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A SUSTAINABLE SHRIMP MARICULTURE INDUSTRY FOR ECUADOR

Edited by Stephen Olsen and Luis Arriaga

International Coastal Resources Management Project

The University of Rhode Island

Factors Affecting the Relative Abundance of Shrimp in Ecuador

Factores que Afectan la Abundancia Relativa del Camarón en el Ecuador

R. Eugene Turner

Resumen

La producción de camarones peneidos en Ecuador tiene significación nacional, en términos de volumen, valor y ocupación de mano de obra. Aunque la producción en piscinas aumento grandemente en los últimos años, los datos disponibles sugieren que la producción por superficie (Kg/ha) ha declinado significativamente. Desde la perspectiva del manejo del recurso, las preguntas claves comprenden: ¿Cuáles son los impactos de la tala del manglar?; ¿Cuál es la variación natural en el reclutamiento?; ¿Se puede aumentar el suministro de postlarvas naturales?; ¿Cómo influye la captura de postlarvas y juveniles en el tamaño del "stock"?.

Después de presentar informaciones sobre el ciclo biológico del camarón y las relaciones del reclutamiento en abiente natural, el autor trata sobre los efectos de áreas pantonosas costeras en el reclutamiento del camarón, sosteniendo que el crecimiento y la supervivencia de las postlarvas en los esteros constituyen, probablemente, los factores más importantes que afectan a la magnitud de la población adulta. Se incluyen ejemplos de Malasia, Filipinas y Golfo de México (Luisiana), en los cuales se demuestra que los rendimientos a largo plazo están relacionados linealmente tanto a la calidad como a la cantidad del habitat intermareal.

Asunto relevante, además de la riqueza orgánica del ecosistema de manglar, es la protección que porporcionan las estructuras de la planta a los camaroneros juveniles, conforme ha sido demostrado en experimentos sobre la relación predador-presa, que son citados en el trabajo.

Se analiza la influencia del clima sobre las fluctuaciones anuales del "stock" de camarones, estableciéndose que en el Ecuador hay una baja variación anual (20%) de la "captura por unidad de esfuerzo" (CPU), en comparación con la de otros países (hasta un 90%). La presencia o ausencia del fenómeno de El Niño, es determinante en las variaciones anuales.

En las conclusiones, el autor expresa que la conservación de la "cantidad de habitat" es altamente significativo para mantener el éxito sostenido en el reclutamiento de los "stocks", puesto que parece que la extensión del habitat es el factor determinante de las densidades potenciales del "stock" natural, que son modificadas anualmente por influencias climáticas.

En consecuencia, la recomendación del autor es la conservación de las zonas de manglares, si el Gobierno desea prevenir grandes cambios en los "stocks" de postlarvas, juveniles y adultos. Donde sea posible, el manglar debe ser restribuído mediante el restablecimiento de la hidrología natural. La zona de amortiguación del manglar alrededor de las áreas taladas debería ser al menos el doble del área talada.

También, concluye en que la industria del camarón presenta signos del aumento de conflictos entre usuarios de los recursos, necesitándose datos precisos para lograr el éxito en la interacción entre todas las partes interesadas.

Finalmente, recomienda divulgar técnicas para aumentar el suministro de postlarvas mediante la disminución de la mortalidad durante su manipuleo.

NOTE TO READER
September 1, 2006

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Introduction

Penaeids are harvested extensively throughout the Ecuadorian coastal zone from boats and in ponds built within the mangrove-lined estuaries. The harvest is of national significance in terms of volume, value and employment (Sutinen et al., this volume). Resource management questions have arisen as the mariculture system developed. For example, trawl fishermen have accused the pond operators of depleting stocks of wild shrimp postlarvae (PL) and juveniles to supply the ponds. As many as 90,000 to 120,000 people may be involved in postlarvae collection each year, and the effects on the shrimp population is unknown. Recent PL shortages have led to serious economic difficulties, particularly for the pond operators; in 1985, 50 percent of the ponds were idle due to a shortage of wild-caught postlarvae, which represent up to one-half of pond operation expenses (LiPuma and Meltzoff, 1985). Many of the ponds are in mangrove zones which are very productive components of the estuarine ecosystem (Cintron, 1981) and contribute to both flora and fauna, including shrimp. Although catches in the ponds increased dramatically in recent years, the available data suggests that the areal rate of production (kg/ha) for all ponds has declined significantly. There are several reasons for this decline:

- The best sites may have already been chosen leaving only the poorest sites for later development.
- For economic reasons ponds may be abandoned or never used.
- The statistics are not accurate.
- Pond operators are now relying more on natural stocking of ponds through tidal action than on stocking with caught larvae.
- Pond fertility is depleted after three harvests, and management steps were not taken before seeding the fourth production period.
- Most ponds were unauthorized and, therefore, were not counted in earlier estimates of productivity.
- Informal exports of shrimp through Peru, among other countries, have also contributed to this skewed appearance.

From a resource management perspective, the key questions to be addressed concerning the relative abundance of natural shrimp stocks are:

- What are the impacts of clearing mangroves?
- What is the natural variation in recruitment?
- Can the natural postlarvae supply be increased?
- How much does the harvest of postlarvae and juveniles influence the offshore stock size?

Life Cycles of Wild Penaeid Shrimp

Shrimp begin life in the open sea as eggs which mature through naplius, protozoeal and zoeal stages. After drifting during the pelagic larval phases, the postlarvae enter lower-salinity estuarine waters on flood tides and seek nutrient-rich substrates, such as mangrove roots, to which they cling until the next tide takes them deeper into the estuary. Eventually the shrimp become benthic (bottom-dwelling), growing larger in the food-rich and predator-reduced environment. After several weeks or months, they return to the ocean, remaining in the shallow zones (Figure 1). Fishermen harvest shrimp from estuaries as postlarvae for stocking ponds, or as subadults and adults in the nearshore and open oceanic waters. For reasons discussed below, most commercially-important penaeid shrimp are assumed to be estuarine dependent.

