risks

1. There is a long history of shellfish-associated illness that has given shellfish the reputation as one of our most deadly foods (Mead *et al.* 1999). In the 1800s when oysters were plentiful and enjoyed widely, it was thought that illness was caused by "bad air," or miasma, emanating from rotting organic matter. It wasn't until the late 1800s that science showed illnesses could be transmitted from person to person, often by sewage-related pathogens such as bacteria or enteric viruses.

2. In 1884 the “Oyster Panic” hit New York when cholera outbreaks resulted in a number of deaths among oyster eaters. That same year, Koch proved sewage-related bacteria were the cause of typhoid, and by 1890 Pasteur’s “germ theory” had become accepted doctrine (Levine and Jucker 2006). At that time, every major city was dumping volumes of untreated human waste and horse manure into their waterways, often near productive shellfish beds. The advent of running water and the invention of the flush toilet at the turn of the century made a severe problem much worse.
3. Around the same time, America was becoming industrialized, leading to the use of a wide variety of newly-developed chemicals. As with sewage, the estuaries around major cities became the repositories for all manner of toxic chemical and industrial wastes, including heavy metals and hydrocarbons. The first oil refinery was built on the New York City’s East River in 1872, and soon oysters taken from estuaries near most major cities began to taste of oil from spills and discharges.
4. In 1925 the surgeon general mandated the formation of the National Shellfish Sanitation Program (NSSP) in response to decades of outbreaks of typhoid fever and cholera related to the consumption of raw oysters (Yuhas 2002). The conferees agreed that shellfish sanitation should be the responsibility of the states, and that states should issue certificates to shippers that met a set of minimum sanitary standards. In the 1940s the NSSP adopted standards to address paralytic shellfish poisoning, and by the 1970s regulations were expanded to consider potential contaminants such as hydrocarbons, heavy metals and pesticides.
5. The National Shellfish Sanitation Program is now controlled by the U.S. Food and Drug Administration (FDA), working in conjunction with state public-health agencies and industry in a collaborative group called the Interstate Shellfish Sanitation Conference (ISSC). The ISSC establishes all regulations for the commercial harvest, processing and sale of shellfish; harvest-area classification; requirements for growing-area patrol and enforcement; and the requirements for facilities that are licensed to buy, sell, process or transport shellfish. All these requirements are set forth in the 570-page Model Ordinance that is reviewed and revised on a regular basis.
6. The Model Ordinance contains guidance on virtually every aspect of shellfish harvest and handling. In order to sell shellfish between states, each state must comply with the basic requirements of the Model Ordinance. These regulations are copied by many nations around the world, although only a few have developed programs rigorous enough that the FDA allows them to export raw products into our markets.
7. Until the mid-1900s, shellfish-related illness continued to plague the industry, but over time, advances in sewage treatment, water-quality monitoring and restrictions on ocean dumping have greatly diminished the risk. In 1948 the passage of the Federal Water Pollution Control Act gave the Environmental Protection Agency (EPA) the authority to limit discharges of wastes into our nation’s waterways. In 1972 the Act (known as the Clean Water Act) was amended, making it illegal to discharge any pollutant into navigable waters and establishing the EPA as the lead authority to establish wastewater treatment plant guidelines.
8. Passage of the Clean Water Act in 1972 was driven in large part by the desire to be able to safely consume raw shellfish. In the years since its passage we have seen significant improvements in the quality of the nation’s waters as a result of the investments in wastewater infrastructure required by the law. During this time period, Rhode Island successfully brought all municipal wastewater treatment plants to secondary treatment capacity. More recently, infrastructure improvements have focused on control of combined sewage overflows and stricter nutrient limits to minimize algal blooms and hypoxic conditions. There are essentially three categories of deleterious substances associated with the consumption of shellfish: sewage-related pathogens (bacteria and enteric viruses), natural pathogens and toxins (toxic algal blooms and naturally-occurring bacteria) and pollutants (heavy metals, hydrocarbons and organic pesticides).
9. In each of these categories there is a complex interaction of the dose, or the amount of pathogens/pollutants consumed, and an individual’s fitness, or health status, that determines whether an individual actually becomes ill. In many cases a modest dose of pathogens or toxins will not have

any effect on a healthy person. It may take tens of thousands of pathogenic bacteria to cause an illness because humans have natural defense mechanisms, (such as an acidic stomach and an immune system to combat the infection). We are typically not even aware that modest amounts of pathogens have been ingested. However, there are some notable exceptions. For instance, it is estimated that as few as 10 Norovirus particles can cause a violent illness (Leon *et al.* 2011).

10. The health status of the individual can also determine whether ingesting a pathogen will elicit a response. Individuals who are immuno-compromised (examples include individuals with liver disease, cancer, diabetes or AIDS or those who are taking immuno-suppressant drugs) are far more susceptible to illness. These individuals may also have a far more severe (perhaps even a fatal) response to an illness, while a healthy person with the same illness might only suffer a few days of unpleasant gastric distress. These individuals should never consume raw proteins, and should be especially wary of raw shellfish in summer.

Section 730. Shellfish Health Risks

730.1. Sewage-Related Pathogens

1. Prior to the Clean Water Act, the most common shellfish health concerns were related to the discharge of untreated or improperly treated sewage into shellfish growing waters. A number of pathogenic bacteria and viruses that are associated with human waste can be introduced into growing waters from a point-source discharge (such as the outfall from a wastewater treatment plant), failing or improperly-functioning individual septic systems, or from overboard discharge by boaters.

2. Fortunately, thanks to the Clean Water Act and regulatory agencies such as the FDA and state public health authorities, we have established strict harvest controls and monitoring requirements for shellfish harvest areas. Illness outbreaks caused by sewage related pathogens from commercially harvested shellfish are now quite rare (CDC 2014). Federal requirements for advanced wastewater treatment mean that most pathogens are safely eliminated prior to discharge, and adequate closure zones restrict shellfish harvesting in areas affected by the discharge. This is not to say however that the problem of sewage overflows into shellfishing waters is solved. Aging sanitary sewer infrastructure and in some areas, ongoing problems with inflow and infiltration of non-sanitary flows into sewer collection systems result in occasional sanitary sewer overflows requiring emergency closure of shellfishing waters. Ongoing investments are needed to rehabilitate older infrastructure and prevent non-sanitary flows from overwhelming treatment facilities.

3. Improvements are also underway to significantly reduce the discharge of combined sewage overflows (CSO) affecting Providence River and Upper Narragansett Bay. The Narragansett Bay Commission's (NBC) CSO abatement project is being undertaken in three phases. Phase I, completed in November 2008, consists of a 3-mile long, 26-foot diameter rock tunnel which stores approximately 62 MG of combined sewage that is pumped back to the Fields Point WWTF for treatment. Phase II, currently under construction and expected to be completed in 2015, focuses on the Woonasquatucket River CSOs and includes CSO interceptors to transport flows from remote CSOs to the main spine tunnel, separation of sanitary and storm sewers, and a constructed wetland treatment facility.

4. Shellfish closures were reduced as a result of Phase I (on average 65 additional days of harvesting in Area A and 45 more days in Area B anticipated) and additional reductions are expected when Phase II is completed in 2015. The final phase of the project to control remaining CSO discharges on the Moshassuck, Blackstone, and Seekonk Rivers, is slated for completion by 2022 with submittal of the Phase III preliminary design report by January 2016.

5. Other sources of sewage known to impact shellfishing waters include sanitary discharges from boats and inadequate onsite wastewater treatment systems. Fortunately, Rhode Island has taken steps to address these sources too. In 1998, Rhode Island became the first state to designate its coastal waters as a No Discharge Area – prohibiting the discharge of treated and untreated boat sewage into RI's marine waters. And in 2007, the Rhode Island Cesspool Act was passed which mandates that all

cesspools located within 200 feet of the coast be abandoned and either upgraded with a new onsite septic system or connected to sewers, if available. Efforts continue to implement both initiatives.

6. While incremental water quality improvements are evident in Narragansett Bay, unfortunately the same can not be said about conditions in the state's shallow coastal waters where due to unacceptable bacteria levels, there has been a continual loss in areas open to shellfishing over the past 50 years. Currently just over 11 square miles of waters designated for shellfish harvesting are prohibited due to elevated bacteria levels – and include such popular recreational shellfishing areas as Palmer River, Barrington River and Hundred Acre Cove, Potowomut Cove, Dutch Harbor, Narrow River, portions of Pt Judith Pond, Green Hill Pond, and Pawcatuck River. Another 21.6 sq miles are conditionally approved for shellfishing due to wet weather impacts with Upper Bay Areas A, B, and C accounting for 15.1 sq miles and Greenwich Bay and Mt Hope Bay/Kickemuit River accounting for 6.5 sq miles. DEM has completed water quality restoration studies for most of these waters closed to shellfishing due to bacteria pollution. Inadequate on-site wastewater treatment and polluted stormwater are common problems identified as contributing to both the wet weather restrictions and shellfishing prohibitions. Significant challenges lie ahead to restore these shellfishing waters.
7. There are occasional cases where fecal waste from non-human sources can contaminate growing waters and result in closures. Waste from warm-blooded animals such as domestic pets, waterfowl, livestock or wildlife will occasionally contaminate growing areas and force harvest closures. Although impacts from these sources are usually associated with rain events, harvest-area closures due to waterfowl pollution are not uncommon. Non-point source contamination from land runoff, failing septic systems or illegal direct connections to storm drains, continue to be a monitoring and regulatory challenge.
8. State monitoring, regulation and patrol of harvest areas constitute the first line of defense against shellfish contamination. Regulators routinely sample growing waters for sewage indicators such as coliform bacteria and coliphage to predict the presence of pathogens in growing areas. Decades of research have allowed regulators to predict how pathogens are distributed by tidal flow and how they are inactivated and diluted in seawater. The discharge of untreated waste by boaters has been prohibited in state waters out to three miles. These steps ensure that our commercially harvested shellfish supply is safe, and that sewage-related illness outbreaks are now quite rare. We continue to see sporadic illnesses associated with recreational harvesters who may be unaware of harvest-area restrictions or collect shellfish illegally from closed areas, suggesting the need for improved education and enforcement (Painter *at al.* 2013).

730.2. Naturally-Occurring Pathogens and Toxins

1. Although most of the shellfish sanitation issues related to the treatment and point-source release of sewage have been solved, the shellfish industry is still challenged to prevent illnesses associated with natural sources. Many naturally-occurring microorganisms can accumulate in shellfish at levels high enough to cause illnesses; two of these are worthy of special mention: *Vibrio* bacteria and various species of toxic phytoplankton. While it is relatively easy to detect, predict and model the distribution of microbial pathogens from point-source discharges such as wastewater treatment plants, pathogens arising from natural sources are more difficult to predict, requiring expensive monitoring efforts.
2. Harmful Algal Blooms (HABs) – Under certain conditions, several species of phytoplankton can bloom to high densities and may produce a variety of toxins that can be accumulated by filter-feeding shellfish. The most common phytoplankton toxins in the U.S. are associated with blooms of dinoflagellates (or occasionally diatoms) often referred to as "red tide". Paralytic Shellfish Poisoning (PSP) refers to a suite of some 20 saxotoxins that can cause a variety of neurological symptoms, from tingling lips to respiratory paralysis. Other species of algae can produce toxins that cause amnesic shellfish poisoning (ASP), diarrheic shellfish poisoning (DSP) and neurotoxic shellfish poisoning (NSP). Many species of toxic algae cause a wide variety of gastrointestinal and neurologic reactions in shellfish consumers around the world.

a. When growing conditions are favorable, algal blooms can discolor the water with their cells, and certain species have caused fish and shellfish mortalities. Filter-feeding shellfish can rapidly accumulate toxins at levels that can cause reactions in humans, and it may take weeks or months after the bloom has subsided for the concentrations in the shellfish to subside. As little as 500 micrograms of the PSP saxotoxin can cause death or paralysis in as little as three hours, and many of the toxins are not fully inactivated by cooking or freezing (FDA 2012). Symptoms typically appear within 30 to 180 minutes of consumption and can be inconsequential or severe. The shellfish themselves are sometimes affected and they may exhibit decreased feeding or in some cases mortalities (Hégaret et al. 2009).

b. Routine sampling by state authorities involves collecting shellfish from growing areas, preparing a puree and injecting the liquid into a mouse for assessment. More recently, various chemical assays have been developed for certain toxins, with many assays regularly evaluated for adoption by the NSSP. Commercial harvesters are well aware of harvest restrictions associated with harmful algal blooms, and illnesses traced to commercially-harvested shellfish consumption are extremely rare. However, recreational harvesters are often unaware of harvest bans and therefore most HAB-related illnesses in the U.S. are associated with recreational harvest (FDA 2012). It is important to note that there have been no HAB-related illnesses in Rhode Island.

3. Natural Pathogens: *Vibrio parahaemolyticus, V. vulnificus* **–** One of the most significant public health challenges for the shellfish industry has been the naturally-occurring *Vibrio* bacteria. Unlike *Vibrio cholera (V.c.)*, these bacteria are not associated with sewage or pollution, but naturally become more abundant when waters are warm. However, like *V.c.* these bacteria can cause severe gastroenteritis, diarrhea, nausea and fevers; in people with weak immune systems *Vibrio* can proliferate in the blood, resulting in serious or sometimes deadly septicemia infections.

a. Vibrio bacteria are ubiquitous in seawater around the world. Although primarily associated with warm waters and more prevalent in southern states, illnesses have been recorded in winter months, and in every U.S. coastal state, including Alaska. Vibrios are chitinolytic bacteria, meaning they can consume the shells of crustaceans such as shrimp, crabs, lobster and copepods. The vast majority of Vibrio strains are not pathogenic, but about 1 percent can cause serious illnesses (DePaola 2003). Vibrio illnesses are commonly related to the consumption (or cross contamination) of improperly cooked crabs, shrimp and shellfish, and to wound infections in swimmers that can be severe and sometimes fatal. Vibrios are also often implicated in infections associated with puncture wounds in fish handlers.

b. Vibrio vulnificus (V.v.) is associated with about 113 illnesses in the U.S. annually a year (half of these being from wound infections) and 31 percent of all V.v. infections are fatal (CDC 2013). Infections in individuals without an underlying condition are rare and usually not serious, but the high mortality rate in at-risk consumers presents a significant challenge to the shellfish industry and to the public-health community. Since the disease is so rare, most doctors will never encounter a case in their lifetimes, meaning that diagnosis is often delayed. Without prompt treatment V.v. infections often progress rapidly, sometimes resulting in septicemia, disfiguring surgeries or death. NSSP efforts to combat V.v. illnesses have focused on keeping shellfish cold to limit post-harvest bacterial growth, along with education of at-risk consumers about the importance of avoiding raw shellfish.

c. Vibrio parahemolyticus (V.p.) infections are far more common than V.v., but the illness is generally far less severe (FDA 2012). The FDA (2005) estimates that it takes an average of 100 million cells to trigger symptoms, and the CDC (2002) estimates that 2,800 illnesses in the U.S annually can be attributed to the consumption of raw oysters (FDA 2005). Infection usually results in mild to severe gastroenteritis within four to 90 hours after ingestion, and symptoms are usually self-limiting within two to six days (FDA 2012).

d. Oysters in particular are able to capture very fine particles, filtering many gallons of water daily, meaning they may accumulate bacteria from the waters as they feed, perhaps concentrating pathogens at levels 100 times those in the surrounding seawater. Clams and mussels feed on slightly larger-sized particles and are less likely to accumulate as high a load of pathogenic bacteria. Nonetheless these shellfish species have been implicated in Vibrio-related illnesses as well. Since consumers usually only eat the adductor muscle of scallops, it is rare that they are associated with microbial or algal toxin-related illnesses.

e. Since it is difficult, costly and currently impractical to monitor growing areas for pathogenic strains, most of the efforts have gone into developing handling procedures that minimize proliferation of Vibrios in shellfish, or in treatments that reduce or eliminate the bacteria in the shellfish after they have been harvested.

f. As soon as shellfish are removed from the water, they “clam up” and stop pumping, so whatever bacteria are inside the shellfish will start to proliferate. Vibrios are especially problematic because they can multiply at astonishing rates. At temperatures above 90°F (32°C) Vibrio can double in 15 minutes or less (Chase and Harwood 2011). Fortunately, most Vibrios cease to grow at temperatures below 50°F (10°C), and at lower temperatures they may be rendered into a viable but non-cultureable state (DePaola et al. 2002). If left to warm up on deck in the sun, an insignificant Vibrio load can double many times, turning previously safe shellfish into potential killers in a matter of hours. For this reason, most of the NSSP post-harvest Vibrio controls have focused on shortening the time it takes to bring shellfish under temperature control in order to arrest bacterial growth. Most states have mandated onboard refrigeration or icing, shade and other measures designed to get the shellfish below 50° (10°C) as quickly as possible. Rhode Island developed its first Vibrio Control Plan for the aquaculture industry (i.e. only for oysters) in 2014 (See Appendix 7.1), which regulates time between harvest and refrigeration among other restrictions geared towards keeping oysters safe for consumption. Table 7.1 summarizes actions listed in the Vibrio Plan.

Table 7.1. Key regulatory items for the aquaculture industry in from the Vibrio Control Plan, effective July 1, 2014.

Temperature Contols	Time of Year effective	Area
Deliver to licensed dealer before deterioration	All year	All
Harvest to dealer in less than 18hrs	Sept15-June30	All
Refrigeration or iced **within 5hrs** of start of harvest	July1-Sept14	Non-Sanitation Area
Shading of shellfish immediately upon harvest	July1-Sept14	Non-Sanitation Area
If removed for husbandry purposes for **less than 12hrs**, must be resubmerged for 48hrs or more	July1-Sept14	Non-Sanitation Area
If removed for husbandry purposes for **more than 12hrs**, must be resubmerged for 168hrs or more	July1-Sept14	Non-Sanitation Area
All oysters exposed to air drying must be resubmerged for 168hrs or more	July1-Sept14	Non-Sanitation Area
Delivery to dealer within 2hrs or placed in refrigeration/adequately iced within 2hrs	July1-Sept14	Designated Sanitation Area

a. As with any pathogen infection, those who are immuno-compromised or taking immuno-suppressant medications are at far greater risk of complications due to infection. While it is rare, at-risk consumers run the risk that V.p. infections may progress into blood infections and septicemia, which, in a very small percentage of cases can result in mortality.

730.3. Pesticides, Heavy Metals, and Hydrocarbons

1. Numerous metals and organic compounds can bio-accumulate in shellfish at levels that could potentially cause health effects in consumers. Many of these compounds tend to be attracted to particles, adsorbing onto surfaces and facilitating their capture and assimilation by filter-feeding shellfish. Metals from natural or industrial sources can be accumulated at different rates depending on a number of factors, including the species of shellfish and the season.

2. Fortunately, modern day discharges of these toxins from municipal and industrial wastewater discharges are strictly regulated. Urban stormwater runoff, particularly from industrial sites and highways, is another well documented source of metals and petroleum hydrocarbons. These pollution sources have more recently been brought under Clean Water Act regulations with promulgation of stormwater general permits. Decades of industrial or mining discharges however have left their legacy in the form of contaminated sediments that can be re-mobilized into the water column by dredging. EvenBut even naturally-occurring metals like cadmium can be harmful to humans when it accumulates in shellfish harvested in certain areas where the metal is naturally abundant such as the Pacific Northwest.
3. Some metals can cause adverse health impacts in humans, including mercury, arsenic, cadmium, lead and chromium. On the other hand, several metals bio-accumulate at levels that have been linked to positive health impacts, including iron, copper and zinc (Dong 2009).
4. A seemingly endless list of chemicals, pesticides and hydrocarbons can potentially cause toxicity. The FDA has established action levels and guidance levels for poisonous or deleterious substances to control the levels of contaminants in food, including shellfish (FDA Federal Register, 1977; FDA, 1985). Action levels represent limits at which FDA will take action to remove shellfish from the market. As new data become available, the list of deleterious substances is revised and new limits are published in the Federal Register and in the Model Ordinance. There are also regulatory levels for a handful of metals established by the Codex Alimentarius Commisssion (CODEX) and different levels established by the European Union for international trade in shellfish.
5. A lot of media coverage has focused on mercury levels in fish, with concerns being raised about fish consumption by pregnant women and young children. Shellfish consumers should be relieved to learn that a recent survey of heavy metals (including mercury) in clams and oysters gathered from up and down the East Coast revealed that levels of heavy metals are well below levels of concern (Levitt, unpublished data).

Section 740. Post-Harvest Processing

1. The FDA has tried to push the industry towards mandatory post-harvest-processing (PHP) in an effort to reduce or eliminate the *Vibrio* load in shellfish. There are currently four ISSC-approved PHP methods: high-pressure processing, cold pasteurization®, extreme freezing and irradiation. Each of these processes kills the shellfish and typically results in textural changes, however, the FDA insists that these treatments preserve the characteristics of raw shellfish.
2. In 1985 the FDA unilaterally mandated PHP treatment for all Gulf Coast oysters harvested between April and October. However, Congressional action forced the FDA to reconsider this mandate. The industry is resistant to mandatory PHP requirements because of fears about processing capacity, cost and the impacts on markets. An FDA study revealed that mandatory PHP in the Gulf would force the closure of hundreds of small shellfish dealers who would not be able to install the required processing machinery, resulting in the loss of thousands of jobs. Industry members also fear that if they are permitted to offer only processed, dead shellfish the markets would be flooded with low-cost, processed shellfish from Asia, and that the raw-bar trade would suffer.
3. Post-harvest-processing greatly reduces or eliminates the risk of Vibriosis and is a prudent way for immuno-compromised individuals to safely enjoy “raw” shellfish. Depuration (holding shellfish in filtered UV-treated seawater) is not currently an approved PHP because tests have not demonstrated that *Vibrio* counts are consistently reduced in these systems. Industry is actively seeking processes that reduce the risk of illness while leaving them with a live, safe product for raw consumption. Studies have demonstrated significant reductions in *Vibrio* levels using high-salinity relay and cold-water, high-salinity depuration. Both techniques hold great promise and deserve additional study.

Section 750. Depuration and Relay

1. Shellfish that have become contaminated can often be made safe for consumption by holding them in clean waters until they purge themselves of contaminants. When this is done by moving them from contaminated waters to beds that are clean, it is called "relay." When it is done in tanks on land in water that is filtered and treated, it is called "depuration." Both activities are heavily regulated by the National Shellfish Sanitation Program and the FDA. The rate at which various contaminants will purge from shellfish depends on the type of contaminant, the species of shellfish and the water temperature.

2. Depuration has been practiced in various ways since 1928, when researchers in Great Britain took mussels contaminated with sewage and held them in tanks with chlorinated seawater until they could be safely consumed (Canzonier 1991). Much of the cutting-edge research on shellfish depuration was done in the FDA's lab in Warwick, R.I. in the 1960s (Cabelli and Heffernan 1971). More recently, micro-filtration, ozone and UV-light treatment have also been used to sterilize seawater. These treatments are quite effective for the removal of bacterial contaminants, provided the initial loads are not excessive and the water is warm enough to encourage normal feeding behavior in the shellfish. Oxidants (such as chlorine, ozone, bromine, peroxide and UV light) will destroy microbial pathogens in seawater; if conditions (salinity, temperature, oxygen) are appropriate for shellfish feeding, bacterial pathogens will typically drop to safe levels in a matter of days (Schneider *et al.* 2009).

3. Several studies have indicated that viral depuration takes longer, and for certain types of viruses, may not be successful in a cost-effective period of time (Le Guyader *et al.* 2006). There is the possibility that certain viral contaminants may bind to the shellfish tissue, or perhaps even become incorporated in cells or vacuoles within the tissues. The time scales for the depuration of metals can be quite protracted and variable. Some studies seem to indicate that *Vibrio* bacteria may be resistant to depuration, although this is an area of active research.

4. Relay of shellfish from contaminated waters into clean waters is widely used as a means to purify shellfish that are mildly contaminated with wastewater microbes. The classification of the source harvest area and the receiving beds, as well as the record keeping and patrol requirements are established by the NSSP and enforced by the State Shellfish Control Authority (SSCA). Relays from mildly-contaminated warm waters (above 50°F or 10°C) can purify shellfish in as little as 24 to 48 hours, so authorities typically require relay periods of two to four weeks. In some jurisdictions relay periods of six to 12 months are mandated. The SSCA is responsible for ensuring that shellfish are safe for consumption following relay (Chalek, 2013).

Section 760. Avoiding Illness from Shellfish

1. In the United States, the commercial shellfish supply is rigidly regulated and monitored by the Food and Drug Administration (FDA) working in conjunction with state public-health agencies and industry. The safety of shellfish can be impacted at virtually every step of the supply chain, and proper handling is vital for insuring that shellfish remain wholesome and uncontaminated. The state regulatory agencies must sample and assess water quality, establish harvest-area controls and patrol harvest areas. Harvesters need to obey harvest-area restrictions and ensure that shellfish are tagged and chilled appropriately. Dealers must track and process shellfish according to strict FDA Hazard Analysis and Critical Control Point procedures (HACCP) (FDA 2011). Extensive record keeping is required at every transfer step, and constant temperature control is essential to ensure that shellfish remain safe.

2. Even the restaurateurs, retailers and end-consumers have responsibilities to ensure shellfish remain safe. The most important consideration is maintaining the temperature below 50°F (10°C) so that microbial pathogens (particularly *Vibrios*) don't proliferate. When purchasing shellfish at a retail outlet, consumers should make sure they have a cooler and icepacks handy for the ride home, and they should select shellfish whose shells are tightly closed (or at least ones that close when tapped). Fresh shellfish should not smell fishy, nor should there be an odor of decay. Perhaps most

importantly, consumers who are immuno-compromised should choose only cooked or post-harvest-processed shellfish. Most pathogens can be eliminated by properly cooking shellfish to an internal temperature of at least 145°F (63°C) for at least 15 seconds. (FDA 2011).

3. For those who enjoy gathering shellfish recreationally, it is important to take the time to check with your state regulators to ensure that the area you are harvesting from is in the "open" classification and that there are no advisories in place regarding harmful algal blooms or harvest closures because of excessive rainfall or even a malfunction at a wastewater treatment plant. Recreational harvesters should bring a cooler with ice packs and make every effort to keep shellfish below 50° until they are consumed.

Table 7.2. RI Department of Health recommendations for shellfish consumption.

RI Department of Health Recommendations for eating shellfish
Do not eat raw shellfish
Cook all shellfish thoroughly
For clams, oysters and mussels: Boil for 5 minutesafter shells open OR steam for 9 minutes
Do not eat clams, oysters, or mussels that do not open after cooking
Boil shucked oysters for at least 3 minutes OR fry in oil that is 375degress for 3 minutes
Eat shellfish promptly after cooking
Refrigerate leftovers
Clean surfaces after coming into contact with raw shellfish
Harvest shellfish from approved areas
Refrigerate shellfish immediately after harvest or purchase

Section 770. Health Benefits of Shellfish Consumption

1. Shellfish are easy to digest and high in protein, with far fewer calories from fat than comparable servings of red meat. Shellfish are a healthy addition to a balanced, low-fat diet. While more than 40 percent of the calories in beef and pork can come from fat (mostly saturated and mono-unsaturated fats), in shellfish that number is 15 to 28 percent, and in shellfish these fats are mainly polyunsaturated "good" fats (King *et al.* 1990). See Figure 7.3 which lists health benefits of consuming certain seafood products, including shellfish.

2. Shellfish are an excellent source of essential omega-3 fatty acids, the "heart-healthy" fats shown to have a wide range of health benefits, including improvements in heart health, retinal development and neural development. (Crawford *et al.* 1999, Dong 2001). The American Heart Association recommends eating two servings of fish and shellfish each week to boost intake of omega-3 fatty acids, which will help decrease arrhythmias, prevent coronary heart disease and lower blood pressure.

3. Some concerns have been raised about the cholesterol content of shellfish. Cholesterol is synthesized by the body and used to produce bile acids, sexual hormones and vitamin D. Cholesterol got a bad reputation when it was linked to coronary heart disease and arteriosclerosis. Shrimp and squid have high cholesterol levels, as do egg yolks and meats with high saturated-fat content. Shellfish cooked in butter or cheese will also have higher fat and cholesterol contents, but molluscan shellfish themselves have cholesterol levels that are less than 50 mg per 100 grams, meaning they can be safely consumed by those trying to limit their dietary cholesterol intake (Byrd-Bredbenner *et al.*, 2009).

4. Shellfish are an excellent source of B-complex vitamins and essential trace minerals such as zinc, iron, copper and calcium, compounds common in multi-vitamins (Liston 1980). An estimated 3.3

million Americans and billions worldwide have iron deficiencies that can lead to anemia, but that could be eliminated with small additions of shellfish to their regular diet. Shellfish are notable for their high zinc content, which is required for healthy immune function, wound repair, the development of sexual organs, insulin function and prostate health (Wardlaw and Smith 2009). Copper is essential for hemoglobin and collagen formation, while B-complex vitamins are crucial in nerve development and many other cellular processes.

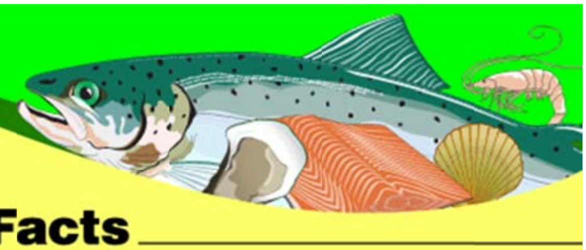
5. A 100-gram serving of oysters will provide more than the recommended daily Dietary Reference Intake of zinc, copper and vitamin B12, as well as 78 percent of the recommended intake of iron (Dong 2001). Clams, scallops and mussels have slightly lower levels of some of these essential minerals, but still are considered excellent sources.

Section 780. Research

1. On the area of human health, examples of recent research include the characterization of populations of the human pathogen V. parahaemolyticus in oysters in Rhode Island waters (Cox and Gomez-Chiarri 2012 and 2013) and the development of diagnostic methods for vibrios pathogenic to humans in shellfish and water (Smolowitz, personal communication).

Table 7.3. Nutrition information for commonly-consumed seafood, including quahogs and oysters (source: SeafoodHealthFacts.org).

Seafood Nutrition Facts



Cooked (by moist or dry heat with no added ingredients), edible weight portion. Percent Daily Values (%DV) are based on a 2,000 calorie diet.

Seafood Serving Size (84 g/3 oz)	Calories	Calories from Fat	Total Fat g	Total Fat %DV	Saturated Fat g	Saturated Fat %DV	Cholesterol mg	Cholesterol %DV	Sodium mg	Sodium %DV	Potassium mg	Potassium %DV	Total Carbohydrate g	Total Carbohydrate %DV	Protein g	Vitamin A %DV	Vitamin C %DV	Calcium %DV	Iron %DV
Blue Crab	100	10	1	2	0	0	95	32	330	14	300	9	0	0	20g	0%	4%	10%	4%
Catfish	130	60	6	9	2	10	50	17	40	2	230	7	0	0	17g	0%	0%	0%	0%
Clams, about 12 small	110	15	1.5	2	0	0	80	27	95	4	470	13	6	2	17g	10%	0%	8%	30%
Cod	90	5	1	2	0	0	50	17	65	3	460	13	0	0	20g	0%	2%	2%	2%
Flounder/Sole	100	15	1.5	2	0	0	55	18	100	4	390	11	0	0	19g	0%	0%	2%	0%
Haddock	100	10	1	2	0	0	70	23	85	4	340	10	0	0	21g	2%	0%	2%	6%
Halibut	120	15	2	3	0	0	40	13	60	3	500	14	0	0	23g	4%	0%	2%	6%
Lobster	80	0	0.5	1	0	0	60	20	320	13	300	9	1	0	17g	2%	0%	6%	2%
Ocean Perch	110	20	2	3	0.5	3	45	15	95	4	290	8	0	0	21g	0%	2%	10%	4%
Orange Roughy	80	5	1	2	0	0	20	7	70	3	340	10	0	0	16g	2%	0%	4%	2%
Oysters, about 12 medium	100	35	4	6	1	5	80	27	300	13	220	6	6	2	10g	0%	6%	6%	45%
Pollock	90	10	1	2	0	0	80	27	110	5	370	11	0	0	20g	2%	0%	0%	2%
Rainbow Trout	140	50	6	9	2	10	55	18	35	1	370	11	0	0	20g	4%	4%	8%	2%
Rockfish	110	15	2	3	0	0	40	13	70	3	440	13	0	0	21g	4%	0%	2%	2%
Salmon, Atlantic/Coho/Sockeye/Chinook	200	90	10	15	2	10	70	23	55	2	430	12	0	0	24g	4%	4%	2%	2%
Salmon, Chum/Pink	130	40	4	6	1	5	70	23	65	3	420	12	0	0	22g	2%	0%	2%	4%
Scallops, about 6 large or 14 small	140	10	1	2	0	0	65	22	310	13	430	12	5	2	27g	2%	0%	4%	14%
Shrimp	100	10	1.5	2	0	0	170	57	240	10	220	6	0	0	21g	4%	4%	6%	10%
Swordfish	120	50	6	9	1.5	8	40	13	100	4	310	9	0	0	16g	2%	2%	0%	6%
Tilapia	110	20	2.5	4	1	5	75	25	30	1	360	10	0	0	22g	0%	2%	0%	2%
Tuna	130	15	1.5	2	0	0	50	17	40	2	480	14	0	0	26g	2%	2%	2%	4%

Seafood provides negligible amounts of *trans* fat, dietary fiber, and sugars.

U.S. Food and Drug Administration
(January 1, 2008)

Section 780. Recommendations

1. No Technical Advisory Committee was established for Section 700 and no recommendations were developed.

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CHAPTER 8. Natural Risks to Shellfish Populations

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Section 800. Introduction

1. A variety of factors are natural risks to shellfish, meaning that they can cause mortality in shellfish or affect their growth and reproduction. These include toxins and pollutants, pathogens, predators, invasive species, and extreme or unusual environmental conditions. Moreover, shellfish can also be a health risk to humans, by accumulating substances or microbes that are harmful to the humans that eat them (See Chapter 7). As filter feeders, shellfish are constantly exposed to a large variety of microbes and substances that can potentially accumulate in oyster tissues if not eliminated by the digestive or the immune systems of these animals. Some of these substances and pathogens are harmful to shellfish, while others may not cause harm to shellfish, but can cause disease in humans that consume raw shellfish. Moreover, although shellfish native to New England waters are adapted to living in challenging environmental conditions, sudden or unusually severe changes in environmental conditions can stress shellfish, affecting their ability to fight and eliminate pathogens and clear toxic substances by depressing their immune and detoxifying systems. The ability of shellfish to deal with environmental stress and pathogens highly depends on their age, genetic make-up, and metabolic resources at the time of the challenge or challenges. For example, adult oysters that have not accumulated enough energetic reserves in the fall, may not be able to survive to the following summer, especially if the winter is unusually long and it was infected with a pathogen such as those that cause Dermo and MSX disease. On another example, while adult oysters are able to survive Roseovarius Oyster Disease, juveniles can succumb to it. On a final example, levels of the human pathogen Vibrio parahaemolyticus in shellfish increase when shellfish are exposed to air (while out of the water), and this increase is faster at warmer air temperatures.

Section 810. Shellfish Issues Identified by Stakeholders

1. Throughout the SMP process, the SMP team met with stakeholders to identify issues and concerns they had regarding all aspects of shellfish, including but not limited to environmental, management, marketing, capacity building, and decision making. The following are the major themes concerning natural risks to shellfish populations. A full list of all issues identified can be found in Appendix 2.2:
   a. There is a need to better understand disease resistance in shellfish.
   b. There is a need to maintain genetic diversity in shellfish stocks in Rhode Island waters.
   c. There is a need to better understand the effects invasive species have on shellfish and associated industries and to develop a management strategy to mitigate negative effects.
   d. There is a need to better understand and mitigate against the risks to shellfish associated with climate change and ocean acidification.
   e. There is a need to understand how predators effect shellfish stocks and industries and consider predator management strategies to protect and possibly increase certain stocks.

Section 820. Natural and Environmental Risks to Shellfish Populations

1. An excellent and very thorough resource compiling information about hazards affecting shellfish has been recently published by the Northeast Regional Aquaculture Center (NRAC; Getchis 2014). In this section, we summarize key points discussed in the NRAC publication, and add some additional information relevant to the management of Rhode Island shellfish resources.

820.1. Climate Change and Environmental Stressors

1. Climate change is the variation in the Earth's climate over time, mainly manifested in changes in water and air temperature, alterations in precipitation, and increases in sea level. Climate change impacts fish and shellfish, their fishers and farmers, and the communities that depend on them (Hollowed *et al.* 2011). Environmental stressors (which are associated with climate change, but can occur due to other natural – or human-induced causes) include salinity, temperature, and pH fluctuations, low dissolved-oxygen concentrations (hypoxia), and habitat alteration. These changes in the environment can also lead to increases in harmful algal blooms, pathogens, and introduced species, and shifts in the species composition, distribution, and abundance of predators, eventually affecting shellfish production. They may also facilitate the spread of diseases into shellfish populations, exacerbate disease where it already exists, or result in the emergence of novel pathogens.
2. In this section we will discuss some of the major threats to shellfish from environmental stressors. Although it is hard to predict what the impacts of climate change will be in local shellfish populations, it is clear that shellfish are likely to experience complex changes in the environment due to climate change and other human influence (such as increased pollution and eutrophication) that may affect their performance. Also, shellfish may be able to handle changes in one of these conditions at a time, but the combination of multiple stressors derived from climate change and other human and natural impacts could have severe impacts on shellfish populations. On the other hand, the negative impacts from changes in one environmental parameter (*e.g.*, ocean acidification) may be diminished by positive impacts of another parameter (*e.g.* temperature). Finally, the impact of these changes may depend on where the shellfish are located (*e.g.* intertidal *versus* subtidal, type of substrate). More research is needed to understand the potential negative and positive impacts of environmental change on local shellfish populations.

820.1.1. Ocean Acidification

1. Acidification resulting from human emissions of carbon dioxide has already lowered and is expected to further lower the pH of seawater in the ocean, making it more acidic (see Waldbusser and Salisbury 2014 for a recent review). Shellfish living in coastal waters are already exposed to large fluctuations in pH, which normally occur in these waters due to biological activity in these nutrient-rich waters. Although shellfish in coastal waters may have evolved tolerance to these pH fluctuations, further acidification due to increased carbon dioxide may increase the amount of time or the timing that shellfish are exposed to more acidic pH, leading to conditions to which shellfish are not adapted to (www.whoi.edu/main/topic/ocean-acidification).

Table 8.1. Selected examples of the responses of molluscan shellfish to ocean acidification (modified from Fabry et al. 2008).

Species	Common Name(s)	CO_2 System Parameters	Sensitivity	Reference
Mytilus edulis	Blue mussel	pH 7.1 / 10 000 ppmv pCO_2 740 ppmv	Shell dissolution, 25% decrease in calcification rate	reviewed in Fabry *et al.* (2008)
Mytilus edulis	Blue mussel	Ω_{arag} = 0.8 for 4 months, pH 7.74, 14C	Increased levels of Vibrio tubiashii in tissues and blood after challenge	Asplund *et al.* (2013)
Crassostrea gigas	Pacific oyster	pCO_2 740 ppmv;	10% decrease in calcification rate	reviewed in Fabry *et al.* 2008
Crassostrea gigas	Pacific oyster	$\Omega_{arag} < 0.8$	Decreased larval production and midstage growth in hatcheries	Barton *et al.* (2012)
Mytilus	Mediterranean	pH 7.3, ~ 5000	Reduced metabolism, growth	reviewed in Fabry

galloprovincialis	Mussel	ppmv	rate	*et al.* (2008)
Placopecten magellanicus	Giant scallop	pH < 8.0	Decrease in fertilization and embryo development	reviewed in Fabry *et al.* (2008)
Mercenaria mercenaria	Northern quahog	$\Omega_{arag} = 0.3$	Juvenile shell dissolution leading to increased mortality	reviewed in Fabry *et al.* (2008)
Argopecten irradians, Crassostrea virginica, Mercenaria mercenary	Bay scallop, Eastern oyster, Northern quahog	pCO_2 66 Pa, 650 ppm	Decreased survival of larvae and delayed metamorphosis in quahogs and scallops; lower growth and delayed metamorphosis in oysters; Eastern oysters more resilient.	Talmage *et al.* (2009); Gobler and Talmage (2014)

Note: The stability of calcium carbonate in water is defined by a term called omega (Ω). Briefly when Ω for aragonite (a form of calcium carbonate that is a frequent component of shellfish shells) is high (Ωaragonite > 1), shell formation is favored; when Ω for aragonite is low (Ωaragonite < 1) the water is termed "corrosive" because dissolution of shells will begin to occur. The levels of Ωaragonite depend, among other things, on pH (the lower the pH the lower that Ωaragonite would be). Levels of pH depend on levels of pCO2 (the higher pCO2, the lower the pH) (Waldbusser and Salisbury 2014). The pH is considered more acidic for seawater when it falls below 8.

2. The effects of ocean acidification can be particularly severe to calcifying organisms, such as corals and shellfish, by affecting the size and weight of shells and skeletons (Table 8.1, see review by Waldbusser and Salisbury 2014). When CO_2 dissolves in seawater, the water chemistry changes such that fewer carbonate ions, the primary building blocks for shells, are available for uptake by shellfish, so they have to spend more energy to build shells. Also, larval and juvenile shellfish shells may dissolve as ocean pH decreases, due to shifts in the chemical reactions that drive the equilibrium of carbonate ions in water. There are differences in susceptibility between species of shellfish and stages of development (Gobler and Talmage 2014, Ries *et al.* 2009). The larval stages of shellfish are highly sensitive to acidification, but negative effects on shellfish performance have also been observed in juveniles and adults. These negative effects are not limited to growth and survival, but also to reproduction, early development, and immune defenses (Harvey *et al.* 2013; Kroecker *et al.* 2013; Waldbusser and Salisbury 2014). Furthermore, ocean acidification can change the quality and quantity of phytoplankton. Not enough is known about the effects of ocean acidification on adult shellfish populations, and how ocean acidification may interact with other simultaneous changes in the environment, ocean warming in particular (Harvey *et al.* 2013). For example, there is some recent evidence that the effects of ocean acidification on shellfish shells are highly dependent on temperature (the effects of acidification on growth are less severe at higher temperatures), as shown in laboratory experiments performed with adult bay mussels (*Mytilus galloprovincialis*) in California (Kroeker *et al.* 2014). There is also evidence in mussels that the negative impacts of ocean acidification on shellfish are minimized when food supply is abundant (Thomsen *et al.* 2013). More research is needed in this area.

820.1.2. Warming Water Temperatures

1. One of the primary direct consequences of climate change is increasing ocean temperature (Levitus *et al*. 2000). Sea surface temperature increased over the 20th century and continues to rise, evidenced by a ~0.45 °C increase per decade in Narragansett Bay since the 1970s, an increase that is more evident in the winter (Figure 7.1; Nixon *et al.* 2009). Changes in ocean or coastal temperature can lead to changes in species distribution, by allowing species to colonize new areas in which they could not previously live or reproduce (reviewed in Doney *et al.* 2012), or conversely the temperature regime can make previously suitable habitat less unsuitable leading to the loss of these species. In Rhode Island waters, this warming trend and changes in other climatological conditions are associated with a change in the timing and the composition of phytoplankton blooms. In particular, the winter/spring bloom, an important source of food for local shellfish, has decreased and even disappeared in some years. Changes in the quantity and quality of phytoplankton can impact the performance of shellfish

that feed on them. These temperature increases may also affect shellfish health if increasing water temperature leads to stress or an increase in pathogen levels. For example, the Eastern oyster was severely afflicted by a southern oyster parasite causing Dermo disease. A 1998 disease survey found this parasite, which was rarely seen north of the Chesapeake Bay until the 1990s, in a large percentage of the oysters in wild oyster populations in Rhode Island. The spread of Dermo is attributed to warming waters by having extended the northern limit of the parasite's range through Rhode Island and up into Maine waters (e.g. Cook *et al.* 1998). Not all effects of temperature increases may be negative; temperature increases may lead to increased growth in shellfish, by extending the season in which they feed, or decreases in the levels of certain predators or pathogens, if these pathogens or predators are better adapted to colder waters.

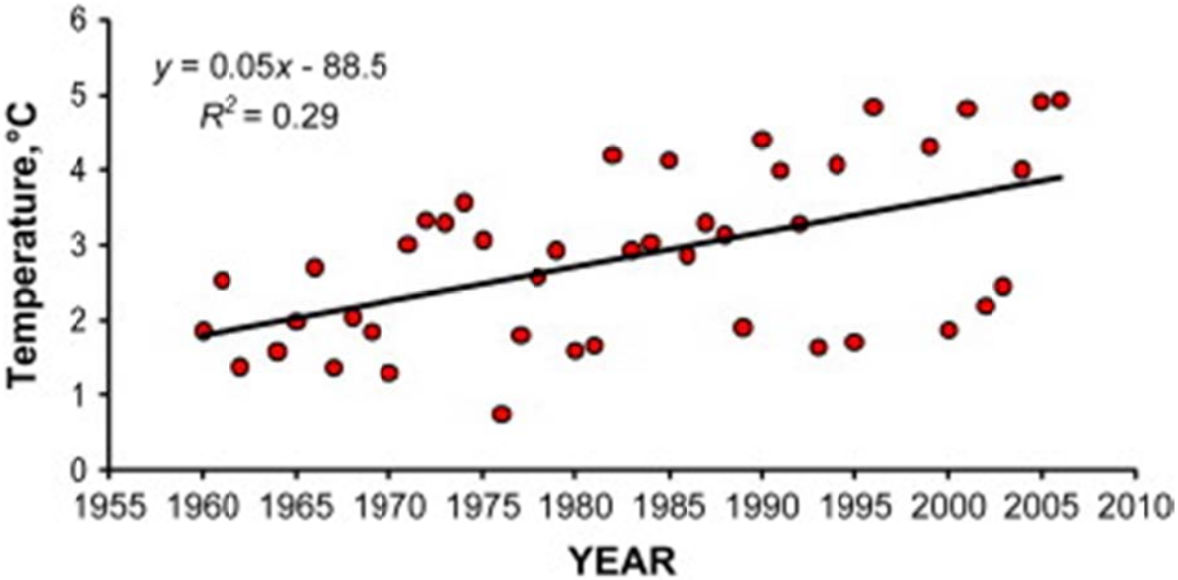

Figure 8.1. Mean surface water temperatures during December, January and February in the middle of the West Passage of Narragansett Bay near Fox Is. as recorded by the sampling of D. Pratt, T.J. Smayda, and the GSO plankton monitoring program (data at http://www.narrbay.org/d_projects/plankton-tsv/plankton-tsv.htm and http://www.gso.uri.edu/phytoplankton/, from Nixon et al. 2009).

820.1.3. Sea Level Rise

1. Sea level rise is caused in large part by warming oceans, as warm water actually expands in size. In response to global warming, the rate of sea level rise has risen at higher rates (about triple) during the 20^{th} century (Rahmstorf 2007). In Rhode Island, the average rate of sea level rise (as recorded at tide gauges in Newport by NOAA, Figure 8.2) from 1930 to 2006 was 2.58 mm per year (0.85 feet in 100 years), and is predicted to rise between 3 – 5 feet from 2012 to 2100 based on available models (RI CRMC). The potential effects of sea level rise on shellfish populations are largely unknown, but it could potentially lead to changes in the distribution of available habitat, as well as changes in patterns of predation and air exposure of intertidal populations, which could then affect shellfish growth patterns and disease susceptibility in these populations (NOAA 2012).

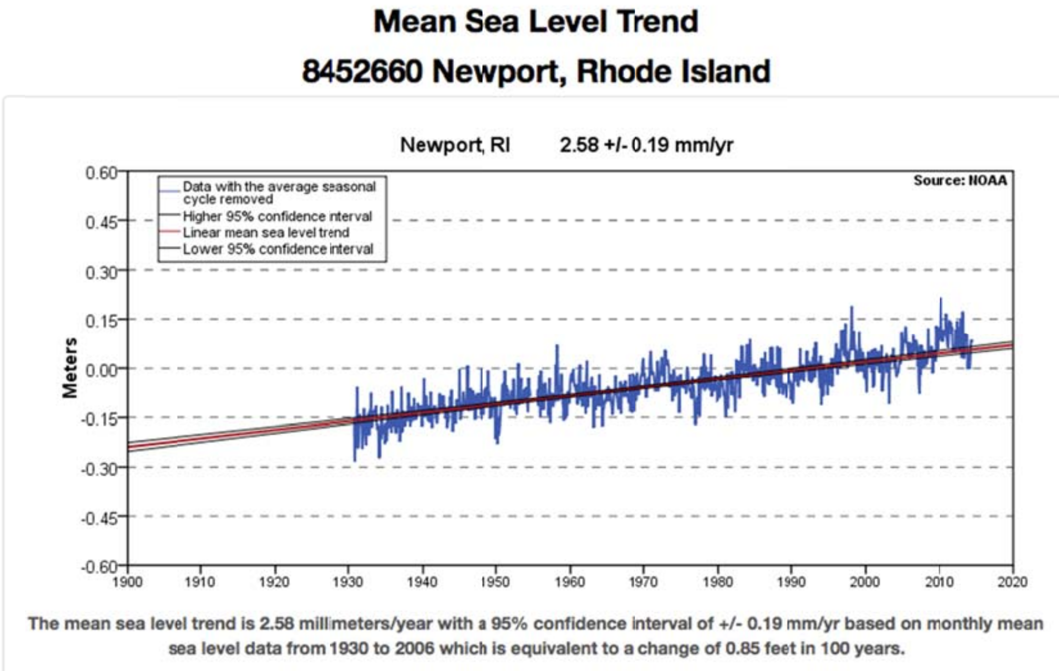

Figure 8.2. Rhode Island sea level recorded at tide gauges in Newport by NOAA (data from http://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=8452660).

820.1.4. Increased Storm Frequency and Severity

1. Climate change has been associated with increased frequency and severity of storms. In addition to losses in gear and structures used in aquaculture leases, storms and hurricanes will affect shellfish habitat and place stress on populations, increasing the chances of disease outbreaks (*e.g.* Feehan *et al.* 2012). For instance, changes in salinity due to either freshwater input on coastal waters or saltwater intrusion in coastal ponds can lead to disease outbreaks, by bringing new pathogens in storm runoff or favoring conditions for certain pathogens (for example, several of the oyster pathogens described in Table 8.3 only seriously affect oysters when salinity is >15 - 20 psu). Increased sedimentation can affect shellfish (mainly oysters) by impacting their ability to filter feed.

820.1.5. Eutrophication

1. Eutrophication is characterized by excessive plant and algal growth due to the increased availability of one or more limiting growth factors needed for photosynthesis (Andersen *et al.* 2006). Nutrient enrichments of water can also cause a variety of water quality problems. Acoording to Smith *et. al.* (1999), the following are effects of eutrophication on shellfish populations:

   a. Increased biomass of marine phytoplankton and epiphytic algae

   b. Shifts in phytoplankton species composition to taxa that may be toxic or inedible (e.g., bloom-forming dinoflagellates)

   c. Changes in macroalgal production, biomass, and species composition (loss of habitat)

   d. Changes in vascular plant production, biomass, and species composition (loss of habitat)

   e. Elevated pH and decreased dissolved oxygen in the water column

   f. Shifts in composition of predator species

   g. Increased probability of kills of recreationally and commercially important animal species due to hypoxia

2. Not all the effects of eutrophication on shellfish are negative (an increase on phytoplankton blooms signifies more food in the water for most shellfish), and the effects are variable between species. Eutrophication, however, is a leading cause of hypoxia, loss of habitat submerged aquatic vegetation, and toxic or harmful algal blooms (Bricker *et al.* 2008).

820.1.6. Low Oxygen Levels and/or Hypoxia

1. Hypoxia (low dissolved oxygen concentration in water) is another secondary effect of the increase in phytoplankton biomass that results from eutrophication. This is a concern in many coastal growing areas, especially those in shallow sheltered (not well mixed) waters with excess nutrient inputs. The increased phytoplankton production (algal blooms) increases the amount of organic material that is deposited to the bottom via sedimentation and the microbial processes associated with the decay of this organic material consume oxygen causing a decrease in the oxygen concentration in surrounding waters (Howarth et al. 2011).

    a. Fishes are more sensitive to hypoxia than crustaceans and echinoderms, while annelids and molluscs are the most tolerant (Vaquer-Sunyer and Duarte 2008). Adult clams and oysters are among the most hypoxia tolerant marine organisms, in part because they can switch to anaerobic metabolic pathways (Stickle et al. 1989). Larval shellfish are more sensitive to low oxygen levels (e.g. Baker and Mann 1994). Most shellfish can tolerate a night of hypoxia, but sublethal impacts may start to appear when oxygen concentrations dip below 3 mg/L (Vaquer-Sunyer and Duarte 2008) and repeated hypoxic events will lead to stress, increased susceptibility to diseases, impaired growth, and may cause direct mortalities (Diaz and Rosenberg 2008). Bivalve growth may be depressed when oxygen levels dip below 1.5 mg/L (Grey et al. 2002)

    b. Potential management strategies – As discussed in other sections, a concerted effort is being made to manage nitrogen inputs in coastal Rhode Island waters and reduce coastal eutrophication and the decreases in oxygen (hypoxia) and increases in pH resulting from it. In addition to management of water quality, selective breeding may be useful in producing strains of shellfish that are more resistant to the negative effects of ocean acidification (Parker et al. 2013) and hypoxia (Samain et al. 2007). Although several strains of oysters selectively bred for disease resistance are available (see below), it is unknown how these strains may perform under the pressure of climate change. The performance of oyster strains selectively bred for fast-growth and resistance to oyster diseases is highly influenced by the environment (including food availability), suggesting the existence of trade-offs between traits. For example, the performance of triploid oysters is dependent on water quality, temperature, and food availability (Harding 2007, Nell 2002), with triploids showing faster growth than diploids when food is abundant, but experiencing relatively higher mortality during periods of low food availability (Garnier-Gere et al. 2002, De Decker et al. 2011). This means that shellfish farmers' choice of oyster strain is likely to be an important decision, particularly in the face of climate change.

2. Harmful Algal Blooms (HABs) – There are many species of phytoplankton that produce toxins and noxious substances to either shellfish or humans. In some cases, blooms of some of these species can be recognized by the color of the bloom (e.g. red tide).

    a. Harmful Algal Blooms (reviewed by Shumway 1990) by species like *Aerococcus anophagefferens* (brown tide), *Cochlodinium polykrikoides* (rust tide), *Karlodinium veneficum,* and *Alexandrium monilatum* can impact the shellfish themselves by interfering with water filtration and food acquisition, or occasionally causing mass mortalities (Hegaret *et al.* 2007, Shumway *et al.* 2006). Although there have been no closures of shellfishing areas due to marine HABs in Rhode Island state waters (http://www.dem.ri.gov/bart/habs.htm), the presence of toxic *Alexandrium* species has been reported (Borkman *et al.* 2014). Moreover, the RI Department of Health closely follows up cyanobacterial blooms (http://www.health.ri.gov/healthrisks/harmfulalgaeblooms/), which are more common in freshwater, and may issue beach closures when a bloom is reported. However, there is no information regarding the role of HABs on shellfish mortalities or decreased performance in

Rhode Island waters. Improved monitoring of HABs and more research are needed to determine the potential risk of HABs to shellfishing in Rhode Island.

b. Management approaches available to growers and resource managers include controling eutrophication (which contribute to HABs), selecting growing areas with infrequent HABs, identifying or developing environmental predictors of HABs, and monitoring for toxins in the tissues or blooms in the environment.

3. Biofouling – This refers to the colonization of surfaces, mopst commonly in aquaculture operations, by microbial or animal species, which, if severe, will lead to a decrease in the amount of water flow (and therefore nutrients and oxygenation) reaching shellfish (Getchis 2014). Biofouling may affect species ability to manage environmental challenges. Monitoring and maintenance of gear is key to successfully manage biofouling.

820.2. Shellfish Parasites and Bacteria

1. Major infectious diseases affecting shellfish in Rhode Island waters. A variety of bacterial and parasitic pathogens affect shellfish in Rhode Island (Table 8.3; Getchis 2014). In general, oysters are more susceptible to disease than bay scallops or soft-shell clams, while quahogs are the most resistant of all. Little is known about diseases affecting whelks. For more details on each of these diseases, see Getchis (2014).

Table 8.2. Major infectious diseases affecting shellfish in Rhode Island waters

Shellfish	Disease	Pathogen (type)	Effects on Shellfish
Eastern oysters	Dermo	*Perkinsus marinus* (protozoan parasite)	Mortality of adult oysters (2 years or more) in late summer and fall, watery or emaciated meats. Strains of oysters with moderate resistance to Dermo and high resistance to MSX are available. In Rhode Island, cultured oysters have in general low prevalence of the disease, and oysters are usually sold before the disease can cause serious mortalities in farms. Strains of oysters with moderate resistant to Dermo, such as NEH, are available (Rawson *et al.* 2010).
Eastern oysters	MSX (Multinucleated Sphere Unknown)	*Haplosporidium nelsoni* (protozoan parasite)	Mortality of adult oysters in late summer and fall, watery meats. Strains of oysters resistant to MSX are available (NEH; Rawson *et al.* 2010).
Eastern oysters	SSO (Seaside Organism)	*Haplosporidium costale* (protozoan parasite)	Mortality of adult oysters in late spring, watery meats.
Eastern oysters	ROD (Roseovarius Oyster Disease)	*Roseovarius crassostreae* (bacteria)	Heavy impact on juvenile oysters less than 25 mm in shell height during summer months. Signs of disease include cessation of growth, one valve becomes larger than the other, and dark rings of shell material are deposited on the inner side of shell surrounding mantle. Management: Purchase seed early in the season and grow in upwellers so it reaches a size >25mm (1 inch) before water temperatures reach 20C. Oyster strains resistant to ROD are available (Flowers and University of Maine Select; Rawson *et al.* 2010)

Shellfish	Disease	Pathogen (type)	Effects on Shellfish
Northern quahogs	QPX (Quahog Parasite Unknown)	Parasite belonging to phylum *Labyrinthulomycota* (protozoan)	Known to cause severe mortality of cultured quahogs, mainly in some growing areas of Cape Cod. In Rhode Island, it has only been reported in cultured quahogs in one lease in the early 2000s, and the disease was contained. Signs include gaping quahogs that surface to the top of the sediment, presence of nodules on meat. Quahogs from southern locations are more susceptible to the effects of the disease, so the use of local broodstock is recommended, as well as the removal of infected clams and the fallowing of growing areas after outbreaks for at least 2 years.
Eastern oysters, blue mussels		Digenean trematodes (several species)	Castration of broodstock in severe infestations.
Blue mussels, northern quahogs, bay scallops		Pea crabs	Decreased growth when infected by large females.
Bay scallops	Hinge ligament disease	Gliding bacteria	Loose hinges in juvenile bivalves due to bacteria destroying the ligament.
Bay scallops	Bacterial infections	Chlamydia and rickettsia	Can cause heavy mortalities in larval and early juveniles, no negative effect detected in adults.
Soft shell clams		Hemocytic neoplasia	Relatively high prevalence in soft-shell clams in Rhode Island. Can cause decreased growth and mortality in adult clams.
Shellfish Hatcheries (all species)	Hatchery mortality	*Vibrio* spp. and other pathogenic bacteria	Larval mortality in hatcheries, which at times could lead to heavy losses.

820.2.1. Methods to Minimize Risk of Parasites and Bacteria

1. Closely monitor the health of wild, cultured, and restored shellfish populations in order to be able to adequately manage populations in cases of sudden and unusual mortalities (rapid response). Establish stable and consistent funding for monitoring programs focusing on following up selected sentinel populations of important shellfish species.
2. Improve diagnostic tools and conduct research to better understand the factors, such as climate and anthropogenic influences, that drive disease in fish and shellfish.
3. In order to improve water quality and minimize stress on shellfish populations, reduce nutrient and pollutant inputs to coastal waters to restore water quality, including healthy dissolved oxygen levels. Monitor water quality routinely and keep good records that will help identify unusual changes in environmental parameters.
4. Prevent or minimize the amplification and transplantation of pathogens, or the introduction of new disease agents, that may occur through aquaculture and restoration activities (see role of Biosecurity Board section below).
5. Conserve populations of shellfish, preserving both abundance and genetic diversity, to maintain a maximum capacity for adaptation to changing climate and disease challenges.
6. Adopt fisheries and aquaculture management strategies that facilitate the evolution of disease resistance in natural populations; for example, by protection of older survivors of multiple disease

challenges as key broodstock (spawning sanctuaries). Investigate the impact of the use of disease-resistant strains by public and private aquaculture on wild populations of shellfish.

820.3. Predation

1. There are a large number of potential predators that consume shellfish, especially when the shellfish are small in size (juveniles). Predators can include birds, starfish, crabs, fish, and predatory gastropods such as whelks or oyster drills (See Table 7.4).

Table 8.3. The most common predators of shellfish in the Northeast US (Flimlin and Beal 1993, Getchis 2014).

Predator Class	Name(s) of predator(s)	Shellfish Species Affected	Impact
Birds	Oystercatchers, gulls, red knots, looks, ducks	Eastern oysters, northern quahogs, bay scallops, blue mussels, softshell clams	Consume shellfish whole – very limited impact to protected shellfish in culture facilities or subtidal locations.
Finfish	Summer flounder, northern puffer, cunner, scup/progy	Eastern oysters, northern quahogs, bay scallops, blue mussels, softshell clams	Limited impact due to low population sizes of these predators.
Echinoderms	Seastar, *Asterias forbesi, A. rubens,* and *A. vulgaris*	Eastern oysters, northern quahogs, bay scallops, blue mussels	Heavy impact when seastar populations are abundant, which happens periodically. As of 2011, the seastar population in Rhode Island coastal waters had crashed due to Seastar wasting disease. As of 2014, there are indications that the populations may be recovering. The seastar pulls the two shells or valves of a bivalve apart with its five arms and inserts its stomach into the exposed shell cavity, secreting digestive juices that destroy the tissues and absorbing the dissolved meat.
Sponges	Boring Sponge (*Cliona* spp.)	Eastern oysters mainly	Boring sponges grow on bivalve shells, burrowing into the shells and weakening the shellfish. They also increase the vulnerability to predators
Crustaceans (crabs)	Asian shore crabs, *Hemigrapsus sanguineus;* Atlantic rock crabs, *Cancer irroratus;* Blue crabs, *Callinectes sapidus;* Green crabs, *Carcinus maenas;* Lady crabs *Callinectes sapidus;* Jonah crabs, *Cancer borealis*	Eastern oysters, northern quahogs, soft shell clams, bay scallops, blue mussels	Heavy impact, depending on the species and size and of the crab. Crabs can effectively prey on juvenile and adult shellfish on substrate or in gear. Many of these species are only a concern during the summer months.

Predator Class	Name(s) of predator(s)	Shellfish Species Affected	Impact
	Mud crabs, *Dsypanopeus sayi, Panopeus herbstii, Rhithropanopeus harnsii*	Eastern oysters, northern quahogs, soft shell clams, bay scallops	Year round threat to small juvenile shellfish on bottom and gear
	Horseshoe crabs, *Limulus polyphemus,* American lobsters, *Homarus americanus*	Eastern oysters, northern quahogs, soft shell clams, blue mussels	A threat to wild and unprotected cultured bivalve shellfish of all sizes on bottom. Currently, limited impact due to low populations sizes of these predators in bay waters.
Gastropods	Atlantic oyster drill, *Urosalpinx cinerea;* Thick lip drill *Eupleura caudate*	Eastern oysters, northern quahogs, soft shell clams, blue mussels	A threat to wild and unprotected cultured bivalve shellfish of all sizes on bottom.
	Whelks, *Busycon carica, Busycotypus canaliculatum,*	Eastern oysters, northern quahogs, soft shell clams	Potentially heavy impact, effective burrowers that can prey on unprotected bivalves (mainly clams) of all sizes on or in bottom substrates by chipping at the valves, inserting a proboscis, and digesting the meats.
	Moon snails *Neverita duplicatus, Euspira heros*	Eastern oysters, northern quahogs, soft shell clams	These snails can bore through the shell, leaving a characteristic tiny hole through the valve.
Polychaete worms	Mud blister worm *Polydora* spp.; Sand worm *Alitta virens;* clam worm *A. succinea;* blood worm *Glycera dibranchiate*	Eastern oysters, soft shell clams, bay scallops	The mud blister worm has a heavy impact on wild and cultured oysters in many sites in Rhode Island, mainly by affecting growth, the appearance of the shell (it burrows into the shell of oysters, leaving a hole filled with mud or feces and covered with shell) and by making the shells flaky and brittle so they break during shucking. Shellfish partially covered by sediments have lower levels of infestation.
Platyhelminths	Oyster flatworm *Stylochus Ellipticus*	Eastern oysters	Meat consumption after penetration through gaps in oyster valves, mainly in summer and fall.
Nemerteans	Milk ribbon worm	Soft shell clams	Mostly prey on juvenile clams in offshore locations, injecting a toxin that digests the meats and leaving a gaping clam.

820.3.1. Protecting Shellfish from Predation

1. Growers use several barriers, such as cages, mesh bags, or netting, to protect shellfish against predators (Leavitt and Burt 2007). Clams are grown under netting until large enough to survive most common predators. In order to be effective, the gear has to be inspected for small predators and cleaned of biofouling routinely. Alternatively, depending on the site, growing shellfish on the bottom may still be profitable, since losses due to predation are compensated by lower capital and labor costs.

2. Other predator control strategies relevant to managing predators affecting wild shellfish populations may include placing baited traps (somewhat effective for starfish, whelks, and crabs), or mopping (dragging weighted cloth mops over the grounds to entangle starfish). Growers have also tried covering mussel rafts with netting to exclude diving ducks. In general, the effectiveness of these strategies is low.
3. Although in an aquaculture setting gear can protect shellfish from large predators, some predators can penetrate into the gear as juveniles, and, if the shellfish in the gear is not routinely monitored and cleaned, these predators (crabs and starfish in particular) then grow rapidly reaching a size that can cause serious damage inside the gear. Monitoring and maintenance of gear is key to successfully manage predators. For wild populations, management practices can be established to selectively fish for predators of important commercial bivalve species.

820.4. Invasive Species

1. Aquatic invasive species are aquatic organisms that invade ecosystems outside their historic range with negative impacts to the diversity of these ecosystems, and in particular native species. Aquatic invasive species can pose a serious threat to the biological diversity of coastal waters and impact aquaculture and fisheries through competition for resources and biofouling. Examples of marine aquatic invaders that have become established in Rhode Island include various species of sea squirts and crabs, such as the European green crab (*Carcinus maenas*), Asian shore crab (*Hemigrapsus sanguineus*), and Chinese mitten crab (*Eriocheir sinensis).* Other invasive species are the lace bryozoan (*Membranipora membranacea*), codium (*Codium fragile*), and the red macroalgae (*Grateloupia turuturu*). Shellfish pathogens such as *Perkinsus marinus,* which causes dermo disease in oysters, are also considered invasive species (RIAIS plan 2007; http://www.rimeis.org/).
2. Management of invasive species involves a coordinated approach at providing regulations that minimize the risk of introduction of invasive species (for example, by regulation of ballast water discharge and treatment, the interstate transport of shellfish species, and the culture of non-native species), intensive monitoring efforts that identify invasions early during the process, and the development and implementation of eradication techniques if available and feasible (http://www.crmc.ri.gov/invasives.html). A good source of information on locally invasive species is the Rhode Island Marine & Estuarine Invasive Species Site (http://www.rimeis.org/).

Section 830. Management of Risks

1. Due to the impact of the risks described above to the health of shellfish populations, as well as the health of humans consuming shellfish, it is critical to establish regulations and best management practices that effectively manage these risks. Since the goals are different, different federal and state agencies regulate natural risks to shellfish (with the goal of protecting shellfish resources) and human health risks from consuming shellfish (with the goal of protecting humans). Both types of risks, however, have critical impacts on the livelihood of fishermen and aquaculturists, since outbreaks of disease in humans lead to closures of the fishery, with the corresponding negative impacts on the industry due to loss of revenue and effects on public perception on the safety of eating shellfish
2. *CRMC Biosecurity Board*

   The Biosecurity Board is an advisory committee under the jurisdiction of the Coastal Resources Management Council (CRMC) that provides advice to the Rhode Island Department of Environmental Management Fish and Wildlife on issues related to the biosecurity of aquatic animals in State waters. The committee is composed of at least one representative from CRMC, one from RIDEM Fish and Wildlife, a finfish and shellfish pathologist, the State veterinarian, representatives from the fishing and aquaculture industries, and representatives of other relevant stakeholder groups (Title 20, Chapter 20-10, Section 20-10-1.1 of the State of Rhode Island General Laws). A key example of an area in which the Biosecurity Board provides advice is on issues related to the intra and interstate transportation of shellfish. Shellfish seed are commonly grown in hatcheries and imported to Rhode Island for use in shellfish culture operations. The Biosecurity Board makes recommendations on the establishment of regulations and processes that govern the importation of seed for the industry, with the goal of minimizing the risk of importation of shellfish pathogens and other organisms (predators and potentially invasive species) associated with shellfish.

3. *CRMC Aquatic Nuisance Species Task Force*

   The CRMC is tasked with the management of invasive species in Rhode Island, and has developed an Aquatic Invasive Species Management Plan (2007) with the advice of the Aquatic Nuisance Species Task Force. Amongst the efforts to manage invasive species, the CRMC has led the development of educational tools geared to involve the public in aiding in the quick recognition of invasive species.

Section 840. Research

1. There is a wealth of recent research relevant to the management of natural risks on Rhode Island shellfish populations. Some of this research has been done in the areas of environmental change, especially on the effects of eutrophication and hypoxia on benthic populations in Narragansett Bay (e.g. Fulweiler *et al.* 2013, Smith *et al.* 2010), as well as on the biology and ecology of harmful algal blooms (e.g. Borkman *et al.* 2012, Harvey and Menden-Deuer 2012). Another active area of research is that of shellfish diseases, thanks to investments in Aquatic Pathology at the University of Rhode Island and Roger Williams University. Much of the shellfish disease research is focused on the management of infectious diseases in oysters and northern quahogs through improved knowledge on host-pathogen interactions (e.g. Hegaret *et al.* 2009, Smolowitz 2013) and mechanisms of disease resistance (reviewed in Gomez-Chiarri *et al.* in press), the development of diagnostic techniques (e.g. Faveri *et al.* 2009, Wilbur *et al.* 2013), and the use of probiotics and other techniques for management of vibriosis in shellfish hatcheries (Karim *et al.* 2013, Pietrak *et al.* 2010). There is also active research on the impacts of invasive species in coastal ecosystems in Rhode Island (e.g. Altieri *et al.* 2010, Newton *et al.* 2013), or the management of invasive species through ballast water treatment methods (Maranda *et al.* 2013).

Section 850. Recommendations

1. There was no Technical Advisory Committee for this chapter and no recommendatiuons were formed.

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CHAPTER 9. Existing Statutes, Regulations, and Other Laws Pertaining to Shellfish

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Section 900. Scope of This Chapter[1]

1. This chapter is intended as a reference document providing an explanation of the existing laws related to shellfish, from harvest to final sale. This document describes the statutes and regulations governing shellfish management on both state and federal levels. It provides a description of these laws and management techniques only, and it is not intended as legal advice. No government authority has adopted the contents of this chapter, and the material herein does not carry the force of law.
2. Although the material in this chapter is comprehensive, it is intended as a snapshot of the current legal framework contemporaneous with the 2014 Rhode Island Shellfish Management Plan. All of the statutes and regulations referenced throughout this chapter are current as of the date of publication. However, as laws are subject to change, a reference section has been included at the end of the chapter to help the reader locate the most up-to-date statutes and regulations. This reference section can be found at Section 960.
3. The Technical Team for Chapter 9 decided to maintain the legal footnotes and citation method (Bluebook) in order to assist the chapter as a reference document. Therefor, footnotes are present throughout and pertain to the 2014 RI DEM regulations that were re-orgainzed in 2014.

Section 910. Definitions

910.1. What does the "law" encompass?

1. The term "law" includes the aggregation of all enforceable rules that control human conduct. The law encompasses statutes (legislation), regulations (agency rules), constitutional provisions, and judicial precedent (court orders and opinions).[2] The combination of all of these sources of law direct shellfish management by regulating resource management, shellfish harvesting, and post-harvest disposition of shellfish.

910.2. What is a "Statute"?

1. A statute is a law that is enacted by a legislative body.[3] Federal statutes are enacted by Congress and are compiled in the United States Code.[4] In Rhode Island, statutes enacted by the Rhode Island General Assembly are compiled into the Rhode Island General Laws.[5]

910.3. What is a "Regulation"?

1. A regulation is a rule or restriction put in place to control human behavior.[6] Regulations of concern for this management plan are those that are enacted by government agencies – particularly by the United States Food and Drug Administration ("US-FDA"), the Rhode Island Department of

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[1] As this reference chapter is legally based, the footnotes will be formatted in Bluebook legal citation as opposed to the citation format used throughout the remainder of the shellfish management plan.
[2] *See* BLACK'S LAW DICTIONARY 962 (9th ed. 2009) (defining "law").
[3] *See id.* at 1542 (defining "statute").
[4] *See, generally,* U.S.C. (2012), *available at* http://www.gpo.gov/fdsys/browse/collectionUScode.action;jsessionid=Z0sfTkTLLT0wT1tBTRsgD2fFm7BwvWdbBGqv6xNT4ndHxf0vv6Fs!606250136!1355477546?selectedYearFrom=2012&go=Go.
[5] *See, generally,* R.I. GEN. LAWS (2013), *available at* http://webserver.rilin.state.ri.us/Statutes/statutes.html.
[6] *See* BLACK'S LAW DICTIONARY 1398 (9th ed. 2009) (defining "regulation").

Environmental Management ("DEM"), the Rhode Island Coastal Resources Management Council ("CRMC"), and the Rhode Island Department of Health ("DOH").

910.4. What is a "Policy"?

1. A policy is a general principle that a government entity uses to guide its management decisions.[7] A policy does not require the formal enactment of statutes or regulations, and it does not carry the force of law. Policies are not self-implementing; they merely guide or inform internal government decisions. Because policies are not enforceable as law, they will not be directly addressed in this chapter. They will only be referenced if they have been codified in a statute or regulation, which would require formal proceedings and give them the force of law.

910.5. Who or what constitutes a "Person"?

1. Legally, unless otherwise specified, the term "person" includes all legal entities, not only individuals but also partnerships, associations, and corporations.[8]

910.6. Who is considered a "Resident" of Rhode Island?

1. For the purposes of shellfish management, DEM has defined a "resident" as "an individual who has had his or her actual place of residence and has lived in the State of Rhode Island for a continuous period of not less than six (6) months."[9]

Section 920. Lay of the Land

920.1. Management of Shellfish, Overview

1. With the expansion of the human population and its capacity to exploit fisheries' resources, government regulation of fisheries is necessary to avoid species' collapse. This need for regulation has long been acknowledged, but the need to avoid regulation that is overly oppressive to fishers – subsistence, recreational, and commercial – is equally important. As these dual goals can be inconsistent with each other, federal and state laws at the constitutional, statutory, and regulatory levels all provide guidance on management of fisheries.
2. The Rhode Island Constitution provides the basic framework that all fishery management in Rhode Island must follow. The Constitution grants a public right to the fishery, but it also limits this access right by requiring that the General Assembly conserve the natural resources of the state and engage in resource planning.[10] Based on this Constitutional mandate, there are three major concerns in regulating the shellfish industry: (1) protecting the ecological integrity of the resource, (2) protecting public health, and (3) minimizing the burden that restrictive measures may impose on the industry that conveys this resource to the consumer.[11]

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[7] *See id.* at 1276 (defining "policy").
[8] See R.I. Dept. of Health, Rules and Regulations Pertaining to the Processing and Distribution of Shellfish § 1.11 (2012) [hereinafter DOH Regulations].
[9] R.I. Dept. of Envtl. Mgmt., Rhode Island Marine Fisheries Statues and Regulations Part I: Legislative Findings § 1.3 (2012) (defining "resident") [hereinafter DEM Regulations Legislative Findings].
[10] R.I. CONST. art. I, § 17.
[11] *See* R.I. CONST. art. I, § 17 (calling for balancing of public access to fishery resources with protection of natural environment); R.I. GEN. LAWS §§ 20-1-1 (calling for use of management techniques to "develop[], preserve[], and maintain[]…the beauty and mystery that wild animals bring to our environment"), 21-14-3 (authorizing DOH to adopt regulations of shellfish businesses as it "deems necessary to ensure the sanitary quality of shellfish brought into this state"), 46-23-1 (declaring Rhode Island's coastal resources to be "a rich variety of natural, commercial, industrial, recreational, and aesthetic assets" and calling for a state policy to "preserve, protect, develop, and, where possible, restore the coastal resources of this state") (2013).

3. The Rhode Island General Assembly emphasized in its legislative findings in regards to fish and wildlife that the state's animal life – including the fishery resources – must be "developed, preserved, and maintained for the beauty and mystery that wild animals bring to our environment."[12] Additionally, in creating the Coastal Resources Management Council, the General Assembly declared it to be the policy of the state to "preserve, protect, develop, and, where possible, restore the coastal resources."[13] These provisions call, generally, for protection of the ecological integrity of the resource – preservation of the state's resources in their natural state – to be balanced against human interests in utilization of the resource. Specifically in regards to fisheries, the needs to protect the ecological integrity as well as the industry must be balanced in management strategies to "prevent overfishing, while achieving, on a continuing basis, the optimum yield from each fishery."[14]

4. Public health protection is the second major concern in shellfish management because shellfish are intimately related to the waters in which they grow and are sometimes consumed raw, thereby increasing consumer health risks if the shellfish have concentrated contaminants from their environments.[15] The major legal framework to protect consumer health is the National Shellfish Sanitation Program's Model Ordinance ("NSSP-MO" or "model ordinance"), which sets requirements for various aspects of shellfish culture, harvest, and processing.[16]

5. The US-FDA has adopted the model ordinance as a binding federal regulation.[17] The NSSP-MO provides mandates for the State Shellfish Control Authority ("SSCA"), which officially in Rhode Island includes both DEM and DOH,[18] although in practice CRMC also carries out some of the SSCA requirements. All states desiring to sell any of their shellfish in interstate commerce must meet the minimum requirements set by the NSSP-MO, but the states are also free to adopt more stringent regulations.[19]

6. Finally, shellfish management must also include considerations of the needs of the shellfishers, including those growing or harvesting commercially, recreationally, and for subsistence. In Rhode Island, the Constitution recognizes the importance of public access to marine resources,[20] mandating consideration of public access for recreational, commercial, and subsistence fishing in any management plan. In crafting its state shellfish management plan, DEM[21] must balance these industry and public access needs with the consumer protection and conservation requirements.

7. Agency Roles

    a. Prior to 1971, DEM or its predecessor entities had fairly exclusive authority[22] over all management issues in the state's waters and coasts, but the General Assembly's response to the

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[12] R.I. Gen. Laws § 20-1-1(a).
[13] *Id.* § 46-23-1(a)(2).
[14] *Id.* § 20-2.1-9(2)(iv)(A).
[15] Nat'l Shellfish Sanitation Program Model Ordinance § III, intro. (2011) [hereinafter NSSP-MO]; Barbara Brennessel, Good Tidings: The History and Ecology of Shellfish Farming in the Northeast 113, 115 (2008).
[16] *See* NSSP-MO, *supra* note 16, §III, intro.
[17] *See id.* § I, purpose.
[18] Interstate Shellfish Sanitation Conference, *Rhode Island SSCA Contacts*, ISSC.ORG (last visited May 16, 2014), http://www.issc.org/Contacts/RhodeIsland.aspx.
[19] NSSP-MO, *supra* note 16, §§ I, purpose; III, introduction (quoting Aug. 12, 1925 letter from the Surgeon General).
[20] R.I. CONST. art. I, § 17.
[21] As both CRMC and DOH also have regulatory roles in regards to shellfish management and consumption, these agencies have roles to play in crafting the shellfish management plan. However, DEM is the agency statutorily charged with drafting a state shellfish management plan. R.I. GEN. LAWS § 20-2.1-9(5) (2013).
[22] The U.S. Army Corps of Engineers also has authority in the coastal waters of Rhode Island, but that authority has been partially delegated to the state. *See, generally,* Dept. of the Army Corps of Engineers, Gen. Permit No. NAE-

federal Coastal Zone Management Act changed that.[23] The General Assembly created the CRMC to manage the resources of the coastal zone, effectively bifurcating regulatory authority over the state's shores and marine waters.[24] DEM still retains the majority of regulatory authority that would impact shellfish management because it has authority over all fish and wildlife of the state,[25] but CRMC has been granted authority to create a management plan for the state's coastal region.[26] As part of that authority, CRMC is charged with identifying and evaluating "all of the state's coastal resources, water, submerged land, air space, fin fish, shellfish, minerals, physiographic features, and so forth."[27] CRMC must identify the potential uses and problems associated with these resources.[28]

b. Although this management planning grants CRMC extensive authority within the coastal zone, it must develop this plan "in cooperation with" DEM as well as the statewide planning program, the economic development corporation, and any other appropriate state agencies.[29] To implement its management plan, CRMC has been granted "exclusive jurisdiction below mean high water for all **development**, **operations**, and dredging…**except** as necessary for the department of environmental management to exercise its power and duties…."[30]

c. When DEM and CRMC authority overlaps, any plans or regulations formulated by CRMC must be submitted to DEM for review, and a DEM response is required indicating whether the plan or regulation is consistent with the RI General Laws and DEM regulations.[31] CRMC must consider DEM's comments and respond in writing to any comments regarding inconsistency with existing law.[32] Essentially, CRMC has authority over physical development along the shoreline and within the state's marine waters,[33] DEM has authority over the management of state fisheries resources,[34] and where these authorities overlap, the agencies have shared authority.

d. Management decisions relating to all marine fisheries in the state are also aided by the Rhode Island Marine Fisheries Council ("RIMFC").[35] The RIMFC is composed of the Director of DEM or a designated representative as well as eight "private citizen members" who possess special knowledge or experience in relation to commercial fishing, recreational fishing, conservation, or resource management.[36] The RIMFC serves in an advisory capacity to the state and its agencies regarding marine fisheries management decisions and may make recommendations for additions or changes to fisheries laws or regulations.[37]

2011-2402 (Feb. 22, 2012), *available at* http://www.crmc.ri.gov/regulations/ArmyGeneralPermitRI_022212.pdf [hereinafter *Corps Gen. Permit*]. *See infra* § 840.2 (discussion of Army Corps authority).

[23] *See* R.I. GEN. LAWS § 46-23-2(a).

[24] *See id.* §§ 46-23-1(b); 46-23-2(a).

[25] *Id.* § 20-1-2.

[26] *Id.* § 46-23-6.

[27] *Id.* §§ 46-23-6(1)(ii)(A), (B).

[28] *Id.* §§ 46-23-6(1)(ii)(C), (D).

[29] *Id.* § 46-23-6(1)(v)(A)(III).

[30] *Id.* § 46-23-6(2)(ii) (emphasis added).

[31] *Id.* § 46-23-6(2)(i).

[32] *Id.* § 46-23-6(2)(i).

[33] *See id.* §§ 46-23-6(2)(ii), (4)(i).

[34] *Id.* § 20-1-2.

[35] *See id.* §§ 20-3-1, -2.

[36] *Id.* § 20-3-1.

[37] *Id.* § 20-3-2.

920.2. National Shellfish Sanitation Program - An Overview

1. The NSSP-MO requires the SSCA to "establish a statewide shellfish safety and sanitation program to regulate: (1) The classification of shellfish growing areas; (2) The harvesting of shellfish; (3) Shellfish processing procedures and facilities; (4) Product labeling; (5) Storage, handling and packing; (6) Shellfish shipment in interstate commerce; (7) Shellfish dealers; and (8) Bivalve aquaculture."[38]

2. DEM is statutorily required to "develop conservation and management plans for the fishery resources of the state."[39] Annually,[40] DEM creates a management plan for the shellfish fishery sector.[41] Like all fisheries and wildlife management, this plan must protect the state's natural resources "for the beauty and mystery that wild animals bring to our environment."[42] The general assembly also requires that:

   > the management of fish and wildlife through the establishment of hunting and fishing seasons, the setting of size, catch, possession, and bag limits, the regulation of the manner of hunting and fishing, and the establishment of conservation policies should be pursued utilizing modern scientific techniques, having regard for the fluctuations of species populations, the effect of management practices on fish and wildlife, and the conservation and perpetuation of all species of fish and wildlife.[43]

3. In addition to ecological protection, the plan – like all fisheries regulations – should also consider "the rights and interests of residents of Rhode Island to engage in fishing including commercial fishing,"[44] recreation,[45] the need to preserve a source of food,[46] and economic stimulation.[47] The importance of the fishing industry to Rhode Island must also be considered, including the impact that regulations have on the "cultural and social framework" of fishing communities.[48]

4. DOH regulates post-harvest handling, processing, and shipping once the shellfish are in the hands of the dealers.[49] However, DEM's plan must address growing area classification, shellfish harvest, transfer from harvester to dealer, and aquaculture. DEM is explicitly statutorily authorized to regulate commercial fishing via (1) types of licenses, endorsements, and associated "limitations on levels of

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[38] NSSP-MO, *supra* note 16, § II, ch. I, §.01(A).
[39] R.I. GEN. LAWS § 20-2.1-9(5); *see also id.* §§ 20-2.1-5, 20-2.1-6, 20-2.1-12 (all calling for management to be consistent with adopted management plans).
[40] DEM must create the annual management plan by December 1 of the preceding year. R.I. Dept. of Envtl. Mgmt., *Commercial and Recreational Saltwater Fishing Licensing Regulations* § 6.2-3(a) (2013) [hereinafter *DEM Licensing Regulations*]. By September 15 each year, DEM is also required to produce an annual report on "the status of fish stocks that are considered to be overfished or were so in the preceding year, the status of fisheries management plans and programs, levels of participation by existing license holders, and the availability of new licenses and endorsements." *Id.* § 6.4.
[41] *DEM Licensing Regulations*, *supra* note 41, § 6.2-1; *see* R.I. Dept. of Envtl. Mgmt. Division of Fish and Wildlife, Marine Fisheries, *2014 Sector Management Plan for the Shellfish Fishery*, DEM.RI.GOV (Dec. 19, 2013), http://www.dem.ri.gov/pubs/regs/regs/fishwild/mpshell.pdf.
[42] R.I. GEN. LAWS § 20-1-1(a); *see also id.* §§ 20-1-2, 20-1-5.
[43] *Id.* § 20-1-1(b). DEM's specific authority over shellfish and other marine resources is contained in R.I. GEN. LAWS § 20-1-2.
[44] *Id.* § 20-2.1-1.
[45] *Id.* § 20-3.2-2(d). The general laws' definition of recreational fishing includes only finfish. *Id.* § 20-2.2-3(5). However, politics and sound management – as well as agency practice to date – would mandate an inclusion of recreational shellfishing.
[46] *Id.* § 20-2.1-2(1).
[47] *Id.* §§ 20-2.1-2(5), 20-3.2-2(c).
[48] *Id.* § 20-2.1-9(2); *see also id.* § 20-2.1-2(5).
[49] See, generally, DOH Regulations.

effort and/or on catch;" (2) "[d]esign, use, and identification of gear;" (3) data collection requirements; (4) spatial and temporal closures of harvest areas; (5) "[l]imitations and/or restrictions on effort, gear, catch, or number of license holders and endorsements;" and (6) "[e]mergency rules…to protect an unexpectedly imperiled fishery resource, to provide access to a fisheries resource that is unexpectedly more abundant, and to protect the public health and safety from an unexpected hazard."[50]

5. Rhode Island general laws also require that fisheries regulations follow certain standards, which closely mirror the national standards found in the Magnuson-Stevens Fisheries Conservation and Management Act.[51] The following standards must be "applied so far as practicable and reasonable" to all state fisheries management laws or regulations:

> (A)…shall prevent overfishing, while achieving, on a continuing basis, the optimum yield from each fishery; (B)…be based upon the best scientific information available; and analysis of impacts shall consider ecological, economic and social consequences of the fishery as a whole; (C)…consider efficiency in the utilization of fisheries resources; except that no such measure shall have economic allocation as its sole purpose; (D)…take into account and allow for variations among, and contingencies in, fisheries, fishery resources, and catches; (E)…consistent with conservation requirements of this chapter (including the prevention and [sic] overfishing and rebuilding of overfished stocks), take into account the importance of fishery resources to fishing communities in order to (I) provide for the sustained participation of those communities, and (II) to the extent practicable, minimize adverse economic impacts on those communities; (G)…(I) minimize by-catch and (II) to the extent by-catch cannot be avoided, minimize the mortality of the by-catch; [and] (H)…promote the safety of human life at sea.[52]

6. DEM regulations also set specific requirements for the contents of the management plans, requiring that the plans work:

> "(a)…(i) to prevent overfishing, while achieving on a continuous basis the maximum sustainable yield from each fishery; and (ii) to restore overfished or depleted stocks to sustainable levels…(b)…be responsive to, and reflective of, changing stock and fishery conditions, and thereby support an adaptive management process…(c)…establish[] management measures that may include a mix of input and output controls, such as limitations or restrictions on effort, gear, catch, areas, times, and/or seasons…(d)…address, and make annual determinations on, the number and availability of licenses and endorsements, and the harvest and gear levels associated therewith…with due regard to: (i) the social and economic well-being of fishers and fishing-dependent communities, particularly the interests of licensed residents who wish to continue fishing commercially in a manner that is economically viable; and (ii) the interests of residents who wish to fish commercially…(e)…to the maximum extent feasible employ methodologies that are consistent with those employed by the National Marine Fisheries Service…(f)…be based on the best scientific information available…(g)…consider the effectiveness of management measures in reducing by-catch, by-catch mortality, and discards…(h)…complement federal and regional management plans and programs…(i)…be consistent with the national standards for fishery conservation and management set forth in the Magnuson-Stevens Fishery

[50] R.I. GEN. LAWS § 20-2.1-9(1).
[51] *Id.* § 20-2.1-9(2)(iv).
[52] Id.

> Conservation and Management Act…[and]…(j)…take into consideration other factors that the Director deems appropriate.[53]

7. In addition to following these standards, an open process that includes stakeholder engagement is required in making regulatory decisions.[54] DEM must also consider the advice of RIMFC in making fisheries management decisions, with the exception of emergency rules.[55] DEM is required to respond, in writing, to all recommendations and advice of the RIMFC in regards to adoption of management plans;[56] however, DEM is not required to adopt any changes recommended by RIMFC.[57] RIMFC is authorized to petition DEM for rulemaking in accordance with its views on the needs of RI fisheries management.[58] RIMFC is charged with providing recommendations to DEM regarding:

> (1) The manner of taking fish, lobsters, and shellfish; (2) The legal size limits of fish, lobsters, and shellfish…; (3) The seasons and hours during which fish, lobsters, and shellfish may be taken or possessed; (4) The numbers or quantities of fish, lobsters, and shellfish which may be taken or possessed; and (5) The opening and closing of areas within the coastal waters to the taking of any and all types of fish, lobsters, and shellfish.[59]

8. RIMFC must also establish an industry advisory committee, which must include commercial fishing representatives, to review RIMFC's recommendations and advise DEM.[60] Additionally, RIMFC is authorized to create other advisory committees to address specific needs or topics.[61] One such committee established by RIMFC is the RI Shellfish Advisory Panel. This group meets regularly to specifically discuss state shellfish issues and provide advice to the RIMFC on those matters. DEM's final plan must include "a concise explanation of the principal reasons for its adoption and [a] response to petitions entered into the hearing record."[62]
9. The NSSP-MO also requires that state agencies maintain records "to demonstrate effective administration" of the management plan.[63] DEM and CRMC will also need to coordinate with DOH in the instance of a shellfish-related illness to determine the source of the shellfish and whether the incident requires alteration of growing area classifications.[64] All of the agencies and other entities discussed in this section must work together in devising shellfish management regulations and plans.

920.3. Rhode Island Constitution

1. Article 1, Section 17 of the Rhode Island Constitution, "Fishery rights—Shore privileges—Preservation of natural resources" provides, in full, that:

> The people shall continue to enjoy and freely exercise all the rights of fishery, and the privileges of the shore, to which they have been heretofore entitled under the charter and

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[53] DEM Licensing Regulations, supra note 41, § 6.2-2.
[54] R.I. GEN. LAWS §§ 20-3.2-2(g), 42-35-3(a)(2).
[55] *Id.* §§ 20-1-5.1; 20-2.1-10. DEM must allow at least a sixty day review period for RIMFC. *DEM Licensing Regulations*, *supra* note 41, § 6.2-3(b).
[56] R.I. GEN. LAWS § 20-1-5.1.
[57] *DEM Licensing Regulations*, *supra* note 41, § 6.2-3(c). DEM must enter RIMFC's recommendations into the hearing record. *Id.*
[58] R.I. GEN. LAWS § 20-2.1-10.
[59] *Id.* § 20-3-2(a).
[60] *Id.* § 20-2.1-11.
[61] *Id.* § 20-2.1-10 (granting authority to RIMFC to "establish any committees and hold any meetings and hearings that it may deem appropriate to fulfill [its] responsibility" to advise DEM).
[62] DEM Licening Regulations, supra note 41, § 6.2-3(d).
[63] NSSP-MO, *supra* note 16, § II, ch. I, § .01(C).
[64] *See id.* § II, ch. II, §§ .01, .02.

> usages of this state, including but not limited to fishing from the shore, the gathering of seaweed, leaving the shore to swim in the sea and passage along the shore; and they shall be secure in their rights to the use and enjoyment of the natural resources of the state with due regard for the preservation of their values; and it shall be the duty of the general assembly to provide for the conservation of the air, land, water, plant, animal, mineral and other natural resources of the state, and to adopt all means necessary and proper by law to protect the natural environment of the people of the state by providing adequate resource planning for the control and regulation of the use of the natural resources of the state and for the preservation, regeneration and restoration of the natural environment of the state.

This section of the state constitution recognizes dual goals of ensuring public access to the coast and its resources as well as preserving those resources for future use and enjoyment.

2. The Constitutional grant of a right to fishery is not, however, an "unqualified"[65] or unlimited right, although that argument has been made and rejected throughout the state's history.[66] The RI Supreme Court has repeatedly held that this constitutional right to a fishery accrues in the public as a whole, not with any individual person or entity.[67] The court has recognized that the General Assembly and DEM have the right to regulate fishery participation in order to manage the fisheries resources, even though this may restrict or even prohibit the access rights of fishermen.[68]

3. State agency authority to regulate fishery access is not unlimited, but it is expansive. The RI Supreme Court has recognized that DEM has broad authority to regulate fisheries, and regulations must generally[69] meet only a minimal level of scrutiny to overcome a constitutional challenge.[70] In order to withstand a challenge, DEM will have to demonstrate that "'a rational relationship exists between the provisions of [the regulation] and a legitimate state interest.'"[71] Under this minimal scrutiny test, DEM "has a wide scope of discretion…which will be upheld so long as [the regulations] bear a reasonable relationship to public health, safety, or welfare."[72] The RI Supreme Court has long recognized a high deference to the legislature and DEM in setting laws aimed to regulate fisheries.[73]

4. This deference to DEM is partially influenced by the history of the constitutional provision. The provision was adopted from the original King Charles Royal Charter when the Constitution was ratified in 1842.[74] The original Charter provision was included because the colony was facing "imminent famine" as a result of scarcity of food resources.[75] In order to reduce the loss of human

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[65] *Cherenzia v. Lynch*, 847 A.2d 818, 824 (R.I. 2004).
[66] *See, generally, Riley v. R.I. Dept. of Envtl. Mgmt.*, 941 A.2d 198 (R.I. 2008) (constitutional challenge brought against DEM implementation of a limited-entry fishery program); *Cherenzia v. Lynch*, 847 A.2d 818 (R.I. 2004) (constitutional challenge brought against state statute baring shellfish harvest via SCUBA equipment in coastal ponds); *State v. Cozzens*, 2 R.I. 561 (1850) (constitutional challenge to leasing submerged lands for aquaculture).
[67] *Riley*, 941 A.2d at 208; *Cherenzia*, 847 A.2d at 825 (quoting *Opinion to the Seante*, 137 A.2d 525, 525-26 (R.I. 1958)); *State v. Kofines*, 80 A. 432, 437 (R.I. 1911).
[68] *Riley*, 941 A.2d at 209 (quoting *Opinion to the Senate*, 137 A.2d at 526).
[69] If a regulation were found to "impinge[] on a fundamental right or create[] a suspect classification" under either the state or federal constitution, then the court would apply strict scrutiny. *Cherenzia*, 847 A.2d at 823. For example, this scrutiny is commonly applied in fisheries management cases when citizens from different states are treated differently under a regulatory scheme. *See infra* § 850.1.
[70] *Riley*, 941 A.2d at 206, 207 (recognizing that a licensing scheme that limits access to the fishery does not invoke a *fundamental* right under the R.I. Constitution and therefore is analyzed only under a rational-basis analysis).
[71] *Id.* at 206.
[72] *Id.* at 211.
[73] *Id.* at 206 (citing *Cherenzia*, 847 A.2d at 825).
[74] *Id.* at 208.
[75] *Id.* at 207.

life, the Charter opened the fishery freely to all inhabitants to attempt to obtain their own food.[76] However, the needs of our state, and our priorities, have since changed, with a shift away from wide necessity for subsistence fishing and towards greater recognition of resource management.[77]

5. Environmental protection is a legitimate public purpose that can justify regulation because the state Constitution charges the general assembly with "provid[ing] for the conservation of the air, land, water, plant, animal, mineral and other natural resources of the state…."[78] The RI Supreme Court has recognized that the state can restrict fishery access in order to accommodate this environmental protection mandate.[79] The Constitution actually mandates that the state engage in "resource planning," and therefore DEM has an obligation to consider resource management with an eye towards conservation.[80] State agencies need to balance this conservation mandate with the general public right of access to the fishery, both granted in the RI Constitution.

920.4. Water Quality and Classifications

1. Under the NSSP-MO and Rhode Island statute, DEM is required to conduct sanitary surveys of all waters of the state and classify those waters regarding shellfish harvesting based on the results of the surveys.[81] Sanitary surveys must include:

> the data and results of: (a) A shoreline survey;[82] (b) A survey of the bacteriological quality of the water; (c) An evaluation of the effect of any meteorological, hydrodynamic, and geographic characteristics of the growing area; (d) An analysis of the data from the shoreline survey, the bacteriological and the hydrodynamic, meteorological and geographic evaluations; and (e) A determination of the appropriate growing area classification.[83]

The surveys must be reviewed annually,[84] reevaluated every three years,[85] and completely resurveyed every twelve years.[86] DEM must also maintain a "marine Biotoxin[87] contingency plan" that sets sampling intervals based on the known likelihood of biotoxin problems in each growing area.[88]

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[76] Id.
[77] *See id.* at 209.
[78] R.I. CONST. art. I, § 17; *Riley*, 941 A.2d at 208.
[79] *Riley*, 941 A.2d at 208.
[80] R.I. CONST. art. I, § 17.
[81] R.I. GEN. LAWS § 20-8.1-4 (2013); NSSP-MO, *supra* note 16, § II, ch. IV, §§ .01, .03(A)(2)(c). DEM currently performs these water quality tests through its Office of Water Resources.
[82] The shoreline survey must include (1) identification and evaluation of actual and potential sources of pollution affecting the growing area; (2) distance and impact from pollution source to growing area; (3) effectiveness of waste treatment systems; (4) determination of whether poisonous or deleterious substances adversely affect the growing area; (5) determination of whether any domestic or wild animals adversely affect the growing area. NSSP-MO, *supra* note 16, § II, ch. IV, Requirements for the Authority, § .01(D)(1).
[83] *Id.* § II, ch. IV, § .01(A)(1).
[84] The annual review must include (1) a field observation of pollution sources; (2) review of water quality samples from the prior year and historically; (3) review of any samples collected from or inspection reports of pollution sources; (4) review of available performance standards for known discharges that impact the growing area; and (5) a "brief report which documents the findings of the annual reevaluation." *Id.* § II. ch. IV, Requirements for the Authority, § .01(C)(5).
[85] The triennial reevaluation shall include (1) a review of water quality samples; (2) evaluation of the effect of new and prior pollution sources; and (3) a "comprehensive report which analyzes the sanitary survey data and makes a determination that the existing growing area classification is correct or needs to be revised." *Id.* § II, ch. IV, Requirements for the Authority, § .01(C)(3)(a). Failure to complete the triennial reevaluation requires that the growing area be placed in the closed status. *Id.* § .01(C)(3)(b).
[86] *Id.* § II, ch. IV, §§ .01(A)(2), (C)(1).

2. The end result of the sanitary survey is the classification of the growing area under one of five possible classifications under the NSSP-MO: (1) approved (shellfish can be harvested for direct consumption); (2) conditionally approved (shellfish can sometimes be harvested for direct consumption depending on external factors such as weather); (3) restricted (shellfish cannot be harvested for direct consumption but may be harvested for pre-consumption treatment[89]); (4) conditionally restricted (meets restricted classification sometimes depending on external factors such as weather); and (5) prohibited (shellfish cannot be harvested for consumption at all).[90] Any growing area that has not had a complete sanitary survey or that has "a sewage treatment plan outfall or other point source outfall of public health significance within or adjacent to the growing area" must be given the designation of prohibited.[91] DEM must maintain both an itemized list of all growing area classifications as well as maps showing the boundaries of the various areas.[92]

3. Classifications must be based upon water quality and other tests mandated by the NSSP-MO. All of these tests must be performed at "a laboratory found to conform or provisionally conform by the FDA or FDA certified State Shellfish Laboratory Evaluation Officer."[93] In testing water quality of growing areas, the NSSP-MO permits use of either a total or fecal coliform standard performed via either adverse pollution condition or systematic random sampling methods.[94] The number and location of sampling stations must be "adequate to effectively evaluate all pollution sources."[95] For any growing area other than prohibited, a minimum of thirty water samples must be collected "under various environmental conditions" before the classification may be applied to that growing area.[96]

4. Growing area classifications are dictated by standards laid out in the NSSP-MO. Growing areas may be classified as approved if a:

> sanitary survey finds that the area is: (a) Safe for the direct marketing of shellfish; (b) Not subject to contamination from human or animal fecal matter at levels that, in the judgment of

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[87] A marine biotoxin is "any poisonous compound produced by marine microorganisms," often algae, that may be accumulated by shellfish. *Id.* § I, Definitions(70).

[88] *Id.* § II, ch. IV, § .04.

[89] *See infra* § 830.6(3) for a discussion of acceptable methods.

[90] NSSP-MO, *supra* note 16, § II, ch. IV, § .03(A)(2)(c); *see id.* §§ II, Definitions (B)(5), (B)(18), (B)(19), (B)(83), (B)(91). The specific water quality standards necessary for each classification are laid out in § II, ch. IV, § .02(D)-(H). It is noteworthy that growing areas in a marina proper can only be given the designation of conditionally approved, conditionally restricted, or prohibited. *Id.* § II, ch. IV, § .05(A). Waters adjacent to a marina must be tested and "[i]f the dilution analysis predicts a theoretical fecal coliform loading greater than fourteen (14) fecal coliform MPN per 100 ml, the waters adjacent to the marina cannot be classified above the conditionally approved classification. *Id.* § II, ch. IV, § .05(B)(4). Maps of R.I. classifications of shellfishing grounds can be found at http://www.dem.ri.gov/maps/index.htm for reference. Dept. of Envtl. Mgmt., *Maps*, RI.GOV (last accessed Nov. 17, 2013).

[91] NSSP-MO, *supra* note 16, § II, ch. IV, §§ .01(B)(1), .03(A)(2)(b). Additional conditions also mandate a prohibited classification, including (1) pollution sources are unpredictable; (2) the growing area is contaminated with fecal waste that places the shellfish at risk of being disease vectors; (3) the concentration of biotoxin is sufficient to cause a public health risk; or (4) the area is "contaminated with poisonous or deleterious substances causing the shellfish to be adulterated." *Id.* § .03(E)(3)(b).

[92] *Id.* § II, ch. IV, § .01(A)(5).

[93] *Id.* § II, ch. III, Requirements for the Authority, § .01(A); *see also id.* §§ .01(B), (D), (E), (F) (details of laboratory requirements).

[94] *Id.* § II, ch. IV, Requirements for the Authority, § .02.

[95] *Id.* § II, ch. IV, Requirements for the Authority, § .02(B).

[96] *Id.* § II, ch. IV, Requirements for the Authority, § .02(C)(1). Only fifteen samples are required if there is no pollution source impacting the growing area. *Id.* § .02(C)(2).

the Authority, presents an actual or potential public health hazard; and (c) Not contaminated with: (i) Pathogenic organisms; (ii) Poisonous or deleterious substances; (iii) Marine Biotoxins; or (iv) Bacteria concentrations exceeding the bacteriological standards for a growing area in this classification.[97]

5. Growing areas may be classified as restricted if a "sanitary survey indicates a limited degree of pollution; and…[l]evels of fecal pollution, human pathogens, or poisonous or deleterious substances are at such levels that shellstock[98] can be made safe for human consumption by either relaying, depuration or low acid-canned food processing."[99] Areas may be given a conditional classification if:

   (a) The area will be in the open status of the conditional classification for a reasonable period of time[100]…; (b) Each potential source of pollution that may adversely affect the growing area is evaluated; [and] (c) Bacteriological water quality correlates with environmental conditions or other factors affecting the distribution of pollutants into the growing areas.[101]

6. As noted in the requirements for the area classifications above, each classification has specific bacteriological water quality requirements. The specific standards are detailed in the chart below.[102] Each growing area must meet one standard based on the "fecal coliform median or geometric mean MPN[103] or MF (mTEC)[104]."[105] Additionally, the growing area water samples must meet either a limit where "not more than ten (10) percent of the samples" exceed a specified MPN or MF (mTEC) **or** "the estimated 90th percentile"[106] does not exceed a specified MPN or MF (mTEC).

[97] *Id.* § II, ch. IV, Requirements for the Authority, § .03(B)(1).
[98] Shellstock means "live molluscan shellfish in the shell" as distinguished from shucked shellfish meat. *Id.* § I, Definitions(B)(110).
[99] *Id.* § II, ch. IV, Requirements for the Authority, § .03(D)(1)(a).
[100] The factors affecting the area water quality must be known, predictable, and "not so complex as to preclude a reasonable management approach." *Id.* § II, ch. IV, Requirements for the Authority, § .03(C)(1).
[101] *Id.* § II, ch. IV, Requirements for the Authority, § .03(C)(1). If the conditional aspect is based on a seasonal marina, monthly water samples are not required when the marina is not operating and the area is in the open status provided that three samples are taken during that period annually. *Id.* § .03(C)(3)(b)(i). If the classification is based on a wastewater treatment plant, combined sewer overflow, or similar point source, monthly water samples are required while the area is in the open status. *Id.* § .03(C)(3)(b)(ii).
[102] All values listed are per 100 ml. To qualify for the status listed, the growing area samples must meet both the median column as well as any one of the additional columns for which a value is listed.
[103] MPN stands for Most Probable Number, and it is "a statistical estimate of the number of bacteria per unit volume…determined from the number of positive results in a series of fermentation tubes." NSSP-MO, *supra* note 16, § I, Definitions(B)(74).
[104] MF (mTEC) is a membrane filtration method, which "produces quantifiable results in 24 hours, [and] provides a direct enumeration of *E. coli* densities." Eric Hargett and Lanny Goyn, Wyoming Dept. of Environmental Quality – Water Quality Divisions, *Modified mTEC Agar, Colilert®, and M-FC Agar – Field Trial Comparison of Bacteria Enumeration Methods in Surface Waters of Eastern Wyoming,* 1 (last accessed Apr. 8, 2014), *available at* *http://deq.state.wy.us/wqd/watershed/Downloads/Monitoring/comp_study_e.coli_final2.pdf*.
[105] NSSP-MO, *supra* note 16, § II, ch. IV, Requirements for the Authority, §§ .02(D)(2), (E)(2), (F)(3), (G)(2), (H)(3), (4).
[106] The estimated 90th percentile is "calculated by: (a) Calculating the arithmetic mean and standard deviation of the sample result logarithms (base 10); (b) Multiplying the standard deviation in (a) by 1.28; (c) Adding the product from (b) to the arithmetic mean; (d) Taking the antilog (base 10) of the results in (c) to get the estimated 90th percentile; and (e) The MPN values that signify the upper or lower range of sensitivity of the MPN tests in the 90th percentile calculation shall be increased or decreased by one significant number." *Id.* § II, ch. IV, Requirements for the Authority, § .02(F)(5).

Table 9.1. Specific bacteriological water quality requirements for Growing Area Classifications.

Growing Area Classification	Median	<10% to 90th Percentile					
		3-tube	12-tube	mTEC	5-tube	3-tube	mTEC
Approved in Remote Status[107]	14 MPN	49 MPN	28 MPN	31 CFU			
Approved Affected by Point Sources[108]	14 MPN	49 MPN	28 MPN	31 CFU			
Approved Affected Solely by Nonpoint Sources[109]	14 MPN	49 MPN	28 MPN	31 CFU	43 MPN	49 MPN	31 CFU
Restricted Affected by Point Sources[110]	88 MPN					300 MPN	163 CFU
Restricted Affected Solely by Nonpoint Sources[111]	88 MPN				260 MPN	300 MPN	163 CFU

NOTE: RIDEM OWR shellfish program along with RIDOH moved to the Membrane Filtration (MF) using mTEC agar for analysis of seawater and pollution source samples in August of 2012. They no longer use the Multiple Tube Fermentation (MPN) procedure. In areas approved for shellfishing a systematic random sampling strategy is utilized and the geometric mean and 90th percentile standards are applied. In Conditionally approved growing areas the geometric mean and no more than 10% of the samples variability standards are applied where adverse pollution condition collection strategy is followed. During the transition to mTEC the data set of 30 samples for Approved waters uses a hybrid weighted 90th percentile. NSSP 2009 Section VIII Interpretation Number: 09-IV@.02-101 was the guidance document on calculating this hybrid standard of which RIDEM OWR shellfish program currently applies for compliance with the variability component of the water quality standard in approved areas. Once all data used in compliance analysis is obtained using the mTEC method the variability 90th percentile variability standard will be 31 CFU/100ml.

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[107] *Id.* § II, ch. IV, Requirements for the Authority, § .02(D)(2). A minimum of two samples must be collected annually, and at least the fifteen most recent samples must be used in the calculation. *Id.* § .02(D)(3).

[108] *Id.* § II, ch. IV, Requirements for the Authority, § .02(E)(2). A minimum of five samples must be collected annually "under adverse pollution conditions from each sample station in the growing area," and at least the fifteen most recent samples must be used in the calculation. *Id.* § .02(E)(3).

[109] *Id.* § II, ch. IV, Requirements for the Authority, §§ .02(F)(3), (4). If following the <10% testing method, the same sampling requirements apply as for areas affected by point sources. *Id.* § .02(F)(6)(a). If following the estimated 90th percentile method, a minimum of six samples must be collected annually from each sample station, and at least the thirty most recent samples must be used in the calculation. Additionally, the sampling schedule must be created "sufficiently far in advance to support random collection with respect to environmental conditions." *Id.* § .02(F)(6)(b).

[110] *Id.* § II, ch. IV, Requirements for the Authority, § .02(G)(2). Sampling requirements are the same as for approved waters affected by point sources. *Id.* § .02(G)(3).

[111] *Id.* § II, ch. IV, Requirements for the Authority, §§ .02(H)(3), (4). Sampling requirements are the same as for approved waters affected solely by nonpoint sources. *Id.* § .02(H)(6).

7. Rhode Island employs only three water classifications in regards to shellfish growing areas: approved, conditionally approved, and prohibited.[112] Approved waters are those "fit for the taking of shellfish for human consumption on a regular basis, according to the criteria established by the" NSSP-MO.[113] These requirements are consistent with the requirement for an approved classification under the NSSP-MO.[114] Conditionally approved waters are those that are "fit for the taking of shellfish for human consumption on an intermittent basis."[115] Growing areas are classified as polluted if they are "unfit for the taking of shellfish for human consumption,"[116] taking into consideration "the volume of sewage that may affect the area; the dilution of that sewage by clean water; the distance of the area from sources of pollution;" and the fecal coliform counts.[117] Harvesting of shellfish from an area classified as polluted is prohibited unless part of a specifically authorized transplant program.[118]

8. In addition to the above classifications, Rhode Island also classifies its water bodies based on a water quality class system, which is designed to meet the state's Clean Water Act obligations.[119] These classes dictate the water quality goals of a waterbody and directly affect what sources of pollutants will be allowed to impact the waterbody.[120] Sea water waterbodies may be given one of four classes. Class SA waters "are designated for shellfish harvesting for direct human consumption," and the water quality criteria required for SA waters match those required for approved waters under the NSSP-MO.[121] Class SB waters allow for shellfish harvesting, but the shellfish must be relayed or depurated before being sold for human consumption.[122] Class SB1 and class SC are not suitable for shellfish harvest, even after employing relay or depuration.[123] Water quality classes will be developed and evaluated biennially,[124] while shellfish growing area classifications are evaluated annually.[125]

9. Each area must also contain a designation of open, closed, or inactive in addition to a general classification.[126] Under Rhode Island law, any area determined to be "unsatisfactory…for the taking of shellfish for human consumption" must be labeled "polluted" and closed to shellfishing.[127] The model ordinance likewise dictates that growing areas classified as prohibited always remain in the closed state.[128] All other growing areas are deemed open by default, but DEM may close them for "(i) An emergency condition or situation; (ii) The presence of biotoxins in concentrations of public health significance; or [sic] (iii) Conditions stipulated in the management plan of conditionally approved or conditionally restricted areas; or (iv) Failure of the Authority to complete a written survey or triennial

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[112] R.I. Dept. of Envtl. Mgmt., Rhode Island Marine Fisheries Statues and Regulations Part XVIII: Shellfish Grounds §§ 18.1(1), 18.1(2), 18.1(6)(i) (2012) [hereinafter DEM Shellfish Grounds Regulations].
[113] R.I. Dept. of Envtl. Mgmt., Aquaculture of Marine Species in Rhode Island Waters § 1.1 (2002) [hereinafter DEM Aquaculture Regulations].
[114] NSSP-MO, *supra* note 16, § II, ch. IV, Requirements for the Authority, § .02(E)(2).
[115] DEM Shellfish Grounds Regulations, supra note 113, § 18.1(2).
[116] *Id.* § 18.1(6)(i).
[117] *Id.* § 18.4 (citing R.I. GEN. LAWS § 20-8.1-4).
[118] *Id.* § 18.5.
[119] *See infra* § 840.4.
[120] *See* R.I. Dept. of Envtl. Mgmt., *Water Quality Regulations*, app. A (2010) (water use classifications) [hereinafter *DEM Water Quality Regulations*].
[121] *Id.* §§ 8(B)(2)(a), 8(D)(3)(Table 2).
[122] *Id.* § 8(B)(2)(b); *see infra* § 830.6(3).
[123] *See DEM Water Quality Regulations*, *supra* note 122, §§ 8(B)(2)(c), 8(B)(2)(d).
[124] *Id.* at app. A (water use classifications).
[125] *DEM Shellfish Grounds Regulations*, *supra* note 113, § 18.4 (citing R.I. GEN. LAWS § 20-8.1-4 (2013)).
[126] NSSP-MO, *supra* note 16, § II, ch. IV, § .03(A)(5).
[127] R.I. GEN. LAWS § 20-8.1-3; *DEM Shellfish Grounds Regulations*, *supra* note 113, § 18.3. For a listing of factors that DEM must consider in determining whether a water body is "polluted," see R.I. GEN. LAWS § 20-8.1-4.
[128] NSSP-MO, *supra* note 16, § II, ch. IV, § .03(A)(5)(a).

review evaluation report."[129] DEM can also use "established tolerance levels for [] particular pathogen isolate[s]," and growing areas will remain open only as long as the tolerance level is not exceeded.[130] Growing areas must also be placed in the closed status upon identification of a new source of pollution until a supplement to the sanitary survey can be completed to incorporate that new source.[131]

10. Growing areas in the closed status must remain closed unless (1) any associated emergency has ended and sufficient time has passed for natural depuration, (2) the requirements of any associated biotoxin or conditional area management plan has been met, and (3) valid analyses have justified the reopening, are in writing, and are kept on file.[132] DEM can also choose to designate a growing area "inactive," which will allow for less frequent monitoring, but the area will remain closed to shellfishing until a full sanitary survey is completed.[133] Inactive status can only be maintained for one to five years and cannot be applied to any growing area that is directly impacted by point source pollution.[134] DEM is also authorized to adopt any necessary regulations in regards to water body classification,[135] but harvesting of shellfish from polluted waters must be prohibited unless part of a state-supervised transplant program.[136]
11. After designating classifications, DEM must announce those classifications via newspaper publication, issue the list with shellfish license renewals, and have a phone line available to shellfishers to call and check on the status of a body of water.[137] In addition to maintaining maps of area classifications, DEM must chart and mark the boundaries of any growing areas that are closed to shellfish harvest.[138]
12. For growing areas designated as conditional, DEM must also draft a management plan for the area detailing the known variables of the pollution sources and a plan to monitor and respond to those sources and other concerns specific to a conditional growing area.[139] All growing areas must also be monitored for *Vibrio vulnificus* and *Vibrio parahaemolyticus* in order to determine whether a *Vibrio* control plan is required.[140] Finally, if a growing area "continues to demonstrate the presence of human pathogen isolates in" the shellfish harvested from that location, DEM and DOH must perform a risk assessment to determine if the area requires closure or reclassification, even if no illnesses have occurred as a result of the pathogens.[141]

920.5. Shellfish Harvesting

1. The state must ensure that harvesters harvest, handle, and transport shellstock in a manner that "prevent[s] contamination, deterioration, and decomposition."[142] The Rhode Island General Assembly has largely charged DEM with promulgating regulations to meet these requirements. Once DEM

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[129] *Id.* § II, ch. IV, §§ .03(A)(5)(a), (b).
[130] *Id.* § II, ch. II, § .03(D)(2)(b).
[131] *Id.* § II, ch. IV, § .03(A)(1).
[132] *Id.* § II, ch. IV, § .03(A)(5)(c).
[133] *Id.* § II, ch. IV, § .03(A)(5)(d).
[134] *Id.* § II, ch. IV, § .03(A)(5)(d).
[135] R.I. GEN. LAWS § 20-8.1-2 (2013).
[136] *Id.* § 20-8.1-5; for discussion of transplant programs, see § 830.6(3)(g)-(i).
[137] R.I. GEN. LAWS § 20-8.1-3; *DEM Shellfish Grounds Regulations*, *supra* note 113, § 18.3.
[138] NSSP-MO, *supra* note 16, § II, ch. VIII, Requirements for the Authority, § .01(D)(1). DEM must also notify licensed harvesters of the current status at the time of license renewal and must disseminate information of closure changes. *Id.* § II, ch. VIII, Requirements for the Authority, § .01(D)(1).
[139] *Id.* § II, ch. IV, Requirements for the Authority, § .03(C).
[140] *Id.* § II, ch. II, Requirements for the Authority, §§ .05(A)(1)(b), .06(A); *see infra* § 830.8(6)(b).
[141] NSSP-MO, *supra* note 16, § II, ch. II, Requirements for the Authority, § .03(D)(1).
[142] *Id.* § II, ch. VIII, Requirements for Harvesters, §§ .02(B), (C), (D), (E), .03.

considers the conservation and economic needs of the fisheries resources based on the best available science, the recommendations of the RIMFC, and public comments, it is authorized to then act on these needs by establishing "fishing seasons, the setting of size, catch, possession, and bag limits, the regulation of the manner of…fishing, and the establishment of conservation policies."[143] Regulations can be state-wide or focused on a particular locality.[144] DEM will set each year's regulations[145] by December 1 of the preceding year.[146]

2. Licensing

   a. The NSSP-MO mandates that the SSCA "assure that a license is required to commercially harvest shellstock, including shellstock harvested from aquaculture."[147] The General Assembly has given DEM the authority to issue licenses for fisheries, including shellfish.[148] The General Assembly has declared that DEM regulations relating to the licensing scheme must consider:

      > (i) The effectiveness of the limitation: (A) In achieving duly established conservation or fisheries regeneration goals or requirements; (B) In maintaining the viability of fisheries resources overall, including particularly, the reduction of by-catch, discards, and fish mortality, and in improving efficiency in the utilization of fisheries resources; [and] (C) In complementing federal and regional management programs; (ii) The impact of the limitation on persons engaged in commercial fishing on: (A) Present participation in the fishery, including ranges and average levels of participation by different types or classes of participants; (B) Historical fishing practices in, and dependence on, the fishery; (C) The economics of the fishery; (D) The potential effects on the safety of human life at sea; (E) The cultural and social framework relevant to the fishery and any affected fishing communities; and (iii) Any other relevant considerations that the director finds in the rule making process.[149]

   b. As of January 1, 2014, the NSSP-MO requires that all licensed harvesters receive training every two years on proper harvest, handling, and transportation practices.[150]

   c. Rhode Island residents are not required to obtain a license for recreational taking of shellfish, provided that they (1) follow the recreational possession limits and (2) do not offer the shellfish for sale,[151] except in Great Salt Pond where a New Shoreham license is required for any shellfish harvesting.[152] Residents looking to harvest shellfish commercially,[153] as well as non-residents

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[143] R.I. GEN. LAWS § 20-1-1(b) (2013).
[144] *Id.* § 20-1-12(a)(2).
[145] The regulations to be set by this date include "[a]vailability of new licenses and endorsements, harvest and gear levels, regulations affecting gear, times and seasons, area closures and restrictions, quotas and catch or landing limits, limits on entry, control dates and data reporting." *DEM Licensing Regulations*, *supra* note 41, § 6.1-11.
[146] Id.
[147] NSSP-MO, *supra* note 16, § II, ch. VIII, Requirements for the Authority, § .01(C)(1).
[148] R.I. GEN. LAWS § 20-2-1.
[149] *Id.* § 20-2.1-9(2).
[150] NSSP-MO, *supra* note 16, § II, Ch. VIII, Requirements for the Harvester, § .01(B).
[151] R.I. Dept. of Envtl. Mgmt., Rhode Island Marine Fisheries Statues and Regulations Part IV: Shellfish § 4.1.2 (2013) [hereinafter DEM Shellfish Regulations].
[152] NEW SHOREHAM, R.I., REV. ORDINANCES ch. 9, § 9-139 (2013) (requiring any person aged fourteen or older to obtain a license from the Town Council prior to taking any shellfish).
[153] Issuance of new commercial licenses is currently limited to state residents. *DEM Shellfish Regulations*, *supra* note 153, § 4.1.5.

seeking to harvest recreationally, must obtain a license.[154] Certain license fees are statutorily set, as seen in Table 9.2.

Table 9.2. Statutorily set license fees in the state of Rhode Island.

Type of License	Cost	RI General Laws/DEM Regulations
Commercial Basic Harvest and Gear Level	$50 for license; $25 for each endorsement	20-2.1-5/Part II, Rule 6.8-2(a)
Commercial Principle Effort	$150 for license; $75 for each additional endorsement	20-2.1-5/Part II, Rules 6.8-3(a), (d)
Commercial Multi-purpose/Full Effort	$300	20-2.1-5/Part II, Rule 6.8-4(a)
Shellfish Dredge License[155]	$200	DEM reg, Part IV, Rules 4.1.4, 6.1
Shellfish Non-dredge Endorsement	$2	20-6-6
Non-resident RI Property Owner Recreational Shellfishing License[156]	$25	20-2-22(d)/Part IV, Rule 4.1.3(c)
Non-resident Non-RI Property Owner Recreational Shellfishing License	$200	20-2-22(a)/Part IV, Rule 4.1.3(a)
Student Commercial Shellfish License (students twenty-three or under)	$50	20-2.1-5(iii)(A)/Part II, Rule 6.8-5(a)
14-Day Recreational License (for non-residents)[157]	$11	20-2-22(b)/Part IV, Rule 4.1.3(b)
Party or Charter Boat License	$25 (biennially)	20-2-27.1(a)
Landing License (for shellfish caught outside of RI waters but landed in RI)	$200	20-2-22(c)

d. Every license expires on December 31 of its issue year.[158] Under state law, licenses are to be renewed[159] annually, with “firm annual renewal deadline[s]” to be set by DEM.[160] DEM has set

[154] *See* R.I. GEN. LAWS § 20-4-1; *DEM Shellfish Regulations*, *supra* note 153, §§ 4.1.1, 4.1.3, 11.1.
[155] This license is available only to residents and is required “to take quahaugs, mussels, and surf clams by dredges hauled by power boat.” *DEM Shellfish Regulations*, *supra* note 153, §§ 4.1.4, 6.1.
[156] This licensing scheme applies to a nonresident “who owns residential real estate in Rhode Island assessed for taxation at the valuation of not less than thirty thousand dollars….” R.I. GEN. LAWS § 20-2-22(d).
[157] This license may only be obtained once per calendar year. *Id.* § 20-2-22(b); *DEM Shellfish Regulations*, *supra* note 153, § 4.1.3(b).
[158] *DEM Licensing Regulations*, *supra* note 41, § 5.42 (defining “License Year”).

the annual renewal deadline as February 28.[161] No review by the commercial fishing license review board is available if the applicant did not submit an application by the deadline or within the sixty day grace period, except in a case of a documented medical hardship.[162] Licenses do not create property rights by statute, and the General Assembly calls for surrender of a license upon non-renewal.[163]

e. DEM is limited in what fees it may charge for licenses not statutorily-set as well as how it may use the income from the license fees. The fees must be set from an annual plan adopted based on "the advice of the marine fisheries council."[164] Fees collected must be used "for the purpose of fishery conservation and restoration and resource enhancement" at least for the first $200,000 collected.[165] If funds beyond $200,000 are raised, those funds may be used for "protection and propagation of" fisheries resources, transplant programs, or other approved fisheries-management activities.[166] DEM, with the advice of RIMFC, must create an annual spending plan for license and vessel declaration fees.[167]

f. For the shellfish sector, DEM has divided licensing into four endorsement categories: quahaug, soft-shell clam, conch (whelk), and other shellfish.[168] As indicated by the license fee scheme outlined above, the RI General Laws call for a tiered commercial licensing system, and the available shellfish licenses are a Multi-Purpose License, a Principal Effort License, a Commercial Fishing License, a Student Shellfish License, and a 65 and Over License.[169]

g. A Principle Effort License "shall allow its holder to fish in a fishery sector [for which the holder has an endorsement] at the full harvest and gear levels," and a Multi-Purpose License "shall allow

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[159] For those in active military service, the renewal requirement is relaxed. A person "holding a valid license and/or landing permit at the time he or she enters active military service" may have his or her license renewed immediately upon return from service. *Id.* § 6.7-4(j).
[160] R.I. GEN. LAWS §§ 20-2-12, 20-2.1-2(7); NSSP-MO, *supra* note 16, § II, ch. VIII, Requirements for the Authority, § .01(C)(2).
[161] *DEM Licensing Regulations*, *supra* note 41, § 6.7-3(c). Applications must be made in person by 4:00 PM, electronically by midnight, or postmarked no later than February 28. If February 28 falls on a Saturday, Sunday, or holiday, the application deadline will be the next business day after February 28. *Id.* A sixty day grace period follows the annual renewal deadline in which an application for renewal may be filed but requires payment of a $200 late fee. *Id.* § 6.7-3(e).
[162] *Id.* § 6.7-10(a).
[163] R.I. GEN. LAWS § 20-2.1-5; *see also DEM Licensing Regulations*, *supra* note 41, § 6.7-2(b).
[164] R.I. GEN. LAWS § 20-2-28.2.
[165] *Id.* § 20-2-28.2; *DEM Licensing Regulations*, *supra* note 41, § 6.5-3.
[166] R.I. GEN. LAWS § 20-2-28.2.
[167] *DEM Licensing Regulations*, *supra* note 41, § 6.5-1. Permissible uses for the fees include "(a) Protection and propagation of marine fish, lobsters, and shellfish; (b) Enforcement of fisheries management regulations; (c) Shellfish transplants; (d) Enhancement of shellfish resources through other technologies including seeding; (e) Fishing port development and construction; (f) Staff support to and expenses incurred by RIMFC; (g) Lease or purchase of land or conservation easements; and (h) Technical support to and expenses incurred by the Department for purposes of managing fisheries resources generally and for the collection, processing, analysis and maintenance of data employed in support of such management." *Id.* § 6.5-2.

[168] *Id.* § 6.1-1(a). These are the current categories utilized by DEM, but DEM may modify them as it deems necessary. *Id.* § 6.1-1(b).
[169] *Id.* §§ 6.8-2, 6.8-3, 6.8-4, 6.8-5, 6.8-6. Licenses are also required to land fish in Rhode Island that were caught in other waters and to purchase fish from harvesters and sell them to distributors or to the public. R.I. GEN. LAWS §§ 20-2.1-7, 20-4-1.2(a) (for fish caught in other than Rhode Island waters), 20-2.1-8(1), (3), 20-6-24 (to purchase from harvesters and resell).

the holder to engage in commercial fishing in all fisheries sectors at the full harvest and gear levels."[170] An endorsement is a "notation on a license that indicates the right to harvest a marine species or group of similar species, the right to utilize a particular type of gear or harvesting method…in accordance with applicable harvest and/or gear restrictions."[171] A Commercial Fishing License entitles the holder to harvest shellfish at Basic Harvest and Gear Level for any fishery for which they hold an endorsement.[172] Full time resident students aged twenty-three and under and any resident over the age of sixty-five may obtain a Student Shellfish License or 65 and Over License, respectively, both of which entitle the holders to harvest at the Basic Harvest and Gear Level.[173] Additionally, a dredge endorsement is required in order to harvest shellfish via dredge for those species for which such harvest method is allowed.[174] Regardless of which license a harvester holds, he or she must be in possession of that license while actively harvesting.[175]

h. DEM is authorized to issue "[n]ew principal effort and multi-purpose licenses that increase the total number of licenses in the fishery…by rule consistent with [a] management plan" established for that year.[176] In determining how many licenses to issue, DEM must give consideration to the dual interests of fishery preservation and enhancement as well as "the rights and interests of residents of Rhode Island to engage in fishing including commercial fishing."[177] DEM adopts an "exit/entry ratio," which is a formula establishing how many new licenses will issue for each license retired or otherwise surrendered.[178] Currently, for quahaug licenses, for every two Multi Purpose or Principal Effort Licenses retired, one new Commercial Fishing License with a quahaug endorsement will be made available, with a minimum of three annually.[179] For Soft Shell Clams, one Commercial Fishing License with Soft Shell Clam endorsement will be made available for every five Multi Purpose, Principal Effort, or Commercial Fishing Licenses retired, with a minimum of three new licenses annually.[180] New Student and 65 and Over Licenses are available to any qualified applicant.[181]

i. When applying for a license, a prospective holder is required to provide a notarized statement containing "(a) Full name; (b) Age; (c) Occupation; (d) Residence address; (e) Mailing address; (f) Weight; (g) Height; (h) Hair color; (i) Eye color; (j) The name of any state or jurisdiction in which the applicant's commercial fishing license and/or permit is currently revoked or suspended; and (k) Driver's License number and state of issuance, or other state-issued photo identification card."[182] The license will not be valid unless it has been "signed and sworn to" by the holder.[183]

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[170] R.I. GEN. LAWS § 20-2.1-5; *see also DEM Licensing Regulations*, *supra* note 41, §§ 6.1-2(a), 6.8-3 (Principal Effort License), 6.8-4 (Multi-Purpose License). Although a multi-purpose license holder is authorized to fish in all fisheries sectors, each fisher must declare "which fishing sectors [he] intends to place significant fishing effort" in, although this declaration is non-binding. R.I. GEN. LAWS § 20-2.1-5.
[171] DEM Licensing Regulations, supra note 41, § 5.24.
[172] *Id.* §§ 6.1-2(b), 6.8-2.
[173] *Id.* §§ 6.1-2(b), 6.8-5(d), 6.8-6(a), 6.8-6(d). There is no fee for the 65 and Over License. *Id.* § 6.8-6(b).
[174] DEM Shellfish Regulations, supra note 153, § 4.1.4; R.I. Dept. of Envtl. Mgmt., Rhode Island Marine Fisheries Statues and Regulations Part VI: Dredging for Shellfish § 6.1 (2012) [hereinafter DEM Dredging Regulations].
[175] R.I. Dept. of Envtl. Mgmt., Rules and Regulations Governing Taking, Possession, Holding, Bartering and Trading of Shellfish § 2.01(c) (2000) [hereinafter DEM Enforcement Regulations].
[176] R.I. GEN. LAWS § 20-2.1-5(3)(D)(iii) (2013).
[177] *See id.* §§ 20-2.1-1, -2(1).
[178] *DEM Licensing Regulations*, *supra* note 41, § 5.26 (defining "Exit/Entry Ratio").
[179] *Id.* § 6.1-10(b).
[180] *Id.* § 6.1-10(c).
[181] *Id.* § 7.4.
[182] *Id.* § 6.7-1.
[183] *Id.* § 6.7-2(a).

Additionally, a license holder must notify the office of boat registration of a change of address within ten days of a move.[184]

j. The Rhode Island General Laws and DEM regulations stipulate a system for renewal and upgrade of licenses. "Applicants who possessed a valid Commercial Fishing License with…Quahaug…, Soft-Shell Clam…,…Whelk…" or Shellfish Other endorsements as of the immediately preceding year may renew their licenses with the same endorsements.[185] These same renewal guidelines apply to holders of Principal Effort Licenses, with all holders able to renew with the same endorsements.[186] Holders of Multi-Purpose Licenses are able to renew their Multi-Purpose Licenses the following year or obtain a Principal Effort License Quahaug, Soft-Shell Clam, Shellfish Other, and/or Whelk endorsements.[187]

k. When new licenses or endorsements are available, the top priority for distributing those licenses will be equally divided between three categories: (i) holders of Commercial Fishing Licenses who have been actively fishing[188] their licenses and are seeking to upgrade their license in the same fishery; (ii) holders of Principal Effort Licenses who have been actively fishing their licenses and are seeking new endorsements; and (iii) "resident crew members who have been actively participating[189] in the same fishery sector for which a new license/endorsement is being sought."[190] Within each of the three categories, applicants will be prioritized based on the length of time they have been active in the fishery.[191]

l. Second priority for new licenses is split equally among two categories: (i) holders of Commercial Fishing Licenses who have been actively fishing their license and are seeking a new endorsement or license upgrade; and (ii) "resident crew members who have been actively participating in any fishery sector."[192] Again, within each category, applicants will be prioritized based on the length of time they have been active in the fishery.[193] Third priority is given to new resident applicants, aged sixteen and older.[194]

m. Holders of a Student or 65 and Over Shellfish License "who have been actively fishing their license, may obtain a Commercial Fishing License with a Quahaug endorsement for the immediately following year."[195] Holders of a Commercial Fishing or Principal Effort License with a Quahaug and/or Soft-Shell Clam endorsement "and have actively fished said endorsement

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[184] *Id.* § 6.7-2(g).
[185] *Id.* § 6.7-4(a).
[186] *Id.* § 6.7-4(b); *see* R.I. GEN. LAWS § 20-2.1-5 (2013).
[187] *DEM Licensing Regulations*, *supra* note 41, § 6.7-4(c). Holders who select the Principal Effort License may also obtain endorsements for Lobster, Non-Lobster Crustacean, Restricted Finfish, and/or Non-Restricted Finfish. *Id.*
[188] Actively fishing means that the fisher "fished at least seventy-five days in the preceding two calendar years, with some of the fishing activity occurring in each of the two years." *DEM Licensing Regulations*, *supra* note 41, § 5.1.
[189] Actively participating means that the person was a crew member who "fished in the fishery with one or more licensed captains at least seventy-five (75) days in the preceding two calendar years, with some of the fishing activity occurring in each of the two years." *Id.* § 5.2.
[190] *Id.* § 6.7-6(a); *see* R.I. GEN. LAWS § 20-2.1-5.
[191] *DEM Licensing Regulations*, *supra* note 41, § 6.7-6(a). If the prioritization still results in more applicants than available licenses/endorsements, a lottery will be held to determine who will receive the available licenses/endorsements. *Id.* § 5.44.
[192] *Id.* § 6.7-6(b); *see* R.I. GEN. LAWS § 20-2.1-5.
[193] DEM Licensing Regulations, supra note 41, § 6.7-6(b).
[194] *Id.* § 6.7-6(c). Non-residents will only be considered for issuance of **new** commercial fishing licenses, even if they have previously participated in a R.I. fishery, if their state of residence would permit a Rhode Island resident to obtain a non-resident fishing license in that state. R.I. GEN. LAWS § 20-2.1-6(1)(ii).
[195] *DEM Licensing Regulations*, *supra* note 41, §§ 6.7-4(d), 6.8-5(e), 6.8-6(e).

as of the immediately preceding year may obtain a Whelk endorsement for the immediately following year."[196]

n. There are two exceptions that allow a person to obtain a license from outside of this exit/entry and prioritization chain: transfer to a family member and sale of business.[197] When a license holder who has been actively fishing his or her license elects to not renew that license, one family or crew member may obtain a new license of the same level and endorsements as the retiree.[198] A family member may also obtain a license if the relative license holder dies or becomes permanently incapacitated.[199] If a license holder is temporarily incapacitated – sufficient to prevent fishing for at least fourteen days – a family member may apply for an operator permit that will allow the family member to fish at the same level as the incapacitated family member.[200] The incapacitated license holder's license will be suspended, but it may be reinstated, and the operator permit terminated, if the licensee regains capacity.[201]

o. Additionally, a licensee may sell his or her business, and the buyer will be entitled to issuance of a new license equivalent to the retired license of the original business owner.[202] Sale of a business involves transfer of a vessel and/or gear from a licensee to a buyer.[203] Direct transfer of a license is prohibited, but once the business owner surrenders his or her license to DEM, the business purchaser may apply for an equivalent license.[204] The buyer must be a Rhode Island resident,[205] and the seller must have been actively fishing his or her license prior to sale.[206]

p. A commercial harvester licensed to harvest shellfish outside of Rhode Island waters who wishes to land the shellfish in Rhode Island must obtain a Rhode Island landing permit.[207] Residents who hold a Landing Permit may renew their landing permit the immediately following year for any fishery.[208] Non-residents holding Landing Permits may obtain Landing Permits in the immediately following year for the same fisheries or for new fisheries subject to eligibility.[209]

3. Harvest Methods

a. The General Assembly and DEM have set certain restrictions on methods for harvesting shellfish in Rhode Island. A vessel used to harvest shellfish must declare a mode of fishing, and may be

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[196] *Id.* § 6.7-4(f).
[197] *See* R.I. GEN. LAWS § 20-2.1-5. DEM defines "family member" in this sense to include "spouse, mother, father, brother, sister, child or grandchild." *DEM Licensing Regulations*, *supra* note 41, § 5.27.
[198] DEM Licensing Regulations, supra note 41, § 6.7-7.
[199] *Id.* § 6.7-9(c).
[200] *Id.* § 6.7-9(e).
[201] Id.
[202] *Id.* § 6.7-8(b).
[203] Id.
[204] *Id.* Although an equivalent license will generally be issued, DEM may issue a lower level license "where necessary to accomplish the purposes of the applicable management plan" in effect at that time. *Id.* § 6.7-8(c).
[205] *Id.* § 6.7-8(a).
[206] *Id.* § 6.7-8(b). The actively fishing requirement may be waived if the seller "is unable to meet the [requirement] due to a material incapacitation." *Id.* § 6.7-8(d).
[207] *Id.* § 6.10-1(a). If the harvester holds a valid Rhode Island commercial fishing license, he or she does not require a landing permit to land shellfish harvested outside of Rhode Island waters. *Id.*
[208] *Id.* § 6.7-4(h). A landing permit will only be issued if the applicant holds a valid federal or non-Rhode Island state harvesting license. *Id.* § 6.10-1(c).
[209] *Id.* § 6.7-4(i). The landing permit will only be issued if the applicant holds a valid federal or non-Rhode Island state harvesting license. *Id.* § 6.10-1(c).

fishing in only one mode at a time: recreational, party/charter, or commercial.[210] Anyone[211] may harvest in recreational mode, and the possession of each person onboard the vessel will be established based on the total vessel possession divided by the number of persons aboard the vessel.[212] A second method – Party/Charter – occurs when the vessel is "carrying one or more passengers for hire for the purpose of engaging in recreational fishing" and requires the vessel to have a party/charter license.[213] Vessels fishing in this mode must follow both the recreational shellfishing regulations as well as any party/charter regulations.[214] Finally, any vessel engaged in harvesting shellfish with the intent to sell the shellfish is engaged in commercial mode,[215] and in addition to the harvester holding a valid commercial license, the vessel must have been declared with DEM.[216] The commercial license holder must operate the vessel,[217] and any unlicensed crew may only assist with culling activities and other indirect harvest operations while under the supervision of the licensed harvester.[218]

b. Use of a diving apparatus to take shellfish by hand is prohibited in Green Hill Pond, Quonochontaug Pond, Charlestown Pond, and Potters Pond.[219] All harvesting of oysters, bay quahaugs, and soft-shell clams "by dredge(s), rakes, or other apparatus operated by mechanical power or hauled by power boats" is prohibited unless authorized pursuant to DEM regulations.[220]

c. Taking of oysters and soft-shell clams is only permitted via digging with hand operated devices.[221] Any tongs[222] cannot be "constructed with teeth which are less than one (1) inch apart on the bar or hav[e] heads constructed with wires, rods, crossbars, or reinforcement that will form a rectangle smaller than one (1) inch by two and one half (2 ½) inches."[223] For bullrakes,[224] "the teeth or tines and basket construction [cannot be] closer than one (1) inch apart or hav[e]

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210 *Id.* § 10.4(a). One vessel/harvester may harvest in multiple modes in a single day, but the catch from the first trip must be landed before initiating a second trip in a different mode. *Id.* § 10.4(b).
211 Other than non-residents without a license.
212 *DEM Licensing Regulations*, *supra* note 41, §§ 10.1(a), (b). If a vessel makes more than one trip per day, the trip totals will be added for cumulative possession for the day. *Id.* § 10.1(c).
213 *Id.* § 10.2.
214 Id.
215 *Id.* § 10.3(b).
216 *Id.* §§ 6.8-8(a), 10.3(a).
217 R.I. Dept. of Envtl. Mgmt., *Rhode Island Marine Fisheries Statues and Regulations Part V: Bay Scallops* § 5.8.7 (2010) (citing R.I. GEN. LAWS § 20-6-5 (2013)) [hereinafter *DEM Bay Scallop Regulations*].
218 *DEM Licensing Regulations*, *supra* note 41, §§ 10.3(g), (h).
219 R.I. GEN. LAWS § 20-6-30(a).
220 *DEM Shellfish Regulations*, *supra* note 153, § 4.5; *see also* R.I. GEN. LAWS § 20-6-7. Use of power hauling is permitted to remove or retrieve bullrakes and tongs from the benthic sediments. R.I. Dept. of Envtl. Mgmt., *Rhode Island Marine Fisheries Statues and Regulations Part X: Equipment Restrictions* § 10.3.1(A)(1) (2013) [hereinafter *DEM Equipment Regulations*]. However, no power hauling equipment may be employed if the bullrakes or tongs onboard exceed "thirty-one and one-half inches (31 ½") measured along a line parallel to the tooth bar," four and one-half (4 ½) inches in tooth length, or twelve (12) inches in basket depth "measured along a line perpendicular to the tooth bar and extending from the tooth bar to any point on the basket." *Id.* §§ 10.3.1(B), (C).
221 R.I. GEN. LAWS § 20-6-15; *DEM Shellfish Regulations*, *supra* note 153, § 4.6 (noting that permissible methods of harvest for soft-shell clams includes "forks, rakes, hoes, tongs, or any other device operated by hand").
222 DEM defines tongs as "any shellfishing implement constructed with heads attached to stales (handles) and pinned at a pivot point to allow the opening and closing of the basket mouth formed by the two." *DEM Equipment Regulations*, *supra* note 222, § 10.2.
223 *Id.* A tolerance of one sixteenth (1/16) inch is permitted because of potential variance in construction. *Id.*
224 DEM defines a bullrake as "any curved metal instrument or basket with four (4) or more metal tines (teeth) which is primarily used to harvest quahaugs." *Id.* § 10.3.

crossbars or reinforcement that will form a rectangle smaller than 1" X 2 ½"."[225] Use of quahuag diving baskets, bags, or combinations are permitted, but the "bar spacing [cannot be] less than one inch by two and one half (1" X 2 ½") with a one sixteenth inch (1/16") tolerance for construction" and the mesh cannot be less than two inches "when measured on the stretch"[226] with an allowed variance of one eighth (1/8) inch.[227]

d. Dredging for quahaugs, scallops, surf clams, ocean quahaugs, or mussels is permitted with some restrictions but requires a dredge endorsement.[228] Until sunrise on the first day of December each year, bay scallops may only be harvested via dip-netting.[229] Starting on December 1, harvesters with dredge endorsements may harvest scallops via dredge provided that they operate no more than six single dredges "the blades of which shall not be more than twenty-eight inches (28") in width and the bag to be used shall not be more than thirty-six inches (36") in length."[230]

e. Taking of surf clams may be done via a hydraulic dredge, but the blade, knife, or manifold must be no greater than forty-eight inches in width, and only one dredge may be used at a time aboard a single vessel.[231] Any dredge used to harvest sea scallops must be no greater than ten and one half feet with a ring size no smaller than four inches, and the mesh size of any net used must be no smaller than ten inch square or diamond.[232] Harvesters may also dredge for ocean quahaugs provided that the harvester holds either a Rhode Island Dredge or Multipurpose license.[233]

f. Dredging for quahaugs is only permitted in areas opened by DEM "[p]ursuant to good conservation practices," and DEM has the authority to close areas to quahaug dredging "at any time there is a danger of depletion of quahaugs or when flagrant violations" of relevant DEM regulations occurs.[234] When a harvester possesses the necessary dredge endorsement and is harvesting in a permissible area, the harvester may take no more than thirty bushels of quahaugs between sunrise and sunset any one day.[235]

g. Any traps, pots, or other stationary devices used to catch shellfish – generally only employed for whelk – must be marked "together with [a] buoy which is attached thereto, with the name or names of the owners thereof or the person or persons using the [device], and the license number

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[225] *Id.* A tolerance of one sixteenth (1/16) of an inch is permitted because of potential variance in construction. *Id.*
[226] On the stretch means "from inside of knot to inside of the knot." *Id.* § 10.4.
[227] *Id.* The bag must be "hung on the square so that when held by the mouth, the twine forms fully opened squares." *Id.*
[228] R.I. GEN. LAWS § 20-6-7 (2013); *DEM Dredging Regulations*, *supra* note 176, § 6.1. Use of dredges are prohibited in the following management areas: Winnapaug Pond, Quonochontaug Pond, Ninigret Pond, Potter Pond, Potowomut Management Area, and Jenny's Creek. *DEM Bay Scallop Regulations*, *supra* note 219, § 5.8.2. Dredging for surf clams and skimmers is also permitted within certain geographical boundaries. R.I. GEN. LAWS § 20-6-7; *DEM Dredging Regulations*, *supra* note 176, § 6.2. While operating a dredge, any oysters, soft-shell clams, bay quahaugs, or bay scallops (unless license to dredge for bay scallops) caught must be immediately returned to the waters from which they were taken. *DEM Bay Scallop Regulations*, *supra* note 219, § 5.8.4; *DEM Dredging Regulations*, *supra* note 176, § 6.2.
[229] DEM Bay Scallop Regulations, supra note 219, § 5.8.1.
[230] *Id.* § 5.8.3.
[231] DEM Shellfish Regulations, supra note 153, § 4.20.1; DEM Dredging Regulations, supra note 176, § 6.8.1; DEM Equipment Regulations, supra note 222, § 10.8.
[232] R.I. Dept. of Envtl. Mgmt., Rhode Island Marine Fisheries Statues and Regulations Part VII: Minimum Sizes of Fish/Shellfish § 7.23.1-4 (2014) [hereinafter DEM Minimum Size Regulations].
[233] DEM Dredging Regulations, supra note 176, § 6.10.1.
[234] *Id.* § 6.4.
[235] *Id.* § 6.5.

or numbers of such person or persons."[236] The harvester must also submit a written report to DEM each January detailing "those locations where the licensee shall be setting…traps during the upcoming fishing season."[237]

h. Certain seasonal restrictions are also created by statue or DEM regulation.[238] The oyster open season is September 15 through May 15.[239] DEM has set the whelk season at January 1 through December 31,[240] and the bay scallop season from sunrise on the first Saturday of November until sunset on the last day of December.[241] Shellfishing is also required to be a daylight activity.[242] The General Laws also require commercial fishers to report catch and effort data if requested by DEM,[243] but DEM is restricted to using this data internally and cannot make the reports available to the public.[244] Any data released to the public must be "aggregated so as to not identify individual fishers, vessels or dealers."[245]

i. Under Rhode Island law, DEM has the authority to close a fishery. The closure may be limited spatially or temporally.[246] However, the closure may also be of an entire fishery, or multiple fisheries, if "[d]eemed necessary in order to protect, manage or restore marine fish, shellfish, crustaceans, and associated marine habitats or other marine resources, protect public health or safety, or address some other public purpose."[247] Fisheries closures "must be…in response to specific conservation or restoration needs."[248] If DEM determines that a complete closure is necessary because "a biological emergency exists which imminently threatens the marine resources of the State," it may enact an immediate closure with no pre-closure notice and hearing requirements.[249] Any closed fishery must be reopened "if and when the original justification for such closure ceases to apply."[250]

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236 R.I. Dept. of Envtl. Mgmt., Rhode Island Marine Fisheries Statues and Regulations Part XI: Commercial Fisheries § 11.12 (2013) [hereinafter DEM Commercial Fisheries Regulations].
237 R.I. Dept. of Envtl. Mgmt., *Rhode Island Marine Fisheries Statues and Regulations Part XIV: Fish Traps* § 14.1 (2010) [hereinafter *DEM Fish Trap Regulations*]. The harvester may set additional traps but must first notify DEM of the intent to set and the location. *Id.*
238 *See* R.I. GEN. LAWS §§ 20-6-2, -3 (2013). The General Assembly set default seasons, but DEM is authorized to change these seasons. *Id.*
239 Id. § 20-6-2; R.I. Dept. of Envtl. Mgmt., Rhode Island Marine Fisheries Statues and Regulations Part VIII: Oyster Regulations § 8.3 (2014) [hereinafter DEM Oyster Regulations].
240 DEM Shellfish Regulations, supra note 153, § 4.35(c).
241 *DEM Bay Scallop Regulations*, *supra* note 219, § 5.3; *cf.* R.I. GEN. LAWS § 20-6-3 (setting the default open season as sunrise of the first day of October until sunset on the last day of December).
242 R.I. GEN. LAWS § 20-6-23; *DEM Shellfish Regulations*, *supra* note 153, §§ 4.2, 4.35(d) (prohibiting setting, raising, or disturbing conch pots or traps "between the hours of one (1) hour after sundown and one (1) hour before sunrise").
243 Currently, DEM does not require that shellfishers supply this data. DEM must amend reporting requirements by December 1 of the year before the amendment will go into effect. *DEM Licensing Regulations*, *supra* note 41, § 6.6-1(c).
244 R.I. GEN. LAWS § 20-4-5; *DEM Commercial Fisheries Regulations*, *supra* note 238, § 11.10.
245 DEM Licensing Regulations, supra note 41, § 6.6-3(c).
246 R.I. GEN. LAWS § 20-2.1-9(1).
247 *Id.* § 20-3.2-3(a)(1). The closure must also be "[b]ased on the best currently available scientific information" and be "developed via public review and stakeholder input…and with the advice of the marine fisheries council; except where the director deems it necessary to institute a closure via emergency rule…." *Id.* § 20-3.2-3(a).
248 *Id.* § 20-3.2-2(g).
249 R.I. Dept. of Envtl. Mgmt., Rhode Island Marine Fisheries Statues and Regulations Part III: Marine Fisheries Council § 3.8 (2014) [hereinafter DEM Council Regulations].
250 R.I. GEN. LAWS § 20-3.2-3(b).

j. Generally, the Director of DEM should consult with the RIMFC before closing a fishery, but he or she may open or close an area prior to meeting with the RIMFC "where he [or she] reasonably believes that a delay would adversely affect the public purposes sought to be served by Title 20 of the General Laws of Rhode Island and/or would pose a danger to the public health."[251] If the Director decides to open or close a fishery prior to the next RIFMC meeting, the Director must:

> (a) Immediately give notice, in writing, to the [RIFMC] members of his/her action, the basis thereof; (b) Immediately give notice of his/her action, in a newspaper of general circulation in the area to be affected thereby; and (c) Place his/her decision to open or close an area on the agenda at the next scheduled [RIFMC] meeting.[252]

k. The Director's decision must subsequently be ratified by the RIMFC or it will "become null and void."[253]

l. Another area restriction available to DEM to manage a fishery is the use of shellfish and marine life management areas.[254] A management area involves:

> the designation of certain portions of the shores of the public waters of the state, or land within the state covered by tidewater at either high or low tide, or portions of the free and common fisheries of the state…for the purpose of enhancing the cultivation and growth of marine species, managing the harvest of marine species, facilitating the conduct by the department of experiments in planting, cultivating, propagating, managing, and developing any and all kinds of marine life, and any other related purpose.[255]

m. Once the management area is designated, DEM may create unique regulations applicable only to that particular management area, including restricting persons or activities from the area entirely.[256] Management areas must be properly referenced with fixed landmarks and marked with "stakes, bounds, buoys, or markers."[257] Designation of a management area may not exceed five years, although the designation may be renewed at the end of its term.[258]

n. Currently, DEM has designated the following shellfish management areas: Bristol Harbor Shellfish Transplant Area, Potter Pond, Pt. Judith Pond, Ninigret (Charlestown) Pond, Quonochontaug Pond, Winnapaug (Brightman) Pond, Potowmut, Greenwich Bay, Conimicut Point, Mill Gut, Kickemuit River, Bissel Cove, High Banks, Sakonnet River, and Jenny's Creek.[259] These areas will remain shellfish management areas unless DEM modifies their status.[260] Possession limits in these shellfish management areas are reduced below the general possession limits for all license holders.[261] Additionally, "use of diving apparatus is prohibited while shoredigging" in management areas.[262] Shoredigging refers to harvesting shellfish close to shore, usually without a vessel. Additional regulations unique to each management area apply and

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[251] DEM Council Regulations, supra note 251, § 3.5.7.
[252] Id.
[253] Id.
[254] R.I. GEN. LAWS § 20-3-4.
[255] Id.
[256] Id.
[257] Id.
[258] DEM Council Regulations, supra note 251, § 3.5.3.
[259] *DEM Shellfish Regulations*, *supra* note 153, § 4.8; *see also DEM Council Regulations*, *supra* note 251, § 3.6 (providing boundary designations for each management area).
[260] DEM Shellfish Regulations, supra note 153, § 4.8.
[261] *Id.*; *see infra* § 830.5(4).
[262] DEM Shellfish Regulations, supra note 153, § 4.8.

are laid down in DEM regs, Part IV, Rules 4.10 through 4.12, 4.22, and 4.24, 4.26 through 4.28. Greenwich Bay Shellfish Management Area has several unique regulations, including that it is only open to shellfish harvesting when declared open by the DEM. Office of Water Resources.[263]

4. Size and Catch Limits

   a. The General Assembly has also set size restrictions on shellfish harvest, which operate as defaults with DEM free to **increase** the minimum sizes.[264] The minimum hinge width[265] for quahogs is one inch, although the statute permits DEM to establish an exemption program that allows licensed food processing facilities to possess smaller quahogs that are shipped into the state, processed, and then shipped back out of the state.[266] The minimum size for soft-shell clams is a shell diameter of two inches along the maximum diameter,[267] and oysters must be at least three inches along the long axis.[268] The minimum size for surf clams is five inches in the longest shell diameter.[269] Scallops cannot be taken commercially or recreationally unless they measure at least three and one-half inches shell length, regardless of whether they were caught in state waters or beyond.[270] Conch minimum size is set at a shell diameter of 2-3/4 inches in diameter and a minimum shell length of 4-3/4 inches.[271] The General Laws require that any seed or undersized shellfish that are inadvertently taken must be immediately returned to the same waters from which they were taken.[272]

   b. All shellfishers are limited in the quantity of shellfish that they can possess and land on any given day. A shellfish is deemed within the "possession" of the shellfisher when he or she exercises "dominion or control over the [shellfish] commencing at the time at which a decision is made not to return the [shellfish] to the immediate vicinity from which it was taken," which decision "must be made at the first practical opportunity."[273] The General Assembly has also set certain catch limits that will operate as the established catch limits if DEM fails to set limits. These limits are

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[263] *Id.* § 4.10.

[264] R.I. GEN. LAWS § 20-6-11(a) (2013). Several other Shellfish Management Areas are also closed to harvesting unless declared open by the Office of Water Resources. *DEM Shellfish Regulations*, *supra* note 153, §§ 4.11.1-2 (Conimicut Point), 4.22.1-1 (Bristol Harbor), 4.24.1-1 (Bissel Cove), 4.26.2 (Kickemuit River), 4.27.2 (Potowomut), 4.28.2 (High Banks). Taking of oysters from Bissel Cove/Fox Island is prohibited until September 15, 2015. *Id.* § 4.12.6-1. Taking oysters from Quonochontaug Pond is prohibited until September 15, 2016, and portions of the Pond are completely closed to shellfishing except for dip net harvest of bay scallops. *Id.* § 4.12.3. Portions of additional management areas are likewise closed to shellfishing except for dip net harvest of bay scallops. *Id.* §§ 4.12.2-1 (Winnapaug Pond), 4.12.4-1 (Ninigret Pond), 4.12.5-1 (Potter Pond).

[265] Hinge width is "the distance between the convex apex of the right shell and convex apex of the left shell." *DEM Shellfish Regulations*, *supra* note 153, § 4.21. Jenny's Creek Shellfish Management Area is closed to all shellfishing until further notice. *Id.* § 4.29.

[266] R.I. GEN. LAWS § 20-6-11; *DEM Shellfish Regulations*, *supra* note 153, § 4.21.

[267] DEM Shellfish Regulations, supra note 153, § 4.21(a).

[268] R.I. GEN. LAWS § 20-6-11(a); *DEM Shellfish Regulations*, *supra* note 153, § 4.21(a); *DEM Oyster Regulations*, *supra* note 241, § 8.2.

[269] *DEM Shellfish Regulations*, *supra* note 153, § 4.20.2-2; *DEM Dredging Regulations*, *supra* note 176, § 6.8.2-2. Smaller surf clams may legally be harvested outside of Rhode Island's territorial waters if the harvester possesses the proper permits from NMFS. However, before entering Rhode Island waters, the harvester must notify the Rhode Island Office of Law Enforcement's dispatcher and provide pertinent information on the vessel, catch, and trip plan. *DEM Dredging Regulations*, *supra* note 176, § 6.8.3.

[270] *DEM Minimum Size Regulations*, *supra* note 234, §§ 7.23.1-1, 7.23.2-1. "Shell length is a straight line measurement from the hinge to the part of the shell that is furthest away from the hinge." *Id.* §§ 7.23.1-1, 7.23.2-1.

[271] DEM Shellfish Regulations, supra note 153, § 4.35(e)(1).

[272] R.I. GEN. LAWS § 20-6-17.

[273] *DEM Regulations Legislative Findings*, *supra* note 9, § 1.3 (defining "possession").

the upper limit of permissible daily possession, but possession limits are reduced in certain management areas.[274]

c. All residents are authorized to take one half bushel[275] of quahaugs, soft shell clams, sea clams, oysters, mussels, and conch as well as one bushel of scallops each day for personal use without obtaining a license.[276] Residents may also recreationally fish for sea scallops and may possess up to five bushels in-shell or forty pounds of shucked sea scallop meat.[277] Non-residents with recreational licenses may take up to one peck each of oysters, quahaugs, soft-shell clams, surf clams, and mussels each day.[278] Only residents may take whelk or bay scallops either recreationally or commercially.[279]

d. DEM has set catch limits at two levels for commercial shellfishing: Basic Harvest Level[280] and Full Harvest Level.[281] Basic Harvest Level entitles the license holder to take three bushels of Quahaug each day.[282] For soft-shell clam, shellfish other, and whelk, all license holders may take the Full Harvest Level.[283] Full Harvest Level permits the holder to take twelve bushels of quahuags, twelve bushels of soft-shell clams, and three bushels of oysters.[284] Persons with commercial licenses may also take up to two-hundred bushels[285] of surf clams and twenty-six cages (832 bushels) of ocean quahaugs each day.[286] A commercial harvester may also take no

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[274] See DEM Shellfish Regulations, supra note 153, § 4.3.

[275] A bushel is equal to 2150.4 cubic inches. *DEM Legislative Findings*, *supra* note 9, § 1.3 (defining "bushel"). A peck is one quarter (1/4) of a bushel. *Id.* (defining "peck"). A quart is one thirty-second (1/32) of a bushel. *Id.* (defining "quart").

[276] R.I. GEN. LAWS § 20-6-1; *DEM Shellfish Regulations*, *supra* note 153, §§ 4.3.1, 4.35.4-1 (conch); *DEM Bay Scallop Regulations*, *supra* note 219, §§ 5.1.1, 5.2.1 (bay scallops); *DEM Oyster Regulations*, *supra* note 241, § 8.4 (oysters). If conch are recreationally fished via a vessel with multiple individuals on board, the total vessel possession limit is one bushel. *DEM Shellfish Regulations*, *supra* note 153, § 4.35.4-1. Additionally, a person recreationally harvesting conchs cannot set more than five pots or traps at a single time. *Id.* § 4.35.4-2.

[277] DEM Minimum Size Regulations, supra note 234, § 7.23.2-2.

[278] R.I. GEN. LAWS § 20-6-10(b); *DEM Shellfish Regulations*, *supra* note 153, § 4.3.3, 4.4(b); *DEM Oyster Regulations*, *supra* note 241, § 8.4.

[279] *DEM Shellfish Regulations*, *supra* note 153, § 4.35(a) (conch); *DEM Bay Scallop Regulations*, *supra* note 219, § 5.1.2 (bay scallops).

[280] Applies to Commercial Fishing License as well as Student and 65 and Over Shellfish License holders. *DEM Licensing Regulations*, *supra* note 41, § 6.1-2(b); *see also id.* §§ 6.8-2 (CFL), 6.8-5(d) (Student), 6.8-6(d) (65+).

[281] Applies to Multi-Purpose and Principal Effort License holders. *DEM Licensing Regulations*, *supra* note 41, § 6.1-2(a); *see also id.* §§ 6.8-3 (PEL), 6.8-4 (MPL).

[282] *Id.* § 8.2-3.

[283] *Id.* §§ 8.2-4, 8.2-5, 8.2-7.

[284] R.I. GEN. LAWS § 20-6-10(a) (2013); *DEM Shellfish Regulations*, *supra* note 153, §§ 4.3.2, 4.4(a); *DEM Oyster Regulations*, *supra* note 241, § 8.4.

[285] This is a total vessel possession limit. *DEM Shellfish Regulations*, *supra* note 153, 4.20.2-1; *DEM Dredging Regulations*, *supra* note 176, § 6.8.2-1. In the Sakonnet River Shellfish Management Area, by-catch of quahaugs are permitted when dredging for surf clams, with a two hundred bushel limit of surf clams, at a ratio of one bushel of bay quahaugs for each ten bushels of surf clams, with a maximum limit of twelve bushels of bay quahaugs. *DEM Dredging Regulations*, *supra* note 176, § 6.9.

[286] *DEM Shellfish Regulations*, *supra* note 153, §§ 4.3.2, 4.4(a), 4.20.2-4; *DEM Dredging Regulations*, *supra* note 176, § 6.10.3. If properly licensed to take surf clams or ocean quahaugs from outside of the territorial waters of Rhode Island, a harvester may possess and land a quantity of these shellfish beyond the state possession limits. However, the harvester may not actively harvest within state waters while in possession beyond the state limit, and must notify the DEM Office of Law Enforcement before entering state waters. *DEM Shellfish Regulations*, *supra* note 153, § 4.20.2-3; *DEM Dredging Regulations*, *supra* note 176, §§ 6.8.2-3, 6.10.4.

more than three bushels of bay scallops each day.[287] Fishers with conch/whelk endorsements may take up to thirty-five bushels each day,[288] but no fisher may place more than three hundred pots or traps at any one time.[289] Non-federally permitted Rhode Island licensed vessels may take up to fifty bushels of in-shell sea scallops or four hundred pounds of shucked sea scallops.[290]

e. Possession limits are reduced when fishing in designated shellfish management areas.[291] Unless otherwise specified for specific management areas, Rhode Island residents may recreationally harvest a maximum of one peck each per day per individual of quahaugs, soft-shell clams, sea clams, mussels, and oysters[292] from management areas.[293] For commercial shellfishers, each license holder is limited to three bushels each per day, and when harvesting from a boat, a maximum of six bushels per boat per day with no more than two license holders permitted to harvest from a single boat.[294] Licensed non-resident recreational shellfishers are limited to one half-peck each per day per license holder.[295] DEM may establish "a reduced shellfish limit" in any management area for a period of up to sixty days.[296] When a management area has had a temporary shellfish limit reduction, recreational limits do not change, but commercial harvest is limited to one bushel each per day per license holder.[297]

5. Post-harvest/Pre-landing

a. Once the shellfish have been harvested, the harvester or aquaculturist must ensure that all actions in regards to the shellfish are executed "so as to prevent contamination, deterioration and decomposition of such shell stock."[298] All vessel surfaces and storage bins must be kept clean with potable water or growing area water from an open area, and the harvester must prevent the shellfish from coming into contact with bilge water.[299] Harvesting vessels are also not permitted to discharge human sewage into the waters of the state.[300] The shellfish must be "washed reasonably free of bottom sediments as soon after harvesting as possible" with potable water or growing area water from an open area.[301]

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[287] *DEM Bay Scallop Regulations*, *supra* note 219, § 5.2.2; *cf.* R.I. GEN. LAWS § 20-6-16 (permitting ten bushels per day, but DEM has elected to lower the daily possession limit).
[288] DEM Shellfish Regulations, supra note 153, § 4.35.1-2.
[289] *Id.* § 4.35.1-3.
[290] *DEM Minimum Size Regulations*, *supra* note 234, § 7.23.1-2. Harvesters with federal permits may possess sea scallops in excess of this limit while in state waters provided that their federal permits authorize the amount possessed and they keep all harvesting gear stowed while in state waters. *Id.* § 7.23.1-3.
[291] DEM Shellfish Regulations, supra note 153, § 4.8.
[292] Oysters may only be harvested between September 15 and May 15. *Id.* Additionally, "[t]he harvest and possession of oysters in Bissel Cove/Fox Island is prohibited…[until] September 15, 2015." *Id.*
[293] *Id.*; *DEM Oyster Regulations*, *supra* note 241, § 8.5 (oysters).
[294] *DEM Shellfish Regulations*, *supra* note 153, § 4.8; *DEM Oyster Regulations*, *supra* note 241, § 8.5 (oysters). In Greenwich Bay Management Area, the commercial shore digging limit of three bushels per day applies only when "sub-area 1 is open to boat harvest, but [the limit is] 1 peck/day/license holder whenever sub-area 1 is not open to boat harvest." *DEM Shellfish Regulations*, *supra* note 153, § 4.8.
[295] DEM Shellfish Regulations, supra note 153, § 4.8; DEM Oyster Regulations, supra note 241, § 8.5 (oysters).
[296] DEM Shellfish Regulations, supra note 153, § 4.9.
[297] Id.
[298] *Id.* § 4.30.1.
[299] *Id.* §§ 4.30.3, 4.30.5.
[300] *Id.* § 4.30.9.
[301] *Id.* § 4.30.8; R.I. Dept. of Envtl. Mgmt., *Rhode Island Marine Fisheries Statues and Regulations Part XIX: Fish/Shellfish Dealer Regulations* § 19.6.4 (2013) [hereinafter *DEM Dealer Regulations*]. If it is not feasible for the harvester to wash the shell stock, the dealer must do so as soon as possible. *Id.* § 19.6.4.

b. The shellfish must be placed in clean containers for transport to a dealer.[302] Commercial harvesters must tag shellstock containers at the harvest location.[303] Harvested shellfish must be placed "in a container which is tagged and labeled with the fisher's name, license number, date, and…area from which shellfish was removed,"[304] species of shellfish contained, and the approximate quantity of shellfish.[305] The harvester tag must be "durable, waterproof, and sanctioned by" DOH."[306] The statement, "THIS TAG IS REQUIRED TO BE ATTACHED UNTIL CONTAINER IS EMPTY OR IS RETAGGED AND THEREAFTER KEPT ON FILE FOR 90 DAYS" must be included in bold, capitalized type on all tags.[307] This tagging process must be completed before leaving a management area from which the shellfish were harvested, removing the shellfish from the boat, or offering the shellfish for sale.[308]

c. Alternative tagging methods may be available under limited circumstances. Bulk tagging – utilizing multiple containers wrapped on a pallet, in a tote, in a net brailer, or other container with a single tag on the entire unit – is permitted provided that DEM approval is obtained.[309] DEM will only grant such approval if all shell stock are harvested in a single growing area on a single day, the unit tag contains a statement that "all shell stock containers in this lot have the same harvest data and area of harvest," and the unit tag provides the number of containers in the unit.[310] If the harvester is also a licensed dealer, he or she may elect to tag the harvested shellfish with a harvester tag or a dealer tag.[311]

d. Unless the SSCA establishes a "commingling plan," it must require that shellfish harvested from different locations or at different times not be commingled.[312] DEM currently requires that no commingling occur, and each container must contain shell stock from only a single growing area.[313] It is also unlawful for anyone to have the shucked meat of more than six shellfish onboard a vessel or to throw opened scallop shells overboard,[314] so shellfish must be landed before being shucked. This applies to whelk as well, which must be "landed whole in the shell."[315]

e. Once washed, stored, and tagged, the harvester must deliver the shell stock to a dealer before sufficient time has passed for the shell stock to deteriorate, with a maximum time of twenty hours from harvest to delivery.[316] During the time between harvest and delivery, the harvester must "not allow shell stock to deteriorate or decompose from exposure to excessive temperature."[317]

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302 See DEM Shellfish Regulations, supra note 153, § 4.30.2.
303 NSSP-MO, *supra* note 16, § II, ch. VIII, Requirements for Harvesters, § .02(F); *DEM Shellfish Regulations*, *supra* note 153, §§ 4.8.1, 4.31.1. Generally, a harvester's tag is required, but if the harvester is also a dealer, he or she may elect to affix a dealer's tag instead. *Id.* § 4.31.4.
304 DEM Shellfish Regulations, supra note 153, § 4.8.1.
305 *Id.* § 4.31.2; *DEM Dealer Regulations*, *supra* note 303, § 19.2.2.
306 DEM Shellfish Regulations, supra note 153, § 4.31.2.
307 *Id.* § 4.31.3; *DEM Dealer Regulations*, *supra* note 303, § 19.2.2.
308 *DEM Shellfish Regulations*, *supra* note 153, §§ 4.8.1, 4.31.1.
309 *Id.* § 4.31.5.
310 Id.
311 *DOH Regulations*, *supra* note 8, § 6.2(b); *see also* NSSP-MO, *supra* note 16, § II, ch. X, § .05(A)(2).
312 NSSP-MO, *supra* note 16, § II, ch. I, § .01(G).
313 DEM Shellfish Regulations, supra note 153, § 4.31.4.
314 R.I. GEN. LAWS § 20-6-21 (2013); *DEM Shellfish Regulations*, *supra* note 153, § 4.23; *DEM Bay Scallop Regulations*, *supra* note 219, § 5.7.
315 DEM Shellfish Regulations, supra note 153, § 4.35(b).
316 *Id.* §§ 4.32.1, 4.32.2. Ocean quahaugs and surf clams are exempt from the twenty hour delivery requirement. *Id.* § 4.32.3.
317 *Id.* § 4.32.1; *see infra* §§ 830.8(1)(c)-(e), (4)(b).

920.6. Aquaculture and Shellfish Gardening

1. Commercial Aquaculture

   a. The NSSP-MO gives states the authority to permit or prohibit aquaculture within their waters, and it places certain mandates upon aquaculture regulation. The model ordinance recognizes two types of aquaculture, with different requirements for each: commercial aquaculture and shellfish gardening.[318]

   b. The RI General Laws permit aquaculture in Rhode Island in "a manner consistent with the best public interest, with particular consideration given to the effect of aquaculture on other uses of the free and common fishery and navigation" and with environmental concerns.[319] Currently, DEM prohibits aquaculture of any "species that are not endemic to Rhode Island" unless specific approval is obtained from the DEM Director, with advice from the CRMC Biosecurity Board.[320] Overall, CRMC supports aquaculture development "where it can be accommodated among other uses of Rhode Island waters."[321] CRMC recognizes the benefits of aquaculture development economically as well as ecologically, but also recognizes that there is a carrying capacity for state aquaculture that should not be exceeded.[322]

   c. For commercial aquaculture projects, the NSSP-MO requires that the SSCA[323] review written operational plans for an aquaculture facility before the facility can begin operation.[324] Operational plans must minimally include:

      > a description of the design and activities of the aquaculture facility, specific location and boundaries of the aquaculture lease and facility, types and locations of structures (rafts, pens, tanks, etc.), species to be cultured, source of these organisms (i.e., wild or cultured), procedures to prevent contamination, program of sanitation and maintenance, description of the water source including details of water treatment, program to maintain water quality, maintenance of records, and how shell stock will be harvested.[325]

   d. If the plan is approved, the NSSP-MO requires that the grower obtain three documents from the state: (1) a permit to operate the aquaculture facility; (2) a harvester's license;[326] and (3) a dealer certification, if applicable.[327] Additionally, the facility operator must obtain a lease of the site to be used for the operation.[328]

   e. In Rhode Island, the regulatory authority for aquaculture is split between DEM and CRMC. DEM is authorized to create regulations and grant permits "governing the taking, possession, sale,

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[318] NSSP-MO, *supra* note 16, § II, ch. VI, § .01(A); *see infra* § 830.6(2)(b).
[319] R.I. GEN. LAWS § 20-10-1.
[320] DEM Aquaculture Regulations, supra note 114, § 2.4.
[321] Coastal Resources Mgmt. Council, Coastal Resources Mgmt. Program § 300.11(B)(1) (2012) [hereinafter *Red Book*].
[322] *Id.* § 300.11(B)(1).
[323] In Rhode Island, DEM and CRMC jointly manage aquaculture, so both agencies would review the operational plan. CRMC is recognized as the primary agency in regards to aquaculture management; however, DEM must approve the operational plan and maintain a copy of the plan. *See DEM Aquaculture Regulations*, *supra* note 114, § 5.1.
[324] NSSP-MO, *supra* note 16, § II, ch. VI, § .03(B). The operational plan "must be upgraded and resubmitted prior to any change(s) occurring in the aquaculture operation." *DEM Aquaculture Regulations*, *supra* note 114, § 5.1.
[325] DEM Aquaculture Regulations, supra note 114, § 1.13; see also id. §§ 2.2, 5.1.
[326] Or other applicable license allowing the aquaculturist to harvest his or her shellfish and sell them to a licensed dealer. *See id.* § 8.2.
[327] NSSP-MO, *supra* note 16, § II, ch. VI, Requirements for Harvester/Dealer, § .02(B).
[328] *Id.* § II, ch. VI, Requirements for Harvester/Dealer, § .02(D).

importation, and transportation of animal or plant species utilized in aquaculture."[329] DEM aquaculture permits must "specify the conditions governing the taking, possession, sale, importation, and transportation of cultured crops utilized in the aquaculture lease or facility."[330] The permit will be automatically renewed every January 1 as long as the aquaculturist files the proper annual reports with the Director by the prior December 1, although the Director may modify the permits if necessary.[331]

f. Because CRMC regulates activities in the state's coastal waters, a CRMC permit – an assent – is required for an aquaculture project as well as a lease of the submerged land that the project will be situated on.[332] In determining whether to grant an assent, CRMC must consult with DEM and RIMFC,[333] and the agencies must consider whether the proposed project is likely to have an adverse impact on the surrounding environment, the wild harvest fishery, or other competing uses of the water.[334] Permitted uses are dependent upon the use category that CRMC has assigned to the water body in question for any particular project – or the shoreline feature for structures or uses on the shoreline.[335] CRMC is also authorized to promulgate regulations relating to aquaculture management, in consultation with DEM and RIMFC.[336] If DEM determines that a permitted aquaculture project "is causing or is likely to cause an immediate danger to marine life or the environment," CRMC is required to hold a hearing on whether the project should be authorized to continue its operations.[337]

g. Once operational, the NSSP-MO requires that an aquaculture facility be inspected at least once every six months.[338] The DEM Director has the authority to "enter and inspect any and all areas subject to an aquaculture permit for the purposes of determining compliance with the terms and provisions of the permit.[339] Records must also be maintained of all construction and operation plans as well as the permits issued for aquaculture projects.[340] State law also requires that the site boundaries be clearly marked and indicate what restrictions are in place at the site.[341] Under CRMC regulations, exclusive use of a lease site is only permitted when such exclusivity is "necessary to the effective conduct of the" aquaculture project and will not unduly limit public

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[329] R.I. GEN. LAWS § 20-10-12(a) (2013); *DEM Aquaculture Regulations*, *supra* note 114, § 2.2. DOH must approve aquaculture permits to be sure that the cultured shellfish will meet the NSSP-MO and DOH's regulations. *Id.* § 2.2.
[330] DEM Aquaculture Regulations, supra note 114, § 2.2.
[331] Id.
[332] R.I. GEN. LAWS §§ 20-10-3, 20-10-6(a); *Red Book*, *supra* note 323, §§ 100.1(A), 160(C) (requiring a CRMC assent for any "alteration or activity" planned within the state tidal waters or along shoreline features, which would include aquaculture facilities); *DEM Aquaculture Regulations*, *supra* note 114, § 2.1.
[333] R.I. GEN. LAWS § 20-10-5(b); *DEM Aquaculture Regulations*, *supra* note 114, § 2.1.
[334] R.I. GEN. LAWS § 20-10-5(c). If necessary, a Rhode Island Pollutant Discharge Elimination System ("RIPDES") permit, issued by DEM, is also required before CRMC may issue an assent. *DEM Aquaculture Regulations*, *supra* note 114, § 2.1.
[335] *See Red Book, supra* note 323, §§ 100.1(C), (D).
[336] R.I. GEN. LAWS § 20-10-11.
[337] *Id.* § 20-10-14. CRMC is also required to create a biosecurity board that meets at least once per quarter and advises CRMC on aquaculture disease issues. *Id.* §§ 20-10-1.1, -1.2.
[338] NSSP-MO, *supra* note 16, § II, ch. VI, § .01(C). The model ordinance provides no explicit requirements on the details of the semi-annual inspections.
[339] *DEM Aquaculture Regulations*, *supra* note 114, § 3.2. CRMC, by virtue of its jurisdiction over activities below mean high water, would likely also have inspection authority for aquaculture facilities. *See* R.I. GEN. LAWS § 46-23-6, 2d (ii) [sic, vii?].
[340] NSSP-MO, *supra* note 16, § II, ch. VI, § .01(B). Aquaculture facilities must also maintain records of their own operations for at least two years, including the source of their shellstock, transplant and harvest dates, and water sources. *Id.* § II, ch. VI, Requirements for Harvester/Dealer, § .02(J).
[341] R.I. GEN. LAWS § 20-10-9.

access of a water body.[342] In addition to boundary markings, "[a]ll aquaculture apparatus must be marked" as required by the applicable CRMC assent.[343]

h. Submerged land leases granted by CRMC bestow a rights-based license in the leased land, but that right is not at the level of a land-based property right. The leases are discretionary, only granted for a period of years, and the lessee must pay annual fees for the lease.[344] The leases are not assignable without prior CRMC approval.[345] Additionally, CRMC reserves the right to revoke a lease if the lessee does not actively use the site for a one year period.[346] The lease does not grant the lessee the right to the naturally occurring shellfish at the site, and the lessee may only harvest shellfish that he or she has stocked at the site.[347]

i. Any shellfish cultured at an aquaculture site are considered the property of the permittee,[348] but he or she must continue to comply with most of the regulations of wild harvest shellfisheries in regards to water quality, harvesting, processing, storage, and shipping,[349] and DEM retains its authority to enforce such regulations.[350] Aquaculture projects are exempted from season, catch, harvest method, and some minimum size restrictions.[351] However, aquaculturists cannot harvest quahaugs until the shellfish have reached a hinge width of one inch unless specifically authorized to possess legal quahaug seed.[352] Aquaculturists who also hold a commercial harvester's license may not be in possession of both cultured and wild shellfish at any time unless they are also licensed dealers and the shellfish are properly stored at their facility,[353] and they may never be in possession of undersized wild shellfish,[354] excluding legally obtained seed.

j. Additionally, the NSSP-MO charges the SSCA with setting certain additional standards for aquaculture projects. First, the state[355] must sanction all seed sources that it deems appropriate for

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[342] *See Red Book*, *supra* note 323, § 300.11(B)(2).
[343] DEM Aquaculture Regulations, supra note 114, § 4.1.
[344] *Red Book*, *supra* note 323, § 160(C)(1); *DEM Aquaculture Regulations*, *supra* note 114, § 1.4. Annual lease fees are $75 for a half-acre, $150 for up to one acre, and $100 additional dollars for each additional acre. Fees must also be paid for transient gear leases. *Red Book*, *supra* note 323, § 160(C)(1).
[345] *See Red Book*, *supra* note 323, § 160(C)(1).
[346] *Id.* § 160(C)(2). Permits can also be revoked if the facility has fallen into disrepair. *Id.* § 300.11(B)(4). The lessee is responsible to return the site to its original condition if a permit is revoked. *Id.* § 300.11(F)(1)(a).
[347] *Id.* § 300.11(E)(5).
[348] R.I. GEN. LAWS § 20-10-13 (2013).
[349] NSSP- MO, *supra* note 16, § II, ch. VI, Requirements for Harvester/Dealer, § .02(I); *DEM Aquaculture Regulations*, *supra* note 114, § 8.2. These include the requirement to "prevent contamination, deterioration and decomposition" of harvested shellfish, to use clean containers for storing shellfish, keeping the harvesting vessel clean with approved water, preventing contact between the shellfish and bilge water, washing shellfish free of bottom sediment as soon as possible after harvest, and not discharging sewage into state waters. *Id.* §§ 9.0, 11.1. The aquaculturist must also tag the shellfish with a proper harvester or dealer tag prior to leaving the aquaculture site, removing the shellfish from a vessel, or offering them for sale. *Id.* §§ 10.1, 10.2, 10.3. If shellfish are harvested from one aquaculture lease site on a single day, DEM approval may be obtained for bulk tagging. *Id.* § 10.4. If the aquaculturist is not a dealer, he or she must also ensure delivery of harvested shellfish to a dealer within twenty hours of harvest. *Id.* § 11.2.
[350] DEM Aquaculture Regulations, supra note 114, § 3.1.
[351] R.I. GEN. LAWS § 20-10-13.1(a); *DEM Aquaculture Regulations*, *supra* note 114, § 2.3. The NSSP-MO requires that the state set a "submarket size" under which aquaculture facilities cannot harvest their product. NSSP-MO, *supra* note 16, § II, ch. VI, § .02(A).
[352] R.I. GEN. LAWS § 20-10-13.1; *DEM Aquaculture Regulations*, *supra* note 114, § 2.3.
[353] DEM Aquaculture Regulations, supra note 114, § 8.3.
[354] *Id.* § 8.4.
[355] The Biosecurity Board, a division within the Coastal Resources Management Council, advises on this matter. *See* R.I. GEN. LAWS §§ 20-10-1.1, -1.2 (creation of the biosecurity board and enumeration of its duties and powers).

aquaculture.[356] A scallop is considered seed if the scallop has "a bright, thin, slightly curved shell with no foreign adherent, the shell having no well-defined raised annual growth line, and the scallop being less than one (1) year old."[357] Quahaugs are considered seed with a shell size of less than 20 mm (0.78"), and oysters with a shell size of less than 32 mm (1.25").[358] Anytime an aquaculturist is shipping shellfish in from another state, he or she must notify DEM in writing "at least five working days prior to entry into the state, and each shipment must be accompanied by a certificate of disease inspection," unless waived by DEM and the Biosecurity Board.[359] All shipments of seed "must be labeled or tagged indicating the origin (operator/company name, license number and body of water), date of importation and destination."[360]

k. The model ordinance requires that seed must not exceed "acceptable levels of poisonous or deleterious substances," and seed from prohibited waters must be cultured for at least six months before harvest.[361] DEM does permit transfer of seed cultured in other than approved waters to an aquaculture site in approved waters as long as the transfer is made in accordance with an approved operational plan.[362] The operational plan must detail how the aquaculturist "intends to track and document the growth and harvest of these shellfish."[363]

l. The aquaculturist must collect seed only from sites and in amounts specified by DEM, and he or she must "notify DEM Divisions of Fish and Wildlife and Law Enforcement in writing at least ten (10) days prior to" collecting, and a DEM Environmental Police Officer may accompany the aquaculturist.[364] Throughout the transfer and growth process, the aquaculturist must keep detailed records on "source, numbers transferred, size composition, time/dates of transfer, [and] harvest and sale of the shellfish."[365] DEM requires that seed transferred from other than approved waters remain in approved waters for a minimum of twelve months before being harvested for human consumption.[366]

m. The licensed aquaculturist is also responsible for any aquaculture gear or other implements located at the aquaculture facility.[367] He or she has a responsibility to maintain said gear and is responsible for its removal at the termination of the operation.[368] He or she "may be required to post a performance bond in the amount specified by CRMC, to be used to return the site, including tidal waters, to the condition that existed prior to the aquaculture, in the event that the gear is abandoned or permit conditions violated."[369]

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[356] NSSP-MO, *supra* note 16, § II, ch. VI, § .02(B).
[357] DEM Shellfish Regulations, supra note 153, § 4.21; DEM Bay Scallop Regulations, supra note 219, § 5.4.
[358] *DEM Aquaculture Regulations*, *supra* note 114, § 1.16. "All measurements are taken along the longest axis." *Id.*
[359] *Id.* § 5.2.
[360] *Id.* § 8.1.
[361] NSSP-MO, *supra* note 16, § II, ch. VI, Requirements for Harvester/Dealer, § .03.
[362] *DEM Aquaculture Regulations*, *supra* note 114, § 8.8. DEM approval is also required for purchase of seed collected by another from other than approved waters. *Id.* § 8.10. If more than ten percent of the shellfish exceed seed size, the transfer is considered relay and is only permitted with express prior permission of DEM and DOH. *See id.* § 8.8; *see infra* § 830.6(3).
[363] DEM Aquaculture Regulations, supra note 114, § 8.9.
[364] *Id.* § 8.10. If a DEM Environmental Police Officer accompanies the aquaculturist, the aquaculturist will be responsible to pay for the officer detail. *Id.*
[365] *Id.* § 8.9. These records must be maintained for a minimum of two years and made available to DOH or DEM upon request. *Id.*
[366] Id.
[367] *Id.* § 4.2.
[368] Id.
[369] Id.

n. Finally, aquaculture regulations must address the impacts of the growing area classification.[370] Aquaculture operations may not be permitted in prohibited waters,[371] unless the operation falls into one of three exempted categories: (1) hatcheries; (2) nursery products that do not exceed ten percent of the market weight; or (3) nursery products that are six months or more from reaching market size.[372] Operations conducted in waters in the closed status[373] or under the restricted classification cannot be harvested for direct sale to the consumer, but must instead be relayed or depurated under the model ordinance,[374] just as wild harvest shellfish must be. DEM does not permit harvest when the area is in the closed status, and an aquaculturist is prohibited from visiting and/or tending his or her site when it is in the closed status, unless permission has been obtained from DEM due to emergency circumstances.[375] Shellfish cultured in approved waters may be harvested for direct sale.[376]

o. The current CRMC policy is to prohibit aquaculture in waters closed under the NSSP-MO "that contain significant shellfish stocks potentially available for relay into approved areas for free and common fishery."[377] This policy does not apply to spat collection, scallop cultivation, marina-based facilities (which would include the upwellers commonly employed for spat growth), or "projects which are designed…to enhance and restore the public resource."[378]

p. Aquaculture projects may also be impacted by CRMC's regulations relating to areas of historic and archaeological significance. CRMC has recognized that sites of archaeological significance are "extremely valuable cultural, educational, economic, and recreational resources" that are threatened by development projects.[379] Therefore, CRMC has codified a policy to "preserve and protect" archaeological sites in the coastal zone, and CRMC may prohibit developments that are likely to have adverse impacts on sites of archaeological significance.[380]

2. Restoration and Shellfish Gardening

a. The General Assembly called for environmental restoration efforts, and it recognized that "the animal life inhabiting [Rhode Island]…can be developed, preserved, and maintained for the beauty and mystery that wild animals bring to our environment."[381] The RI General Laws mandate a protective stance for natural resources, including shellfish.[382] Specifically, DEM is

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[370] *See id.* § 8.5. If the growing area classification changes after the aquaculture operation has begun, the aquaculturist must make changes as required by the new classification, and DEM assumes no liability for such changes. *Id.* § 8.6.
[371] NSSP-MO, *supra* note 16, § II, ch. VI, Requirements for Harvester/Dealer, § .02(E).
[372] *Id.* § II, ch. VI, Requirements for Harvester/Dealer, § .01.
[373] Other than prohibited waters.
[374] NSSP-MO, *supra* note 16, § II, ch. VI, Requirements for Harvester/Dealer, § .02(G).
[375] DEM Aquaculture Regulations, supra note 114, § 8.7.
[376] NSSP-MO, *supra* note 16, § II, ch. VI, Requirements for Harvester/Dealer, § .05(B)(1); *see DEM Aquaculture Regulations*, *supra* note 114, § 8.5.
[377] *Red Book*, *supra* note 323, § 300.11(B)(8). Also, any project proposing to culture non-indigenous species must obtain specific approval, and the project's protocol to avoid accidental release must be approved by the CRMC Bio-Security Board. *Id.* § 300.11(C)(10).
[378] *Id.* § 300.11(B)(a). However, upwellers are prohibited in Type I waters even if associated with existing structures. *Id.* § 300.11(E)(3).
[379] *Id.* § 220(B)(2).
[380] *Id.* § 220(C)(1).
[381] R.I. GEN. LAWS § 20-1-1(a) (2013).
[382] *Id.* §§ 20-1-5 (holding that the director "shall protect…shell fisheries throughout the state), 20-2.1-9(2)(i) (charging the director to consider "duly established conservation or fisheries regeneration goals" and "maintaining the viability of fisheries resources overall" in setting licensing systems), 20-2.1-9(2)(iv) (establishing "standards for fishery conservation and management" to guide fishery management decisions).

charged with, in coordination with CRMC, addressing the restoration needs of oysters in the state.[383] The General Assembly noted that the "[o]yster fishery has historically been important to Rhode Island for economic and ecosystem benefits" and has been in decline from its historic levels.[384] Therefore, DEM is instructed to consider oyster restoration needs and solicit federal funds that are available to help in the state's oyster restoration efforts.[385] Shellfish restoration efforts in Rhode Island may also be recommended by or coordinated through the Rhode Island Habitat Restoration Team, a group composed of agency and non-profit representatives that work to facilitate restoration efforts in the state.[386]

b. The NSSP-MO also authorizes shellfish gardening in the state, if the state chooses to permit gardening.[387] Shellfish gardening is "non-commercial shellfish culture for the purposes of enhancing water quality, or enhancing natural stocks and not for sale for consumption."[388] If the state permits shellfish gardening, it must issue permits to gardeners or maintain a register of shellfish gardening activities.[389] It must also set permit conditions and determine what water classifications to permit gardening in.[390] The state additionally has a duty to advise gardeners of the risks of consuming gardened shellfish, and the agency may require gardeners to maintain records of the disposition of the gardened shellfish.[391]

3. Relay and Depuration

a. Shellfish growing naturally or cultured in restricted or other closed waters cannot be directly harvested for human consumption, but they can be harvested and then 'treated' via depuration, relay, or other limited treatments to become safe for human consumption.[392]

b. The depuration process involves taking shellfish harvested from other than approved waters to a land-based facility[393] where they are intensively flushed with clean water to reduce pathogen concentration.[394] States may choose to permit or prohibit depuration as one option to cleanse contaminants from shellfish tissues.[395] However, if a state does choose to permit depuration, it must first develop "an effective program to: (1) Control shellstock harvesting by special license…; (2) Control shellstock transportation between the harvest area and the depuration facility to prevent shellstock from being illegally diverted to direct marketing; [and] (3) Approve the design and construction of the depuration facility…."[396]

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[383] *Id.* § 20-2-45(c).
[384] *Id.* §§ 20-2-45(1), (2).
[385] *Id.* § 20-2-45(b).
[386] *See* Coastal Resources Mgmt. Council, *The Rhode Island Habitat Restoration Team*, RI.GOV (last accessed Apr. 5, 2013), http://www.crmc.ri.gov/habrestteam.html.
[387] NSSP-MO, *supra* note 16, § II, ch. VI, § .04. As shellfish gardening is an offshoot of aquaculture, it would also be jointly regulated by CRMC and DEM. Because DEM's primary regulatory role regarding aquaculture is in regards to harvest, CRMC would be the agency with primary authority for shellfish gardening. *See* R.I. GEN. LAWS §§ 20-10-3, -12.
[388] NSSP-MO, *supra* note 16, § II, Definitions (B)(99).
[389] *Id.* § II, ch. VI, § .04(A).
[390] *Id.* § II, ch. VI, § .04(B).
[391] *Id.* § II, ch. VI, §§ .04(C), (D).
[392] *Id.* § II, ch. VI, Requirements for Harvester/Dealer, § .02(G).
[393] Currently, there are no depuration facilities in Rhode Island, but the federal requirements are discussed here for consideration should depuration be attempted in the state in the future.
[394] *See* NSSP-MO, *supra* note 16, §§ II, Definitions(B)(30), ch. XV, Requirements for the Dealer, § .02(A)(4); BRENNESSEL, *supra* note 16, at 120.
[395] NSSP-MO, *supra* note 16, § II, ch. XV, Note.
[396] *Id.* § II, ch. XV, Requirements for the Authority(A).

c. If depuration is permitted, each depuration plant must prepare a Depuration Plant Operating Manual, which DEM or DOH would need to approve.[397] Critical to an operating plan is a minimum of forty-four hours of depuration treatment for all shellfish.[398] The plants must also meet sanitary standards for water and ice quality as well as maintain records of their operations.[399] DEM or DOH would also need to inspect depuration plants monthly.[400] There are currently no depuration plants in Rhode Island and no provisions in the Rhode Island General Laws or DEM or DOH regulations to permit depuration of shellfish from polluted waters. The only reference to depuration in Rhode Island law is found in DEM's Water Quality Regulations, which note that any shellfish harvested in class SB waters would require relay or depuration before being sold for human consumption.[401]

d. Another option for harvest from restricted or otherwise closed growing areas[402] is shellfish relay,[403] a process in which shellfish are transferred from these closed areas to approved waters where the shellfish purge contaminants from their tissues as they filter the 'clean' waters.[404] Under the NSSP-MO, the water quality in the approved waters must be closely monitored, and the SSCA must "establish species-specific critical values for water temperature, salinity, and other environmental factors which may affect the natural treatment process."[405] DEM must ensure that the transfer waters maintain these critical values and that the shellfish remain in the waters for sufficient time to reduce contaminant levels in their tissues to levels safe for human consumption.[406]

e. Relay grow-out time lengths must be verified through contaminant reduction studies.[407] These studies must demonstrate that, after the specified post-relay grow-out period, contaminant levels in the relayed shellfish are equal to the levels in shellfish cultured entirely in approved waters.[408] Post-relay grow-out must be at least fourteen days,[409] and contaminant reduction studies may be waived if the grow-out period is at least sixty days if the waters the shellstock are relayed from meet certain water quality restrictions.[410] DEM must also establish whether relay would be permitted throughout the year or only during certain seasons.[411] Once shellstock have been

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[397] *Id.* § II, ch. XV, Requirements for the Authority(C).
[398] *Id.* § II, ch. XV, Requirements for the Dealer, § .01(B)(1).
[399] *Id.* §§ II, ch. XV, Requirements for the Authority(D), Requirements for the Dealer, § .02.
[400] *Id.* § II, ch. XV, Requirements for the Authority(D).
[401] DEM Water Quality Regulations, supra note 122, § 8(B)(2)(b).
[402] Except those classified as prohibited. NSSP-MO, *supra* note 16, § II, ch. V, § .01(A).
[403] Relay is also known as shellfish transplant, which DEM defines as "The removal of shellfish from polluted waters or bottom areas proposed to be dredged and the transport of those animals to a Management Area for harvest at a later date." *DEM Licensing Regulations*, *supra* note 41, § 5.62 (defining "Shellfish Transplant"). For purposes of this document, "relay" will be used to refer to this process broadly or as a private aquaculture venture while "transplant" will be used to refer to a state-led, public venture.
[404] NSSP-MO, *supra* note 16, § II, Definitions (B)(85). Low acid canning is also a treatment option that may be approved, and regulations of low acid canning mirror most of the relay regulations. *See id.* § II, ch. V, § .03(A).
[405] *Id.* § II, ch. V, § .02(A).
[406] *Id.* § II, ch. V, §§ .01(B), (C), .02(A).
[407] *Id.* § II, ch. V, § .02(B).
[408] *Id.* For contaminants that FDA has established tolerance levels for, relayed shellfish must also have contaminant concentrations below these tolerance levels. *Id.*
[409] *Id.* § II, ch. V, § .02(D). Grow-out of less than fourteen days is permitted for container relays, but only if extensive testing demonstrates that the product consistently depurates within that shortened period. *Id.* § II, ch. V, § .02(E).
[410] *Id.* § II, ch. V, § .02(C).
[411] *Id.* § II, ch. V, § .02(F).

relayed, the area must be placed in a closed status and clearly marked until the prescribed relay grow-out period is complete and the shellfish are approved to be harvested.[412]

f. If DEM chooses to permit shellfish relay, it must "develop and maintain an effective program to control the harvest, transport, replanting, and security of the shellstock…to prevent shellstock from being illegally diverted to direct marketing."[413] Part of this program must be a licensing scheme specifically for those engaged in relay projects.[414] Additionally, DEM will need written operating procedures shared with DOH because any agencies that jointly manage a relay program must share operating procedures.[415] If shellfish will cross state boundaries between initial culture and depuration, a memorandum of understanding is required with the partner state to ensure that both states will meet NSSP-MO requirements for their respective roles in the relay process.[416]

g. Relay can be accomplished as a private aquaculture endeavor or as a public transplant program in which the state would transfer shellfish from closed areas into approved waters and set regulations for the eventual harvest of those shellfish after sufficient depuration time in the approved waters to "insure [sic] their cleanliness."[417] In Rhode Island, shellfish occurring or grown in waters with a class SB designation[418] are eligible for relay or depuration.[419] The RI General Laws permit but do not require establishment of a transplant program, permitting the Director "after requiring all necessary safeguards, to transfer shellfish from uncertified waters of the state to approved areas."[420] The Director is also permitted to "make rules and regulations governing the reharvest of those shellfish to the best economical benefit of the state after all necessary safeguards to insure their cleanliness."[421] Funds can be sought from the General Assembly for state-sponsored or state-run transplant programs.[422]

h. Rhode Island has engaged in public transplant projects in the past,[423] and DEM has established regulations to govern those transplants.[424] Before selecting an appropriate SB class water body to transfer the shellfish from, DEM conducts water quality studies to ensure that the shellfish will be safe for human consumption after transplant and a grow-out period.[425]

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[412] *Id.* § II, ch. V, § .04(E).
[413] *Id.* § II, ch. V, § .04(A).
[414] *Id.* § II, ch. V, § .03(A).
[415] *Id.* § II, ch. V, § .04(B).
[416] *Id.* § II, ch. V, § .04(C).
[417] R.I. GEN. LAWS § 20-6-26 (2013).
[418] *See supra* § 830.4.
[419] DEM Water Quality Regulations, supra note 122, § 8(B)(2)(b).
[420] R.I. GEN. LAWS §§ 20-2-44, -6-26; *see also DEM Shellfish Regulations*, *supra* note 153, § 4.14. DEM is specifically permitted to conduct transplants of bay scallops "as may be appropriate to enhance scallop stock, seed depleted areas, and further the scallop harvest." R.I. GEN. LAWS § 20-6-22; *DEM Bay Scallop Regulations*, *supra* note 219, § 5.5.
[421] R.I. GEN. LAWS § 20-6-26; *see also DEM Shellfish Regulations*, *supra* note 153, § 4.14.
[422] R.I. GEN. LAWS § 20-2-44.
[423] R.I. Dept. of Envtl. Mgmt., 2010 Consolidated Assessment and Listing Methodology For Section 305(b) and 303(d) Integrated Water Quality Monitoring and Assessment Reporting, § 5.4.7 (June 2009), available at http://www.dem.ri.gov/programs/benviron/water/quality/pdf/finlcalm.pdf [hereinafter *Water Quality Assessment Reporting*]. The transplant program has been operated by DEM's Division of Fish and Wildlife in cooperation with the Narragansett Bay Commission, the Rhode Island commercial shellfishing industry, and DOH. *Id.*
[424] *DEM Council Regulations*, *supra* note 251, §§ 3.7.1 - 3.7.8; *DEM Shellfish Regulations*, *supra* note 153, §§ 4.15, 4.16.
[425] See Water Quality Assessment Reporting, supra note 425, § 5.4.7.

i. Licensed harvesters are then engaged[426] to harvest the shellfish from designated closed areas, but they must surrender their licenses to a DEM employee while they are engaged in the transplant process.[427] The harvesters then harvest shellfish within the designated transplant area during the hours designated for such harvesting.[428] Once they have finished harvesting, they must turn over the harvested shellfish to DEM, and their licenses will be returned to them when they have turned over all shellfish aboard.[429] Once the shellfish have been transferred, the planting area "shall be marked out and dredging, raking, or tonging [in that area] shall be prohibited except under the special direction of the director."[430] Once the area is again open for harvesting, DEM may hire harvesters to harvest the transferred shellfish, sell the shellfish, and use the profits to help fund future transfers.[431]

j. Currently, DEM regulations prohibit private relay other than the transfer of shellfish from other than approved waters as seed.[432] If more than ten percent of the shellfish exceed seed size, relay of these shellfish out of other than approved waters is permitted only with express prior approval of both DEM and DOH,[433] which has not yet occurred for any project. If an aquaculturist were to obtain permission to raise shellfish in other than approved waters, DEM would treat all shellfish held by that aquaculturist as if they had been in other than approved waters unless the aquaculturist can demonstrate otherwise.[434]

920.6.1. Agricultural Statutes

1. Although Title 20 includes the majority of the statutes relevant to shellfish management, the state agriculture statutes also have an impact. The General Assembly has expressed – in the agricultural statutes – an interest in promoting local, sustainable food supplies.[435] Therefore, the General Assembly laid down a goal of developing and supporting local, sustainable agriculture and seafood production, as well as promoting consumption of local foods.[436] It also directs DEM to "establish and administer a program to promote the marketing of Rhode Island seafood and farm products grown and produced in Rhode Island for the purpose of encouraging the development of the commercial fishing and agricultural sectors in the state."[437] As part of this mandate, DEM is instructed to collect information on seasonal supply, demand, and prices of seafood and use that information to help inform its program, including advising buyers, sellers, and the public.[438]

2. Another major agricultural law that impacts shellfish management is the Right to Farm Act, which was enacted to respond to concerns that urban growth was threatening agricultural land, which was detrimental to the displaced farmers, the local food supply, and the environment.[439] Although the

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[426] DEM may limit the maximum shellfish harvest as well as the maximum number of harvesters involved as long as "the limit is determined in a fair and equitable manner." *DEM Dredging Regulations*, *supra* note 176, § 6.7.8.
[427] DEM Council Regulations, supra note 251, § 3.7.1.
[428] *Id.* §§ 3.7.2, 3.7.3.
[429] *Id.* § 3.7.5; *see also id.* §§ 3.7.1, 3.7.4. Harvesters may also be employed to replant the shellfish in a new location. In that case, the harvesters must present their harvest to the DEM employee present before proceeding to the approved planting area. *Id.* § 3.7.5.
[430] R.I. GEN. LAWS § 20-6-27 (2013); *DEM Shellfish Regulations*, *supra* note 153, § 4.15.
[431] R.I. GEN. LAWS § 20-6-28; *DEM Shellfish Regulations*, *supra* note 153, § 4.16.
[432] See DEM Aquaculture Regulations, supra note 114, §§ 8.8, 8.9.2.
[433] Id.
[434] *Id.* § 8.9.1.
[435] R.I. GEN. LAWS § 2-25-2.
[436] *Id.* §§ 2-25-3(1), (4).
[437] *Id.* § 2-1-8.
[438] Id.
[439] *See id.* § 2-23-2.

statutory language expressly includes aquaculture in this Act,[440] the terms of the Act do not have major implications on aquaculture management. The Act declares a policy of "promot[ing] an environment in which agricultural operations are safeguarded against nuisance actions arising out of conflicts between agricultural operations and urban land uses"[441] and exempts agricultural operations from nuisance claims "related to odor, noise, dust, or pesticides."[442] Nuisance claims and the purpose of the Act do not bear a strong connection to aquaculture, and therefore, the Act's impact on aquaculture projects is uncertain.

3. Similarly, the state's Preservation of Agricultural Use Act provides only minor – if any – protections for aquaculture projects. The Act's application is limited to parcels of at least five contiguous acres.[443] For these larger parcels, the purpose of the Act is to protect the conveyed development rights by limiting the application of new laws that could restrict or prohibit agriculture on those parcels.[444] Therefore, future laws that would "inhibit the agricultural rights" of the property owner do not apply to these parcels.[445] Parcel owners will be assured of their right to continue agricultural development of their land along with any associated and necessary development.[446]

4. The application of the Preservation of Agricultural Use Act to aquaculture is questionable. The definition of "agricultural land" itself is worded to target dry land because the land must be "suitable for agriculture by reference to soil type, existing use for agricultural purposes and other criteria" and it "may include **adjacent** pastures, ponds, [or] natural drainage areas."[447] Even more persuasive of the inapplicability of this Act to aquaculture is the definition of "development rights" under the Act. Development rights are defined as "the right of the fee simple owner to develop" the property.[448] The interest held by an aquaculturists in the lease site is a temporary, revocable use right, not an indefinite, complete fee simple interest.[449] Since a key purpose of the Act is to protect development rights, there would be no application to aquaculture sites. Finally, although "agricultural operation" is defined to expressly include aquaculture,[450] the definition is merely borrowed from the Right to Farm Act. Therefore, the overall purpose of the Preservation of Agricultural Use Act should be given more weight than the inclusion of aquaculture in a definition borrowed from another Act with a unique purpose.

920.7. Enforcement

1. A vital component of the state shellfish management plan required by the NSSP-MO is an "effective program to control shellstock growing areas" and enforce violations.[451] This program must include a harvester licensing scheme, identification of permissible harvesting areas, patrol of all growing areas, and assessment of penalties for noncompliance.[452] To increase compliance, DEM is required to

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440 *Id.* § 2-23-4(a).
441 *Id.* § 2-23-3.
442 *Id.* § 2-23-5(a).
443 *Id.* § 2-23.2-2(1).
444 *Id.* § 2-23.2-1.
445 *Id.* § 2-23.2-4.
446 *Id.* § 2-23.2-3.
447 *Id.* § 2-23.2-2(1) (defining agricultural land as defined in R.I. GEN. LAWS § 42-82-2) (emphasis added).
448 *Id.* § 2-23.2-2(3) (defining development rights as defined in R.I. GEN. LAWS § 42-82-2).
449 *See supra* § 830.6(1)(g).
450 R.I. GEN. LAWS § 2-23.2-2(2) (defining agricultural operation as defined in R.I. GEN. LAWS § 2-23-4).
451 NSSP-MO, *supra* note 16, § II, ch. VIII, Requirements for the Authority, § .01(A)(1).
452 *Id.* § II, ch. VIII, Requirements for the Authority, § .01(A)(2).

disseminate information on public health risks along with "a current, comprehensive, itemized listing of all harvest areas" and their classifications at least once a year to all licensed harvesters.[453]

2. The heart of any enforcement program is patrol of growing areas, and the model ordinance sets specific patrol requirements. Patrol of all areas closed to harvest must be "at sufficient intervals to deter illegal harvesting."[454] A risk category must be assigned to each growing area based on shellfish productivity, ease of harvest, and difficulty of patrol.[455] Patrol frequencies must increase with increasing risk of illegal and harmful harvest.[456] A patrol requires that a properly trained patrol officer[457] monitor the majority of a patrol area during a harvestable day[458] based on a DEM-issued patrol policy document.[459]

3. The model ordinance does allow certain exceptions for the patrolling requirement. If an area has no natural shellfish productivity because of water quality, bottom surface, or any other reason, DEM does not need to patrol that area.[460] Patrol is also not required if the authority knows that shellfish harvest in an area is not economically feasible.[461] Finally, for areas harvested exclusively under aquaculture operations with no commercially harvested natural shellfish source, DEM may choose to undergo the regular patrolling schedule or create a Risk Management Plan, which details an alternative monitoring and enforcement plan sufficient to prevent illegal harvest in that location.[462]

4. The NSSP-MO calls for penalties for noncompliance by harvesters, including administrative hearings, fines, license suspension, and seizure of illegally obtained shellfish.[463] In addition to any fines or imprisonment called for in state statutes and DEM regulations, any violation of a shellfish management law may result in suspension or revocation of the violator's shellfishing license.[464] Additionally, a license or permit may be denied if the applicant willfully makes any false statements on the application, and the applicant may be fined up to $50.[465] Forging or counterfeiting a license, or fishing without a license or with an expired license, is a misdemeanor and subject to a fine of not more than $500 and imprisonment for up to ninety days.[466] An applicant making a false statement or a person who counterfeits a license will not be eligible to apply for a new license, endorsement, or other

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453 *Id.* § II, ch. VIII, Requirements for the Authority, § .01(A)(3).
454 *Id.* § II, ch. VIII, Requirements for the Authority, § .01(B)(2).
455 *Id.* § II, ch. VIII, Requirements for the Authority, § .01(B)(4).
456 *Id.* § II, ch. VIII, Requirements for the Authority, § .01(B)(2) (prescribing a minimum of four patrols per thirty harvestable days for low risk areas, eight patrols for medium risk areas, and sixteen patrols for high risk areas).
457 *Id.* § II, ch. VIII, Requirements for the Authority, § .01(B)(6).
458 *Id.* § II, ch. VIII, Requirements for the Authority, § .01(B)(2). A harvestable day "refers to a day during which tidal, weather and other conditions make it possible to harvest shellfish. When tidal, weather, or other conditions prohibit harvesting on a particular day, that day is not included in the 30-day period." *Id.*
459 *Id.* § II, ch. VIII, Requirements for the Authority, § .01(B)(7).
460 *Id.* § II, ch. VIII, Requirements for the Authority, § .01(B)(3)(a)(i).
461 *Id.* § II, ch. VIII, Requirements for the Authority, § .01(B)(3)(a)(ii).
462 *Id.* § II, ch. VIII, Requirements for the Authority, § .01(B)(3)(b).
463 *Id.* § II, ch. I, § .02(H).
464 *DEM Council Regulations*, *supra* note 251, § 3.9 (citing R.I. GEN. LAWS § 20-3-6 (2013)); *see also* R.I. GEN. LAWS § 20-6-24(d); *DEM Licensing Regulations*, *supra* note 41, § 6.12-1(a); R.I. Dept. of Envtl. Mgmt., *Rhode Island Marine Fisheries Statues and Regulations Part IX: Shellfish Buyer's License - Statutes* § 9.2(d) (2003) [hereinafter *DEM Shellfish Buyer Regulations*]; *DEM Enforcement Regulations*, *supra* note 177, § 8.01.
465 *DEM Licensing Regulations*, *supra* note 41, § 6.12-2(a). If the false statement is discovered after the license has been issued, the license "shall be null and void and shall be surrendered." *Id.* § 6.12-2(b).
466 *Id.* §§ 6.12-3(a) (forgery), 6.12-4(a) (fishing without a license), 6.12-4(b) (fishing with expired license).

permit for one year after the penalty is imposed.[467] Aquaculturists face the same penalties as wild harvesters, and their aquaculture permits may be suspended or revoked for violations of law.[468]

5. Harvesters who possess valid licenses – or who are residents harvesting recreationally – will also be subject to fines or imprisonment for violating any of the harvesting regulations. If a person exceeds the recreational harvest possession limit, that person may be fined up to $50 for each half bushel over the limit, imprisoned for up to thirty days, or both.[469] Commercial harvesters violating the possession limits will be subject to six month license suspension for the first offense and license revocation for a second offense.[470] Additionally, a commercial harvester who is dredging for quahaugs and exceeds the possession limit will be subject to a fine of $100, imprisonment for up to thirty days, or both.[471] Anyone found harvesting at night will be fined up to $1,000, imprisoned for three years, or both.[472] Fishing at night is a serious offense and can bring felony convictions.

6. Any person found in possession of undersized shellfish will be fined not less than $10 and not more than $50 for every fifteen undersized shellfish in his or her possession.[473] Harvesting scallops or oysters outside of scallop season will subject the harvester to a fine of not less than $50 and not more than $500 or imprisonment for thirty days.[474] Any dredging done during the applicable closed season will result in a fine of between $20 and $100, imprisonment for up to thirty days, or both, even if the harvester is not in possession of any shellfish.[475] Dredging quahaugs without a license will result in a $250 fine and impoundment of the vessel and dredge for the first offense.[476] Harvesting in a polluted area may lead to arrest, seizure of shellfish as well as any associated vessels, dredges, tongs, rakes, or other implements, a fine not exceeding $500, and/or imprisonment for up to one year.[477] Violation of any regulations related to transplants will subject the harvester to a fine not exceeding $500, imprisonment for up to thirty days, or both.[478]

7. Violations relating to whelks have some unique aspects. Failure to mark a trap will subject the harvester to a fine of between $20 and $500 for each offense, as well as seizure of the applicable trap.[479] Night fishing for whelk subjects the harvester to a fine of between $1,000 and $5,000,

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[467] *Id.* §§ 6.12-2(c), 6.12-3(b).
[468] DEM Aquaculture Regulations, supra note 114, § 3.3.
[469] *DEM Shellfish Regulations*, *supra* note 153, § 4.7 (citing R.I. GEN. LAWS § 20-6-9).
[470] *See id.* §§ 4.33.1, 4.33.2-1, 4.33.2-2.
[471] DEM Dredging Regulations, supra note 176, § 6.5.
[472] R.I. GEN. LAWS § 20-6-23.
[473] *DEM Shellfish Regulations*, *supra* note 153, §§ 4.21(a), 4.35(e)(2). For undersized scallops, the fine will be between $20 and $100. *Id.* § 4.21; *DEM Bay Scallop Regulations*, *supra* note 219, § 5.4. If the undersized shellfish are commingled with legal size shellfish, and at least ten percent of the container contains undersized shellfish, the entire container of shellfish may be seized. *DEM Shellfish Regulations*, *supra* note 153, § 4.21(a).
[474] *DEM Bay Scallop Regulations*, *supra* note 219, § 5.3 (scallops); *DEM Oyster Regulations*, *supra* note 241, § 8.3 (oysters). Offering scallops for sale while out of season, unless frozen after a legal harvest, will result in a fine of between $20 and $100, imprisonment for up to thirty days, or both. *DEM Bay Scallop Regulations*, *supra* note 219, § 5.6.
[475] DEM Bay Scallop Regulations, supra note 219, § 5.8.5.
[476] *DEM Dredging Regulations*, *supra* note 176, § 6.6. The vessel impoundment may last for between thirty and sixty days. *Id.* Any subsequent violations will subject the harvester to imprisonment for up to thirty days and impoundment of the vessel and dredge for between ninety and 120 days. *Id.*
[477] *DEM Shellfish Grounds Regulations*, *supra* note 113, §§ 18.10 (citing R.I. GEN. LAWS § 20.8.1-10), 18.11 (citing R.I. GEN. LAWS § 20-8.1-11). For subsequent offenses, the fine is raised to a maximum of $2,000 and the period of imprisonment is raised up to a maximum of four years. *Id.* § 18.11.
[478] R.I. GEN. LAWS § 20-6-29; *DEM Shellfish Regulations*, *supra* note 153, § 4.17.
[479] DEM Commercial Fisheries Regulations, supra note 238, § 11.12.

imprisonment for up to one year, or both.[480] Interfering with another person's whelk trap will subject the interferer to a fine of not more than $1,000, imprisonment for one year, or both for each offense.[481]

8. When multiple persons are onboard a vessel involved in "a violation of the size, possession, or daily limit," the owner of the vessel – or the operator if the owner is not onboard – will be deemed to be the responsible party.[482] Any costs incurred as a result of impounding any vessel or equipment will be assessed against the owner, and the impounded vessel or equipment will not be released until the owner has paid the costs.[483]

9. Any person aggrieved by an enforcement action, including suspension or revocation of a license or permit, "may appeal there from in accordance with the provisions of the Administrative Procedures Act, Chapter 35 of Title 42."[484] A request for an adjudicatory hearing (appeal) must be filed in writing with the Administrative Adjudication Division within twenty calendar days of receipt of the enforcement action.[485] A person seeking appeal has thirty calendar days to file if the enforcement action relates to suspension or revocation of a license or permit.[486]

920.8. Post-Harvest Health Regulations

1. Requirements for Harvesting to Landing

    a. The Rhode Island Department of Health's authority begins at the point of harvest and continues until the shellfish is sold to a final consumer,[487] although DEM retains authority as well.[488] From the time the harvester or aquaculturist removes the shellfish from the state waters, he or she has an obligation to "conduct all activities and operations…so as to prevent contamination, deterioration and decomposition of such shell stock."[489] Any vessels used to harvest and transport shellstock must be "properly constructed, operated and maintained to prevent contamination, deterioration and decomposition of shell stock."[490] Boat decks and any containers used to store the harvested shellstock must be "kept clean with potable water or water from the growing area in approved classification or the open status of conditional areas."[491] The vessels and storage containers must also be designed, and bilge pumps located, to ensure that bilge water does not

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[480] *DEM Shellfish Regulations*, *supra* note 153, § 4.35.7. In an emergency situation, the harvester may seek authorization of DEM to remove pots or traps during prohibited hours. *Id.*
[481] *Id.* § 4.35.6(b). If the person holds a license, the license may also be revoked for one year. *Id.*
[482] DEM Council Regulations, supra note 251, § 3.11; DEM Minimum Size Regulations, supra note 234, § 7.12.
[483] DEM Dredging Regulations, supra note 176, § 6.7.
[484] R.I. GEN. LAWS § 20-6-24(e) (2013); *DEM Council Regulations*, *supra* note 251, § 3.9 (citing R.I. GEN. LAWS § 20-3-6); *DEM Shellfish Buyer Regulations*, *supra* note 466, § 9.2(e).
[485] R.I. GEN. LAWS § 42-17.7-9; *DEM Council Regulations*, *supra* note 251, § 3.9.1; *DEM Shellfish Buyer Regulations*, *supra* note 466, § 9.3(a).
[486] R.I. GEN. LAWS § 42-17.7-9; *DEM Shellfish Buyer Regulations*, *supra* note 466, § 9.3(b).
[487] *See* R.I. GEN. LAWS § 21-14-3 (authorizing DOH to adopt regulations "regarding sanitation as [the director] shall deem necessary with reference to conduct of a shellfish business…[or] to assure the sanitary quality of shellfish brought into this state for sale in this state").
[488] *See* R.I. GEN. LAWS § 20-1-2.
[489] *DEM Shellfish Regulations*, *supra* note 153, § 4.30.1; *see also* NSSP-MO, *supra* note 16, § II, ch. VIII, Requirements for the Harvester, § .02(B).
[490] *DEM Shellfish Regulations*, *supra* note 153, § 4.30.4; *see also* NSSP-MO, *supra* note 16, § II, ch. VIII, Requirements for the Harvester, § .02(C)(1).
[491] *DEM Shellfish Regulations*, *supra* note 153, § 4.30.3; *see also* NSSP-MO, *supra* note 16, § II, ch. VIII, Requirements for the Harvester, § .02(C)(1)(d).

come into contact with and contaminate the harvested shellstock.[492] The discharge of human sewage from a harvest vessel into state waters is prohibited,[493] and the SSCA is charged with educating all harvesters and dealers on the public health concerns of discharging human sewage into growing area waters.[494] Cats, dogs, and other animals are not allowed onboard a harvesting vessel.[495]

b. Once harvested, the shellstock "shall be washed reasonably free of bottom sediments as soon…as possible" with potable water or water from an open growing area.[496] The shellfish may then be stored onboard in containers made of safe materials and kept clean throughout their use as shellfish storage.[497] If necessary, "effective coverings shall be provided on harvest boats to protect shellstock from exposure to: (i) Hot sun; (ii) Birds; and (iii) Other adverse conditions."[498]

c. Shellstock onboard a harvest vessel must not be allowed "to deteriorate or decompose from exposure to excessive temperature" and must be delivered to a dealer before such exposure can occur.[499] The model ordinance requires that the shellstock be delivered to a dealer in accordance with either (1) the state's *Vibrio vulnificus* Control Plan; (2) the state's *Vibrio parahaemolyticus* Plan; or (3) the following matrix based on ambient air temperature:[500]

Table 9.3. Maximum allowable hours from shellstock's exposure to receipt at dealer's facility as determined by ambient air temperature.

Average Monthly Maximum Air Temperature[501]	Maximum Hours From Exposure to Receipt at a Dealer's Facility[502]
<50° F (10° C)	36 hours

[492] *DEM Shellfish Regulations*, *supra* note 153, §§ 4.30.5, 4.30.6, 4.30.7; *see also* NSSP-MO, *supra* note 16, § II, ch. VIII, Requirements for the Harvester, § .02(C)(1).
[493] *DEM Shellfish Regulations*, *supra* note 153, § 4.30.9; *see also* NSSP-MO, *supra* note 16, § II, ch. VIII, Requirements for the Harvester, § .02(D)(1). An approved marine sanitation device or portable toilet must be available onboard all vessels. NSSP-MO, *supra*, § II, ch. VIII, Requirements for the Harvester, § .02(D)(3).
[494] NSSP-MO, *supra* note 16, § II, ch. VIII, Requirements for the Harvester, § .02(D)(2).
[495] *Id.* § II, ch. VIII, Requirements for the Harvester, § .02(C)(2).
[496] *DEM Shellfish Regulations*, *supra* note 153, § 4.30.8; *see also* NSSP-MO, *supra* note 16, § II, ch. VIII, Requirements for the Harvester, § .02(E). "The harvester shall be primarily responsible for washing shell stock. If shell stock washing is not feasible at the time of harvest, the dealer shall assume this responsibility." *DEM Shellfish Regulations*, *supra*, § 4.30.8; NSSP-MO, *supra*, § II, ch. VIII, Requirements for the Harvester, § .02(E).
[497] *DEM Shellfish Regulations*, *supra* note 153, § 4.30.2; *see also* NSSP-MO, *supra* note 16, § II, ch. VIII, Requirements for the Harvester, § .02(C)(1)(c).
[498] NSSP-MO, *supra* note 16, § II, ch. VIII, Requirements of the Harvester, § .02(C)(f).
[499] DEM Shellfish Regulations, supra note 153, § 4.32.1.
[500] NSSP-MO, *supra* note 16, § II, ch. VIII, Requirements for the Authority, § .02(A). Ocean quahaugs and surf clams are exempt if the products are intended for thermal processing. *Id.* § II, ch. VIII, Requirements for the Dealer, § .02(G); *see infra* §§ 830.8(6)(b), (c).
[501] The average monthly maximum air temperature is to be established by the SSCA by averaging the maximum monthly temperatures for the previous five years. NSSP-MO, *supra* note 16, § II, ch. VIII, Requirements for the Dealer, § .02(C).
[502] This time begins to run as soon as the first shellstock harvested is no longer submerged in the water of the growing area. *Id.* § II, ch. VIII, Requirements for the Dealer, § .02(D).

50-60° F (10-15° C)	24 hours
>60-80° F (15-27° C)	18 hours
>80° F (27° C)	12 hours

d. DEM has prohibited any time between harvest and delivery to a dealer above twenty hours.[503] Harvesters are also required, under the model ordinance, to provide "trip records to the initial dealer demonstrating compliance with the time to temperature requirements."[504] When buy boats[505] are used, in addition to meeting all of the other sanitation requirements outlined above, they must also employ temperature control for the shellstock that provides an ambient air temperature of 45° F (7.2° C) or less within two hours of leaving the harvest area.[506] Prior to landing,[507] shellfish must be properly tagged or labeled as described above.[508]

e. Once a shellfisher lands his or her catch, the shellfish must be sold to a licensed dealer.[509] If the shellfisher lands the shellfish and then transports it to the dealer in a vehicle, the vehicle or containers must be equipped with automatic refrigeration controls and be capable "of maintaining the ambient temperature in the storage area at temperatures of 45° F (7.2° C) or less."[510] The point of sale[511] is a critical control point[512] "where a shellfish dealer takes possession of shellfish at a location where it will be processed and/or will [be] shipped to another dealer or retail establishment."[513] Because it is a critical control point, the point of sale requires extensive monitoring and records.[514]

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503 *DEM Shellfish Regulations*, *supra* note 153, § 4.32.2. Ocean quahaugs and surf clams are exempt from this regulation. *Id.* § 4.32.3.
504 NSSP-MO, *supra* note 16, § II, ch. VIII, Requirements for the Dealer, § .02(E).
505 Buy boats are dealer vessels that purchase shellfish from harvesters while still on the water. A buy boat is "considered an extension of the shellfish business facility" and must abide by all dealer requirements. *DOH Regulations*, *supra* note 8, § 1.3.
506 *Id.* § 6.8.
507 Landing is defined as "the point at which shellstock is put on land or a dock." NSSP-MO, *supra* note 16, § I, Definitions(B)(62).
508 See DEM Dredging Regulations, supra note 176, § 6.8.3; see also supra §§ 830.5(5)(b), (c).
509 R.I. GEN. LAWS § 20-6-24(a) (2013); DEM Licensing Regulations, supra note 41, § 6.8-9(a); DEM Shellfish Regulations, supra note 153, § 4.1.6; DEM Shellfish Buyer Regulations, supra note 466, § 9.2(a); DEM Enforcement Regulations, supra note 177, § 2.03.
510 *DOH Regulations*, *supra* note 8, § 10.3; *see also* NSSP-MO, *supra* note 16, § II, ch. IX, § .01(D) (requiring maintenance of an ambient air temperature of 50° F (10° C or less)).
511 The point of sale is defined as "[t]he point in time and place where ownership of a given quantity of fish, shellfish, and/or crustaceans is transferred from a licensed fisher to a licensed dealer." *DEM Licensing Regulations*, *supra* note 41, § 5.51.
512 A critical control point is "a point, step or procedure in a food process at which control can be applied, and a food safety hazard can as a result be prevented, eliminated or reduced to acceptable levels." NSSP-MO, *supra* note 16, § I, Definitions(B)(24); *see infra* § 830.8(3).
513 NSSP-MO, *supra* note 16, § I, Definitions(B)(92).
514 *See id.* § I, Definitions(B)(92).

f. To ensure sanitary safety of the shellfish at the point of sale, the dealer is only permitted to purchase shellfish from a licensed harvester or a licensed dealer.[515] If shellstock is purchased from a licensed harvester, the dealer must ensure that it was "(i) Harvested…from an approved or conditionally approved area in the open status as indicated by the tag; and (ii) Identified…with a tag on each container or transaction record on each bulk shipment."[516] If the shellfish is obtained from another dealer, the selling dealer must have "identified the shellstock with a tag on each container or transaction record with each bulk shipment."[517] The shellfish must also be adequately iced or kept at an ambient or internal temperature at or below 45° F (7.2° C).[518]

g. At the point of sale, the harvester must show his or her commercial harvesting license to the dealer before the transaction can be completed.[519] The harvester is required, under the model ordinance, to provide the initial dealer with a trip record that evidences compliance with the time to temperature requirements.[520] Each sale must be documented in "a 2-part transaction form to be used on a credit card type imprinting machine" that records information from both the dealer's card printing machine and the harvester's license.[521] The dealer's imprinting machine must include the dealer's name and address, license number, and employer identification number.[522] In addition to the information from the dealer's printing machine and the harvester's license, the dealer must also record: "[1] [the] area of Rhode Island waters from which shellfish were obtained…[;] [2] quantity of shellfish[;] [3] type of shellfish[;] [4] purchase price of shellfish[;] [5] date and time of transaction"; and [6] the signature of the harvester.[523] Additionally, the dealer must create and maintain a transaction record regarding the sale, which "includes shellfish harvest and sale records, ledgers, purchase records, invoices and bills of lading."[524]

2. Dealer Licensing

a. A dealer is a person licensed to engage in a shellfish business,[525] which includes "one of the following: [bartering,] processing, labeling, storing except in commercial warehouses, or transporting except by common carrier shellfish which are to be offered for sale or sold."[526] Dealer is a generalized term used to describe anyone engaging in a shellfish business from the point of purchase from a harvester to the point of sale to the consumer, but there are several classifications applicable to dealers based on the specific tasks they are licensed to perform.

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[515] See DOH Regulations, supra note 8, § 12.5.
[516] *Id.* § 12.5; *see* 21 C.F.R. § 123.28(c) (2013); NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .01(A)(1); *DEM Dealer Regulations*, *supra* note 303, § 19.2.2.
[517] *DOH Regulations*, *supra* note 8, § 12.5; *see* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .01(A)(2).
[518] *DOH Regulations*, *supra* note 8, § 12.5; *see* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .01(A).
[519] DEM Shellfish Regulations, supra note 153, § 4.1.7; DEM Dealer Regulations, supra note 303, § 19.2.1-3; DEM Enforcement Regulations, supra note 177, §§ 2.04, 4.01.
[520] NSSP-MO, *supra* note 16, § II, ch. VIII, Requirements for the Harvester, § .02(G)(2).
[521] DEM Enforcement Regulations, supra note 177, § 4.03.
[522] *Id.* § 4.02.
[523] *Id.* § 4.03.
[524] NSSP-MO, *supra* note 16, § I, Definitions(B)(119); *DEM Licensing Regulations*, *supra* note 41, § 5.63.
[525] *DOH Regulations*, *supra* note 8, § 1.6; *DEM Licensing Regulations*, *supra* note 41, § 5.19. Person includes an individual, trust or estate, partnership, or corporation. *DOH Regulations*, *supra* note 8, § 1.6.
[526] *See* R.I. GEN. LAWS § 21-14-1(8) (2013); *DEM Licensing Regulations*, *supra* note 41, § 5.19; *DEM Enforcement Regulations*, *supra* note 177, § 1.01. Transportation agents and common carriers are not required to be licensed dealers in order to transport shellfish. *DOH Regulations*, *supra* note 8, § 10.11.

b. Dealers may be licensed as shellstock shippers, shucker-packers, repackers, reshippers, importers, or post harvest processors under the NSSP-MO.[527] In addition to the license classification, when the dealer purchases directly from a harvester, he or she is referred to as a primary dealer.[528] A secondary dealer is one who purchases shellfish from another dealer.[529] A shellstock shipper is a "dealer who grows, harvests, buys, or repacks and sells shellstock," but is not authorized to shuck or repack shucked shellfish.[530] A person licensed as a shucker-packer may shuck shellfish, pack and repack shucked shellfish, repack shellstock, and ship and receive shellstock in interstate commerce.[531] A repacker is authorized to repack shellstock or shucked shellfish as well as to ship and receive shellstock in interstate commerce.[532] However, a repacker is not authorized to shuck shellfish.[533] A reshipper is authorized to purchase shellstock or shucked shellfish from a dealer and sell that shellfish to other dealers, wholesalers, or retailers, provided that the shellfish is not repacked or relabeled while in the reshipper's possession.[534]

c. An importer, whom can be a shellstock shipper, shucker-packer, repacker, or reshipper, is any dealer "who introduces molluscan shellfish into domestic commerce" and may, but need not, take physical custody of the shellfish at any point in the sale and shipment.[535] A post harvest processor designation is "given to a shellfish dealer that has incorporated a post harvest process" and can only be applicable to a shucker-packer.[536] A wholesaler or retailer is not considered a dealer and may buy and sell shellfish without obtaining a dealer license.[537] Additionally, in Rhode Island, a dealer may obtain a multi-purpose dealer license, which allows the dealer to purchase and sell all marine species including shellfish, or a shellfish dealer's license, which only allows the dealer to purchase and sell shellfish.[538] An out-of-state buyer desiring to purchase shellfish within Rhode Island must either obtain a Rhode Island dealer license[539] or be a listed business on the United States Public Health Service, Food and Drug Administration list of state certified shippers.[540]

d. Before engaging in any shellfish business, the prospective dealer must apply to DOH for the applicable dealer's license.[541] Every dealer must submit an operational plan to DOH prior to

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[527] NSSP-MO, *supra* note 16, §§ I, Definitions(B)(13), (30), (52), (84).
[528] DOH Regulations, supra note 8, § 1.13.
[529] *Id.* § 1.17.
[530] NSSP-MO, *supra* note 16, §§ I, Definitions(B)(112), II, ch. X, § .04(B)(3); *DOH Regulations*, *supra* note 8, §§ 1.21, 6.1(b), (c).
[531] NSSP-MO, *supra* note 16, §§ I, Definitions(B)(114), II, ch. X, § .04(B); *DOH Regulations*, *supra* note 8, §§ 1.23, 6.1.
[532] NSSP-MO, *supra* note 16, §§ I, Definitions(B)(95), II, ch. X, §§ .04(B)(2), (3); *DOH Regulations*, *supra* note 8, §§ 1.15, 6.1(b)(i), (c).
[533] NSSP-MO, *supra* note 16, § II, ch. X, § .04(B)(2)(c); *DOH Regulations*, *supra* note 8, § 6.1(b)(iii).
[534] NSSP-MO, *supra* note 16, §§ I, Definitions(B)(99), II, ch. X, § .04(B)(4); *DOH Regulations*, *supra* note 8, §§ 1.16, 6.1(d).
[535] NSSP-MO, *supra* note 16, § I, Definitions(B)(52).
[536] *See id.* § I, Definitions(B)(84).
[537] R.I. GEN. LAWS § 21-14-10 (2013); *see DOH Regulations*, *supra* note 8, § 2.1; *DEM Dealer Regulations*, *supra* note 303, § 19.2.1-4; *DEM Enforcement Regulations*, *supra* note 177, § 3.01(a). The dealer provisions also do not apply to "persons buying surf clams or ocean quahaugs for use as bait." *DEM Enforcement Regulations*, *supra*, § 3.01(c).
[538] *DEM Licensing Regulations*, *supra* note 41, §§ 6.11-2(a) (multi-purpose license), 6.11-4(a) (shellfish license).
[539] DEM Shellfish Regulations, supra note 153, § 4.35.3.
[540] DEM Dealer Regulations, supra note 303, § 19.2.1-5; DEM Enforcement Regulations, supra note 177, § 3.01(b).
[541] R.I. GEN. LAWS § 21-14-2; see also DOH Regulations, supra note 8, § 2.2; DEM Dredging Regulations, supra note 176, § 6.11-1(a); DEM Dealer Regulations, supra note 303, §§ 19.1.2, 19.2.1; DEM Enforcement Regulations, supra note 177, § 3.01.

constructing or converting the dealer facility.[542] The operational plan is "a written description of the design and activities of the facility specific to, but not limited to, the species of shellfish to be processed, the source of the shellfish to be processed, how the shellfish will be processed, and how the required records will be maintained."[543]

e. All applicants are required to have a fixed place of business within Rhode Island where records will be maintained and be available for inspection.[544] Upon receipt of an application and operational plan, DOH must conduct a "comprehensive, onsite inspection" no more than 120 days before issuance of the license.[545] If DOH finds that the applicant's facility meets the requirements for a shellfish business, then DOH will issue the applicable dealer license upon receipt of the fee.[546] The DOH Director may choose to refuse a dealer license for anyone who has been convicted of a violation of the shellfish statutes and regulations of the state.[547]

f. If the applicant also wishes to be certified for inclusion on the federal shellfish shippers list, which is required in order to sell shellfish out of state,[548] he or she may request such certification from DOH as part of his or her application for a dealer's license.[549] In order to be eligible for certification, he or she must meet all requirements of the NSSP-MO in addition to all Rhode Island dealer requirements.[550] All applicants seeking certification must "[h]ave and implement a [Hazard Analysis Critical Congrol Point ("HACCP")][551] Plan, and have a program of sanitation monitoring and record keeping in compliance with 21 CFR 123."[552] The applicant must also obtain training on processing, handling, and transportation practices within ninety days of licensing, with a requirement to repeat the training every two years.[553]

g. Once the dealer has been issued a license, he or she may engage in any shellfish business activities authorized by the license.[554] The dealer will be issued an identification number, which must be used on all records in order to identify the dealer.[555] Only one number may be given to a single dealer at a single location; however, if the dealer runs separate entity businesses at different locations, multiple certifications and numbers may be issued.[556] Additionally, multiple entities may share a facility and each be issued a unique certification and identification number.[557] Each license is valid for a one year period and must be renewed at the end of that period.[558] DOH has

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[542] *DOH Regulations*, *supra* note 8, §§ 2.11, 2.12.
[543] *Id.* § 1.10.
[544] NSSP-MO, *supra* note 16, § II, ch. X, §§ .04(A)(3), .08(B)(1); *DOH Regulations*, *supra* note 8, §§ 2.10, 10.15(a); *DEM Dredging Regulations*, *supra* note 176, § 6.11-1(d); *DEM Dealer Regulations*, *supra* note 303, 19.1.2.
[545] R.I. GEN. LAWS § 21-14-2; NSSP-MO, *supra* note 16, § II, ch. I, § .02(A)(1); *DOH Regulations*, *supra* note 8, § 2.4.
[546] R.I. GEN. LAWS § 21-14-2; *DOH Regulations*, *supra* note 8, § 2.4.
[547] R.I. GEN. LAWS § 21-14-2; *DOH Regulations*, *supra* note 8, § 2.9.
[548] DOH Regulations, supra note 8, § 5.2.
[549] *Id.* § 5.1.
[550] Id.
[551] *See infra* § 830.8(3).
[552] NSSP-MO, *supra* note 16, § II, ch. X, § .04(A)(2).
[553] *Id.* § II, ch. X, § .04(A)(2). At least one individual involved in the dealer shellfish business must participate in the required training. *Id.* § .04(A)(2)(c)(ii).
[554] DOH Regulations, supra note 8, § 2.6.
[555] *See* NSSP-MO, *supra* note 16, § I, Definitions(B)(15).
[556] *Id.* § II, ch. I, § .02(A)(4).
[557] *Id.* § II, ch. I, § .02(A)(5).
[558] R.I. GEN. LAWS § 21-14-2 (2013); *DEM Licensing Regulations*, *supra* note 41, § 6.11-1(e); *see also* NSSP-MO, *supra* note 16, § II, ch.I, § .02(A)(3).

set the annual license period to run from January 1 through December 31.[559] Licenses may be suspended or revoked for violation of any of the state laws relating to shellfish business operation, including statutes and DEM or DOH regulations.[560]

h. Rhode Island dealers seeking to buy shellfish harvested outside of Rhode Island waters or out-of-state dealers seeking to buy Rhode Island shellfish must be included on the United States Public Health Service, Food and Drug Administration list of state certified shippers.[561] Additionally, any state dealer looking to sell shellfish out of state must be on the list.[562] This interstate certified shellfish shippers list ("ICSSL") is "an FDA publication of shellfish dealers, domestic and foreign, who have been certified by a state or foreign Authority as meeting the public health control measures" of the NSSP-MO.[563]

i. In order to qualify for placement on the ICSSL, the applicant must comply with all sanitation requirements of the NSSP-MO,[564] and compliance must be confirmed by a DOH inspection prior to certification or renewal.[565] The dealer must meet the HACCP[566] requirements by having "(i) A HACCP plan accepted by the Authority; (ii) No critical deficiencies; (iii) Not more than two (2) key deficiencies; [and] (iv) Not more than two (2) other deficiencies."[567] Additionally, in regards to non-HACCP sanitation and other NSSP-MO requirements, the dealer must have "(i) No critical deficiencies; (ii) Not more than two (2) key deficiencies; [and] (iii) Not more than three (3) other deficiencies."[568] Any deficiencies found during the initial inspection must also be corrected based on a compliance schedule issued by DOH.[569]

j. If, after a successful inspection, DOH issues a certification, the agency must then notify the US-FDA of the certification so that US-FDA can place the dealer on the ICSSL.[570] The notification must include a designation of the dealer as a shucker-packer, repacker, shellstock shipper, reshipper, depurator, post harvest processor, aquaculturist, and/or wet storage authorized dealer.[571] All certifications expire annually, and a new inspection is required prior to renewal of certification.[572] DOH must maintain records documenting each dealer's compliance with the requirements for at least three years, including inspection reports, notification letters, enforcement actions, sampling and testing results, and administrative hearing records.[573] DOH can suspend or revoke certification for a violation of any applicable shellfish laws,[574] and it must notify US-FDA of any suspension or revocation so that US-FDA can remove the dealer from the ICSSL as necessary.[575]

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[559] DOH Regulations, supra note 8, § 2.7.
[560] R.I. GEN. LAWS §§ 20-6-24(d), 21-14-2; *DOH Regulations*, *supra* note 8, § 2.8; *DEM Shellfish Buyer Regulations*, *supra* note 466, § 9.2(d).
[561] DEM Enforcement Regulations, supra note 177, §§ 3.01(b), 3.04; see DOH Regulations, supra note 8, § 5.2.
[562] DOH Regulations, supra note 8, § 5.2.
[563] NSSP-MO, *supra* note 16, § I, Definitions(B)(57).
[564] DOH Regulations, supra note 8, § 5.1.
[565] *See* NSSP-MO, *supra* note 16, § II, ch. I, § .02(A)(1).
[566] *See infra* § 830.8(3).
[567] NSSP-MO, *supra* note 16, § II, ch. I, § .02(B)(1).
[568] Id.
[569] *See id.* § II, ch. I, § .02(B)(2).
[570] *Id.* § II, ch. I, § .02(E)(1).
[571] Id.
[572] *Id.* § II, ch. I, §§ .02(A)(3), (C)(1).
[573] *Id.* § II, ch. I, § .02(A)(7).
[574] *See id.* § II, ch. I, § .02(D).
[575] *Id.* § II, ch. I, § .02(E)(2).

3. Hazard Analysis Critical Control Point ("HACCP") Plans

   a. HACCP is a "systematic, science-based approach used in food production as a means to assure food safety."[576] A HACCP plan is a "written document that delineates the formal procedures that a dealer follows to implement the HACCP requirements."[577] Every prospective dealer is required to first conduct a hazard analysis, and if that analysis indicates that "one or more food safety hazards[578]…are reasonably likely to occur," the dealer must create and implement a HACCP plan.[579] If a dealer is required to create or implement a HACCP plan and fails to do so, all shellfish in the dealer's possession will be considered adulterated.[580] Secondary dealers and re-shippers are not required to have a HACCP plan unless they wish to be listed on the ICSSL.[581]

   b. The first step in the HACCP process is to "conduct a hazard analysis to determine the food safety hazards that are reasonably likely to occur for each kind of shellfish product processed by that dealer and to identify the preventative measures[582] that the dealer can apply to control those hazards."[583] A food safety hazard is considered reasonably likely to occur if "a prudent dealer would establish controls because experience, illness data, scientific reports, or other information provide a basis to conclude that there is a reasonable possibility that it will occur in the particular type of shellfish product being processed in the absence of" hazard controls.[584] Food safety hazards may occur before, during, or after harvest as well as at the processing plant or elsewhere.[585] Critical control points[586] identified by DOH, the NSSP-MO, or US-FDA should be given particular consideration in the analysis.[587] If a dealer does not find any food safety hazards as part of the analysis, no HACCP plan is required. However, he or she must reassess the hazard analysis if "there are any changes that could reasonably affect whether a food safety hazard now exists.[588]

   c. If a HACCP plan is required, the plan must be specific to each processing location as well as each kind of shellfish product being processed.[589] At a minimum, a HACCP plan must:

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[576] *Id.* § I, Definitions(B)(46).
[577] *Id.* § I, Definitions(B)(47).
[578] A food safety hazard is "any biological, chemical or physical property that may cause a food to be unsafe for human consumption." *Id.* § I, Definitions(B)(43).
[579] *See* 21 C.F.R. § 123.6(b) (2013); *see DOH Regulations*, *supra* note 8, §§ 2.5, 7.2.
[580] 21 C.F.R. § 123.6(g).
[581] DOH Regulations, supra note 8, § 7.0.
[582] A preventative measure is any "physical, chemical, or other factors that can be used to control an identified food safety hazard." *Id.* § 1.12.
[583] *Id.* § 7.1; *see also* 21 C.F.R. § 123.6(a); NSSP-MO, *supra* note 16, § II, ch. X, § .01(A).
[584] *DOH Regulations*, *supra* note 8, § 7.1; *see also* 21 C.F.R. § 123.6(a); NSSP-MO, *supra* note 16, § II, ch. X, § .01(A).
[585] *DOH Regulations*, *supra* note 8, § 7.1; *see also* 21 C.F.R. § 123.6(a); NSSP-MO, *supra* note 16, § II, ch. X, § .01(A).
[586] A critical control point is "a point, step or procedure in a food process at which control can be applied, and a food safety hazard can as a result be prevented, eliminated or reduced to acceptable levels." NSSP-MO, *supra* note 16, § I, Definitions(B)(24).
[587] *DOH Regulations*, *supra* note 8, § 7.1; *see also* 21 C.F.R. § 123.6(a); NSSP-MO, *supra* note 16, § II, ch. X, § .01(A). The identified critical control points include: (1) receipt of shellfish; (2) temperature control; (3) repacking; (4) storage; and (5) transport. *See DOH Regulations*, *supra* note 8, §§ 12.6(b), 12.8, 13.2, 14.1; *see also* NSSP-MO, *supra* note 16, §§ I, Definitions(B)(92); II, ch. XIII, § .01(A); ch. XI, Requirements for Dealers, § .01(B)(2), (E). Each critical control point will be discussed in more detail where appropriate in this section.
[588] 21 C.F.R. § 123.8(c).
[589] *DOH Regulations*, *supra* note 8, § 7.2; *see also* 21 C.F.R. § 123.6(b); NSSP-MO, *supra* note 16, § II, ch. X, § .01(B). The plan "may group kinds of shellfish products together or group kinds of production methods together, if

(a) List the food safety hazards that are reasonably likely to occur, as identified in [the hazard analysis] and that must be controlled for each shellfish product. Consideration should be given to whether any food safety hazards are reasonably likely to occur as a result of the following: (i) Natural toxins; (ii) Microbiological contamination; (iii) Chemical contamination; (iv) Pesticides; (v) Drug residues; (vi) Unapproved use of direct or indirect food or color additives; and (vii) Physical hazards; (b) List the critical control points for each of the identified food safety hazards, including as appropriate…[a]t a minimum, the critical control points [specifically listed in the regulations];[590] (c) List the critical limits[591] that must be met at each of the critical control points [at a minimum including the critical limits enumerated in the regulations];[592] (d) List the procedures, and frequency thereof, that will be used to monitor each of the critical control points to ensure compliance with the critical limits; (e) Include any corrective action plans that have been developed in accordance with section 7.6(b) to be followed in response to deviations from critical limits at critical control points; (f) Provide for a record keeping system that documents the monitoring of the critical control points. The records shall contain the actual values and observations obtained during monitoring; (g) List the verification procedures, and frequency thereof, that the dealer will use in accordance with section 7.7(a).[593]

d. The HACCP plan may also include non-HACCP sanitation controls, or those controls may be monitored independently.[594]

e. Finally, the NSSP-MO requires that, "if a dealer elects to use a process to reduce the level(s) of one target pathogen or some target pathogens, or all pathogens of public health concern in shellfish, and wishes to make labeling claims regarding the reduction of pathogens," the dealer must include in the HACCP plan methods to ensure that the target pathogens will be reduced to safe levels by the intended process.[595] If such a post harvest process is employed, the dealer may

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the food safety hazard, critical control points, critical limits, and procedures required to be identified and performed [in the plan] are identical" for the entire group. *DOH Regulations*, *supra*, § 7.2; *see also* 21 C.F.R. § 123.6(b); NSSP-MO, *supra*, § II, ch. X, § .01(B).

[590] Alternatively, "the dealer may establish other critical control points which the dealer can demonstrate to the Department through a hazard analysis that the food safety hazard is not reasonably likely to occur, the critical control point is not required with the exception of receiving which shall always be considered a critical control point." *DOH Regulations*, *supra* note 8, § 7.3(b)(i); *see also* NSSP-MO, *supra* note 16, § II, ch. X, § .01(C)(2)(a).

[591] A critical limit is "the maximum or minimum value to which a physical, biological, or chemical parameter must be controlled at a critical control point to prevent, eliminate or reduce to an acceptable level the occurrence of the identified food safety hazard." NSSP-MO, *supra* note 16, § I, Definitions(B)(26).

[592] Alternatively, "the dealer may establish other critical limits which the dealer has demonstrated provide equivalent public health protection with the exception of receiving which shall always be considered as a critical control point." *DOH Regulations*, *supra* note 8, § 7.3(c); *see also* NSSP-MO, *supra* note 16, § II, ch. X, § .01(C)(3).

[593] *DOH Regulations*, *supra* note 8, § 7.3; *see also* 21 C.F.R. § 123.6(c); NSSP-MO, *supra* note 16, § II, ch. X, § .01(C).

[594] *DOH Regulations*, *supra* note 8, §§ 7.5, 7.12; *see also* 21 C.F.R. § 123.6(f); NSSP-MO, *supra* note 16, § II, ch. X, § .01(E).

[595] NSSP-MO, *supra* note 16, § II, ch. XVI(A). Such a HACCP plan must "include: (a) Process controls to ensure that the end point criteria are met for every lot; and (b) A sampling program to periodically verify that the end point criteria are met." *Id.* The dealer must also validate the process by demonstrating that it will achieve the necessary reductions in pathogen(s). *Id.*

label the product as "processed for added safety" or "processed to reduce [pathogen(s)]."[596] Once created, the plan must be signed by either "the most responsible individual on site at the processing facility or by a higher level official of the dealer," which will signify that the plan has been accepted for implementation.[597]

f. All HACCP plans must also undergo a verification process to ensure that the plan "is adequate to control food safety hazards that are reasonably likely to occur, and that the plan is being effectively implemented."[598] Verification is required at least annually, and it is also required whenever a change occurs that could affect the hazard analysis or the HACCP plan "in any way."[599] Verification activities[600] include: (1) a review of any consumer complaints; (2) calibration of monitoring instruments; and (3) periodic end-product or in-process testing, as the dealer elects.[601] The plan must be immediately modified if the reassessment indicates plan inadequacy.[602] The final element of a verification is a records review that includes: "(1) The monitoring of critical control points…;[603] (2) ***The taking of corrective actions***…;[604] (3) The calibrating of any process monitoring instruments[605] used at critical control points and the performing of any periodic end-product or in-process testing that is part of the dealer's verification activities."[606] Any calibration of monitoring instruments or product testing must be recorded and the documents maintained consistent with the record keeping requirements of the regulations.[607]

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[596] *Id.* § II, ch. XVI(B).

[597] *DOH Regulations*, *supra* note 8, § 7.4(a); *see also* 21 C.F.R. § 123.6(d)(1); NSSP-MO, *supra* note 16, § II, ch. X, § .01(D)(1). The plan must be re-signed if it is modified and when it is verified. *DOH Regulations*, *supra*, § 7.4(b); *see also* 21 C.F.R. § 123.6(d)(2); NSSP-MO, *supra*, § II, ch. X, § .01(D)(2).

[598] *DOH Regulations*, *supra* note 8, § 7.7(a); *see also* 21 C.F.R. § 123.8(a); NSSP-MO, *supra* note 16, § II, ch. X, § .01(G)(1).

[599] *DOH Regulations*, *supra* note 8, § 7.7(a)(i); *see also* 21 C.F.R. § 123.8(a)(1); NSSP-MO, *supra* note 16, § II, ch. X, § .01(G)(1). Changes may include "[r]aw materials or source of raw materials, product formulation, processing methods or systems, finished product distribution systems, or the intended use or consumers of the finished product." *DOH Regulations*, *supra*, § 7.7(a)(i); *see also* 21 C.F.R. § 123.8(a)(1). The reassessment must be performed by person(s) appropriately trained to do so. *DOH Regulations*, *supra*, § 7.7(a)(i); *see also* 21 C.F.R. § 123.8(a)(1).

[600] These are the domestic verification requirements. For imported products, special verification procedures are required and can be found in 21 C.F.R. § 123.12.

[601] *DOH Regulations*, *supra* note 8, § 7.7(a)(ii); *see also* 21 C.F.R. § 123.8(a)(2); NSSP-MO, *supra* note 16, § II, ch. X, § .01(G)(1).

[602] *DOH Regulations*, *supra* note 8, § 7.7(a)(i).

[603] This review is done "to ensure that the records are complete and to verify that they document values that are within the critical limits. This review shall occur within one (1) week of the day that the records are made." *DOH Regulations*, *supra* note 8, § 7.7(a)(iii)(1); *see also* 21 C.F.R. § 123.8(a)(3); NSSP-MO, *supra* note 16, § II, ch. X, § .01(G)(1).

[604] This review is done "to ensure that the records are complete and to verify that appropriate corrective actions were taken…. This review shall occur within one (1) week of the day that the records are made." *DOH Regulations*, *supra* note 8, § 7.7(a)(iii)(2); *see also* 21 C.F.R. § 123.8(a)(3); NSSP-MO, *supra* note 16, § II, ch. X, § .01(G)(1).

[605] This review is done "to ensure that the records are complete, and that these activities occurred in accordance with the processor's written procedures. These reviews shall occur within a reasonable time after the records are made." *DOH Regulations*, *supra* note 8, § 7.7(a)(iii)(3); *see also* 21 C.F.R. § 123.8(a)(3); NSSP-MO, *supra* note 16, § II, ch. X, § .01(G)(1).

[606] *DOH Regulations*, *supra* note 8, § 7.7(a)(iii) (emphasis in original); *see also* 21 C.F.R. § 123.8(a)(3); NSSP-MO, *supra* note 16, § II, ch. X, § .01(G)(1).

[607] *DOH Regulations*, *supra* note 8, § 7.7(c); *see also* 21 C.F.R. § 123.8(d); NSSP-MO, *supra* note 16, § II, ch. X, § .01(G)(3).

g. Certain tasks in regards to HACCP plans must be completed only by properly trained personnel. These tasks include: (1) developing the HACCP plan; (2) reassessing or modifying the HACCP plan as part of the verification or corrective action processes; and (3) performing a HACCP record review.[608] Proper training requires that the person have "successfully completed training in the application of HACCP principles to shellfish processing at least equivalent to that received under standardized curriculum recognized as adequate by [DOH] or who is otherwise qualified through job experience."[609] Job experience qualifies "if it has provided knowledge at least equivalent to that provided through the standardized curriculum as determined by" DOH.[610] The trained person can be a dealer employee, but he or she need not be.[611]

h. Whenever a verification, inspection, or other assessment reveals that a deviation from a critical limit has occurred, the dealer must take corrective action to remedy the problem.[612] One method to approach corrective actions is to have a corrective action plan, which becomes part of the HACCP plan, in which the dealer "predetermine[s] the corrective actions that [he or she] will take whenever there is a deviation from a critical limit."[613] The corrective action plan must (1) describe the steps to be taken to correct the deviation, (2) assign responsibility for those steps, and (3) have a method in place to ensure that any adulterated product does not reach the market.[614] If a deviation occurs and the dealer does not have a corrective action plan, the dealer shall:

> (i) Segregate and hold the affected product, at least until [steps (ii) and (iii) herein are completed]; (ii) Perform or obtain a review to determine the acceptability of the affected product for distribution…; (iii) Take corrective action, when necessary, with respect to the affected product to ensure that no product enters commerce that is either injurious to health or is otherwise adulterated as a result of the deviation; (iv) Take corrective action, when necessary, to correct the cause of the deviation; (v) Perform or obtain timely reassessment by [a trained individual] to determine whether the HACCP plan needs to be modified to reduce the risk of recurrence of the deviation[; and (vi) M]odify the HACCP plan as necessary.[615]

i. All corrective actions must be properly documented according to records regulations.[616]

j. Dealers must maintain extensive documentation as part of their HACCP compliance.[617] All records must include: (1) dealer name and location; (2) the date and time of the recorded activity;

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[608] *DOH Regulations*, *supra* note 8, § 7.9(a); *see also* 21 C.F.R. § 123.10; NSSP-MO, *supra* note 16, § II, ch. X, § .01(I)(1).
[609] *DOH Regulations*, *supra* note 8, § 7.9(a); *see also* 21 C.F.R. § 123.10; NSSP-MO, *supra* note 16, § II, ch. X, § .01(I)(1).
[610] *DOH Regulations*, *supra* note 8, § 7.9(b); *see also* 21 C.F.R. § 123.10; NSSP-MO, *supra* note 16, § II, ch. X, § .01(I)(1).
[611] *DOH Regulations*, *supra* note 8, § 7.9(c); *see also* 21 C.F.R. § 123.10 2013; NSSP-MO, *supra* note 16, § II, ch. X, § .01(I)(3).
[612] *DOH Regulations*, *supra* note 8, § 7.6(a); *see also* 21 C.F.R. §§ 123.7(a), 123.8(b); NSSP-MO, *supra* note 16, § II, ch. X, §§ .01(F)(1), (G)(2).
[613] *DOH Regulations*, *supra* note 8, § 7.6(b); *see also* 21 C.F.R. § 123.7(b); NSSP-MO, *supra* note 16, § II, ch. X, § .01(F)(2).
[614] *DOH Regulations*, *supra* note 8, § 7.6(b); *see also* 21 C.F.R. § 123.7(b); NSSP-MO, *supra* note 16, § II, ch. X, § .01(F)(2).
[615] *DOH Regualtions*, *supra* note 8, § 7.6(c); *see also* 21 C.F.R. § 123.7(c); NSSP-MO, *supra* note 16, § II, ch. X, § .01(F)(3).
[616] *DOH Regulations*, *supra* note 8, § 7.6(d); *see also* 21 C.F.R. § 123.7(d); NSSP-MO, *supra* note 16, § II, ch. X, § .01(F)(4).

(3) the signature or initials of the person performing the recorded activity; and (4) the identity of the product or production code, if applicable.[618] Records must be maintained at the dealer's facility for one year – if the product is sold fresh – or two years – if the product is sold frozen.[619] Records that relate to equipment, processes, studies, or evaluations rather than specific product must be maintained for at least two years.[620] Although records must generally be kept at the dealer's processing facility, if the facility is closed seasonally or is a vessel with storage capacity limitations, the records may be maintained at another accessible location as long as they are available upon request.[621] All records must be available to DOH or DEM upon request for review and copying "at reasonable times."[622]

4. Dealer Operations

   a. Once a dealer has taken possession of shellfish, there are several operational requirements that he or she must meet including temperature control, proper tagging and labeling, sanitation requirements both for the facility and for handling the shellfish, and proper packing and storing techniques. First, no dealer may possess undersized shellfish with the exception of non-quahaug shellfish obtained from an aquaculture operation.[623] If the dealer is in legal possession of cultured undersized shellfish, the shellfish must be appropriately tagged, and the dealer must maintain records that document the source of the shellfish, including lease site and harvest date.[624] Additionally, the dealer must "reject dead or inadequately protected shellstock" at the point of receipt.[625]

   b. Temperature control is an identified critical control point and is vital to proper dealer operations.[626] Once shellstock have been placed under temperature control, the dealer is required to ensure continued temperature control until sale via adequate icing[627] or maintaining an ambient

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[617] Records may be kept on computers as long as the method of retention is approved by DOH. *DOH Regulations*, *supra* note 8, § 7.8(g); *see also* 21 C.F.R. § 123.9(f); NSSP-MO, *supra* note 16, § II, ch. X, § .01(H)(7).
[618] *DOH Regulations*, *supra* note 8, § 7.8(a); *see also* 21 C.F.R. § 123.9(a); NSSP-MO, *supra* note 16, § II, ch. X, § .01(H)(1).
[619] *DOH Regulations*, *supra* note 8, § 7.8(b); *see also* 21 C.F.R. § 123.9(b)(1); NSSP-MO, *supra* note 16, § II, ch. X, § .01(H)(2). Container tags do not need to be kept for this period unless they constitute the method of preserving the required information. *DOH Regulations*, *supra*, § 7.8(f); *see also* 21 C.F.R. § 123.9(e); NSSP-MO, *supra*, § II, ch. X, § .01(H)(6).
[620] *DOH Regulations*, *supra* note 8, § 7.8(c); *see also* 21 C.F.R. § 123.9(b)(2); NSSP-MO, *supra* note 16, § II, ch. X, § .01(H)(3).
[621] *DOH Regulations*, *supra* note 8, § 7.8(d); *see also* 21 C.F.R. § 123.9(b)(3); NSSP-MO, *supra* note 16, § II, ch. X, § .01(H)(4).
[622] *DOH Regulations*, *supra* note 8, § 7.8(e); *see also* 21 C.F.R. § 123.9(c); NSSP-MO, *supra* note 16, § II, ch. X, § .01(H)(5). Such documents are not available for public disclosure "unless they have been previously disclosed to the public…or they relate to a product or ingredient that has been abandoned and they no longer represent a trade secret or confidential commercial or financial information." 21 C.F.R. § 123.9(d)(1).
[623] DEM Dealer Regulations, supra note 303, § 19.3.1.
[624] *Id.* § 19.3.2.
[625] *DOH Regulations*, *supra* note 8, § 9.8(c).
[626] *See id.* § 12.6(b); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .01(B)(2). A dealer must have "a temperature measuring device accurate to +/- 2°F for use in monitoring product temperatures." *DOH Regulations*, *supra,* § 8.2(c)(v); *see* NSSP-MO, *supra,* § II, ch. XI, Requirements for Dealers, § .02(B)(1)(e).
[627] Adequately iced means "that the amount and application of the ice is sufficient to ensure that immediate cooling begins and continues for all shellfish. If ice slurry is used and the shellfish are submerged the presence of ice in the slurry indicates adequate icing." NSSP-MO, *supra* note 16, § I, Definitions(B)(1).

temperature at or below 45° F (7.2° C).[628] The dealer must not allow the shellstock to be without ice, mechanical refrigeration, or some other form of temperature control for more than two hours at any point once temperature control has begun.[629] If the shellstock is shucked prior to entering temperature control, the shucked shellfish must be chilled to an internal temperature of 45° F (7.2° C) or less within three hours of shucking.[630] If the shellstock was chilled prior to shucking, it must be cooled within four hours of removal from refrigeration for shucking.[631] If heat shock[632] is used, the shucked meats must be cooled within two hours of the heat shock process.[633] Shellfish must be stored at or below 45° F (7.2° C) or covered with ice.[634] Frozen shellfish must be frozen solid within twelve hours of initiating freezing and stored at or below 0° F (-17.8° C).[635]

c. Just as harvesters are required to tag shellfish in order to allow the shellfish to be traced back to their harvest date and location, dealers are also required to tag shellfish to allow such tracking.[636] The dealer must keep the harvester tag affixed to the shellfish container until the container is shipped or emptied.[637] The dealer must affix his or her dealer tag prior to shipping or immediately after removing the harvester tag.[638] The dealer tag must:

> contain the following indelible, legible information in the order specified…: [1] the dealer's name and address; [2] the dealer's certification number…; [3] the date of harvest; [4] the most precise identification of the harvest location as is practicable including the initials of the state of harvest, and the DOH/DEM designation[639]…; [5] when the shellfish has been placed in wet storage in a dealer's operation, the statement: 'THIS PRODUCT IS A PRODUCT OF (NAME OF STATE) AND WAS WET STORED AT (FACILITY CERTIFICATION NUMBER) FROM (DATE) TO (DATE)'; [6] the type and quantity of shellfish; and [7] the following statement in bold capitalized type on each tag: 'THIS TAG IS REQUIRED TO BE ATTACHED UNTIL CONTAINER IS EMPTY OR IS RETAGGED AND THEREAFTER KEPT ON FILE FOR 90 DAYS.'[640]

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628 *DOH Regulations*, *supra* note 8, § 12.6(b); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .01(B)(2).
629 *DOH Regulations*, *supra* note 8, § 12.6(b); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, §§ .01(B)(2), (D)(5).
630 *DOH Regulations*, *supra* note 8, § 12.7(a); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .01(D)(1).
631 *DOH Regulations*, *supra* note 8, § 12.7(b); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .01(D)(2).
632 *See infra* §§ 830.8(4)(y) – (aa).
633 *DOH Regulations*, *supra* note 8, § 12.7(c); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .01(D)(3).
634 *DOH Regulations*, *supra* note 8, § 12.8; *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .01(E).
635 *DOH Regulations*, *supra* note 8, § 9.8(i).
636 *DEM Enforcement Regulations*, *supra* note 177, § 5.03. If the shellfish is part of the federal management program (surf clams or ocean quahaugs) and are caught in federal waters, the dealer must follow federal tagging protocol. NSSP-MO, *supra* note 16, § II, ch. X, § .05.
637 *DOH Regulations*, *supra* note 8, § 6.2(a); *DEM Dealer Regulations*, *supra* note 303, § 19.6.2-1; *see also* NSSP-MO, *supra* note 16, § II, ch. X, § .05(A)(1).
638 DEM Dealer Regualtions, supra note 303, § 19.6.2-2.
639 DOH has indexed growing areas, and the designation can be found in Appendix A of DOH Shellfish Regulations.
640 *DOH Regulations*, *supra* note 8, § 6.3(b); *DEM Dealer Regulations*, *supra* note 303, § 19.6.2-5; *see* NSSP-MO, *supra* note 16, § II, ch. X, § .05(B)(2); *DEM Enforcement Regualations*, *supra* note 177, § 5.03.

d. If the product is intended for raw consumption, the dealer tag must also include a consumer advisory statement.[641] The model ordinance also requires that any in-shell product intended for direct sale to the consumer additionally contain a "sell by" or "best if used by" date on the dealer tag as well as a consumer advisory of the risks of consuming raw or undercooked shellfish and the need to keep the product refrigerated.[642] The tag must be durable, waterproof, sanctioned by DOH, and at least 2 5/8" by 5 1/4".[643]

e. If the harvester tag is left on the container when the dealer tag is affixed, the dealer tag need not repeat the information available on the harvester tag.[644] If the dealer removes the harvester tag, the harvester tag must be kept for ninety days, and the dealer must have a method to maintain the identity of the shellfish during processing, affixing a dealer tag by the end of processing.[645] A dealer may tag a bulk or lot (e.g. pallet) instead of individual containers if the dealer has a processing plan approved by DOH to ensure that the identity of the shellfish will be maintained throughout shellfish processing.[646] Any tag used in bulk shipment must include a statement that "'All shellstock containers in this lot have the same harvest date and area of harvest'" as well as the number of individual containers included in the lot.[647] A transaction record must accompany any bulk/lot shipment with "the name of the consignee who must be a certified dealer."[648]

f. If a dealer transfers shellfish to reusable containers, the dealer must have a system in place to maintain the identity of the shellfish throughout the handling, processing, and storage process.[649] If returnable, reusable containers are used between dealers, the containers need not have the standard dealer tags, but a transaction record must be included that indicates: "(i) The original shucker-packer's name and license number; (ii) The shucking date; and (iii) The quantity of shellfish per container and total number of containers."[650] If a dealer is using master shipping cartons, the master cartons do not need to be labeled as long as each individual container is properly labeled.[651]

g. Additionally, there are requirements for labels placed on shucked shellfish meat that will reach the consumer, which must be in legible and indelible form.[652] Every package "containing less than 64 fluid ounces of fresh or frozen shellfish shall have: (i) The shucker-packer's or repacker's

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[641] *DOH Regulations*, *supra* note 8, § 6.3(b)(viii); *see* NSSP-MO, *supra* note 16, § II, ch. X, §§ .06(A)(11), .07(B)(1).
[642] NSSP-MO, *supra* note 16, § II, ch. X, § .07(B)(1). If in-shell product is sold in containers of five pounds or less and is intended for retail sale, only the shipping container requires a full dealer tag. The individual product containers need only contain a label sufficient to allow the shellstock to be traced back to its lot as well as a consumer advisory. *Id.* § II, ch. X, §§ .05(B)(6), .07(B)(1)(k)(3).
[643] *DOH Regulations*, *supra* note 8, §§ 6.3(a), (b); *DEM Dealer Regulations*, *supra* note 303, § 19.6.2-4; *see also* NSSP-MO, *supra* note 16, § II, ch. X, § .05(B)(1) (requiring dealer tag of a size 13.8 square inches).
[644] NSSP-MO, *supra* note 16, § II, ch. X, § .05(B)(3).
[645] *DOH Regulations*, *supra* note 8, § 6.4(a); *see also* NSSP-MO, *supra* note 16, § II, ch. X, § .05(D)(1).
[646] *DOH Regulations*, *supra* note 8, § 6.4(c); *see also* NSSP-MO, *supra* note 16, § II, ch. X, §§ .05(C)(1), (D)(3). This option does not apply to sale to reshippers. NSSP-MO, *supra*, § II, ch. X, § .05(C)(1)(a). If the described dealer tags are not used, the dealer must apply tags including a "statement that 'All shellstock containers in this lot have the same harvest date and area of harvest';" the harvest date; the growing area identification; the original dealer license number; and the number of individual containers in each lot, unless the dealer is part of DOH's commingling plan. *DOH Regulations*, *supra* note 8, § 6.4(d); *see also* NSSP-MO, *supra* note 16, § II, ch. X, § .05(D)(4).
[647] NSSP-MO, *supra* note 16, § II, ch. X, § .05(C)(1)(c).
[648] *DOH Regulations*, *supra* note 8, § 6.5; *see also* NSSP-MO, *supra* note 16, § II, ch. X, § .05(C)(1)(b).
[649] NSSP-MO, *supra* note 16, § II, ch. X, § .06(A)(1).
[650] *DOH Regulations*, *supra* note 8, § 6.6(a); *see also* NSSP-MO, *supra* note 16, § II, ch. X, § .06(A)(2).
[651] *DOH Regulations*, *supra* note 8, § 6.6(b); *see also* NSSP-MO, *supra* note 16, § II, ch. X, § .06(A)(3).
[652] *DOH Regulations*, *supra* note 8, § 6.6(g).

license number on the label; and (ii) A 'SELL BY DATE' which provides a reasonable subsequent shelf-life or the words 'BEST IF USED BY' followed by a date when the product would be expected to reach the end of its shelf life."[653] If the package contains more than 64 fluid ounces, the same requirement applies, except that a 'DATE SHUCKED' is required rather than a "sell by" or "best by" date.[654] Frozen shellfish must be labeled as frozen.[655] If the dealer "thaws and repacks frozen shellfish, the dealer shall label the shellfish container as previously frozen."[656]

h. Extensive sanitation requirements also exist for both handling of shellfish and for maintenance of the dealer facilities. Upon receipt of shellfish product, the dealer may sort the shellfish by type, size, or any other basis; however, the original tags must be maintained in close proximity during sorting to ensure the identity of the shellstock is not lost.[657] Commingling of shellfish from different lots is not permitted unless the dealer is part of DOH's commingling plan.[658] DOH's commingling plan only permits commingling of shellfish from different harvest areas or different days by a primary dealer.[659] Only "partial containers that are left over at the end of the day's production" may be commingled.[660] Commingled shellfish cannot come from more than two harvest areas or two harvest dates, and both harvest areas or dates must be listed on the dealer tag.[661] DOH does not permit comingling of aquaculture product under any circumstance.[662]

i. If the harvester did not wash the shellstock free of bottom sediments, the dealer must do so as soon as possible using potable water or water from a growing area in the approved or open conditionally approved classification.[663] If the dealer uses a recirculating water system to wash the shellstock, the system must be approved by DOH and must have a water treatment and disinfection system that is subject to daily water quality testing.[664] Shellstock "shall not be placed in containers with standing water for the purposes of washing shellstock or loosening sediment."[665]

j. Before storing shellstock, the dealer must ensure that it is both reasonably free of sediment and dead shellfish have been culled (removed).[666] Shellstock and shucked shellfish must be stored in a

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[653] *Id.* § 6.6(d); *see also* NSSP-MO, *supra* note 16, § II, ch. X, §§ .06(A)(5), (6). Any lot code used by the dealer must be separate and distinct from these expiration dates on the labels. NSSP-MO, *supra*, § II, ch. X, § .06(A)(10).
[654] *DOH Regulations*, *supra* note 8, § 6.6(e); *see also* NSSP-MO, *supra* note 16, § II, ch. X, § .06(A)(7). If the product is repacked, the original shucking date must be listed, not the repacking date. *DOH Regulations*, *supra*, § 6.7; *see also* NSSP-MO, *supra*, § II, ch. X, § .06(B).
[655] NSSP-MO, *supra* note 16, § II, ch. X, § .06(A)(9).
[656] *DOH Regulations*, *supra* note 8, § 6.6(f); *see also* NSSP-MO, *supra* note 16, § II, ch. X, § .06(A)(8).
[657] DEM Dealer Regulations, supra note 303, § 19.6.3; DEM Enforcement Regulations, supra note 177, § 5.02.
[658] *DEM Dealer Regulations*, *supra* note 303, § 19.6.1; *DEM Enforcement Regulations*, *supra* note 177, § 5.01; *see also* NSSP-MO, *supra* note 16, § II, ch. I, §§ .01(G)(1), (2). Cultured and wild harvest crop cannot be commingled; shellfish harvested on different days or from different locations cannot be commingled. *DEM Dealer Regulations*, *supra*, § 19.3.3.
[659] *DOH Regulations*, *supra* note 8, at app. B (commingling plan).
[660] Id.
[661] Id.
[662] Id.
[663] DEM Dealer Regulations, supra note 303, § 19.6.4.
[664] NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .02(A)(3)(b). An ultra-violet disinfection system is acceptable as long as the water turbidity does not exceed twenty nephelometric turbidity units. *Id.* § .02(A)(3)(c).
[665] *DOH Regulations*, *supra* note 8, § 8.3(a)(iii); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .02(C)(1)(c).
[666] *DOH Regulations*, *supra* note 8, § 9.8(a).

manner to protect them from contamination.[667] Shucking buckets must be completely emptied at the packing room to ensure that no overage is returned to the shucker.[668] The dealer must not allow "use of dip buckets for hand or knife rinsing;" not keep any containers or covers on site that bear a certification number not associated with the dealer;[669] thoroughly "drain, clean as necessary, and pack shucked shellfish meats promptly after delivery to the packing room;" and conform to applicable food additive regulations.[670]

k. Non-handling based sanitation requirements are also in place. Each dealer who processes shellfish must "have and implement a written sanitation standard operating procedure…or similar document that is specific to each location where fish and fishery products are produced. The [standard operating procedure] should specify how the processor will meet those sanitation conditions and practices that are to be monitored."[671] DOH has classified the sanitation monitoring requirements as follows:

> (a)…Safety of water for processing and ice production; (b)…Condition and cleanliness of food contact surfaces; (c)…Prevention of cross contamination; (d)…Maintenance of hand washing, hand sanitizing and toilet facilities; (e)…Protection from adulterants [such as lubricants, fuel, pesticides, and cleaning compounds]; (f)…Proper labeling, storage, use of toxic compounds; (g)…Control of employees with adverse health conditions; and (h)…Exclusion of pests.[672]

l. Control of these monitoring points may be included in the HACCP plan or may be independently monitored by the dealer.[673] The dealer must maintain sanitation control records that document this monitoring and any applicable corrections undertaken.[674]

m. In regards to safety of the water supply, the dealer must have a potable water supply on-site.[675] If that water supply is from a private source, it must be tested prior to use, again every six months, and any time that the supply has been repaired or disinfected.[676] Any ice must be made on-site from this potable water supply via a commercial ice machine or come from a facility sanctioned by DOH.[677] Any ice not made on-site must be inspected upon arrival and rejected if it is not protected from contamination.[678] Ice must be stored "in a safe and sanitary manner to prevent

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[667] *Id.* §§ 8.3(a)(i), (ii); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, §§ .02(C)(1)(a), (b).
[668] *DOH Regulations*, *supra* note 8, § 9.8(b).
[669] Unless documentation exists to "verify the legitimate source of the containers and the containers contain shellfish from that source." *Id.* § 9.8(e).
[670] *Id.* §§ 9.8(d), (e), (g), (h).
[671] 21 C.F.R. § 123.11(a) (2013).
[672] *DOH Regulations*, *supra* note 8, § 7.10; *see also* 21 C.F.R. § 123.11(b); NSSP-MO, *supra* note 16, § II, ch. X, § .02(A).
[673] *DOH Regulations*, *supra* note 8, § 7.12; *see also* 21 C.F.R. § 123.11(d); NSSP-MO, *supra* note 16, § II, ch. X, § .02(C).
[674] *DOH Regulations*, *supra* note 8, § 7.11; *see also* 21 C.F.R. § 123.11(c); NSSP-MO, *supra* note 16, § II, ch. X, § .02(B).
[675] *DOH Regulations*, *supra* note 8, § 8.1(a); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .02(A)(1)(a).
[676] *DOH Regulations*, *supra* note 8, § 8.1(b); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .02(A)(1)(b).
[677] *DOH Regulations*, *supra* note 8, § 8.1(d); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, §§ .02(A)(2), (E)(4)(c).
[678] *DOH Regulations*, *supra* note 8, § 8.5(d); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .02(E)(4)(a).

contamination."[679] Any steam that comes into contact with food surfaces must be "free from any additives, or deleterious substances."[680]

n. All plumbing and related facilities must be designed, installed, modified, repaired, and maintained in order to prevent contamination of any water supply or cross-contamination with another water supply.[681] Shellstock washing, storage tanks, or other plumbing "shall be fabricated from safe materials and tank construction shall be such that it: (i) Is easily accessible for cleaning and inspection; (ii) Is self-draining; and (iii) Meets the requirements for food contact surfaces."[682] Adequate ventilation must be provided "to minimize condensation in areas where food is stored, processed or packed."[683]

o. Food contact surfaces must also be kept in a sanitary condition.[684] All equipment and utensils must be: "(i) Constructed in a manner and with materials that can be cleaned, sanitized, maintained or replaced in a manner to prevent contamination of shellfish products; (ii) Free from any exposed screws, bolts, or rivet heads on food contact surfaces; and (iii) Fabricated from food grade materials."[685] All joints on food contact surfaces must: "(i) Have smooth easily cleanable surfaces; and (ii) [Be] welded."[686] Shucking blocks must be: "(i) Easily cleanable; (ii) Fabricated from safe material; (iii) Solid, one piece construction; and (iv) Easily removed from the shucking bench, unless the block is an integral part of the bench."[687] Equipment and utensils must be stored "in a manner to prevent splash, dust, and contamination."[688]

p. Food contact surfaces, including equipment and utensils, must be cleaned and sanitized to prevent contamination of shellfish.[689] The dealer is required to: "(i) Provide adequate cleaning supplies and equipment, including three compartment sinks, brushes, detergents, and sanitizers, hot water and pressure hoses…within the plant; (ii) Sanitize equipment and utensils prior to the start-up of each day's activities and following any interruption during which food contact surfaces may have been contaminated; and (iii) Wash and rinse equipment and utensils at the end of each day."[690] "All conveyances and equipment which come into contact with stored shellstock shall be cleaned and maintained in a manner and frequency as necessary to prevent shellstock contamination."[691]

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[679] *DOH Regulations*, *supra* note 8, § 8.5(e); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .02(E)(4)(b).
[680] *DOH Regulations*, *supra* note 8, § 8.1(c); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .02(E)(6).
[681] *DOH Regulations*, *supra* note 8, § 8.1(f); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .02(A)(4).
[682] *DOH Regulations*, *supra* note 8, § 8.1(g); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .02(B)(1)(h).
[683] *DOH Regulations*, *supra* note 8, § 8.5(f); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .02(E)(5).
[684] Unless in continuous use since 1988 or earlier, all food contact surfaces must conform with *Shellfish Industry Equipment Construction Guidelines*. NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .02(B)(1)(a).
[685] *DOH Regulations*, *supra* note 8, § 8.2(a); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .02(B)(1)(b).
[686] *DOH Regulations*, *supra* note 8, § 8.2(b); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .02(B)(1)(c).
[687] *DOH Regulations*, *supra* note 8, § 8.2(c); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .02(B)(1)(d).
[688] *DOH Regulations*, *supra* note 8, § 8.3(a)(iv); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .02(C)(1)(d).
[689] *DOH Regulations*, *supra* note 8, § 8.2(f).
[690] *Id.*; *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .02(B)(2)(a).
[691] *DOH Regulations*, *supra* note 8, § 8.2(g).

Shucking containers shall be washed, rinsed, and sanitized before each filling.[692] A test kit or other device must be available "that accurately measures the parts per million concentration of sanitizing solutions."[693] In order to ensure that shellfish are protected from contamination by adulterants during handling, all food contact surfaces must be cleaned with "compounds and sanitizing agents only in accordance with applicable federal and state laws and regulations."[694] Any lighting fixtures or other suspended glass over the shellfish handling areas must be safety glass.[695]

q. Dealers must ensure that employees follow applicable sanitation requirements, including specific employee-based requirements. If finger cots or gloves are used, they shall be: "(i) Made of impermeable materials except where the use of such material is inappropriate or incompatible with the work being done; (ii) Sanitized at least twice daily; (iii) Cleaned more often, if necessary; (iv) Properly stored until used; and (v) Maintained in a clean, intact, and sanitary condition."[696] All employees must "wash their hands thoroughly with soap and water and sanitize their hands in an adequate handwashing facility: (1) Before starting work; (2) After each absence from the work station; (3) After each work interruption; and (4) Any time when their hands may have become soiled or contaminated."[697]

r. The dealer is required to provide an adequate number[698] of handwashing facilities with water at a minimum temperature of 110° F (43° C) with a hot and cold water mixing valve.[699] The handwashing facilities must be conveniently located in relation to work areas, separate from the three compartment sinks required for equipment and utensil cleaning, and plumbed directly to a sewage disposal system.[700] At least one handwashing sink must be located in the packing room.[701] The handwashing facilities must include a sufficient supply of cleansing soap, single use towels or hand drying device, an "easily cleanable waste receptacle," and handwashing signs in "a language understood by the employees."[702] The dealer must also provide an "adequate number of conveniently located, toilets…with an adequate supply of toilet paper in a suitable holder" in

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[692] *Id.* § 8.2(h); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .02(B)(2)(b); *DOH Regulations*, *supra*, § 8.2(j). Containers that may have become contaminated during storage shall be re-sanitized or discarded. *DOH Regulations*, *supra*, § 8.2(i); *see also* NSSP-MO, *supra*, § II, ch. XI, Requirements for Dealers, § .02(B)(2)(c).

[693] *DOH Regulations*, *supra* note 8, § 8.2(f)(iv); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .02(F)(2)(d).

[694] *DOH Regulations*, *supra* note 8, §§ 8.5(a), (c); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, §§ .02(E)(1), (3).

[695] *DOH Regulations*, *supra* note 8, § 8.5(b); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .02(E)(2).

[696] *DOH Regulations*, *supra* note 8, § 8.2(k); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .02(B)(2)(e).

[697] *DOH Regulations*, *supra* note 8, § 8.3(b)(ii); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .02(C)(3)(b).

[698] *DOH Regulations*, *supra* note 8, § 9.2(f)(ii); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .02(D)(2)(d).

[699] *DOH Regulations*, *supra* note 8, § 8.4(a); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .02(D)(1) (requiring temperatures of 100° F (37.8° C)).

[700] *DOH Regulations*, *supra* note 8, §§ 9.2(a), (b), (c); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .02(D)(2).

[701] *DOH Regulations*, *supra* note 8, § 9.2(d); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .02(D)(3).

[702] *DOH Regulations*, *supra* note 8, § 9.2(e); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .02(D)(4).

order to ensure that wastes are properly removed from the site.[703] Additionally, the toilet room doors must be "tight fitting, self closing, and…not open directly into a processing area."[704]

s. Employees with adverse health conditions are also regulated as they pose a threat to public health if the disease is communicable. The dealer is required to "take all reasonable precautions to assure that any employee with a disease in the communicable stage which might be transmissible through food shall be excluded from working in any capacity in which the employee may come in contact with the shellfish or food contact surfaces."[705] Such diseases of concern include: (1) Norovirus; (2) Hepatitis A virus; (3) *Shigella spp.*; (4) Enterohemorrhagic or Shiga Toxin-producing *Escherichia coli*; or (5) *Salmonella tyhpi*.[706] Employees with open wounds may continue to work provided that the wound is properly covered with an impermeable barrier and a single-use glove, if the wound is on the hand.[707]

t. Toxic compounds cannot be stored at the dealer facility unless they are "necessary for plant activites."[708] Toxic compounds must be stored separately, grouped as follows: (1) insecticides and rodenticides; (2) cleaning agents; and (3) caustic acids, polishes, and other chemicals.[709] Toxic compounds must not be stored above shellfish or food contact surfaces.[710] All toxic compounds shall be applied only as necessary and in accordance with state and federal law.[711] The dealer must also operate the facility in a manner that assures that pests are excluded from the facility.[712]

u. Additional sanitation requirements exist for the physical facility, but record keeping of these requirements is not required.[713] The facility shall be maintained in good repair, and all animals and unauthorized persons shall be prohibited from shellfish storage, handling, processing, and packaging areas.[714] Air pump intakes must be located "in a protected place" with air filters "installed on all blower air pump intakes."[715] Ventilation and temperature control systems "shall not create conditions that may cause the shellfish products to become contaminated."[716] The

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[703] *DOH Regulations*, *supra* note 8, §§ 8.4(b)-(d); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, §§ .02(D)(5), (6)(b), (c).
[704] *DOH Regulations*, *supra* note 8, § 9.2(i); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .02(D)(6)(a).
[705] *DOH Regulations*, *supra* note 8, § 8.7(a); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .02(G)(1).
[706] NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .02(G)(1).
[707] *DOH Regulations*, *supra* note 8, § 8.7(b); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .02(G)(3).
[708] *DOH Regulations*, *supra* note 8, § 8.6(a); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .02(F)(1)(a).
[709] *DOH Regulations*, *supra* note 8, § 8.6(b); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .02(F)(1)(b).
[710] *DOH Regulations*, *supra* note 8, § 8.6(c); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .02(F)(1)(c).
[711] *DOH Regulations*, *supra* note 8, §§ 8.6(d)-(f); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .02(F)(2).
[712] *DOH Regulations*, *supra* note 8, § 8.8; *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .02(H).
[713] DOH Regulations, supra note 8, § 9.0; see also id. § 9.2(j).
[714] *Id.* §§ 9.1(a), (b); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, §§ .02(H), .03(A)(1), (H)(4)(c).
[715] *DOH Regulations*, *supra* note 8, § 9.1(c); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .02(E)(7).
[716] *DOH Regulations*, *supra* note 8, § 9.3; *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .03(C)(1).

dealer must assure that "dirt and other filth are excluded" from the facility.[717] Lighting must be sufficient for good manufacturing practices.[718]

v. Facilities shall be located and constructed so as to avoid flooding during ordinary high tides.[719] If the facility does flood, shellfish processing and packing activities shall cease until the waters have receded and the building is cleaned and sanitized.[720] Any shellfish that came into contact with the flood waters must be discarded or used for a non-food use.[721] All plumbing and fixtures "shall be designed, installed, modified, repaired, and maintained to provide a water system that is adequate in quantity and under pressure, and includes…[c]old and warm water at all sinks."[722]

w. The facilities for shucking and packing must be located in separate rooms or separated by a partition or sufficient spacing.[723] Any other activities that could contaminate the shellfish must be separated from all shellfish handling activities by "adequate barriers."[724] All floors in dry areas must be "hard, smooth, [and] easily cleanable."[725] Floors in wet areas "shall be constructed of easily cleanable, impervious, and corrosion resistant materials which: (A) Are graded to provide adequate drainage;[726] (B) Have even surfaces, and are free from cracks that create sanitary problems and interfere with drainage; [and] (C) Have sealed junctions between floors and walls to render them impervious to water."[727] Walls and ceilings in handling and storage rooms "shall be constructed of easily cleanable, corrosion resistant, impervious materials."[728]

x. The grounds around the dealer facility and all waste storage and disposal systems "shall be maintained to be free from conditions which may result in shellfish contamination…includ[ing], but not…limited to: (a) excessively dirty or dusty parking lots, grounds or roads; (b) Rodent, insect, or bird attraction and harborage; and (c) Inadequate drainage."[729] All necessary insect and vermin control measures shall be taken, including installation of tight fitting, self-closing doors, using screens of not less than 15 mesh per inch, and controlled air currents.[730] A "safe, effective

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[717] *DOH Regulations*, *supra* not 8, § 9.1(f); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .03(A)(3).
[718] NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .03(C)(2).
[719] *DOH Regulations*, *supra* note 8, § 9.1(d); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .03(A)(2)(a).
[720] *DOH Regulations*, *supra* note 8, § 9.1(e)(i); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .03(A)(2)(b).
[721] *DOH Regulations*, *supra* note 8, § 9.1(e)(ii); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .03(A)(2)(b).
[722] *DOH Regulations*, *supra* note 8, § 9.2(f); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .03(B)(1).
[723] *DOH Regulations*, *supra* note 8, § 9.2(g); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .02(C)(2)(a).
[724] *DOH Regulations*, *supra* note 8, § 9.2(h); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .02(C)(2)(b).
[725] *DOH Regulations*, *supra* note 8, § 9.2(j)(i); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .03(A)(5)(b).
[726] Adequate drainage includes requiring "backflow preventers such as air gaps." *DOH Regulations*, *supra* note 8, § 9.2(g); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .03(B)(2).
[727] *DOH Regulations*, *supra* note 8, § 9.2(j)(ii); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .03(A)(5)(c).
[728] *DOH Regulations*, *supra* note 8, § 9.2(k); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .03(A)(5)(d).
[729] *DOH Regulations*, *supra* note 8, §§ 9.2(l), 9.5(c); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .03(A)(b) (requiring only prevention of rodent attraction and harborage and inadequate drainage).
[730] *DOH Regulations*, *supra* note 8, § 9.4; *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .03(A)(4).

means of sewage disposal" is required,[731] and all waste disposal must be done in accordance with federal and state laws.[732] All non-edible materials, including shells, must be "promptly and effectively removed from the shucking bench or table."[733] Drainage or waste pipes cannot be installed over shellfish storage or processing areas."[734]

y. All equipment must be "constructed in a manner and with materials that can be cleaned, sanitized, maintained, or replaced."[735] Equipment and all other contact and non-contact surfaces shall be cleaned "in a manner and at a frequency appropriate to prevent contamination of shellfish and food contact surfaces."[736] Shucking benches, contiguous walls, stands and stools for the shucker, and any "non-food contact surfaces in shellfish storage or handling areas" must "use easily cleanable, corrosion-resistant, durable, impervious materials, free from cracks."[737] Shucking benches shall drain completely, rapidly, and away from any shellfish on the benches.[738] Dealers must have "sufficient refrigeration" capable of cooling shellfish as required by DOH regulations.[739]

z. Additional sanitary requirements apply to employees and supervisors. Employees involved in handling shucked shellfish shall: "(a) Wear effective hair restraints; (b) Remove any hand jewelry that cannot be sanitized or secured; (c) Wear finger cots or gloves if jewelry cannot be removed; [and] (d) Wear clean outer garments, which are rinsed or changed as necessary to be kept clean."[740] Employees shall not store clothing or personal belongings, eat, drink, spit, or use any form of tobacco in areas where shellfish are shucked, packed, or stored, as well as any cleaning areas.[741] An individual must be designated to supervise general plant activities, and that person must be reliable, competent, trained in proper food handling techniques, and knowledgeable of personal hygiene and sanitary practices.[742] That individual must supervise cleaning activities "to assure cleaning activities do not result in contamination of shellfish or food contact surfaces."[743] The supervisor must also "assure that proper sanitary practices are implemented, including: (1)

[731] *DOH Regulations*, *supra* note 8, § 9.2(h); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .03(B)(3).
[732] *DOH Regulations*, *supra* note 8, § 9.5(a); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .03(D)(1).
[733] *DOH Regulations*, *supra* note 8, § 9.5(b); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .03(D)(2).
[734] *DOH Regulations*, *supra* note 8, § 9.2(i); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .03(B)(4).
[735] *DOH Regulations*, *supra* note 8, § 9.6(a); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .03(E)(1).
[736] *DOH Regulations*, *supra* note 8, § 9.7; *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, §§ .03(E)(4), (5).
[737] *DOH Regulations*, *supra* note 8, § 9.6(b); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .03(E)(2).
[738] *DOH Regulations*, *supra* note 8, § 9.6(c); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .03(E)(3).
[739] *DOH Regulations*, *supra* note 8, § 9.6(d).
[740] *Id.* §§ 9.10(a)-(d); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, §§ .02(C)(3)(c)(i)-(iv).
[741] *DOH Regulations*, *supra* note 8, § 9.10(e); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .02(C)(3)(c)(v).
[742] *DOH Regulations*, *supra* note 8, §§ 9.11(a), (c); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, §§ .03(H)(1), (3). All employees must be trained in "proper food handling and personal hygiene practices." *DOH Regulations*, *supra*, § 9.11(d)(iii)(1).
[743] *DOH Regulations*, *supra* note 8, § 9.11(b); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .03(H)(2).

Plant and equipment clean-up; (2) Rapid product handling; and (3) Shellfish protection from contamination."[744]

aa. If the dealer elects to use heat shock to prepare the shellstock for shucking, DOH and the model ordinance place additional requirements on the dealer's activities. Heat shock is "the process of subjecting shellstock to any form of heat treatment prior to shucking, including steam, hot water or dry heat, to facilitate removal of the meat from the shell without substantially altering the physical or organoleptic characteristics of the shellfish."[745] In establishing the heat shock process to be used, the dealer:

> shall assure that the critical factors which may affect the heat shock process have been adequately studied and provided for…include[ing]: (a) Type and size of shellfish; (b) Time and temperature of exposure; (c) Type of process; (d) Size of tank, tunnel or retort; (e) Water to shellfish ratios in tanks; and (f) Temperature and pressure monitoring devices.[746]

bb. The dealer must also ensure that the heat shock process "does not: (a) Change the physical and organoleptic properties of the species; (b) Kill the shellfish prior to shucking; and (c) Increase microbial deterioration" of the shellfish.[747] The shellstock must be shucked and the meat must be cooled to 45° F (7.2° C) within two hours of the heat shock process.[748] If tanks are used for heat shock, the tank must be drained and flushed at three hour intervals to remove mud and debris.[749]

cc. The dealer must submit "the scheduled process for heat shock" to DOH for approval prior to implementation.[750] Once approved, the dealer must post the schedule "in a conspicuous location [and m]ake sure all responsible persons are familiar with the requirements."[751] The dealer must retain complete records of the heat shock process and implementation.[752]

dd. Storage of shellfish represents another critical control point where extra sanitation and protection requirements apply.[753] Shucked and packed shellfish must be stored in covered containers and in

[744] *DOH Regulations*, *supra* note 8, § 9.11(d)(ii); *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .03(H)(4)(b). Supervisors must also monitor all "employee hygiene practices, including handwashing, eating, and smoking at work stations, and storing personal items or clothing." *DOH Regulations*, *supra*, § 9.11(d)(i); *see also* NSSP-MO, *supra*, § II, ch. XI, Requirements for Dealers, § .03(H)(4)(a).

[745] NSSP-MO, *supra* note 16, § I, Definitions(B)(51).

[746] *DOH Regulations*, *supra* note 8, § 12.2; *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for the Authority, § .01(B).

[747] *DOH Regulations*, *supra* note 8, § 12.3; *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for the Authority, § .01(C).

[748] *DOH Regulations*, *supra* note 8, § 12.7(c). The shellfish must be cooled immediately after a hot dip heat shock process via either dipping in an ice bath or flushing with flowing potable water. *Id.* § 9.9(c).

[749] *Id.* § 9.9(c)(B). If the water temperature is kept at or above 140° F, the tanks need only be flushed at the end of each day of operation. *Id.* § 9.9(c)(A).

[750] *Id.* § 12.1; *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for the Authority, § .01(A). The schedule may be developed by DOH or any qualified person "with adequate facilities for conducting the appropriate studies." *DOH Regulations*, *supra*, § 12.1.

[751] DOH Regulations, supra note 8, § 9.9.

[752] *Id.* § 12.4; *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for the Authority, § .01(D).

[753] *See DOH Regulations*, *supra* note 8, § 12.8; *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .01(E).

a storage area with an ambient air temperature of 45° F (7.2° C) or less.[754] Shellfish may be stored dry – out of water[755] – or wet – submerged in water.

ee. Wet storage "may be used to store, condition, remove sand or to add salt to shellstock."[756] It may only be engaged in by a licensed dealer.[757] Wet storage may only be performed with shellstock harvested from growing areas in the approved or open conditionally approved classification,[758] and the wet storage must occur "in containers or floats in natural bodies of water or in tanks containing natural or synthetic seawater at any permitted land-based activity or facility."[759] In addition to DOH regulations, all applicable DEM and CRMC regulations but be abided.[760]

ff. The model ordinance requires that all wet storage activities be subject to permitting by the SSCA.[761] In Rhode Island, any dealer seeking to engage in wet storage in open waters must apply to CRMC for an assent, and the application should be included with the aquaculture application if it is related to an aquaculture operation.[762] The application must include an operational plan "specifying how the wet storage…will be carried out."[763] CRMC will "determine the structural suitability of any apparatus used for in-water storage," but DOH must also approve the wet storage facility design, structure, and methods to ensure compliance with the NSSP-MO.[764] Additionally, DEM must evaluate a wet storage application and can "limit or restrict the wet storage and transplant activities in areas within waterways that are considered to be at risk for the transmission of shellfish diseases."[765] Wet storage "shall be practiced only…in strict compliance with the provisions in the written approval" from DOH, CRMC, and DEM.[766]

gg. The model ordinance also requires that the SSCA approve and maintain records of the wet storage activities, including: (1) construction and remodeling plans for the facility; (2) operational plans; (3) permits; and (4) inspection documents.[767] Dealers must maintain records for two years, including records of the source of the shellfish, the amounts stored, and the times/dates of storage

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[754] *DOH Regulations*, *supra* note 8, § 12.8; *see also* NSSP-MO, *supra* note 16, § II, ch. XI, Requirements for Dealers, § .01(E). Instead of mechanical refrigeration, shellfish packages may be stored covered in ice. *DOH Regulations*, *supra*, § 12.8.
[755] *See* NSSP-MO, *supra* note 16, § I, Definitions(B)(35).
[756] *DOH Regulations*, *supra* note 8, § 16.3; *see also* NSSP-MO, *supra* note 16, § II, ch. VII, Requirements for the Dealer, § .02(A).
[757] *DEM Dealer Regulations*, *supra* note 303, § 19.5.14. A dealer with only a reshippers license is not permitted to engage in wet storage. NSSP-MO, *supra* note 16, § II, ch. VII, Requirements for the Authority, § .01(E).
[758] *DOH Regulations*, *supra* note 8, § 16.1; *see also* NSSP-MO, *supra* note 16, § II, ch. VII, Requirements for the Dealer, § .01(A).
[759] NSSP-MO, *supra* note 16, § I, Definitions(B)(121).
[760] DOH Regulations, supra note 8, § 16.0.
[761] NSSP-MO, *supra* note 16, § II, ch. VII, Requirements for the Authority, § .01(A).
[762] *DEM Dealer Regulations*, *supra* note 303, §§ 19.5.1, 19.5.2. If the wet storage is associated with an aquaculture operation, the wet stored products must remain separate from the products being actively cultured. *Id.* § 19.5.5.
[763] *Id.* § 19.5.8. Both DOH and DEM must approve this operational plan. *Id.*
[764] *DOH Regulations*, *supra* note 8, § 16.14(c); *DEM Dealer Regulations*, *supra* note 303, § 19.5.4; *see* NSSP-MO, *supra* note 16, § II, ch. VII, Requirements for the Dealer, § .04(A)(3). "The wet storage facility or operation evaluation shall include a review of: (i) The purpose of the wet storage activity, such as holding, conditioning or increasing the salt content of shellstock; (ii) Any species specific physiological factors that may affect design criteria; and (iii) The plan giving the design of the onshore storage facility, source and quantity of water to be used for wet storage, and details of any water treatment system." *DOH Regulations*, *supra*, § 16.14(d)(iii); *see* NSSP-MO, *supra*, § II, ch. VII, Requirements for the Dealer, § .04(A)(4).
[765] DEM Dealer Regulations, supra note 303, § 19.5.13.
[766] *DOH Regulations*, *supra* note 8, § 16.5; *see also* NSSP-MO, *supra* note 16, § II, ch. VII, Requirements for the Dealer, § .02(C).
[767] NSSP-MO, *supra* note 16, § II, ch. VII, Requirements for the Authority, § .01(B).

and disposition.[768] SSCA must also inspect the storage activities at least once annually for activities in offshore natural bodies of water, at least once every six months for flow-through systems, and semi-annually for recirculating systems.[769] DOH must evaluate and approve all wet storage facilities annually.[770]

hh. For open-water wet storage, the storage facility must be in the same waters where the shellfish were harvested; otherwise, a closed tank system must be employed.[771] Open-water wet storage is only permitted in approved or open conditionally approved waters.[772] If there is a change in growing area classification, the SSCA must notify all dealers with wet storage facilities impacted by that change within twenty-four hours,[773] and dealers so notified must alter their storage accordingly.[774] Product wet stored in conditionally approved waters that are closed during storage must remain in the wet storage location until the conditionally approved waters are again placed in the open status.[775] Wet storage of shellfish that have been depurated may only be done in the facility in which they were depurated.[776]

ii. If wet storage is to be performed in a land-based system of continuous flow-through design, the water must come from a growing area classified as approved without the need for disinfection or as other than approved if "the source water is continuously subjected to disinfection and it is sampled daily following disinfection."[777] Prior to use of other than approved water, a study is required "to demonstrate that the disinfection system will consistently produce water that tests negative for the coliform group under normal operating conditions."[778] If other than approved

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[768] *DEM Dealer Regulations*, *supra* note 303, § 19.5.7; *see also* NSSP-MO, *supra* note 16, § II, ch. VII, Requirements for the Dealer, § .02(G); *DOH Regulations*, *supra* note 8, § 16.10 (requiring maintaining records sufficient to trace the shellstock back to its wet storage location and maintenance of those records for only one year).

[769] NSSP-MO, *supra* note 16, § II, ch. VII, Requirements for the Authority, § .01(C).

[770] *DOH Regulations*, *supra* note 8, § 16.8; *DEM Dealer Regulations*, *supra* note 303, § 19.5.12. The evaluation "shall include an inspection of the near shore storage site and floats, or the wet storage operation." *DOH Regulations*, *supra*, § 16.8. "The near shore site evaluation shall include: (a) The location of near shore storage sites and floats; and (b) The examination of the construction of shellstock containers, if used, to ensure the free flow of water to all shellstock." *DOH Regulations*, *supra*, § 16.12; *see* NSSP-MO, *supra* note 16, § II, ch. VII, Requirements for the Dealer, § .03(B). The evaluation shall also include inspection of the operation's plan and operating procedures if the wet storage is performed in an onshore facility. *DOH Regulations*, *supra*, § 16.14(b); *see* NSSP-MO, *supra*, § II, ch. VII, Requirements for the Dealer, § .04(A)(2).

[771] DEM Dealer Regulations, supra note 303, § 19.5.10.

[772] *DOH Regulations*, *supra* note 8, § 16.11; *DEM Dealer Regulations*, *supra* note 303, § 19.5.12. "Conditions and water quality…shall be sufficient to minimize the potential for compromising the sanitary quality of the shellstock during storage." *DOH Regulations*, *supra*, § 16.7; *see* NSSP-MO, *supra* note 16, § II, ch. VII, Requirements for the Dealer, § .02(E).

[773] NSSP-MO, *supra* note 16, § II, ch. VII, Requirements for the Authority, § .01(D).

[774] DEM Dealer Regulations, supra note 303, § 19.5.12.

[775] *DOH Regulations*, *supra* note 8, § 16.11; *see also* NSSP-MO, *supra* note 16, § II, ch. VII, Requirements for the Dealer, § .03(A) (additionally permitted relay or depuration of shellstock wet stored in conditionally approved waters in the closed status).

[776] *DOH Regulations*, *supra* note 8, § 16.4; *see also* NSSP-MO, *supra* note 16, § II, ch. VII, Requirements for the Dealer, § .02(B).

[777] *DOH Regulations*, *supra* note 8, § 16.15; *see also* NSSP-MO, *supra* note 16, § II, ch. VII, Requirements for the Dealer, § .04(C)(2)(a). This daily sampling must indicate that the water is negative for the coliform group. *DOH Regulations*, *supra*, § 16.17; *see also* NSSP-MO, *supra*, § II, ch. VII, Requirements for the Dealer, § .04(C)(2)(c).

[778] *DOH Regulations*, *supra* note 8, § 16.16; *see also* NSSP-MO, *supra* note 16, § II, ch. VII, Requirements for the Dealer, § .04(C)(2)(b). "The study shall: (a) Include five sets of three samples from each disinfection unit or at the inlet to at least one of the wet storage tanks served by the disinfection system; (b) Include one sample daily for five consecutive days from the source water prior to disinfection; (c) Use NSSP recognized methods to analyze the samples to determine coliform levels; (d) Require all samples of disinfected water to be negative for the coliform

water "is located between the intake of a flow-through wet storage system and the land-based facility then the [SSCA] may require periodic verification of the system's integrity to ensure that the other than approved water does not infiltrate into the intake pipe."[779]

jj. If wet storage is to be performed in a land-based recirculating system, a study is required "to demonstrate that the disinfection system for the recirculating system will consistently produce water that tests negative for the coliform group under normal operating conditions."[780] Once in operation, the system water must be sampled weekly and test negative for the coliform group.[781] If ultra-violet treatment is used to disinfect the water, a set of three samples of disinfected water and one sample of source water is required within twenty four hours of installation of new bulbs to ensure that the system remains free of the coliform group.[782]

kk. Any land-based wet storage facility must use source water that meets the bacteriological standards for approved or conditionally approved water in the open status prior to disinfection, unless the water is obtained from a well.[783] If water from other than approved growing areas is used, a "water supply sampling schedule shall be included in the dealer's operating procedures."[784] Disinfected water cannot have any detectable level of the coliform group.[785] If coliform is detected in even a single sample of disinfected water, daily sampling "shall be immediately instituted until the problem is identified and eliminated."[786] If a sample detects fecal coliform greater than or equal to 14 MPN per 100 ml, the dealer must cease use of the system, and DOH must evaluate the stored shellstock to determine if it requires recall or destruction.[787]

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group; and (e) Be repeated if any sample of disinfected water during the study is positive for the coliform group." *DOH Regulations*, *supra*, § 16.16.

[779] NSSP-MO, *supra* note 16, § II, ch. VII, Requirements for the Dealer, § .04(C)(2)(d).

[780] *DOH Regulations*, *supra* note 8, § 16.18; *see also* NSSP-MO, *supra* note 16, § II, ch. VII, Requirements for the Dealer, § .04(C)(3)(a). The study requirements are the same for the study to be performed for a flow-through system using other than approved water. *DOH Regulations*, *supra*, § 16.18. If "make-up water of more than 10 percent of the water volume in the recirculating system is added from a growing area source classified as other than approved, a set of three samples of disinfected water and one sample of the source water prior to disinfection shall be collected within a 24 hour period to reaffirm the ability of the system to produce water free from the coliform group." *DOH Regulations*, *supra*, § 16.20; *see also* NSSP-MO, *supra*, § II, ch. VII, Requirements for the Dealer, § .04(C)(3)(c).

[781] *DOH Regulations*, *supra* note 8, § 16.19; *see also* NSSP-MO, *supra* note 16, § II, ch. VII, Requirements for the Dealer, § .04(C)(3)(b). Failure to meet this weekly water sampling requirement is cause for termination of the system by DOH. *DOH Regulations*, *supra*, § 16.22.

[782] *DOH Regulations*, *supra* note 8, § 16.21; *see also* NSSP-MO, *supra* note 16, § II, ch. VII, Requirements for the Dealer, § .04(C)(3)(d).

[783] *DOH Regulations*, *supra* note 8, § 16.24(a)(i); *see also* NSSP-MO, *supra* note 16, § II, ch. VII, Requirements for the Dealer, § .04(C)(1)(a) (permitting use of water meeting minimally the classification of restricted). Water obtained from a well must meet the requirements of DOH regulation § 8.1. *DOH Regulations*, *supra*, § 16.24(a)(ii); *see also* NSSP-MO, *supra*, § II, ch. VII, Requirements for the Dealer, § .04(C)(1)(b).

[784] *DOH Regulations*, *supra* note 8, § 16.24(a)(iii); *see also* NSSP-MO, *supra* note 16, § II, ch. VII, Requirements for the Dealer, § .04(C)(1)(c).

[785] *DOH Regulations*, *supra* note 8, § 16.24(a)(vi); *see also* NSSP-MO, *supra* note 16, § II, ch. VII, Requirements for the Dealer, § .04(C)(1)(f). The coliform level must be "measured by a recognized multi-tube MPN test per 100 ml. for potable water." *DOH Regulations*, *supra*, § 16.24(a)(vi).

[786] *DOH Regulations*, *supra* note 8, § 16.24(a)(vii); *see also* NSSP-MO, *supra* note 16, § II, ch. VII, Requirements for the Dealer, § .04(C)(1)(g). Daily sampling must continue "until the elimination of the problem is demonstrated by three (3) consecutive negative results." *DOH Regulations*, *supra*, § 16.24(a)(viii). Once the problem is resolved, a three sample test must be run within the first twenty four hour period of operation. NSSP-MO, *supra*, § II, ch. VII, Requirements for the Dealer, § .04(C)(1)(h).

[787] *DOH Regulations*, *supra* note 8, § 16.24(a)(viii).

ll. Disinfection is permitted via ultra-violet treatment, but only if the turbidity of the source water does not exceed 20 nephelometric turbidity units.[788] "Disinfection or other water treatment such as the addition of salt cannot leave residues unless they are Generally Recognized as Safe" or they will not affect the shellstock's survival, quality, or activity while in wet storage.[789] All disinfection units must be cleaned and serviced "as frequently as necessary to assure effective water treatment."[790] Results of water testing must be maintained for two years.[791]

mm. Shellstock to be wet stored must be "harvested, identified and shipped to the wet storage operation in accordance with" all DOH regulations related to transport of shellstock.[792] Prior to placement in wet storage, the shellstock "shall be protected from physical, chemical or thermal conditions which may compromise the shellstock's survival, quality or activity during wet storage."[793] The shellstock must be washed and culled prior to placement in wet storage.[794] Any dealer who wet stores shellstock from another state and then ships the shellstock as a product of Rhode Island shall have "an operational plan approved by the Department which describes how this labeling change will be employed in assuring that shellstock can be traced to its source."[795]

nn. If the shellstock are held in containers in wet storage, the containers must be approved by DOH and appropriately marked to indicate that they contain wet stored wild or cultured shellstock.[796] Comingling of shellstock is not permitted in wet storage unless as part of DOH's comingling plan.[797] If multiple lots are wet stored at the same time, each lot must be tagged or labeled to maintain its unique identity.[798] Bivalve mollusks may not be mixed with other species in the same tank, and if a common water supply is used for multiple tanks, the disinfected water must enter the bivalve tanks before entering other tanks.[799]

oo. Facility design regulations also exist for wet storage operations. All operations:

> Shall meet the following design, construction, and operating requirements: (i) Effective barriers shall be provided to prevent entry of birds, animals, and vermin into the area. (ii) Storage tanks and related plumbing shall be fabricated of safe material and shall be easily cleanable. This requirement shall include: (1) Tanks constructed so as to be easily accessible for cleaning and inspection, self-draining and fabricated from nontoxic, corrosion resistant materials; and (2) Plumbing designed

[788] *Id.* § 16.24(a)(ix); *see also* NSSP-MO, *supra* note 16, § II, ch. VII, Requirements for the Dealer, § .04(C)(1)(i).
[789] *DOH Regulations*, *supra* note 8, § 16.24(a)(v); *see also* NSSP-MO, *supra* note 16, § II, ch. VII, Requirements for the Dealer, § .04(C)(1)(e).
[790] *DOH Regulations*, *supra* note 8, § 16.24(a)(x); *see also* NSSP-MO, *supra* note 16, § II, ch. VII, Requirements for the Dealer, § .04(C)(1)(j).
[791] *DOH Regulations*, *supra* note 8, § 16.24(a)(iv); *see also* NSSP-MO, *supra* note 16, § II, ch. VII, Requirements for the Dealer, § .04(C)(1)(d).
[792] *DOH Regulations*, *supra* note 8, § 16.2; *see id.* § 10.0.
[793] *Id.* § 16.6; *see also* NSSP-MO, *supra* note 16, § II, ch. VII, Requirements for the Dealer, § .02(D).
[794] *DOH Regulations*, *supra* note 8, § 16.25(a); *see also* NSSP-MO, *supra* note 16, § II, ch. VII, Requirements for the Dealer, § .04(D)(1). Mussels may be culled after removal from wet storage instead because they are adversely affected by culling. *DOH Regulations*, *supra* note 8, § 16.25(a).
[795] *DOH Regulations*, *supra* note 8, § 16.9; *see also* NSSP-MO, *supra* note 16, § II, ch. VII, Requirements for the Dealer, § .02(F).
[796] DEM Dealer Regulations, supra note 303, § 19.5.6.
[797] *DOH Regulations*, *supra* note 8, §§ 16.13, 16.25(b); *see also* NSSP-MO, *supra* note 16, § II, ch. VII, Requirements for the Dealer, §§ .02(H), .03(C).
[798] *DOH Regulations*, *supra* note 8, § 16.13; *see also* NSSP-MO, *supra* note 16, § II, ch. VII, Requirements for the Dealer §§ .02(H), .03(C).
[799] *DOH Regulations*, *supra* note 8, § 16.25(c); *see also* NSSP-MO, *supra* note 16, § II, ch. VII, Requirements for the Dealer, § .04(D)(3).

> and installed so that it can be cleaned and sanitized on a regular schedule, as specified in the operating procedures. (iii) Storage tank design, dimensions, and construction are such that adequate clearance between shellstock and the tank bottom shall be maintained. (iv) Shellstock containers, if used, shall be designed and constructed so that the containers allow the free flow of water to all shellstock within a container.[800]

pp. If the wet storage tanks are located within a building, the building must meet all of the sanitation requirements for a shellfish processing facility.[801] If the tank is located outside, a cover must be used and remain closed during operation to prevent entry of birds, animals, and vermin.[802]

qq. Repacking constitutes another critical control point.[803] A licensed dealer may only repack shellfish that originated from another licensed dealer and are properly identified with an appropriate tag or label.[804] The shellfish must be received and maintained at an internal temperature of 45° F (7.2° C) or less, and ensure that the shellfish do not exceed that temperature for more than two hours at any point.[805] Once repacked, the shellfish must be kept in covered containers and at an ambient air temperature of 45° F (7.2° C) or less or covered with ice.[806] Throughout the repacking process, all DOH sanitation requirements must be met.[807] Any dealer "whose activity consists of trucks or docking facilities only" is prohibited from repacking shellstock.[808]

rr. Every dealer is required to "maintain complete, accurate and legible records of the Department's required information in a form authorized by the Department."[809] Transaction records must be maintained that are sufficient to:

> (i) Document that the shellfish are from a source authorized under [DOH regulations]; (ii) Permit a container of shellfish to be traced back to the specific incoming lot of shucked shellfish from which it was taken; (iii) Permit a lot (or commingled lots) of shucked shellfish or a lot of shellstock to be traced back to the growing area(s), date(s) of harvest, and if possible, the harvester or group of harvesters.[810]

ss. Purchases and sales must be recorded in a permanently bound ledger book, in authorized shipping/sales documents, or by "other recording methods acceptable to and authorized by" DOH.[811] All records shall be maintained for at least one year for fresh shellfish and at least the

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[800] *DOH Regulations*, *supra* note 8, § 16.23(a); *see also* NSSP-MO, *supra* note 16, § II, ch. VII, Requirements for the Dealer, § .04(B)(1).
[801] *DOH Regulations*, *supra* note 8, § 16.23(b); *see id.* § 9.0; *see also* NSSP-MO, *supra* note 16, § II, ch. VII, Requirements for the Dealer, § .04(B)(2).
[802] *DOH Regulations*, *supra* note 8, § 16.23(c); *see also* NSSP-MO, *supra* note 16, § II, ch. VII, Requirements for the Dealer, § .04(B)(3).
[803] See DOH Regulations, supra note 8, § 13.2.
[804] Id.
[805] *Id.*; *see also* NSSP-MO, *supra* note 16, § II, ch. XII, §§ .01(A), (B).
[806] *DOH Regulations*, *supra* note 8, § 13.3; *see also* NSSP-MO, *supra* note 16, § II, ch. XII, § .01(C).
[807] NSSP-MO, *supra* note 16, § II, ch. XII, § .02; *see DOH Regulations*, *supra* note 8, §§ 8.0, 9.0.
[808] NSSP-MO, *supra* note 16, § II, ch. XIII, § .03(F)(3)(b).
[809] *DOH Regulations*, *supra* note 8, § 10.15(b); *see also* NSSP-MO, *supra* note 16, § II, ch. X, § .08(B)(2).
[810] *DOH Regulations*, *supra* note 8, § 10.15(c); *see also* NSSP-MO, *supra* note 16, § II, ch. X, § .08(B)(2) (also requiring ability to trace wet storage history).
[811] *DOH Regulations*, *supra* note 8, § 10.15(d); *see also* NSSP-MO, *supra* note 16, § II, ch. X, § .08(B)(3). These entries must be made within seventy-two hours of the purchase or sale. NSSP-MO, *supra*, § II, ch. X, § .08(B)(3)(b).

longer of two years or the life of the product for frozen shellfish.[812] In addition to maintaining records, all Rhode Island dealers are required "to obtain and utilize a personal computer in working condition which is capable of submitting an electronic report to the Standard Atlantic Fisheries Information System" ("SAFIS").[813] Reporting to SAFIS must be completed for federally regulated species, as required by federal law.[814]

tt. In order to ensure that all dealers are complying with these operational requirements, DOH is required to make regular inspections of dealer facilities.[815] Inspections must occur within thirty days of initiation of the dealer operation and again at least quarterly for shucker-packers or repackers and at least semiannually for all other dealers.[816] DEM is also authorized to inspect dealer facilities, but their inspections cannot involve inspection for sanitary violations.[817]

uu. At the end of the inspection, the inspector must provide an inspection form listing any deficiencies to the person in-charge at the dealer's facility.[818] The inspector shall request a signed acknowledgment of receipt from the person receiving the inspection form.[819] DOH inspectors are authorized to seize all shellfish if the dealer is found in violation of any of the health laws as well as to make a complaint for the violation.[820]

vv. When an inspection detects a deficiency, or when the dealer becomes aware of a deficiency outside of an inspection format, the deficiency must be corrected.[821] If an inspection detects a critical deficiency,[822] the deficiency must be corrected during the inspection or the dealer must

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Maintenance of records as computer files is permissible as long as DOH approves the format. *DOH Regulations*, *supra*, § 10.15(f); *see also* NSSP-MO, *supra*, § II, ch. X, § .08(B)(5).

[812] *DOH Regulations*, *supra* note 8, § 10.15(e); *see also* NSSP-MO, *supra* note 16, § II, ch. X, § .08(B)(4).

[813] DEM Dealer Regulations, supra note 303, § 19.14.2(A).

[814] *Id.* § 19.14.2(B).

[815] R.I. GEN. LAWS § 21-14-12 (2013); *DOH Regulations*, *supra* note 8, § 4.1.

[816] NSSP-MO, *supra* note 16, § II, ch. I, § .02(F)(1). Inspections must occur during periods of activity. *Id.* If a dealer has demonstrated exemplary compliance with sanitation requirements, a performance based inspection program ("PIP") may be applied to that dealer. *Id.* § II, ch. I, § .02(G)(1). Under a PIP, DOH must inspect the dealer's facility at least once a year, which may be the inspection required prior to annual recertification. *Id.* § II, ch. I, § .02(G)(2). A dealer will be eligible for a PIP if he or she has "demonstrated a history of satisfactory compliance for the previous three-year period," including full inspection compliance, annual recertification, no critical deficiencies, no more than one key deficiency, no more than two other deficiencies, timely correction of any deficiencies, and no repetition of deficiencies. *Id.* § II, ch. I, § .02(G)(3).

[817] R.I. GEN. LAWS § 20-6-24(f); *DEM Shellfish Buyer Regulations*, *supra* note 466, § 9.2(f); *DEM Dealer Regulations*, *supra* note 303, § 19.8; *see* R.I. GEN. LAWS § 21-14-12.

[818] *DOH Regulations*, *supra* note 8, §§ 17.1, 17.3; *see also* NSSP-MO, *supra* note 16, § II, ch. I, § .02(F)(2). The inspector must documents "specific factual observations of violative conditions or other deviations," and provide a time frame for correction of those violations. *DOH Regulations*, *supra*, §§ 17.1 (documenting), 17.2 (timeframe).

[819] *DOH Regulations*, *supra* note 8, § 17.3. If the recipient declines to sign, the inspector must inform that person that: "(1) An acknowledgment of receipt is not an agreement with findings, (2) Refusal to sign an acknowledgement of receipt will not affect the permit holder's obligation to correct the violations noted in the inspection report within the time frames specified, and (3) A refusal to sign an acknowledgement of receipt is noted in the inspection report and conveyed to the Department's historical record for the dealer." *Id.* § 17.4.

[820] *Id.* § 4.1.1.

[821] 21 C.F.R. § 123.11(b) (2013).

[822] A critical deficiency is "a condition or practice which: (a) Results in the production of a product that is unwholesome, or (b) Presents a threat to the health or safety of the consumer." NSSP-MO, *supra* note 16, § I, Definitions(B)(25).

cease production.[823] If the dealer becomes aware of "an imminent health hazard" caused by an emergency such as fire, flood, electrical interruption, loss of water service, sewage backup, misuse of toxic materials, illness outbreak, or other unsanitary occurrence, the dealer must discontinue operations and notify DOH immediately.[824] Any shellfish processed during the critical deficiency must be considered by DOH and recalled if deemed necessary.[825] Failure to immediately correct a critical deficiency is just cause to suspend or revoke a dealer's certification.[826]

ww. If an inspection detects a key[827] or other[828] deficiency, DOH and the dealer must develop a compliance schedule to correct the deficiency.[829] DOH requires that all noncritical violations be corrected within ninety calendar days of the inspection.[830] If an inspection detects four or more new key deficiencies, DOH must consider either revising the compliance schedule, suspending or revoking the dealer's certification, or seeking administrative remedies.[831]

5. Shellfish Transportation

a. Shipping of shellfish constitutes another critical control point at which extensive monitoring is required.[832] Dealers may only ship shellstock that is: (1) obtained from a licensed harvester or dealer; (2) harvested from an approved or open conditionally approved growing area; and (3) properly tagged.[833] The dealer must also ensure that, once placed under temperature control, all shellfish must remain iced or maintained at a temperature of 45° F (7.2° C) or less throughout the shipping process.[834] If the shipping time will exceed four hours, a time-temperature monitoring and recording device must be utilized,[835] and the final receiving dealer must keep the time-

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[823] *DOH Regulations*, *supra* note 8, § 17.7(a); *see also* NSSP-MO, *supra* note 16, § II, ch. I, § .02(H)(2)(a). DOH may agree to an extension of time to correct a critical violation, but that extension cannot exceed ten calendar days after the inspection. *DOH Regulations*, *supra*, § 17.7(b). All information about a critical violation, including its correction, must be entered on the inspection report. *DOH Regulations*, *supra*, § 17.8(a). If an extension of time is granted, DOH must verify correction upon notification from the dealer that a correction has been undertaken. *DOH Regulations*, *supra*, § 17.8(b).

[824] *DOH Regulations*, *supra* note 8, § 17.5(a). Once discontinued, DOH approval must be obtained before restarting operations. *Id.* § 17.6. If any part of the processing facility was unaffected by the emergency, operations in that unaffected region may continue. *Id.* § 17.5(b).

[825] NSSP-MO, *supra* note 16, § II, ch. I, § .02(H)(2)(c). If a recall is deemed necessary, DOH must "[i]mmediately notify the enforcement officials for FDA and any other Authorities where the product was distributed." *Id.*

[826] NSSP-MO, *supra* note 16, § II, ch. I, § .02(H)(2)(b).

[827] A key deficiency is "a condition or practice which may result in adulterated, decomposed, misbranded or unwholesome product." *Id.* § I, Definitions(B)(59).

[828] An "other deficiency" is "a condition or practice that is not defined as critical or key and is not in accordance with the requirements of" the NSSP-MO. *Id.* § I, Definitions(B)(77).

[829] *DOH Regulations*, *supra* note 8, § 17.9(a); *see also* NSSP-MO, *supra* note 16, § II, ch. I, § .02(H)(2)(d).

[830] *DOH Regulations*, *supra* note 8, § 17.9(a). DOH may extend this time limit, but only if "no health hazard exists or will result from allowing an extended schedule for compliance." *Id.* § 17.9(b).

[831] NSSP-MO, *supra* note 16, § II, ch. I, § .02(H)(2)(e).

[832] *See DOH Regulations*, *supra* note 8, § 14.1; *see also* NSSP-MO, *supra* note 16, § II, ch. XIII, § .01(A).

[833] *DOH Regulations*, *supra* note 8, § 14.1; *see id.* § 10.10; *see also* NSSP-MO, *supra* note 16, § II, ch. XIII, §§ .01(A)(1), (2).

[834] *DOH Regulations*, *supra* note 8, §§ 10.3, 10.9, 10.10, 14.2, 14.3; *see also* NSSP-MO, *supra* note 16, § II, ch. XIII, § .01(B)(2). When shipping shellstock, the internal body temperature must not exceed 50° F (10° C). *DOH Regulations*, *supra*, § 10.9. When transporting shellstock to the initial dealer, the ambient air in the conveyance need be only 50° F (10° C). NSSP-MO, *supra*, § II, ch. IX, § .01(C). The NSSP-MO requires that oysters harvested under a state *Vibrio* control plan instead be cooled according to the applicable control plan. NSSP-MO, *supra*, § II, ch. XIII, § .01(B)(3).

[835] *DOH Regulations*, *supra* note 8, § 10.14(b).

temperature chart on file and available to DOH.[836] When at points of transfer, such as loading docks, the dealer must ensure that the shellfish do not remain without adequate ice or mechanical refrigeration for more than two hours.[837] These requirements also apply to all reshipping of shellfish.[838]

b. All general sanitation requirements must be met as well throughout the shipping process.[839] Containers used for shellfish storage and transport shall be constructed to allow for easy cleaning and maintained to prevent contamination.[840] The containers must be cleaned with potable water and cleaning detergents "acceptable for food contact surfaces."[841] If the cargo consists only of shellfish, the cargo must be shipped on pallets unless it is a bulk shipment.[842] If the cargo contains non-shellfish products, the shellfish must be protected from contamination, shipped on pallets, and have no other cargo placed on or above the shellfish unless the shellfish are in sealed, crush resistant, waterproof containers.[843]

c. Additionally, any trucks used to ship shellfish must be "properly constructed, operated, and maintained to prevent contamination, adulteration, cross-contamination, deterioration, and decomposition" of the shellfish.[844] Trucks must be pre-chilled if "ambient air temperatures are such that unacceptable bacterial growth or deterioration may occur."[845] Cats, dogs, and other animals are not permitted in any part of a vehicle used to store shellfish for transport.[846]

d. Every shellfish shipment must be accompanied by a shipping document.[847] This document must contain: "(i) The name, address, and certification number of the shipping dealer; (ii) The name and address of the major consignee; and (iii) The kind and quantity of the shellfish product."[848] The document must also be sufficient to:

> (i) Document that the shellfish are from a source authorized under these requirements; (ii) Permit a container of shellfish to be traced back to the specific incoming lot of shucked shellfish from which it was taken; (iii) Permit a lot (or comingled lots) of shucked shellfish or a lot of shellstock to be traced back to the growing area(s), date(s) of harvest, and if possible, the harvester or group of harvesters.[849]

e. This document must be maintained by the receiving dealer and made available to DOH upon request.[850]

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836 *Id.* § 10.14(e).
837 *Id.* §§ 10.12, 14.2; *see also* NSSP-MO, *supra* note 16, § II, ch. XIII, § .01(B)(2). Frozen shellfish may not be allowed to thaw. *DOH Regulations*, *supra*, § 10.12.
838 *DOH Regulations*, *supra* note 8, §§ 15.1, 15.2; *see also* NSSP-MO, *supra* note 16, § II, ch. XIV, § .01.
839 NSSP-MO, *supra* note 16, § II, ch. XIII, §§ .02, .03; *see DOH Regulations*, *supra* note 8, §§ 8.0, 9.0.
840 *DOH Regulations*, *supra* note 8, § 10.6; *see also* NSSP-MO, *supra* note 16, § II, ch. IX, § .02(A).
841 *DOH Regulations*, *supra* note 8, § 10.7; *see also* NSSP-MO, *supra* note 16, § II, ch. IX, § .02(B).
842 NSSP-MO, *supra* note 16, § II, ch. IX, § .03(B).
843 *Id.* § II, ch. IX, § .03(C).
844 DOH Regulations, supra note 8, § 10.1.
845 *Id.* § 10.2.
846 *Id.* § 10.5; *see also* NSSP-MO, *supra* note 16, § II, ch. IX, § .01(F).
847 *DOH Regulations*, *supra* note 8, § 10.8(a); *see also* NSSP-MO, *supra* note 16, § II, ch. X, § .08(A)(1).
848 *DOH Regulations*, *supra* note 8, § 10.8(b); *see also* NSSP-MO, *supra* note 16, § II, ch. X, § .08(A)(2).
849 *DOH Regulations*, *supra* note 8, § 10.15(c); *see also* NSSP-MO, *supra* note 16, § II, ch. IX, § .05.
850 *DOH Regulations*, *supra* note 8, § 10.8(c); *see also* NSSP-MO, *supra* note 16, § II, ch. X, § .08(A)(3). If the shipment is divided among multiple dealers, each dealer must maintain sufficient records to trace the shellfish history. *DOH Regulations*, *supra*, § 10.8(d); *see also* NSSP-MO, *supra*, § II, ch. X, § .08(A)(4).

6. Shellfish-related Illness

   a. The model ordinance requires that the SSCA have procedures in place for investigating incidents of shellfish-related illness and disease.[851] When two or more persons from the same household[852] are implicated in a potential shellfish-related illness, the SSCA shall:

      > determine whether an epidemiological association exists between the illness and the shellfish consumption by reviewing: (1) Each consumer's food history; (2) Shellfish handling practices by the consumer and/or retailer; (3) Whether the disease has the potential or is known to be transmitted by shellfish; and (4) Whether the symptoms and incubation period for the illnesses are consistent with the suspected etiologic agent.[853]

   b. If a link between the illness and shellfish consumption is detected, the SSCA "shall: (1) Conduct an investigation of the illness outbreak within 24 hours to determine whether the illness is growing area related or is the result of post-harvest contamination or mishandling[; and] (2) Determine whether to initiate a voluntary recall."[854] If an investigation is not possible within twenty-four hours, the growing area that was the source of the implicated shellfish must be closed until the investigation is carried out.[855] If the source is found to be related to post-harvest handling, the SSCA "shall: (1) Notify[] receiving states, the ISSC and the FDA Regional Shellfish Specialist of the problem; and (2) Initiate a voluntary recall."[856]

   c. If, upon investigation, the source of the shellfish illness is traced back to a growing area problem, the SSCA shall:

      > (1) Immediately place the implicated portion(s) of the harvest area(s) in the closed status;[857] (2) Notify receiving states, the ISSC and the FDA Regional Shellfish Specialist that a potential health risk is associated with shellfish harvested from the implicated growing area; (3) As soon as determined by the Authority, transmit to the FDA and receiving states information identifying the dealers shipping the implicated shellfish; and (4) Promptly initiate recall procedures consistent with the Recall Enforcement Policy…[for] all implicated products.[858]

   d. The SSCA must also consider whether reclassification of the growing area is appropriate.[859] If the closure was from naturally-occurring pathogens, the SSCA must "follow an existing marine biotoxin contingency plan, if appropriate," collect and analyze relevant samples, and keep the area closed until pathogen levels have returned to safe levels.[860] The growing area must remain closed until the SSCA verifies that the contamination or risk no longer exists.[861]

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[851] NSSP-MO, *supra* note 16, § II, ch. I, § .01(F).
[852] Or one person in the case of paralytic shellfish poisoning.
[853] NSSP-MO, *supra* note 16, § II, ch. II, Requirements for the Authority, § .01(A).
[854] *Id.* § II, ch. II, Requirements for the Authority, § .01(B). The SSCA must produce a written report of the investigation. *Id.* § II, ch. II, Requirements for the Authority, § .01(H)(3).
[855] *Id.* § II, ch. II, Requirements for the Authority, § .01(E).
[856] *Id.* § II, ch. II, Requirements for the Authority, § .01(D).
[857] The closure may be limited to certain species if the identified pathogen or risk is species-specific. *Id.* § II, ch. II, Requirements for the Authority, § .01(G).
[858] *Id.* § II, ch. II, Requirements for the Authority, § .01(C).
[859] *Id.* § II, ch. II, Requirements for the Authority, § .01(F).
[860] *Id.* § II, ch. II, Requirements for the Authority, § .01(G).
[861] *Id.* § II, ch. II, Requirements for the Authority, § .01(H)(1). The growing area must remain closed "for a minimum of 21 days if the illness is consistent with viral etiology." *Id.* § II, ch. II, Requirements for the Authority, § .01(H)(2).

e. Even absent illness, if potential contaminants are detected in shellfish meats, the NSSP-MO requires that the SSCA take action. If human pathogens are found in shellfish meats, the SSCA "shall investigate the harvesting, the distribution, and the processing of the shellfish."[862] If the investigation reveals a problem with the growing area, the SSCA must close the area until the proper response is determined, reclassify the growing area if necessary, and determine whether to initiate a recall of harvested shellfish."[863] If the problem is traced to post-harvest handling, the SSCA must take necessary action to correct the problem and determine whether to initiate a recall.[864] These same responses are required when "toxic substances, including heavy metals, chlorinated hydrocarbons, and natural toxins" are detected in shellfish meats at levels of public health significance.[865]

f. The final illness-related concern addressed by the model ordinance is illness associated with *Vibrio vulnificus* and *Vibrio parahaemolyticus*. Annually, the SSCA shall assess *Vibrio* illnesses associated with shellfish consumption, including a record of all illnesses reported within both Rhode Island and states receiving Rhode Island shellfish, the number of illnesses per event, and actions taken by the SSCA in response to these events.[866]

g. An annual risk evaluation must be conducted for *Vibrio vulnificus* that shall:

> consider each of the following factors, including seasonal variations in the factors, in determining the risk of *Vibrio vulnificus* infection from the consumption of shellfish harvested from the State's growing waters…(a) The number of *Vibrio vulnificus* cases etiologically confirmed and epidemiologically linked to the consumption of commercially harvested shellfish from the State; and (b) Levels of *Vibrio vulnificus* in the growing waters and in shellfish, to the extent that such data exists; and (c) The quantity of harvest from the area and its uses i.e. shucking, half shell, PHP.[867]

h. If the risk evaluation indicates "two (2) or more etiologically confirmed, and epidemiologically linked *Vibrio vulnificus* septicemia illnesses from the consumption of commercially harvested raw or undercooked oysters that originated from the growing waters of that state within the previous ten (10) years," a *Vibrio vulnificus* control plan must be established.[868] Once a state is required to create a *Vibrio vulnificus* control plan, it must continue to maintain and implement that plan indefinitely.[869] The SSCA is required to produce a *Vibrio vunificus* **contingency** plan if only one etiologically confirmed *Vibrio vunificus* illness has occurred or there is sufficient evidence of levels of *Vibrio vulnificus* in the growing waters that an illness is "reasonably likely"[870] to occur.[871]

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[862] *Id.* § II, ch. II, Requirements for the Authority, § .03(A).
[863] *Id.* § II, ch. II, Requirements for the Authority, § .03(B)(3). A voluntary recall is required when the pathogens exceed established tolerance levels. *Id.* § .03(B)(4).
[864] *Id.* § II, ch. II, Requirements for the Authority, § .03(C)(3).
[865] *Id.* § II, ch. II, Requirements for the Authority, § .04.
[866] *Id.* § II, ch. II, Requirements for the Authority, § .02.
[867] *Id.* § II, ch. II, Requirements for the Authority, § .05(A).
[868] *Id.* § II, ch. II, Requirements for the Authority, § .05(C); *see id.* § .05(E) (providing necessary control plan provisions).
[869] *Id.* § II, ch. II, Requirements for the Authority, § .05(B).
[870] Reasonably likely to occur means that "the risk constitutes an annual occurrence." *Id.* § II, ch. II, Requirements for the Authority, § .06(A).
[871] *Id.* § II, ch. II, Requirements for the Authority, § .05(D); *see id.* § .05(F) (providing necessary contingency plan provisions).

i. Every state from which oysters are harvested shall perform an annual risk evaluation for *Vibrio parahaemolyticus*.[872] The risk evaluation shall consider the following factors and whether the risk of infection from oyster consumption is reasonably likely to occur:

> (1) The number of *Vibrio parahaemolyticus* cases epidemiologically linked to the consumption of oysters commercially harvested from the State; and (2) Levels of total and tdh+ *Vibrio parahaemolyticus* in the area, to the extent that such data exists; and (3) The water temperatures in the area; and (4) The air temperatures in the area; and (5) Salinity in the area; and (6) Harvesting techniques in the area; and (7) The quantity of harvest from the area and its uses i.e. shucking, half-shell, PHP.[873]

j. The SSCA must develop and implement a *Vibrio parahaemolyticus* control plan if the risk evaluation indicates that illness is reasonably likely to occur or if the state has had an illness outbreak linked with *Vibrio parahaemolyticus* within the past five years.[874] The key to either control plan is temperature control, and if a control plan is implemented, shellfish must be cooled to an internal temperature of 55° F (12.7° C) or 50° F (10° C) within times specified in a *Vibrio vulnificus* or *Vibrio parahaemolyticus* control plan, respectively.[875]

k. Rhode Island has not yet met the threshold requirements for either *Vibrio* control plan, and therefore DOH has not developed a control plan. However, DOH does permit dealers to "use a process to reduce *Vibrio vulnificus* levels in shellfish."[876] If a dealer elects to use such a process, the dealer shall:

> have a HACCP plan approved by the Department for the process which includes: (a) An end point criteria for the process as non-detectable (<3 MPN/gram) to be determined by use of the *Vibrio vulnificus* FDA approved EIA procedure of Tamplin, et al, as described in Chapter 9 of the FDA *Bacteriological Analytical Manual*, 7th edition, 1992; and (b) A sampling program to demonstrate that the end point criteria is met.[877]

l. Any shellfish so processed must also be labeled to indicate that the process has occurred.[878]

7. Enforcement

a. The final element of health protection in regards to shellfish regulation is enforcement of the health laws. DOH is primarily responsible for enforcing the health statutes and regulations, and "the director shall not be required to enter into any recognizance nor to give surety for any costs" related to enforcement actions.[879] Authorized DOH agents may seize any shellfish in the possession of a person violating a health law or regulation and may make complaints for those violations.[880]

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[872] *Id.* § II, ch. II, Requirements for the Authority, § .06(A).
[873] Id.
[874] *Id.* § II, ch. II, Requirements for the Authority, §§ .06(B)(1), (3); *see also id.* § .06(B)(4) (providing the requirements for a control plan). The model ordinance also requires control plan production if monthly water temperatures exceed specified thresholds, but no threshold is given for growing areas in the Atlantic Ocean north of New Jersey. *Id.* § .06(B)(2).
[875] *Id.* § II, ch. XIII, § .01(B)(3).
[876] DOH Regulations, supra note 8, § 11.1.
[877] Id.
[878] *Id.* § 11.2.
[879] R.I. GEN. LAWS § 21-14-11 (2013).
[880] *Id.* § 21-14-14; *see id.* §§ 21-14-13, 21-14-9; *DOH Regulations*, *supra* note 8, § 3.2.

b. When a complaint is made and followed by a conviction, punishment may include: (1) imprisonment not exceeding three months or a fine not exceeding $100 for the first offense; (2) imprisonment not exceeding six months or a fine not exceeding $200 for a second offense; and (3) imprisonment not exceeding one year or a fine not exceeding $500 for subsequent offenses.[881] Suspension or revocation of a dealer's license is also permitted for violation of any of the health statutes or regulations.[882] DOH may also immediately, temporarily, suspend a dealer's license if "continuation in practice would constitute an immediate danger to the health, safety, and welfare of the public."[883] A hearing on the license suspension must be held within ten days after the suspension.[884] A person convicted of any health regulation violation may also be denied future licenses.[885]

920.9. Municipal Control

1. Municipalities have no shellfish management requirements in Rhode Island, but they could enact shellfish management ordinances as part of their general police powers.[886] However, municipalities must act only on authority granted to them by their individual charters or by the general laws.[887] Under the RI General Laws, municipalities may enact ordinances – which could include shellfish management ordinances – that are "not repugnant to law" as long as the municipality finds that a management ordinance is "**necessary**…for the well ordering, managing, and directing of the prudential affairs and police of their respective towns and cities."[888]
2. Additionally, any municipal ordinances would need to reach an issue not covered by or inconsistent with the Rhode Island General Laws, DEM regulations, or CRMC regulations; otherwise, the municipal ordinance will merely be preempted by the existing state law. This raises the question, given DEM and CRMC's extensive shellfish management, whether municipalities could find shellfish management ordinances to be "necessary."
3. One particular question that is commonly raised is whether a municipality could ban shellfish harvesting in its waters or limit harvest to municipal residents. Courts in other jurisdictions have approved municipal ordinances limiting shellfishing rights to residents.[889] These jurisdictions have generally upheld such residency requirements as long as they serve legitimate municipal interests, particularly stock management.[890] However, these cases do not resolve the issue in Rhode Island. In the states where these ordinances have been enacted, state statutes specifically authorized municipal regulation of shellfisheries.[891] Rhode Island lacks explicit state authority for municipal shellfish regulation. This lack of explicit authority combined with preemption by agency regulation would

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[881] R.I. GEN. LAWS § 21-14-15; see also R.I. Dept. of Envtl. Mgmt., Rules and Regulations Governing the Suspension/Revocation of Commercial Marine Fisheries, Shellfish Buyer, Lobster Dealer, Finfish Dealer, and Multi-purpose Dealer, Licenses Issued Pursuant to Title 20 of R.I.G.L. 'Fish and Wildlife', § 1 (1999) (providing for the following penalties for dealers violating R.I. GEN. LAWS Title 20 regulations: first violation- up to thirty day license suspension; second violation- up to ninety day license suspension; third violation- up to one year license suspension; subsequent violations- up to revocation).

[882] DOH Regulations, supra note 8, § 2.8.

[883] *Id.* § 17.10.

[884] Id.

[885] *Id.* § 2.9.

[886] *See* R.I. GEN. LAWS § 45-6-1(a).

[887] *Id.* § 45-2-1. Therefore, the individual charter of a municipality must be consulted to determine the extent of the authority of that particular municipality.

[888] *Id.* § 45-6-1(a).

[889] *See Barlow v. Town of Wareham*, 517 N.E.2d 146, 147 (Mass. 1988); *State v. Alley*, 274 A.2d 718, 722 (Me. 1971).

[890] *Barlow*, 517 N.E.2d at 147; *Alley*, 274 A.2d at 722.

[891] *Barlow*, 517 N.E.2d at 148; *Alley*, 274 A.2d at 719.

raise the burden on any municipality seeking to regulate shellfish within its borders, but it does not foreclose the possibility because the municipality is still entitled to enact necessary ordinances under its police powers.[892]

4. One municipality in Rhode Island has unique control over shellfish regulations: New Shoreham (Block Island). The General Assembly has granted New Shoreham the right to "enact any ordinances to protect and regulate the taking of shellfish and other fish in Great Salt Pond, and…impose penalties for violations of these ordinances."[893] This statute limits DEM's authority to regulate shellfish within the Great Salt Pond; however, CRMC retains full management authority within the Pond because the statute is limited to the regulation of "taking" of shellfish.[894]

Section 930. Indirect Management Impacts on Shellfish

930.1. Magnuson – Stevens Act – New England Fisheries Management Council and National Marine Fisheries Service

1. Under the Magnuson-Stevens Fishery Conservation and Management Act ("MSA"),[895] regional fishery management councils were created,[896] and those councils were granted the authority to create fishery management plans that – once approved by the Secretary of Commerce – govern the management of any fishery that exists beyond the waters of a single state.[897] If a regional council has not submitted a proposed fishery management plan for a particular species and the Secretary of Commerce believes that federal regulation is required, the Secretary may promulgate her or his own plan,[898] which is generally carried out through the National Marine Fisheries Service ("NMFS").

2. DEM's management plan cannot be incompatible with any NMFS-approved plan involving a fishery "engaged in predominately within the exclusive economic zone."[899] Management of fish species off of Rhode Island falls under the jurisdiction of the New England Fishery Management Council ("NEFMC").[900] NEFMC currently manages nine fishery management plans, only one of which involves shellfish: sea scallops.[901] Additionally, two shellfish species harvested by Rhode Island shellfishers – the surf clam and the ocean quahaug – are managed by the nearby Mid-Atlantic Fishery Management Council.[902] Therefore, DEM's independent regulatory authority over shellfish in Rhode Island waters is limited to the bay quahaug, eastern oyster, soft-shell clam, bay scallop, blue mussel, whelk, and razor clam.[903]

3. Additionally, although the MSA does not place any direct mandates on DEM in managing the state's shellfish resources, the fisheries management standards outlined in the RI General Laws[904] mirrors the national standards for fishery conservation and management laid down in the MSA.[905] Additionally,

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892 *See* R.I. GEN. LAWS § 45-6-1(a).
893 *Id.* § 20-3-7; *DEM Council Regulations*, *supra* note 251, § 3.10.
894 *See* R.I. GEN. LAWS § 20-3-7.
895 Magnuson-Stevens Fishery Conservation and Management Act, 16 U.S.C. §§ 1801 et seq (2012).
896 *Id.* § 1852(a)(1).
897 *See id.* § 1852(h)(1).
898 *Id.* § 1854(c)(1).
899 *Id.* § 1856(b) (providing the Secretary with the authority to regulate such a fishery within state waters if the Secretary finds that the State has "taken any action, or omitted to take any action, the results of which will substantially and adversely affect the carrying out of" the federal FMP).
900 *Id.* § 1852(a)(1)(A).
901 NEW ENGLAND FISHERY MANAGEMENT COUNCIL, http://www.nefmc.org/ (last visited Mar. 30, 2013).
902 MID-ATLANTIC FISHERY MANAGEMENT COUNCIL, http://www.mafmc.org/ (last visited Apr. 5, 2013).
903 *See*, *generally*, 2014 Sector Mgmt. Plan for the Shellfish Fishery, *supra* note 42.
904 R.I. GEN. LAWS § 20-2.1-9(2)(iv) (2013).
905 *See* 16 U.S.C. § 1851(a).

DEM regulations call for state fishery management plans to be "consistent with" the MSA's national standards.[906] Therefore, interpretation of these national standards under the MSA will provide guidance on how the similar standards laid down in the RI General Laws will be interpreted.

930.2. The Army Corps of Engineers

1. Under the Rivers and Harbors Act, the U.S. Army Corps of Engineers ("Corps") must approve any discharge or deposit of "any refuse matter of any kind" into "any navigable water of the United States."[907] Additionally, construction of any "wharf, pier,…or other structures" in any navigable waters is prohibited without authorization of the Corps.[908] The Corps also has authority under the CWA to regulate the discharge of dredge or fill material into waters of the United States.[909] These provisions will come into play in aquaculture projects and any other shellfish management that involves placing any matter into the waters of Rhode Island because "refuse" and "obstruction" have both been broadly interpreted by the courts to encompass "virtually any foreign material."[910]
2. In Rhode Island, many projects do not require direct application to the Corps for a permit but instead fall under the General Permit ("GP") granted for the state.[911] "[A]ctivities in waters of the United States…that have no more than minimal individual, secondary, and cumulative impacts on the aquatic environment in waters of the U.S. within the boundaries of and off the coast of the State of Rhode Island" do not require an individual application to the Corps but instead may be approved by the CRMC.[912] However, the Corps retains the authority to review these projects and impose special conditions "that are determined necessary to minimize adverse navigational and/or environmental effects or based on any other factor of the public interest."[913]
3. The GP lays out criteria for two types of projects – Category 1 and Category 2.[914] Category 1 projects need only applicable state authorization while Category 2 projects require Corps authorization, which may be obtained as part of the state permitting process.[915] To qualify as a Category 1 project, the project must (1) meet the definition of Category 1 laid out in Appendix A of the GP, which provides criteria based on the type of project; (2) "[m]eet the terms" of the GP; (3) meet the General Conditions of the GP; (4) receive required state approvals; and (5) "[n]ot [be] located on the Narragansett Land Claim Settlement Area or sites that may influence this area."[916] Category 2 projects have identical requirements except that Appendix A provides different definitions for Category 2 and there is no requirement that the project not be located on the Narragansett Land Claim Settlement Area.[917]

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[906] DEM Licensing Regulations, supra note 41, § 6.2-2(i).
[907] Rivers and Harbors Act, 33 U.S.C. § 407 (2012).
[908] *Id.* § 403.
[909] Clean Water Act, 33 U.S.C. § 1344 (2012).
[910] *U.S. v. Lambert*, 915 F.Supp. 797, 804 (S.D.W.V. 1996) (citing *U.S. v. Standard Oil Co.*, 384 U.S. 224, 226-230 (1966)).
[911] *Corps Gen. Permit*, *supra* note 23, at intro, § I. The permit applies to projects that would require permits under both RHA § 10 and CWA § 404. *Id.* § II.
[912] *Id.* at intro; *see id.* § II(1). CRMC would be the agency to directly handle Corps permitting matters, but the General Permit makes clear that there are also potential approvals required by DEM depending on the scope of the project. *Id.* § II(1).
[913] *Id.* § III.
[914] *Id.* § I.
[915] Id.
[916] *Id.* § II(2)(A).
[917] *Id.* § II(2)(B).

4. There are 39 General Conditions laid out in the GP[918] that all Category 1 and Category 2 projects must meet, including delineating the waters that will be impacted by the project;[919] ensuring that there are "no more than minimal direct, secondary, and cumulative adverse environmental impacts;"[920] ensuring that there is "no unreasonable interference with navigation;"[921] and "minimiz[ing] or eliminat[ing] the discharge of pollutants."[922] Projects that meet all 39 General Conditions in addition to the other requirements listed above for Category 1 and Category 2 can utilize the GP and submit their permitting applications exclusively to state agencies without having to apply directly to the Corps.

930.3. National Aquaculture Policy, Planning, and Development Act

1. This statute establishes a national policy to promote aquaculture operations to increase United States aquaculture production rather than relying on seafood imports, which has been an increasing trend in our nation because our wild fisheries are largely overfished.[923] Recognizing that federal and state regulations often inhibit aquaculture development, Congress declared "a national aquaculture policy" to promote development of aquaculture facilities.[924] The primary mandate of this Act is to require the Secretaries of the Federal Departments of Agriculture, Commerce, and Interior to conduct research on scientific, technical, legal, and economic aspects of aquaculture and create a National Aquaculture Development Plan,[925] making this increased information widely available to any entity interested in aquaculture development.[926] However, this statute sets no substantive requirements or mandates that states are required to follow. Nevertheless, this national policy may be considered in crafting state shellfish management regulations, giving recognition to Congress' desire to increase national aquaculture production.

930.4. The Clean Water Act

1. In the Clean Water Act ("CWA"), Congress recognized the great importance of water quality, including the need for water quality sufficient for propagation of shellfish that are safe for human consumption.[927] While the CWA seeks to improve water quality nationally, it also recognizes that the majority of powers relevant to achieving water quality improvements rest with the state.[928] However, using its commerce power,[929] Congress, and by assignment the United States Environmental Protection Agency ("US-EPA"), are able to impose certain requirements and restrictions on state management. DEM and other state agencies are then required to take action and regulate consistently with the provisions of the CWA.

2. Under the CWA, the DEM is required to adopt water quality standards, which must be approved by US EPA, that consist of three basic elements: designated uses, water quality criteria and an anti-degradation policy. DEM must also assess the quality of the state's waters relative to their water quality standards (designated uses and water quality criteria), and as part of this assessment, develop a list identifying waters that do not meet water quality standards, known as the 303d list of impaired

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918 *Id.* § III.
919 *Id.* § III(2)(b).
920 *Id.* § III(3)(a).
921 *Id.* § III(14)(a).
922 *Id.* § III(23)(a).
923 *See* National Aquaculture Policy, Planning, and Development Act, 16 U.S.C. § 2801(a) (2012).
924 *See id.* §§ 2801(a), (b)(1).
925 *Id.* §§ 2803(a), 2804(a).
926 *See id.* § 2804(a)(1).
927 Clean Water Act, 33 U.S.C. § 1251(a)(2) (2012).
928 *Id.* § 1251(b).
929 *See* U.S. CONST. art. I, § 8, cl. 3.

waters. For each water body and water quality impairment on the list, DEM must determine the total maximum daily load (TMDL) of pollutants that the waterbody can accept and still meet water quality standards.

3. In order to protect public health and natural resources, such as shellfish, DEM regulates point sources of pollution. This is the backbone of the state's water pollution control strategy, which includes developing & enforcing permit limitations for municipal and industrial wastewaters, storm water, & combined sewer overflows discharged directly to the waters of the state, as well as industrial wastewaters discharged to municipally-owned treatment facilities. The program currently oversees permit compliance for 29 major discharges, approximately 130 minor discharges, & approximately 250 storm water discharges. DEM works with its counterparts in Massachusetts and US EPA, to ensure that permits developed for point sources of pollution in Massachusetts are sufficiently protective of Rhode Island's waters. The Clean Water Act provides for interstate conferences in cases where agreement cannot be reached between states on the control of both point and non-point sources of pollution. These CWA provisions have direct bearing on shellfish management given that shellfish may only be harvested from waters so designated (Class SA) and where water quality is meeting all applicable water quality standards – consistent with both CWA and the National Shellfish Sanitation Program.

930.5. Atlantic Coastal Fisheries Cooperative Management Act

1. Rhode Island has signed the Atlantic States Marine Fisheries Compact ("Compact"), which "promote[s] the better utilization of the fisheries, marine, shell and anadromous, of the Atlantic seaboard…for the promotion and protection of such fisheries" and not for price fixing or similar economic purposes.[930] Under the Compact, the Atlantic States Marine Fisheries Commission ("ASMFC"), on which each participating state has three representatives,[931] studies the Atlantic seaboard fisheries and recommends management methods that will conserve these fisheries.[932] The ASMFC also provides advice to state agencies to aid in their management decisions.[933] Prior to 1993, the advice of the ASMFC was only advisory. However, that changed with the passage of the Atlantic Coastal Fisheries Cooperative Management Act ("ACFCMA").[934]

2. Under the ACFCMA, the ASMFC is given the authority to establish fishery management plans, in consultation with NEFMC, for fish stocks that transition between waters of different states.[935] States are required to implement and enforce regulations consistent with these management plans.[936] If a state fails to comply with a management plan under this Act, the Secretary of Commerce can "declare a moratorium on fishing in the fishery in question within the waters of the noncompliant State."[937] However, there are currently no shellfish managed under the ACFCMA.[938] Therefore, DEM still maintains ultimate management authority over the bay quahaug, eastern oyster, soft-shell clam, bay scallop, blue mussel, whelk, and razor clam.[939]

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[930] *See* R.I. GEN. LAWS § 20-8-1 (2013) (quoting Atlantic States Marine Fisheries Compact, Pub. L. No. 77-539, 56 Stat. 267, art. I (1950)).
[931] *Id.* (quoting Atlantic States Marine Fisheries Compact art. III).
[932] *Id.* (quoting Atlantic States Marine Fisheries Compact art. IV).
[933] *Id.* (quoting Atlantic States Marine Fisheries Compact art. IV).
[934] Atlantic Coastal Fisheries Cooperative Management Act, 16 U.S.C. §§ 5101 et seq (2012).
[935] *Id.* § 5104(a)(1).
[936] *Id.* § 5104(b)(1).
[937] *Id.* § 5106(c)(1).
[938] Atlantic States Marine Fisheries Commission, *Managed Species*, ASMFC.ORG (last visited Apr. 2, 2013), http://www.asmfc.org/.
[939] *See*, *generally*, 2014 Sector Mgmt. Plan for the Shellfish Fishery, *supra* note 42.

930.6. Agricultural Statutes

1. Like the RI General Laws, the federal statutes also have a series of agricultural statues that can be read to include aquaculture, and even wild harvest fisheries.[940] None of these statutes directly impact shellfish management. However, state agencies are authorized to take action to maintain market conditions for state agricultural products under these statutes.[941] Therefore, DEM can consider market conditions in its management decisions, although it cannot place greater weight on market conditions than on other statutorily mandated factors discussed earlier, such as water quality and restoration.

Section 940. Tangential Management Impacts

1. The laws discussed above all have some direct relevance to shellfish management specifically because they deal with resource management, fisheries issues, water quality, or some other shellfish-related topic. However, other laws take a more cross-cutting or procedural approach and impact most management decisions regardless of the subject matter. Although these laws influence all of DEM's management decisions and therefore are not specific to shellfish management, it is important to touch on them here because they still impact shellfish management decisions.

940.1. The Federal and Rhode Island Constitutions

1. Although the United States Constitution does not have any provisions protecting fishery resources as the RI Constitution does, it does contain several provisions that influence management decisions. The commerce clause grants the federal government, through Congress, the authority to enact laws to regulate interstate commerce.[942] The commerce clause has been granted a very broad reach, and Congress has used this clause to regulate everything from growing wheat for personal use[943] to intrastate railroad fares.[944] The commerce clause is the root of the federal government's power to regulate fisheries that move beyond state waters under the MSA.[945]

2. Even though several species of Rhode Island shellfish remain unregulated by the federal government under its commerce clause power, the clause still impacts state management decisions through the dormant commerce clause, which prohibits states from enacting laws that "'place [the state] in a position of economic isolation'" by favoring state businesses over those of other states without a legitimate public purpose.[946] To be approved under the commerce clause, state laws must (1) not discriminate against interstate commerce, (2) serve a legitimate local purpose, and (3) consider alternatives before being adopted.[947] State regulatory schemes that impact interstate commerce have been approved provided that they serve some legitimate state interest and their impact on interstate commerce is "purely incidental, indirect, and beyond the purposes of the legislation."[948] The most likely implication of the commerce clause for shellfish management will be on any regulations that attempt to promote local harvest.

3. Not only are state laws prohibited from discriminating against interstate commerce, but they also may not discriminate against any cognizable group without cause.[949] Courts have set a high bar on how

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[940] *See* 7 U.S.C. §§ 451, 1626, 1638(2)(A) (2012).
[941] *Id.* § 602.
[942] *See* U.S. CONST. art. I, § 8, cl. 3.
[943] See, generally, Wickard v. Filburn, 317 U.S. 11 (1942).
[944] See, generally, Houston E. & W. T. Ry. Co. v. US, 234 U.S. 342 (1914).
[945] *See* Magnuson-Steven Fishery Conservation and Management Act, 16 U.S.C. § 1801(a)(3) (2012).
[946] *See Philadelphia v. New Jersey*, 437 U.S. 617, 623 (1978) (quoting *Baldwin v. Seelig*, 294 U.S. 511, 527 (1935)).
[947] *Healey v. Bendic*, 628 F.Supp. 681, 690 (D.R.I. 1986) (citing *Huges v. Oklahoma*, 441 U.S. 322, 336 (1979)).
[948] *Bayside Fish Co. v. Gentry*, 297 U.S. 422, 426 (1936); *see also Silz v. Hesterberg*, 211 U.S. 31, 40-41 (1908).
[949] U.S. CONST. amend. XIV, § 1. The Rhode Island Constitution also protects equal protection under a similar framework as the Federal Constitution. R.I. CONST. art. I, § 2.

restrictive a law must be to violate the equal protection clause when the law does not impinge on a recognized fundamental right or discriminate against a suspect classification, applying a minimal scrutiny standard.[950] Under minimal scrutiny, a court will approve a law if it serves a legitimate state purpose and does so in a reasonable manner.[951] In responding to a challenge of a Rhode Island law that prohibits collection of shellfish via use of a diving apparatus in four coastal ponds, the Rhode Island Supreme Court held that the law did not violate the equal protection clause because there were legitimate safety and resource management purposes to restricting harvesting by diving apparatus in those ponds.[952]

4. However, courts have found equal protection violations when regulations discriminate against discrete groups without a justifiable purpose. For example, a New York federal court held that a town ordinance violated the equal protection clause when it prohibited persons from obtaining shellfish licenses unless they had been state residents for at least one year.[953] Complete restriction of nonresidents from a fishery is also likely to lead to challenges under the privileges and immunities clause, which prohibits states from denying nonresidents the same rights their residents enjoy without a legitimate purpose.[954]

5. The final federal constitutional implication for shellfish management is the takings clause. The takings clause prohibits states from depriving any person of property rights without due process of law and just compensation.[955] Fishing licenses and aquaculture sites are specifically designed as revocable licenses, not irrevocable private property rights,[956] which reduces, but does not eliminate, the risk of takings challenges when licenses or aquaculture permits are revoked. However, regulatory actions could be subject to takings challenges if they substantially restrict any individual's right to use of her or his property or if the license is revoked without due process.[957] The Rhode Island Constitution specifically provides that the "powers of the state…to regulate and control the use of land and waters in the furtherance of the preservation, regeneration, and restoration of the natural environment, and in furtherance of the protection of the rights of the people to enjoy and freely exercise the rights of fishery and the privileges of the shore…shall be an exercise of the police powers of the state, shall be liberally construed, and shall not be deemed to be a public use of private property."[958] Therefore, the likelihood of successful takings claims is low in regards to regulations that impact activities on public water bodies; however, the scope of takings law is far more complex than can be fully explored in this document.

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[950] *See Baldwin v. Fish and Game Commission of Montana*, 436 U.S. 371, 389 (1978); *Cherenzia v. Lynch*, 847 A.2d 818, 823 (R.I. 2004). In *Baldwin*, the U.S. Supreme Court held that a Montana law charging non-residents 7.5 times more than residents for an elk-hunting license did not violate the equal protection clause because the state made a "rational, and not invidious" decision that nonresidents must pay more because state taxes are used to fund elk management. *Baldwin*, 436 U.S. at 389. In *Cherenzia*, the court held that shellfishing is not a recognized fundamental constitutional right and additionally held that those seeking to collect shellfish with SCUBA equipment did not qualify as a suspect classification entitled to heightened protection. *Cherenzia*, 847 A.2d at 823.

[951] *Baldwin*, 436 U.S. at 389; *Cherenzia*, 847 A.2d at 823.

[952] *Cherenzia*, 847 A.2d at 825.

[953] *Hassan v. Town of East Hampton*, 500 F.Supp. 1034,1036, 1043 (E.D.N.Y. 1980).

[954] *See* U.S. CONST. amend. XIV, § 1; *Conn ex rel Blumenthal v. Crotty*, 346 F.3d 84, 88 (2d Cir. 2003) (holding that a New York law prohibiting non-resident lobster permit holders from harvesting in certain areas was a violation of the privileges and immunities clause).

[955] U.S. CONST. amend. V (incorporated to the states via *id.* amend. XIV).

[956] R.I. GEN. LAWS § 20-2.1-5 (2013); *see id.* § 20-10-14 (permitting revocation of aquaculture permit for "immediate danger" to the environment provided that proper procedures are followed, including a public hearing).

[957] *See* U.S. CONST. amend. V; *Lucas v. South Carolina Coastal Council*, 505 U.S. 1003, 1019 (1992).

[958] R.I. CONST. art. I, § 16.

6. Although the state may freely regulate activities on public water bodies without much fear of a takings claim, actions taken in regards to individuals – such as a denial of a permit to operate an aquaculture facility – may also face challenges under the due process clause. If a person is entitled to procedural due process, the government must provide a hearing before depriving the person of an impacted liberty or property interest.[959] In order to show that a person has a property interest, he or she must have "more than a unilateral expectation" of a grant of some benefit but must instead "'have a legitimate claim of entitlement.'"[960] The Rhode Island Supreme Court held that no protected property interest exists "'[w]here state law gives the issuing authority broad discretion to grant or deny license applications in a closely regulated field.'"[961] Although the state courts have not yet considered precisely what due process requires for denial or revocation of aquaculture permits, this language indicates that at least the initial grant or denial of a permit does not rise to the level of a property interest.

940.2. Other Federal Statutes

1. Federal statutes with frequent or intensive impacts on shellfish management have already been discussed,[962] but some federal statutes will only impact management decisions in limited circumstances. These include the National Environmental Policy Act ("NEPA"), the Coastal Zone Management Act ("CZMA"), the Endangered Species Act ("ESA"), the Marine Mammal Protection Act ("MMPA"), and the Archaeological Resources Protection Act ("ARPA").
2. NEPA requires that federal agencies prepare environmental assessments and impact statements for all "major Federal actions significantly affecting the quality of the human environment."[963] Although NEPA only provides mandates for federal, not state, agencies,[964] its requirements do apply to any actions within the state that require federal approval. Any activity that requires federal approval will trigger NEPA review and require an environmental assessment.
3. The CZMA is the federal government's attempt to encourage states to create comprehensive coastal management plans through offering funding incentives and other benefits.[965] Rhode Island has crafted its coastal zone management plan in the form of CRMC's Coastal Resources Management Program and the various Special Area Management Plans developed to study and address specific management issues within the state.[966] Under the CZMA, federal actions in waters off the state need to be evaluated for consistency with state management plans.[967]
4. The ESA prohibits "taking" any endangered or threatened species, which includes any harm or harassment.[968] Any project seeking to move forward despite potential conflict with an endangered or threatened species must apply to the Endangered Species Committee for an exemption.[969] Similarly, the MMPA prohibits "taking" any marine mammal with limited exceptions.[970] The ARPA prohibits

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[959] *Mosby v. Devine*, 851 A.2d 1031, 1037, 1038 (R.I. 2004) (citations omitted).
[960] *Id.* at 1037 (quoting *Lynch v. Gontarz*, 386 A.2d 184, 188 (R.I. 1978)).
[961] *Id.* at 1048 (quoting *Erdelyi v. O'Brien*, 680 F.2d 61, 63 (9th Cir. 1982)).
[962] *See supra* §§ 840.1, 840.3, 840.4, 840.5, 840.6.
[963] Nat'l Envtl. Pol'y Act, 42 U.S.C. § 4332(2)(C) (2011).
[964] *See id.* § 4332(2).
[965] *See* Coastal Zone Mgmt. Act, 16 U.S.C. §§ 1452, 1455 (2012).
[966] *See Red Book*, *supra* note 323, at Acknowledgments (noting that the CRMP was approved by the federal government in 1978 as the state's coastal zone management plan).
[967] 16 U.S.C. § 1456(c)(1)(A).
[968] Endangered Species Act, 16 U.S.C. §§ 1532(19), 1539(a)(1) (2012). For projects requiring federal approval, a biological assessment is required if any endangered species are located at the project location. *Id.* §§ 1537(b), (c).
[969] *Id.* § 1537(e).
[970] Marine Mammal Protection Act, 16 U.S.C. § 1372(a) (2012).

excavation or disturbance of an archaeological resource without a permit.[971] All of these statutes have the potential to impact development projects, e.g., aquaculture facilities, located in state waters.

Section 950. References for Up-to-date Statutes and Regulations

1. The statutes and regulations referenced in this chapter are current as of the date of publication. However, such laws are subject to change over time. To aid the reader in locating the current laws, this section will provide references on where to look for updated statutes and regulations.
   a. Rhode Island General Laws: http://webserver.rilin.state.ri.us/Statutes/statutes.html
   b. Department of Environmental Management Regulations:
      i) http://www.dem.ri.gov/pubs/regs/index.htm (index for all DEM regulations)
      ii) http://www.dem.ri.gov/pubs/index.htm#regprops (alternate index of regulations also providing recent proposed regulatory changes)
      iii) http://www.dem.ri.gov/pubs/regs/regs/fishwild/rimftoc.htm (Division of Fish and Wildlife Marine Fisheries regulations)
   c. Coastal Resources Management Council Regulations: http://www.crmc.ri.gov/regulations/RICRMP.pdf
   d. Department of Health: http://sos.ri.gov/documents/archives/regdocs/released/pdf/DOH/7068.pdf
   e. All Rhode Island Regulations: http://sos.ri.gov/rules/index.php (searchable compilation of all state regulations where regulations can be searched by keyword and department)
   f. National Shellfish Sanitation Program Model Ordinance: http://www.fda.gov/food/guidanceregulation/federalstatefoodprograms/ucm2006754.htm

[971] Archaeological Resources Protection Act, 16 U.S.C. § 470ee(a) (2012).

CHAPTER 10. Conclusion and Summary

By Azure Dee Cygler, Coastal Resources Center, URI

Section 1000. Summary of the SMP

1. The SMP is the state's first comprehensive management plan for shellfish. The document is a culmination of an open, transparent stakeholder process consisting of public meetings, identification of issues, and technical team-generated management recommendations. This document represents two years of collaboration between RI DEM, CRMC, the wild harvest and aquaculture industries, the public, non-profits, researchers, other state and federal agencies, funders, and more, facilitated by the Coastal Resources Center/ Rhode Island Sea Grant at URI. All issues and forums were recorded and considered throughout the process and are available in this document and on www.RISMP.org. All management recommendations provided were generated through Technical Advisory Committees and vetted through the SMP Coordinating Team. Public comment was solicited and submitted comments were discussed and considered by the Coordinating Team. The principles contained within the SMP were signed by the CRMC and RI DEM at a November 2014 Final Event Celebration.
2. Chapter 1 offers an introduction to the SMP, the process, and the various principles, vision, goals, and objectives of the effort. Chapter 2 details the ecology of various commercially important shellfish species and their habitat range and characteristics. Chapter 3 provides biological and morphological descriptions of the key shellfish species considered in the SMP. Chapter 4 provides a comprehensive description of commercial/recreational wild harvest of shellfish as well as describes the aquaculture industry. Chapter 5 describes the shellfish resource assessment and management process currently underway in the state. Chapter 6 describes the economic aspects of shellfish, including research and marketing efforts underway. Chapter 7 and 8 respectively describe the human risks associated with consuming shellfish as well as the natural risks to shellfish populations in the Bay and salt ponds. Chapter 9 provides a legal description of the existing statues and regulations pertaining to shellfish in the state. Three chapters provide management recommendations (Ch.2, 3, and 4) which are summarized in a table in Chapter 11.
3. The SMP provides management recommendations to state agencies concerning shellfish resources and industries, generated through a two-year public process. This document provides a comprehensive description of shellfish resources and associated industries in the state, and is intended to be adaptive, evaluated and updated regularly by state agencies and partners.
4. It is important to note that the recommendations contained within this SMP are all considered important and can benefit the shellfish resources/industry in many ways. However, the state agencies will need to prioritize these recommendations due to strained resources. In addition, 2015 will mark changes in administration due to the 2014 elections which will bring new priorities which are a challenge to foresee and plan for. Therefore, while it is the hope and intention of the SMP that these recommendations will be implemented, it is likely that challenges such as funding sources, shifting government leadership, etc. will lead to prioritization of these recommendations.

Section 1010. Future Considerations

1. Ecosystem-Based Management – Ecosystem-based management is a process by which resources are managed considering the ecosystem as a whole; it does not manage individual units in isolation from that ecosystem. With regard to shellfish, this approach is critical in considering not only the status of the various stocks of shellfish that are commercially or recreationally harvested or grown, but the various effects shellfish have on the environment, human activities on and near the water, and future implications of climate change and other threats. An ecosystem approach collects scientific data on these ecosystem components (including humans), models where possible the interactions between these contributors, and institutes polices and management measures that strive to balance the diverse needs of these resources and industries to make them more sustainable. The SMP is intended to

present facts and current research on aspects of shellfish, coupled with issues identified by stakeholders, and offer advice to state agencies to manage according to need, science, and sustainability. It is the responsibility of these agencies, guided and facilitated by others in the state, to continue to evaluate policies to ensure they take into accounts the many ecosystem interactions and dynamics.

2. Adaptive Management – Adaptive management involves a structured, iterative process of resource management decision-making. Shellfish resources and industries are changing rapidly – from a decline in the number of young quahoggers, to a rise in the number of oysters produced in the state – these changes must be considered and reflected in management practice. The CRC has employed adaptive management for numerous projects in the U.S. and abroad, following a strategic process for effecting change (Figure 10.1). This utilizes collaboration and a stakeholder-driven process to 1) identify and assess issues, 2) Use those issues to prepare a program or document, 3) Formally adopt and fund the effort into the future, 4) Implement the recommendations that result from the process, and 5) Evaluate the program's effectiveness. This process ensues through iterative loops that grow larger as the scope of the effort grows. This process is important but often not practiced due to time and resource restraints; however, state agencies can be assisted with this process by groups like CRC and other neutral facilitators who are equipped to conduct a detailed issues assessment and program development.

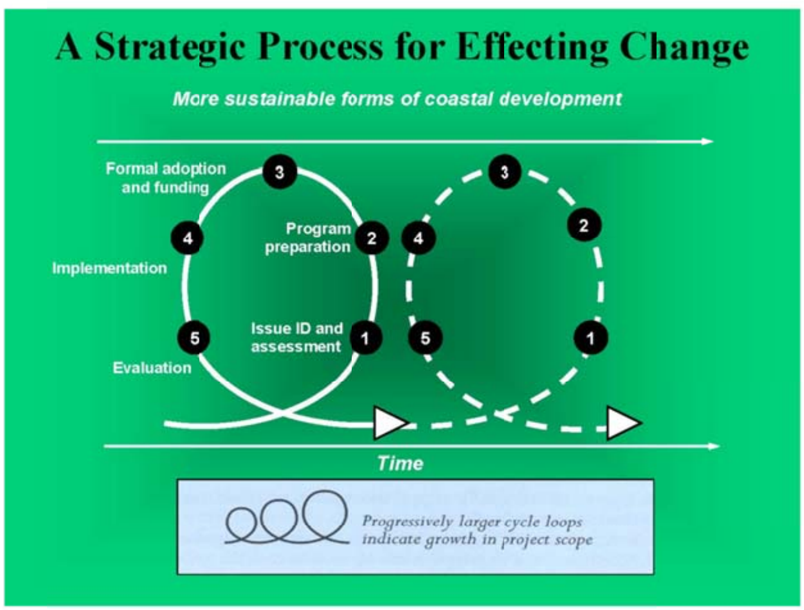

Figure 10.1. Process of adaptive management employed by CRC and others world-wide.

Section 1020. SMP in the Future, Looking forward

1. *Implementation Plan* – The SMP process has crafted management recommendations; the next step is for state agencies to develop a way to implement these recommendations. An Implementation Plan will be developed in 2015 through a committee of state agencies and will include goals, responsible parties, resources, sustainable funding suggestions, and timelines. The Plan will act as a guide for state agencies to carry out the important recommendations; a tracking mechanism will be developed to ensure the tasks are completed. State agencies will be responsible for these recommendations and implementing them; however, the CRC will help ensure that the public are informed of the resulting Implementation Plan through the SMP listserv, website, and public meetings.

2. *Research Agenda* – In addition to the Implementation Plan, a Research Agenda will be crafted in 2015. This plan will detail the various research needs identified in the SMP process and contained within the recommendations. Many of the recommendations are not specific to management but rather list research needs and gaps in the scientific understanding of a subject relating to shellfish. Some examples of research needs include: 1) Enhancing our understanding of the role shellfish play as potential eutrophication mitigation mechanisms, 2) Clarification of the impacts, or lack thereof, of harvesting on shellfish populations, 3) Efforts to better quantify the correlation between eelgrass and aquaculture, and 4) Understanding specific impacts from climate change to shellfish resources, their ecosystems, and the industries they support. The Research Agenda will be facilitated by CRC and include state agencies and regional researchers on a Working Committee. Specifics on the Research Agenda will include a list of the research needs, possible funding sources, suggested partners and roles, and timelines.
3. While practicing ecosystem-based, adaptive management is an important and effective strategy for shellfish management, it must be recognized that the state is strained in both people and monetary resources, presenting a great challenge to our state agency partners. However, working with institutions like CRC/URI and others to facilitate these types of processes, can not only ease the burden on state agencies, but ensure that the process of policy-making is inclusive, available to the wider community of stakeholders at all junctions of the effort, and matches the needs and issues that are most important and pressing. State agencies can rely not only on the people-power of these facilitating institutions, but the specific knowledge-set on stakeholder processes that these institutional leads possess that are not necessarily trained or inherent skills at the state agency level. Overall, a stakeholder-driven process has been proven to be effective and should be strived for by agencies conducting future resource management planning.

CHAPTER 11. Matrix of Recommendations

1. The following table provides a summary of all the management/research recommendations generated through the SMP process by the various Technical Advosory Committees. In addition to the actual management/research recommendation, a column is provided which offers the rationale for some of the recommendations or why the recommendation is considered needed or important. The two columns to the right of the table: 1) reference which chapter the recommendation corresponds to and 2) provides a course approximation of the resources needed to accomplish each recommendation. The resource needs are ranked either 1 (a lot of resources expected), 2 (moderate resources expected), or 3 (low resources expected to accomplish the recommendation). These rankings are intended to be initial, quick assessements of how difficult the recommendation would be to accomplish. A more detailed discussion and prioritization of these recommendations will occur in 2015 through an Implementation Plan developed by DEM and CRMC, facilitated by CRC/RI Sea Grant.
2. While each recommendation is important to some or all aspects of shellfish resource management, it is important to note that both DEM and CRMC, the agencies tasked with shellfish management activities, face severe resource contraints in terms of finances and personal. A critical aspect of the implementation planning in 2015 will be to identify additional and sustainbable funding sources which can assist the agencies in carrying out their current missions and duties, as well as support the various management recommentations resulting from the SMP. Creative funding sources and leverage opportunites will be important to identify to assure the SMP recommendations are carried through to the best extent possible.

Table 11.1. Summary of All SMP Management Recommendations.

	Shellfish Management Plan Recommendation	Rationale	SMP Chapter	Resource Needs
1	A dialog should be started to further define the need and the positives and negatives of monitoring harmful algal blooms in Rhode Island waters. This dialog should also consider dovetailing harmful algal bloom monitoring efforts, if warranted, with ongoing monitoring for bivalve disease organisms such as MSX, Dermo, and others, so that a comprehensive monitoring program is in place that neither overlaps nor conflicts with other programs and efforts.	*Borkman et al. (2012) suggest monitoring for biotoxins, which while still found only locally at present, are becoming more widespread and severe in recent years. Shumway (1990) suggests the use of satellite imagery to monitor and track algal blooms.*	Chapter 2	3
2	A dialogue should be started to explore the need for adapting current nutrient management strategies in light of changes in phytoplankton dynamics in Narragansett Bay including changes resulting from climate change. The focus would be on the nutrient dynamics related to the winter-spring phytoplankton blooms. Research may be needed to provide an improved understanding of the nutrient levels needed to support desirable ecosystem functioning.	*Higgins et al. (2011) suggest using oyster aquaculture as part of a nutrient trading program, and provide some values for nitrogen and phosphorus removal typical of oysters raised in aquaculture settings (e.g., Chesapeake Bay).*	Chapter 2	*3*
3	Given the potential multiple benefits of planting shell cultch, further effort should be expended to better define the benefits of planting cultch, barriers to cultch use (e.g., USACE "fill" definition issues), and the potential for using cultch in Rhode Island waters. Green et al. (2013) go so far as to say that shell planting is an important shellfish management tool.	*Planting of shell cultch has been suggested as a mechanism to buffer pH change in sediments (Green et al., 2009, 2013), and numerous references note improved settlement of various bivalves species in the presence of shell material (Kassner 1995; Carriker 1961).*	Chapter 2	*3*
4	Continue to improve the Leavitt et al. (2013) model for larval disbursal so that it can be used to simulate future precipitation scenarios that are likely given changing climate, and to then use that information for management of spawning sanctuaries. Existing model runs suggest that wind, and perhaps tidal phase at larval release time, may be significant components of larval dispersal and should be investigated more thoroughly and incorporated into the model as appropriate.		Chapter 2	*2*
5	Impacts of subaqueous soil pH change should be a consideration for study as it relates to bivalve larval settlement.	*Research of larval behavior in settlement site selection is needed as it is poorly defined at present in the scientific literature, yet appears to be a critical element defining the abundance and distribution of adult populations.*	Chapter 2	*2*

	Shellfish Management Plan Recommendation	Rationale	SMP Chapter	Resource Needs
6	Assess the degree of difficulty and cost of data collection relative to the value of being able to identify oyster habitat, and develop a plan to collect the needed data, if warranted.	*Hines and Brown (2012) note that a Site Suitability Index model developed by North et al. (2010) is particularly robust, and would be a useful tool for Rhode Island if the proper data were available.*	Chapter 2	*3*
7	Discussion of the likely outcomes and impacts of changing climate on bivalve populations and the ecological community they are a part of should be undertaken, and mitigation and adaptation strategies developed around them so that the shellfish industry is better prepared for future conditions.		Chapter 2	*2*
8	Habitat improvement recommendations for oyster reefs and soft-shell clams should be developed, and sites for restoration and improvement identified.		Chapter 2	*2*
9	Production per unit area will vary by grower, based on their management regime to maintain and/or improve shellfish production; this needs to be considered in any ecosystem-based management scheme for shellfish in Rhode Island, and for considering the ecological carrying capacity of ecosystems for shellfish aquaculture. This will need some research to better define production per unit area based on farm management techniques.		Chapter 2	*2*
10	A holistic approach to shellfish management should be taken, and as such, care should be taken to implement recommendations and to conduct management in ways that multiple outcomes and/or benefits are considered. This holistic approach needs to incorporate both ecological as well as sociological issues, research, and findings.		Chapter 2	*1*
11	There is a need for research to better quantify the correlation between eelgrass and aquaculture (e.g., improved light penetration/reduced turbidity) so that an ecosystem-based approach to planning aquaculture and eelgrass restoration can be pursued. These efforts should be aware of and point out the potential "Catch-22" of eelgrass presence limiting the expansion/use of bottom for aquaculture; growers should not be "punished" for providing the conditions that lead to increased eelgrass health and its resulting expansion.		Chapter 2	*2*

	Shellfish Management Plan Recommendation	Rationale	SMP Chapter	Resource Needs
12	There should be a discussion around the creation of "available for aquaculture" or "best sites for aquaculture" map and/or database for use in promoting the growth of aquaculture in Rhode Island. This should be done in a way that will reduce conflict and improve permitting and decision-making efficiency. Such a map should show ecological parameters that promote good shellfish growth, and descriptions of use of waters (e.g., boating, fishing, etc.) to best avoid conflicting uses.		Chapter 2	*2*
13	Adaptive shellfish management should be the norm for Rhode Island, evaluating management regimes every few years so that new research, new techniques and technologies, and new understanding of coastal ecosystems, particularly in light of changing climatic conditions, can be amended into management and planning.		Chapter 2	*1*
14	A dialog should be started that addresses the need to not excessively reduce nutrient inputs to Narragansett Bay during winter months so that sufficient nutrients are available to primary producers to fuel critical winter-spring phytoplankton blooms. There may be research needed to define what a “critical level” of nutrients is, specifically for Narragansett Bay, and should include need for research on nitrogen reduction leading to bivalve food limitation.		Chapter 2	*1*
15	A program should be developed to evaluate spawning sanctuaries, their use overall in Rhode Island, and their effectiveness in promoting and sustaining bivalve populations. This should include a clear definition of what is meant by “effectiveness” of a spawning sanctuary as there is some contention that they serve little purpose because in dense concentrations adults have lower reproductive output. Questions such as iI that better than no output? How much better is it? and Is that enough to justify designating and managing areas as spawning sanctuaries? need to be asked and answered.		Chapter 2	*2*
16	Pea crabs are a barrier to successful, inshore mussel aquaculture in Rhode Island; there is a need for research into mechanisms that can lead to the elimination of pea crabs from mussels grown in Rhode Island coastal waters.		Chapter 2	*2*

	Shellfish Management Plan Recommendation	Rationale	SMP Chapter	Resource Needs
17	Henry and Nixon (2008) suggest research be conducted on the nutritional values of the differing Skeletonema species of Narragansett Bay, and to relate these findings to reported changes in quahog shell growth rates to determine any cause-and-effect. Such information may have implications for shellfish management.		Chapter 2	*2*
18	There is a need for research into the role of Codium fragile, and other species that have been reported, or have the potential, to act as replacement (for eelgrass) settlement substrate. This research must consider the long-term roles replacement species play in the ecology of scallop populations. Special emphasis should be placed on how replacemenmt species act as settlement substrate regarding habitat enhancement and predator protection in areas where eelgrass has been lost.		Chapter 2	*1*
19	Research on Mercenaria genotypes and for increased ability to calcify under conditions of increased CO2/reduced pH should be undertaken. This information may be useful in managing this species sustainably as ocean acidification progresses.		Chapter 2	*2*
20	Further research is needed to more clearly define the impacts, or lack thereof, of harvesting on shellfish populations, particularly using dredge harvest techniques.		Chapter 2	*2*
21	Information is needed on the role of shellfish as potential eutrophication mitigation mechanisms in Rhode Island waters. Specifically, storage of nitrogen in shellfish and the amount removed and exported from the ecosystem under various harvesting and consumption schemes, and on long-term storage of nitrogen in sediments, if any, in bivalve communities.		Chapter 2	*1*
22	Scientific research needs must be prioritized, time frames for needed research information developed, and possible funding mechanisms identified and where possible secured.		Chapter 2	*3*
23	There is the need for integration of contemporary understanding about shellfish ecology, fishery economics, and social science implications in Rhode Island into a holistic framework, so that this can be applied to resource management initiatives. The Rhode Island Bays, Rivers and		Chapter 2	*2*

	Shellfish Management Plan Recommendation	Rationale	SMP Chapter	Resource Needs
	Watersheds Coordination Team Science Advisory Committee may be a fitting entity to fulfill this integration need.			
24	Better information on size–age structure of whelk populations in Rhode Island waters is needed, and needs to form the basis for management to ensure sustainability.	*Research suggests that whelk populations are likely to be over harvested due to pressure on the population from an excessive taking of females because of their larger size.*	Chapter 2	*2*
25	MANAGEMENT: Expand the goals and objectives of the shellfish sector management plan to include all commercially harvested shellfish species in Rhode Island. Develop an ecosystem-based shellfish management plan that addresses the unique characteristics of each of RI's significant water bodies rather than a one size fits all approach.	*Overall shellfish management strategies for R.I. - Fisheries management is a dynamic undertaking that is constantly being refined as more information on the biological, ecological, economic and social characteristics of the variety of shellfish resources included within this shellfish management plan become available. Establishing an overall goal and identifying what strategies will be used to achieve the goal(s) specified are an important consideration in Rhode Island shellfish management.*	Chapter 3	*2*
26	RESEARCH: To set scale and specificity of Rhode Island's shellfish management efforts, it is necessary to expand our knowledge of the population structure, larval distribution, site characteristics, and other important environmental and biological factors associated with each of the shellfish species harvested in the state.		Chapter 3	*1*
27	As we better understand the role of closed areas in shellfish stock structure and distribution, this knowledge must be factored into the overall management process; Generate baseline information on closed area population dynamics, stock assessments should be conducted in Prohibited Areas.	*With overall reproductive effort of most shellfish species directly related to environmental conditions and with most shellfish having a reproductive strategy relying on external fertilization, the composition and distribution of the shellfish population and its interaction with the natural environment plays a critical role in determining the ability of the resource to sustain itself under increasing fishing pressure.*	Chapter 3	*1*
28	If the current stock structure in Prohibited Areas does reduce the growth and larval productivity of shellfish populations then it is recommended that relays/transplants of quahogs out of high density areas (in Prohibited/Restricted waters) be conducted to reduce overall stock density		Chapter 3	*2*
29	Find a creative way to fund relays/transplants, should they be necessary to improve overall shellfish productivity in Rhode Island waters. One option could be a surcharge on harvested products that support a shellfish management program.		Chapter 3	*3*

	Shellfish Management Plan Recommendation	Rationale	SMP Chapter	Resource Needs
30	RESEARCH: Continue to explore the role of closed areas in quahog stock structure and larval supply and distribution. Consider how management may be altered to accommodate this new information. Explore the relationship between primary productivity and the productivity of the harvested resource for use as a management tool. Develop better estimates of minimum viable population size for all commercial shellfish species.		Chapter 3	*1*
31	MANAGEMENT: Consider the size class composition and potential growth rate of shellfish resources as a component to the areal management of harvest within RI waters. Change the state mandate to include economic considerations in the management of shellfish resources. Set harvest area openings to optimize stock stability first and economic return second.	*Shellfish size variability and economic return - A harvested quahog is a unique commodity; in that, it is marketed as four different products based on the overall size of the animal. In differentiating between littlenecks, top necks, cherrystones and chowders, the value of a quahog changes with the size of the animal, where it's worth decreases as it gets larger (see Chapter 6). This is also true for other shellfish species. Therefore, the size structure of a managed population of shellfish can be an important factor in the commercial value of the resource.*	Chapter 3	*1*
32	RESEARCH: Expand our knowledge of the size class composition and growth rates of shellfish resources in local waters. Develop relevant information on the economics of shellfish harvesting in Rhode Island, including: Seasonal cycling of the market value of shellfish harvested, and sensitivity of shellfish market values to changes in supply over the seasonal cycle.		Chapter 3	*2*
33	MANAGEMENT: Develop a formal external peer review process to evaluate the stock assessment programs used to manage all shellfish commercially harvested in Rhode Island. The frequency of review should be every 2 years for quahogs and every 3-4 years for other shellfish.	*Stock Assessment - Improve our knowledge of the spatial distribution of shellfish in the state. The first stage in the proper management of an exploited natural shellfish resource is to define the fishery, which involves not only identifying the fishery characteristics (fishery dependent data; such as harvest method, expended effort, landings, etc.) but also collecting unbiased (fishery independent) estimates of the resource, including the distribution and population structure of the fished resource (Hogarth et al. 2005). In Rhode Island, of the twelve species of shellfish that have been identified in this SMP, only one (the quahog Mercenaria mercenaria) is being routinely sampled as a component to the management of the fishery. Programs to monitor the soft shell clam and the two whelk species recently*	Chapter 3	*2*
34	MANAGEMENT: Continue effort to improve on the stock survey process. Develop a regular re-calibration schedule for the hydraulic dredge. Further refine operations and evaluate the hydraulic dredge under a variety of sampling conditions, e.g. substrate types, depths, towing speed, pump conditions, etc. Explore the use of video assessment to calibrate the sampling gear.		Chapter 3	*1*
35	MANAGEMENT: Consider other sampling methods that may be easier, cheaper, more reliable or effective. Continue the effort to employ a quahog research fleet for stock surveys. Identify a level for their involvement, e.g. shallow areas where dredge can't go, i.e. the coves (to start). Explore other uses of a wild harvester research fleet, e.g.		Chapter 3	*2*

	Shellfish Management Plan Recommendation	Rationale	SMP Chapter	Resource Needs
	environmental assessment. Find a mechanism to fund the fleet's involvement in assessment	*have been implemented although they are new and the long-term continuation of these programs is not guaranteed. Therefore, the bulk of the discussion on stock assessment will focus on the quahog stock assessment program.*		
36	MANAGEMENT: Improve communication between management agencies and users such that everyone is familiar with the use of data for management purposes. Better communicate assessment methods and data used to make management decisions. Release data to the public to add transparency to the management process, e.g. Summarize and release fishery dependent data (SAFIS) in a timely manner and release fishery independent data (stock surveys, etc.) annually. Expand the level of detail provided in the annual Shellfish Sector Management Plan and improve the notification and distribution of the document.		Chapter 3	*2*
37	MANAGEMENT: Encourage continued refinement of the management process, including coordination between fishermen and regulators.		Chapter 3	*3*
38	RESEARCH: Continue developing techniques to involve commercial fishermen as collaborators in data collection required for improved management. Explore better and more efficient methods for stock assessment for all of the shellfish resources routinely harvested in Rhode Island waters.		Chapter 3	*3*
39	MANAGEMENT: Allow spat collection devices to be deployed to supply aquaculture operations but restrict the effort to pre-settlement larval collection only. Do not allow collection of post-settlement juveniles for any activity unless sanctioned as a management strategy by RI-DEM Marine Fisheries.	*Concerns about using wild stock for aquaculture (seed collection & utilization) - A common practice for shellfish aquaculture is to rely on natural spatfall to provide the seed resources required for on-growing on the farm. However, collecting wild spat may impinge on resource availability as the wild spat grows and recruits into the fishery.*	Chapter 3	*3*
40	RESEARCH: Expand our knowledge about pre- and post-settlement dynamics in structuring recruitment into the shellfish fishery, especially developing more information on all of the species listed under this SMP.		Chapter 3	*1*
41	MANAGEMENT: Continue to use shellfish nursery systems to enhance post-set survival of small shellfish. Explore implementing habitat manipulation strategies to enhance shellfish recruitment and survival, e.g. shell cultching to enhance oyster recruitment.	*Managing to optimize post-set survival of shellfish - Post-settlement dynamics are a driving factor in structuring the populations of commercially important shellfish species, particularly the degree of*	Chapter 3	*2*

	Shellfish Management Plan Recommendation	Rationale	SMP Chapter	Resource Needs
42	RESEARCH: Continue to investigate the role of post-set mortality on structuring shellfish populations. Develop research to address whether habitat manipulation is a viable means to promote shellfish populations in the state. Does working a shellfish area aerate the ground and provide a more favorable environment for recruitment? Are there other means to affect sediment biogeochemistry to enhance shellfish settlement and survival?	*post-set mortality (REF). Many factors contribute to post-set mortality, including predation, disease, and hypoxia, and these will be considered in the following sections. One of the first considerations in managing post-set conditions is to address habitat quality for post-set shellfish species. Adequate habitat can provide shelter, protection from predation, improved growing conditions and numerous other advantages for the growing individual.*	Chapter 3	*2*
43	MANAGEMENT: Monitor the variability in predator populations and integrate that information into the management process. RI needs a nimble management system that can respond quickly to changes in predation pressure as the population's change. Consider implementing a state-wide predator control program for selected predators, based on best available science.	*Better understand the role of natural mortality in structuring populations - predation*	Chapter 3	*1*
44	MANAGEMENT: Develop creative ways to exploit predators that provide an economic incentive to remove – Composting, bounty, and/or new product development.		Chapter 3	*1*
45	MANAGEMENT: Encourage the continued development of a whelk fishing effort in Narragansett Bay		Chapter 3	
46	RESEARCH: Look at unexploited populations to better understand the role that predation may play in structuring the population of shellfish. Use Providence River and/or other closed areas for studies. Continue to investigate the role of post-set mortality on structuring shellfish populations.		Chapter 3	*1*
47	MANAGEMENT: Clarify oversight of shellfish movements to include all aspects of handling shellfish, including restoration and enhancement. Reaffirm current oversight of shellfish movement and management for potential risks by the Biosecurity Board - To manage inter- and intra-state transport of shellfish; and support the advisory capacity of the Biosecurity Board to include all agencies managing shellfish resources in the state.	*Better understand the role of natural mortality in structuring populations - disease*	Chapter 3	*3*

	Shellfish Management Plan Recommendation	Rationale	SMP Chapter	Resource Needs
48	MANAGEMENT: Support a state-wide shellfish disease monitoring program - Shift the cost to the state for disease monitoring rather than task farmers and fishers with this responsibility (or share cost between state and industry).		Chapter 3	*2*
49	RESEARCH: Develop quicker and lower cost methods to detect common shellfish diseases.		Chapter 3	*3*
50	RESEARCH: Continue to work to improve genetics-based disease resistance/tolerance for farmed oysters grown in RI.		Chapter 3	*2*
51	RESERCH: Need to explore the ramifications of climate change on shellfish disease processes for state waters.		Chapter 3	*3*
52	MANAGEMENT: Continue monitoring the bay for developing hypoxia events, including mapping of critical areas.	*Better understand the role of natural mortality in structuring populations - hypoxia*	Chapter 3	*2*
53	MANAGEMENT: Work to decrease nutrient loading in the bay to reduce the potential for hypoxic events to occur.		Chapter 3	*1*
54	MANAGEMENT: Use our knowledge of hypoxia to influence management decisions, e.g. sanctuary siting.		Chapter 3	*3*
55	MANAGEMENT: Apply our knowledge of hypoxia to influence management decisions that may be impacted by hypoxic events, e.g. shellfish sanctuary siting.		Chapter 3	*3*
56	RESEARCH: Continue studies of hypoxia in the Bay, including modeling of Bay-wide hydrodynamics and measuring the factors influencing hypoxic events. Research on the real impact of hypoxia on shellfish resources. Do we know what impact hypoxia has on the various shellfish stages?		Chapter 3	*1*
57	RESEARCH: Encourage the continued research on the role of shellfish in mitigating eutrophication in coastal waters. Does hypoxia/anoxia affect predator populations as well as resource?		Chapter 3	*3*

	Shellfish Management Plan Recommendation	Rationale	SMP Chapter	Resource Needs
58	MANAGEMENT: Develop effective tools & guidelines for shellfish restoration/enhancement.	*Providing an adequate supply of larvae/juveniles to replenish fished populations is a critical component to any fisheries management scenario. In addition to natural recruitment, one strategy that has been in use for a number of years is the protection and enhancement of broodstock in the form of spawning sanctuaries and/or broodstock enhancement. A second strategy that has been applied is to enhance the stock of juvenile shellfish by protecting them during their highly vulnerable larval and post-set stages and releasing them as they become more adept at surviving in the wild. Are these strategies something that can be used in Rhode Island?*	Chapter 3	*2*
59	MANAGEMENT: Support shellfish restoration/enhancement where effective. Utilize current information when considering site locations for spawner sanctuaries.		Chapter 3	*3*
60	RESEARCH: Expand information gathering on efficacy of shellfish restoration/enhancement programs – i.e. continue to monitor and evaluate. Encourage continued research in this area. Utilize current information when considering site locations for restoration and/or spawner sanctuaries. Determine the impact of shellfish population densities on reproductive potential of the population. Continue to investigate the effectiveness of spawner sanctuaries, in terms of their capacity to produce larvae and their efficacy in distributing larval shellfish to appropriate target areas		Chapter 3	*2*
61	MANAGEMENT: Shellfish restoration/ enhancement in RI needs to be carefully evaluated to gauge the effectiveness and long-term sustainability of these programs. Need to demonstrate success (at some level) from a biological perspective. If deemed to be worthwhile, then provisions need to be made in RI shellfish management to encourage the continued efforts in shellfish restoration/enhancement. Clear guidelines and a defined management protocol needs to be developed to oversee restoration/enhancement efforts in RI. Must include an evaluation process. Need to include site monitoring as a component to any restoration effort (including disease monitoring). Should appoint an overseer to process and manage restoration projects, similar to CRMC aquaculture coordinator. Needs to deal with Biosecurity (seed movement, disease testing), Siting, and Permitting. Develop a regulatory mechanism by which shellfish can be placed in areas needing mitigation (i.e. Prohibited waters) to assist in reducing the impacts of excess nutrients. Expand educational activities associated with shellfish restoration/enhancement to promote these activities and the environmental benefits generated.	*A third strategy for restoring or enhancing shellfish resources is to apply aquaculture technology to the early development stages of the shellfish and releasing the juveniles to the wild as they achieve a size threshold that reduces the risk of mortality due to predation or other environmental stresses.*	Chapter 3	*2*

	Shellfish Management Plan Recommendation	Rationale	SMP Chapter	Resource Needs
62	RESEARCH: A careful evaluation of the efficacy of restoration/enhancement activities is necessary to warrant any further development in these programs. Including an economic analysis of the cost/benefit of the program.		Chapter 3	*2*
63	RESEARCH: Develop procedures to enhance the effectiveness of shellfish restoration/enhancement programs, including handling and planting strategies to minimize predation and other losses, and improved siting criteria.		Chapter 3	*1*
64	MANAGEMENT: As information becomes more available, address stock-based management if necessary. Continue to use native broodstock where possible when undertaking a shellfish restoration/enhancement program. Need to maintain enough genetic variability to allow for adaptation	*A knowledge of the overall genetic structure of shellfish populations and the role that artificial breeding of these species may play in changing that genetic structure have been on the minds of scientists, farmers and managers for many years (e.g. Wilkins 1975). Advances in gene measurement and our understanding of genetic diversity have dramatically improved in recent years and could lead to increased application of genetic information to management decision-making.*	Chapter 3	*2*
65	RESEARCH: Continue studies addressing population genetics of shellfish species in the state. Understand the genetic diversity of local shellfish stocks. Study metapopulation structure in the bay and the coastal ponds. Estimate minimum viable population size for local waters to monitor impact from restoration/enhancement activities. Continue to work to improve genetics-based disease resistance/tolerance and other positive attributes for farmed shellfish grown in RI. Investigate the contribution of aquaculture stocks to wild population.		Chapter 3	*2*
66	MANAGEMENT: Rhode Island should continue participation in the region-wide Northeast ANS Panel, to ensure that regulations and management of ANS introductions are uniform throughout the region and that all states are in compliance with whatever strategies are in place. Develop an extensive educational campaign to prevent accidental introductions. Support the Biosecurity Board's oversight of inter- and intra-state shellfish movement - Include invasive pests in criteria for managing shellfish transport intra- and inter-state. Rhode Island should utilize the guidelines provided by the ICES Code of Practice on the Introductions and Transfers of Marine Organisms 2004 if intentional introductions are proposed in the state.	*In addition to predators, shellfish are impacted by a variety of other pest species. Some of these are native but a large number of pests have been introduced via a variety of mechanisms. Regardless of their source, these pests can affect the productivity, availability and marketability of local shellfish.*	Chapter 3	*1*

	Shellfish Management Plan Recommendation	Rationale	SMP Chapter	Resource Needs
67	RESEARCH: Encourage more research on husbandry strategies or management practices to reduce impact of pest species. Understand the primary vectors for introductions of exotic species into RI.		Chapter 3	*1*
68	MANAGEMENT: Continue to monitor changes in RI climate and waters and the biotic changes associated with these environmental changes. Continue the phytoplankton monitoring, finfish trawl survey and shellfish stock assessment survey currently operating in RI.	*Local environmental conditions represent a dynamic milieu that currently are experiencing a relatively rapid rate of change, lead by an upward swing of atmospheric levels of greenhouse gases, primarily carbon dioxide (Mellilo et al. 2014). The end result of changing conditions is dramatic changes in environmental parameters such as climate (temperature and weather patterns) and aquatic conditions (sea level rise and acidification), which may bring about significant changes to Rhode Island shellfish populations.*	Chapter 3	*2*
69	RESEARCH: Produce more information on the impact of anthropogenically-driven climate change as it relates to management issues.		Chapter 3	*2*
70	MANAGEMENT: Educate all parties as to the risks associated with shellfish growing in contaminated areas. Know your history and source of shellfish purchased for consumption. When harvesting shellfish, post-harvest handling is a critical step in ensuring the safety of the product for consumption. Continue to monitor shellfish for human health risks and manage those resources as recommended by the NSSP Model Ordinance. Explore the role of shellfish in remediation of nutrient inputs in local waters and utilize this strategy as a component to nitrogen management strategies throughout the state, if appropriate.	*In addition to global insults in water quality derived from human activity, such as ocean acidification, local changes in environmental quality are equally, if not more, important in affecting local shellfish resources. Contaminants from industry, sewage and other upland sources introduced into our local waterways can render shellfish unfit through a range of impacts from unsuitable for human consumption to direct mortality of the mollusk.*	Chapter 3	*2*
71	RESEARCH: Continue to encourage research on contaminant dynamics in RI shellfish. Investigate the contaminant uptake and depuration kinetics of juvenile shellfish held in Prohibited waters during early stages of their life cycle.		Chapter 3	*3*
72	RESEARCH: Encourage further studies on the potential role of shellfish in nutrient management in local waters.Evaluate the impact of shellfish deposits as sources of organic loading to sediment, i.e. benthic-pelagic coupling.		Chapter 3	*31*

	Shellfish Management Plan Recommendation	Rationale	SMP Chapter	Resource Needs
73	MANAGEMENT: Increase educational efforts directed at Rhode Island citizens to allow for an informed decision-making process when managing shellfish resources. Maintain open communication among all stakeholders to ensure that information is being exchanged in a constructive and informative manner.	*Relates to isseues raised by stakeholders including ecological impacts from aqaculture and biological carrying capacity. In its simplest form, the carrying capacity represents the maximum number of individuals or activities an environment can support for a long period of time. The question of carrying capacity arises as the waters of Rhode Island are more and more in demand for a variety of uses, from recreational sailing to food production.*	Chapter 3	*2*
74	RESEARCH: Encourage the further development of Spatial Tools – EcoPath, EcoSpace, etc. and their application to RI conditions.		Chapter 3	*2*
75	The state should conduct a thorough analysis of the DEM Jerusalem facility and the potential benefits of renovating the facility for the purpose of enhancing shellfish resources and associated industries in the state.	*The Jerusalem facility is ideally located to support shellfish enhancement efforts and is being underutilized at present. Ideas for use may include a remote-set facility, a public-private hatchery, or other functions to support restoration efforts.*	Chapter 4	2
76	Develop updated use maps to guide management decisions by state agencies. Maps should be updated frequently, incorporating input from all user groups utilizing the best available mapping tools. Maps should be shared online allowing ease of use by the public. Form a "Use Conflicts Working Group" to offer recommendations on the best strategies to minimize user conflicts in state waters.	*Use conflicts are a continuing issue as the number and intensity of coastal uses increases. Comprehensive, updated maps would ensure that all of these uses are documented. Formation of a "Use Conflicts Working Group" representing all user groups will ensure that the concerns of all stakeholders are heard. The maps will also be available to all state agencies to aid in their decision making.*	Chapter 4	2
77	Create an eco-history, a living history and portrait of shellfishing, restoration and aquaculture in Rhode Island.	*The long and colorful history of shellfisheries in Rhode Island plays a significant role in our cultural heritage, sense of place, and iconic artifacts. Knowledge of participants should be preserved for future generations while the opportunities to garner oral histories are still available.*	Chapter 4	2
78	Recognize via formal state processes that management of shellfish populations should be based on balancing total services provided, including the many important and critical ecological, social, and economic services in addition to extractive services.	*Shellfish reefs and beds are critical habitats that provide ecological, social and economic services to the community. It should be a formally recognized role of the state agencies to manage these habitats to maximize the services they provide to the community,*	Chapter 4	2

	Shellfish Management Plan Recommendation	Rationale	SMP Chapter	Resource Needs
		including, but not solely limited to, managing populations based on extraction.		
79	DEM and industry should work cooperatively to establish clear goals for Shellfish Management Areas (SMAs) and develop criteria for evaluating existing SMAs, including spawner sanctuaries. This effort should involve the evaluation of regular monitoring protocols, assessment of area performance based on management objectives, and adjustments for SMAs that do not meet certain functional criteria. Investigate the effectiveness of spawner sanctuaries for species other than quahogs.	*Most of the management areas have been in existence for a number of years with very little evaluation of whether they are achieving management objectives. The locations and reduced harvest measures in winter management areas and spawner sanctuaries, in particular, should be evaluated using a scientific approach and modern assessment tools.*	Chapter 4	1
80	Edit DEM shellfish regulations to improve clarity. Provide links to all state and federal regulations that apply to shellfish (F&W, OWR, DOH) on a single webpage.	*The DEM F&W regulations are confusing and repetitious. Editorial review will improve clarity and utility while making it easier to recognize the ways in which federal and state regulations dovetail.*	Chapter 4	3
81	Host semi-annual meetings of Shellfish Advisory Panel (SAP) to be scheduled in the spring and fall that are open and advertised to the public for dialog exchange (e.g. of concerns and ideas) and to provide updates on stock assessments.	*Scheduled semi-annual meetings of the SAP would provide the opportunity for open communication between DEM and industry to exchange updates and concerns. Attendance may be greater at these meetings than other SAPs that are scheduled on an as needed basis.*	Chapter 4	3
82	Adopt a statewide habitat restoration program for the promotion of ecosystem services. Establish a formal RI Shellfish Restoration Group to be jointly administered by CRMC and DEM. Where feasible, the habitat restoration program should align with complementary watershed restoration efforts to enhance success. The habitat restoration program should also involve the creation of a website to compile information on all restoration activities in state waters.	*The state should support shellfish restoration to promote critical ecological, social, and economic services. A RI Shellfish Restoration Group consisting of state, federal, and NGO representatives already meets on an irregular basis to provide information on ongoing restoration projects throughout the state; therefore, creating a formal meeting structure and schedule would build upon current practice. A website will ensure that all information collected by the group is available to interested parties. Compiling and making information publicly available may foster enhanced collaboration, participation and potential funding for restoration activities.*	Chapter 4	2

	Shellfish Management Plan Recommendation	Rationale	SMP Chapter	Resource Needs
84	Support targeted transplants for population enhancement and restoration purposes when the best available science suggests that it would be of benefit. Montoring should be undertaken to evaluate effectiveness of transplants.	*State, University and NGO researchers are developing tools that will aid in the determination of best management strategies and potential locations for transplant areas and donor sites. If done appropriately, the transfer of broodstock from closed areas to open areas has the potential to benefit the fishery while not adversely impacting the resource.*	Chapter 4	2
85	Increase public outreach and dissemination of information on legal and safe harvesting and handling methods for shellfish, especially within the recreational community. Ensure adequate educational/informational materials are provided to out-of-state recreational licensees. Develop multi-lingual educational materials describing safe harvest and handling practices. Display materials at major recreational fishing access points, tourism centers, and businesses that sell shellfishing equipment and licenses.	*Shellfish-related illnesses are an increasing threat. Recreational harvesters should be aware of potential concerns. The risk of illness could be reduced by providing education about prohibited areas to harvest and proper handling of shellfish. Beyond impacts on human health, illness associated with recreational harvest can lead to negative press and lower prices for commercial harvest and aquaculture products.*	Chapter 4	2
86	Establish a protocol within DEM Office of Water Resources (and potentially DEM Enforcement) for maintaining signage delineating prohibited waters. DEM should provide GPS coordinates of open/closure line boundaries in the annual Notice of Polluted Shellfishing Grounds and/or maps (for reference purposes only) made available on the DEM website to assist harvesters in accessing areas open to shellfishing.	*Due to vandalism and sometimes harsh environment, it is not uncommon to find signs in disrepair or missing entirely. It is an ongoing task to ensure that signs are in place and in good repair. These signs are official markers for enforcing harvest prohibitions from polluted waters. GPS coordinates and online maps would facilitate compliance and enforcement. Coordinates would compliment, not replace, signs or landmarks.*	Chapter 4	3
87	DEM Office of Water Resources should make water quality closure areas and updates more accessible to harvesters. The first phase should be developing a more technologically advanced method for disseminating alerts and closures (i.e. text message alerts, listservs, etc.). The second phase should be to develop a smart phone/tablet application for shellfish harvesters that provides information including, but not limited to, user's current location, open/closed waters, harvest limits, size limits, and DEM contact information (OWR hotline, website link).	*The shellfish hotline is an effective, but antiquated method of providing information on pollution closures. Additionally, most recreational harvesters are not familiar with the hotline and/or nomenclature of the growing areas. Increasing numbers of recreational and commercial harvesters have access to computers/smartphones/GPS units that would provide another option for checking open/closed status through a map based interface and/or through plotting open/closure line boundary coordinates. A*	Chapter 4	2

	Shellfish Management Plan Recommendation	Rationale	SMP Chapter	Resource Needs
		more technologically advanced method/offering multiple methods for disseminating alerts and closures might allow for a wider audience to be reached.		
88	Prior to opening, areas that meet criteria to no longer be classified as prohibited waters should be evaluated to determine the level of harvest that can occur without impacting the sustainability of the resource. Every effort should be made to prevent overharvesting due to derby fishing in newly opened areas.	*Areas closed to shellfishing serve as de facto marine reserves and contain large biomass of broodstock. The ecological and economic impacts of open harvest on previously closed areas must be closely evaluated before opening new grounds to harvest at full levels. Closed areas are linked to open areas by larval dispersal so localized depletions could have bay-wide impacts.*	Chapter 4	2
89	Develop a document that clearly outlines and defines the rules associated with direct marketing for shellfish and how to obtain appropriate licenses. Make this information more accessible to the public by linking this document on DOH, CRMC and DEM websites. Investigate the establishment of a DOH license for the shucking of bay scallops only.	*Many shellfishermen are not aware of the possibility of obtaining a dealers license or the procedures to follow. Some shellfish may be entering the market without proper oversight. If procedures were more clearly communicated shellfishermen might take the initiative to develop legitimate dealer businesses.*	Chapter 4	2
90	Using seed quahogs to restock shellfish beds that are easily accessed by recreational harvesters should be considered as one option for contending with localized depletion of the resource. This effort should begin as a pilot program using the Galilee Escape Road in Narragansett, a popular recreational area.	*Recreational shellfishing can draw more economic activity to the state through ecotourism, as well as enhance our cultural ties to shellfish through the tradition of recreational shellfishing. Therefore, such areas should be stocked to promote and accommodate recreational fishing in the state.*	Chapter 4	2
91	Work to obtain accurate, spatially explicit data on shellfish resources through cooperative efforts of DEM and industry. Educate harvesters through DEM on the procedures and importance of accurate tagging and reporting of shellfish catch by fishermen and dealers. Explore an industry-based data collection program. Give state support for the concept of a public-private hatchery for quahogs, oysters, and bay scallops in order to support the wild harvest industry growth and sustainability.	*Resource managers are hampered by a paucity of spatially explicit density and effort data. SAFIS and tagging areas give coarse, but useful data to aid in management of the resource and in protection of human health and safety. Data collected by fishermen (validated by dredge tows) could provide useful information on densities of shellfish species and fishing effort.* *There is interest by the private sector to explore the idea of restocking quahogs, scallops, and oysters*	Chapter 4	2

	Shellfish Management Plan Recommendation	Rationale	SMP Chapter	Resource Needs
		through a dedicated seeding program using a public-private hatchery. The premise with such a program is to enhance the commercial and recreational wild hjarvest industries and contribute to imporved water quality Bay-wide. This should be discussed further and a feasibility study undertaken to test locations and output potential of such a hatchery and dedicated seeding program.		
92	Continue collaborative research to better understand whelk species characteristics central to guiding management decisions. Evaluate ecological and economic impacts of potential management measures.	*More information is needed on these species and the fishery to guide management.*	Chapter 4	2
93	Develop and pursue modifications to the commercial licensing program that address several issues and concerns, including but not limited to: • Establishing equity with regard to the costs of difference licenses and endorsements that afford the same harvest opportunities;	*Only 17% of active quahog fishermen are under the age of 40. Changes need to be made to make the fishery more attractive to a younger generation and ensure that they can make a living wage. Increasing the bushel limits would allow fishermen to make a reasonable day's pay. The requirement to obtain a license 4 months prior to the end of the school year is seen as a barrier to getting younger people involved in the fishery. The cost of obtaining a (PEL) license and all 4 shellfish endorsements has risen to $375, plus $25 for a commercial vessel declaration; that makes a fully endorsed PEL $75 more than a Multipurpose License and creates inequities within the fishery. The CFL (entry-level) license has been phased out in the finfish and lobster fisheries; it may make sense to consider phasing it out in the shellfish fisheries as well. The purpose and utility of species-specific endorsements – as a tool for controlling effort and/or a means for parsing license fees -- warrant re-examination. The use of license fee revenues to support the State's shellfish management needs, in whole or in part, warrants a thorough evaluation.*	Chapter 4	222
94	• Expanding opportunities for obtaining and using student licenses, including a more flexible application period, and a higher bushel limit; Eliminating the CFL category, or increasing the bushel limit for CFL holders; • Collapsing the endorsements associated with PELs and/or CLFs (i.e. quahogs, soft-shelled clams, whelks, other shellfish);		Chapter 4	2
95	• Determining the total costs associated with DEM's shellfish management program, assessing those costs in relation to the contribution from license fee revenues, and re-structuring the license fees to achieve an appropriate and sustainable level of cost recovery.		Chapter 4	2

	Shellfish Management Plan Recommendation	Rationale	SMP Chapter	Resource Needs
96	Investigate adopting the ISSC guidelines regarding transfer of seed shellfish from upwellers in prohibited waters to leases in approved waters to reduce the time period that seed is required to stay in approved waters from 12 months to 6 months.	*The ISSC spends considerable time validating its recommendations using best available science and have defined 6 months as an adequate amount of time for depurating seed shellfish transplanted from prohibited to approved waters. The best available science indicates that deleterious substances are not accumulating in shellfish seed cultured in prohibited areas and that a shorter purge time in open waters would lessen the administrative and enforcement burden without increasing the risk to public health.*	Chapter 4	3
97	Develop an MOU designating CRMC as an authorized aquaculture lease inspector on behalf of DEM to assist in meeting the ISSC guidelines for semi-annual aquaculture lease inspections. Clearly define the roles of each agency in the oversight of existing leases.	*The state has been found out of compliance with ISSC guidelines regarding the frequency of aquaculture inspections. Designating CRMC as a State Shellfish Control Authority would reduce the inspection burden on DEM.*	Chapter 4	3
98	Define roles and responsibilities of the state agencies and NGOs regarding restoration activities. Develop guidelines for the permitting of projects that are explicitly for the purpose of restoration. Develop additional CRMC permit categories for restoration and community shellfish propagation projects.	*Numerous state agencies have some authority or interest in restoration activities including: DEM F&W, DEM OWR, DEM Enforcement, CRMC, and DOH. The roles of each of these agencies needs to be clearly defined so that restoration activities can go forward in a timely, safe and effective manner. Restoration permitting guidelines should be established to ensure a timely and predictable permitting process.*	Chapter 4	3
99	Pursue a RI Shellfish Initiative in coordination with NOAA's National Shellfish Initiative.	*Partner with wild harvesters, restoration interests (TNC, NOAA, STB, OGRE, etc.), aquaculturists, and state and federal resource managers to identify key threats and opportunities, research needs, and potential sources of funds to improve access, optimize extraction, maximize ecosystem services and improve markets for RI shellfish.*	Chapter 4	2

	Shellfish Management Plan Recommendation	Rationale	SMP Chapter	Resource Needs
100	Conduct a feasibility study to explore establishment of carbon and nutrient credit markets. Compile existing literature on the extraction and sequestration of nitrogen and carbon by shellfish. Examine nutrient credit trading opportunities in other states and internationally to determine if market-based nutrient and carbon reduction programs are appropriate for Rhode Island.	*A study of market-based programs to incentivize nutrient and carbon extraction in other states and nations will help us determine if such a program might be suitable for adoption in Rhode island to help us attain our goals for nutrient and carbon mitigation.*	Chapter 4	2
101	CRMC and DEM should develop a plan to continue to preserve existing and enhance public access. The state should also strive to preserve and expand working waterfront access (i.e. parking, dockage, boat ramps, foot paths) by working with town municipalities in the development of appropriate Harbor Management Plans.	*Access to many public rights of way are concealed or otherwise hindered. Affordable dockage and access for the shellfish industry is becoming limited, particularly as the industry is expanding. Parking at some boat ramps and public access points is an issue that should be addressed.*	Chapter 4	2
102	Continue efforts through the RISMC to promote local shellfish products. Encourage involvement of wild harvest shellfishermen by scheduling meeting times more amendable to their schedules.	*Effective marketing by individual fishermen or small dealers is a difficult task. The efforts of the RISMC should be continued so that fishermen may obtain better prices and dealers are able to sell more product. The state can foster collaboration between the wild harvest fishermen, aquaculturists, dealers, etc. through the existing marketing efforts. Other outlets from promotion may be ongoing Rhode Island Commerce Corporation (formerly Economic Development Corporation) projects and educational campaigns.*	Chapter 4	3
103	Public health and safety messages should be delivered in a manner that causes the least impact to the industry. While the official policy may be to recommend against the consumption of raw shellfish, officials should recognize that consumption of raw shellfish is a low-risk behavior for healthy consumers and is a cultural tradition that supports significant economic activity in the state. Health risks are primarily a concern for at-risk consumers and cautionary messages should focus on these individuals.	*State officials that make recommendations against the consumption of raw shellfish should consider that their public statements can have grave negative economic impacts on the shellfish industry. When making public consumer advisories, officials should consider whether the message is likely to prevent illness, and focus on statements most likely to correct unhealthy behaviors while minimizing the impacts to in-state businesses that work to provide a safe product suitable for raw consumption.*	Chapter 4	3

	Shellfish Management Plan Recommendation	Rationale	SMP Chapter	Resource Needs
104	Identify potential new and alternative funding sources for restoration efforts. Evaluate potential funding sources (such as from license fees, fertilizer taxes, dredging fees, etc.) and how neighboring states fund restoration efforts.	*The majority of funding for restoration activities in the State is obtained by NGOs. The State should identify long-term, sustainable funding sources to bolster shellfish restoration efforts for ecosystem services and fisheries enhancement. Eutrophication and hypoxia are two major issues impacting Narragansett Bay that may be lessened by reducing the amount of nutrients in the Bay and mitigated through shellfish restoration. Adding a tax on fertilizer use or increasing shellfish populations that remove nutrients via nutrient bio-extraction and subsequent harvest are options for potentially reducing total nutrient load in the Bay.*	Chapter 4	2
105	Develop a public outreach and education program to educate recreational harvesters regarding health and safety issues, safe storage and handling of shellfish, and notice of pollution closures. This program could involve the creation of an in-state recreational license or registry (free or fee).	*Shellfish related illnesses are an increasing threat. In particular, recreational harvesters may be unaware of proper harvesting and handling methods and the associated health risks. The risk of illness could be reduced by providing education on prohibited areas to harvest and proper handling of shellfish. Illness associated with recreational harvest has the potential to harm markets and depress prices. Recreational licenses would also provide a means of assessing the recreational fishing effort and potential impacts on the resource.*	Chapter 4	2
106	Develop spatially explicit population models that include populations in closed waters to better understand localized populations and connectivity of meta-populations. Support monitoring studies to enhance and refine models and research to these ends, including exploring opportunities to utilize non-state collected data for management (e.g. URI, NGOs).	*Resource managers are hampered by a paucity of spatially explicit density and effort data. However spatial stock assessments should be completed, to the best extent possible, across Rhode Island waters that allow for assessment of individual (i.e. localized) populations or connected meta-populations of species. Identification of other valid sources of data will be required to meet this objective.*	Chapter 4	1

	Shellfish Management Plan Recommendation	Rationale	SMP Chapter	Resource Needs
107	Conduct research to better understand bay scallop reproductive and population characteristics in RI waters. Develop a less subjective definition of a legally harvestable scallop and determine if the population can sustain an increase in the daily bushel limit.	*Bay scallops are easily managed in that there is only one spawning season and only scallops that have not had the opportunity to spawn need protection. The current definition of a legally harvestable scallop is subjectively based on superficial shell characteristics. A less subjective definition might allow managers to raise daily harvest limits on adult scallops to make the fishery more financially feasible.*	Chapter 4	1
108	The industry should develop an "apprenticeship program" for people who wish to learn more about and/or enter the fishery. This program could take the form of an informative webpage.	*Very few new fishermen are entering the fishery and the fleet is aging. Only 17% of active quahog fishermen are under the age of 40. Education about opportunities in the wild shellfish harvest sector might increase participation. The industry should undertake such a task (rather than DEM) and should work with an outreach group, such as RI Sea Grant, URI, CRC, RISD, etc.*	Chapter 4	3
109	Develop and assess tools to evaluate recreational harvest activity. Include an evaluation of the economic return to the state from recreational shellfishing.	*Little is known about the harvest and effort of recreational fishermen, or about the economic return of this activity to the state. Localized depletions at some of the more popular locations is a commonly observed result of over harvesting by recreational diggers. The factors that contribute to elevated recreational fishing pressure need to be better understood to aid in spatial management, especially in the coastal ponds.*	Chapter 4	2
110	Increase collaboration/consultation between the DEM Department of Agriculture and the aquaculture industry. Build a working relationship between industry and the Department of Agriculture that will allow a cross-understanding of issues, concerns, and needs as well as open the door to opportunities for research and industry support.	*Aquaculture is defined as agriculture under state statute. The relationship with DEM agriculture up to this point has been minimal.*	Chapter 4	3
111	Evaluate the merits and potential hazards related to permitting the collection of wild mussel spat in closed waters for use by aquaculture operations. Evaluate the rates of uptake and elimination of deleterious substances to develop appropriate protocols. Conduct additional research	*Mussel spat could be collected from the water column to be used on lease sites without impacting wild sets of mussels. Collection in closed waters would reduce use conflicts with wild harvest fishermen.*	Chapter 4	2

	Shellfish Management Plan Recommendation	Rationale	SMP Chapter	Resource Needs
	as necessary.			
112	Develop clearly defined watershed level goals for restoration efforts to better understand extent of restoration needed to achieve desired services (e.g. water quality improvements, fisheries enhancement, etc.). Develop clear monitoring protocols and metrics for determining restoration efficacy and adopt existing protocols where they exist (e.g. RI oyster monitoring manual; National Monitoring and Metrics Manual for Monitoring Oysters). Provide recommendations to practitioners on increasing potential success.	*Restoration goals should be clearly defined at estuary levels prior to implementing projects to better determine extent and type of habitat restoration needed and the services to be achieved from restoration effort(s) (e.g. water quality improvements, fisheries enhancement, etc.). Restoration is a costly process that should be monitored and evaluated to increase the chance of success. Developing and collecting performance information may improve the cost-effectiveness and increase benefits of future restoration efforts.*	Chapter 4	1
113	The state should develop a plan to allow for shellfish restoration in closed waters consistent with ISSC guidelines, and when human health and enforcement concerns can be met.	*Many of the best suited areas for shellfish restoration are located in closed waters and increased shellfish populations in these waters may help improve water quality. However, water quality must also be sufficient to sustain shellfish growth and reproduction (e.g. sufficient dissolved oxygen). BMP documents may be used as guidance in the development of restoration projects to alleviate some of the enforcement and health concerns. New technologies (video cameras, etc.) may be used to reduce the monitoring required by enforcement officers. The substantial amount of shellfish that naturally reside in some closed waters has become less of a health risk in recent years due to effective enforcement and education but still remains an issue of great concern. The potential human safety issues need to be balanced with the habitat services restored populations could provide including improved water quality, fin fish production, and nitrogen reduction.*	Chapter 4	2

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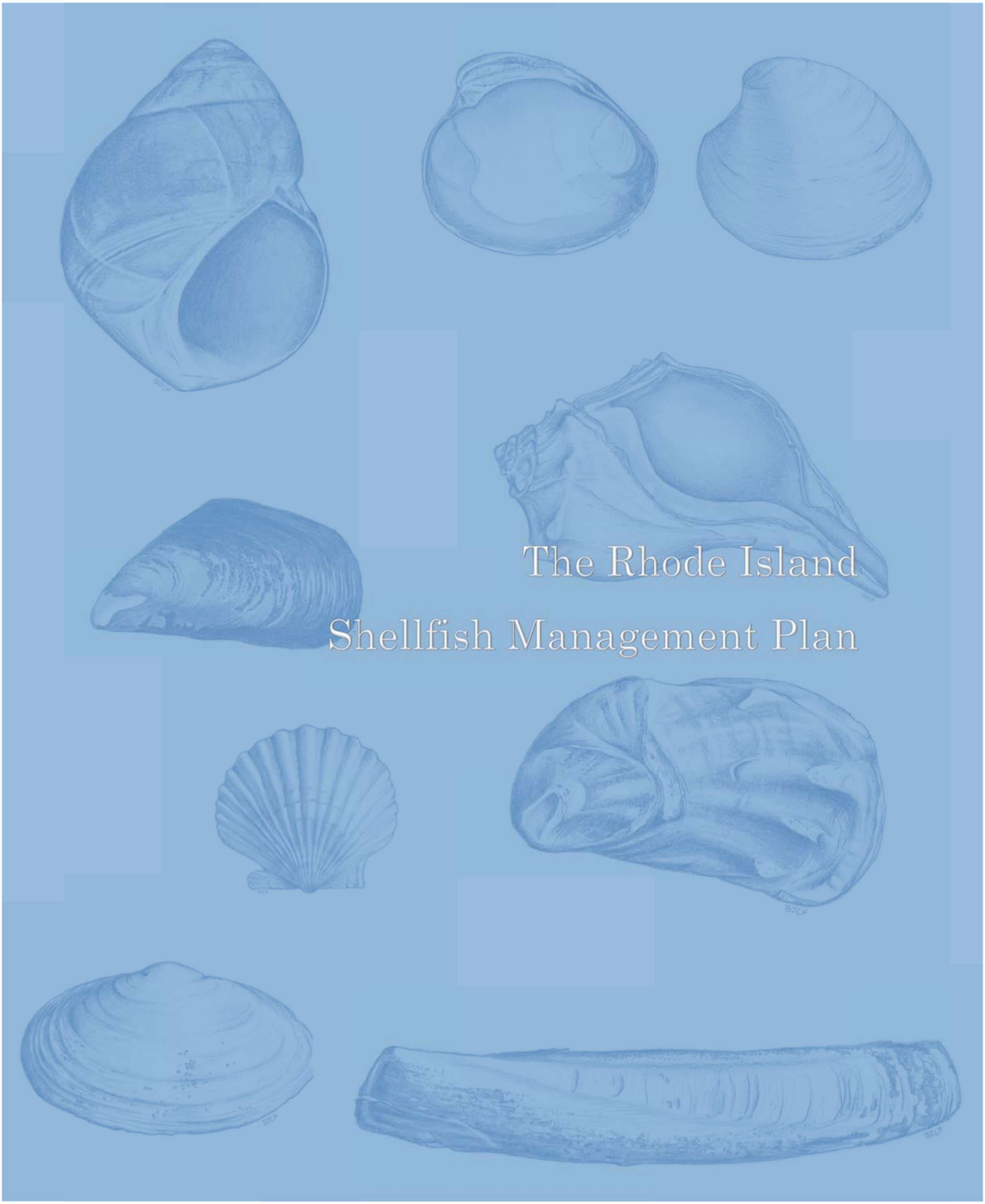
The Rhode Island Shellfish Management Plan



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