The capability of estuarine mangrove areas to support major fisheries is widely acknowledged by scientists, but not well understood. The juveniles of many commercially important fisheries congregate in shallow zones for feeding and refuge from predators. Such behavior makes these species more adaptable for mariculture operations. Shrimp, in particular, take advantage of favorable shallow water habitats during critical life cycle stages. Various studies have revealed that shrimp postlarvae are present virtually all year in mangrove waters, although numbers fluctuate seasonally in relation to the lunar, diurnal and tidal cycles.

Shrimp Recruitment Relationships

Penaeid shrimp stocks suffer the greatest mortality when the organism is smallest. In many fisheries, variations in recruitment of an age group into the exploited stock is driven by adult spawning biomass size. But stock recruitment relationships for penaeid shrimp are not clearly demonstrable (Garcia, 1983) because the adult stock size is determined by the changes in juvenile, even postlarvae abundance, and is not primarily related to changes in adult spawning biomass.

However, there are reasonable causal relationships between larval and juvenile abundances and the subsequent densities (Garcia and LeReste, 1981). In turn, the stock recruitment success is clearly dependent on climatic factors, predation levels, food supply and habitat quality. Of these, though not precisely defined for penaeid shrimp, habitat is considered the principal long-term factor influencing sustained shrimp harvests. Shrimp mariculture in Ecuador may have contributed to the change in the dominant species, from Penaeus occidentalis to P. vannamei. P. vannamei is more adaptable to coastal ponds environments, and inefficient techniques may release to the estuary 1,000 pounds of 16-20 gram preadult shrimp during the harvest of a single 10 hectare pond.

Effects of Coastal Wetland Area on Recruitment of Penaeid Shrimp Stocks

Coastal Wetland Area and Shrimp Stock Size

Researchers agree that larval shrimp movement and recruitment from the spawning sites offshore into estuaries are probably the most important factors affecting the harvestable adult population size (Garcia and LeReste, 1981; Garcia, 1983; Turner and Brody, 1983). Although estuarine salinity and temperature changes affect the annual potential for postlarvae survival, the long-term yields are linearly related to both the quantity and quality of intertidal habitat. Despite the difficulty in obtaining reliable measures of fishing effort and landings, there are several examples of the habitat-yield relationship throughout the world.

Jothy (1984) provides data from Malaysia relating mangrove area and shrimp yields (Figure 2). Although the author does not describe the time period of the shrimp landings data nor the amount of fishing effort, there is a clear relationship between shrimp landings and mangrove area in each of the states along Malaysia's coastline.

Pauly and Ingles (1986) compiled similar statistics for the Philippines and the same relationship holds between shrimp landings and mangrove zone (Figure 3). The researchers live in the Philippines and had access to long-term data on both the artisanal and commercial trawl catches. They eliminated under- and over-reporting of catch data and the abuse of mangrove areal estimates for economic interests concerned with the mangrove lumber concession.

Long-term data and monitoring from the entire northern Gulf of Mexico are also available. The area of intertidal vegetation is also well known through several surveys since 1960, with the area of vegetation directly and linearly related to the tidal landings in any one year (Figure 4). The vegetation in these estuaries is not dominated by mangroves (except in isolated cases). There is also no significant relationship between water surface area and landings, except for a possible inverse relationship. In addition, the species of shrimp caught are directly related to the kinds of intertidal coastal vegetation in each area.

The same direct relationship between commercial harvests of penaeid shrimp and intertidal vegetation is found worldwide, though it changes with latitude, rising with decreasing latitude until around 5o N/S where it declines (Figure 5).

The important commercial species in Ecuador are listed in Table 1 and distribution of harvest by species is shown in Table 2.

The relationships of wetland area to penaeid shrimp yields have been indirectly tested through large-scale changes in wetland areas. Several examples have been documented with various degrees of success (Figure 6, Table 3).

In Louisiana, the coastal wetland loss rate is 0.8 percent per year (Craig et al., 1979; Turner, 1979, 1982; Turner et al., 1982). Changes in vegetation are accompanied by changes in the shrimp catch in direct relation to the loss or gain of wetlands in each estuary. There are also demonstrated relationships between the quality of estuarine wetlands and shrimp catch. Due to the loss of wetland areas over the past 30 years, more salt-tolerant vegetation has dominated, with accompanying increase in brackish shrimp species (Figure 7).

In Japan, Doi (1983) showed that the decline in yields of P. japonicus was proportional to land reclamation in the estuary (Figure 8). However, the intertidal land was mostly unvegetated, shallow mudflats. Morgan and Garcia (1982) noted a long-term decrease in the recruitment of P. semisuculatus in Kuwait and Saudi Arabia related to estuarine land reclamation. In El Salvador, mangroves were cleared for agriculture and the shrimp fisheries declined, though the fisheries analysis is far from complete due to difficulty in obtaining good estimates of landings and effort (Daugherty, 1975).

Finally, in the People's Republic of Vietnam, the chemical defoliation of the southern coastal zone during the latest war caused widespread loss of mangroves. Though the analysis is not generally available to the scientific community for review, there apparently was a severe decline in coastal fisheries stocks, including shrimp (Norman, 1983).

Causal Relationships Leading to the Wetland-Stock Relationships

Experiments in predator-prey interactions in wetlands show similar patterns in shrimp yields. For example, wetlands blocked off from the estuary with levees or bulkheads result in decreased numbers of adult shrimp at the altered sites (Mock, 1967; Trent et al., 1976). Although the wetland edge is particularly high in organics, a more important factor may be the protection from predators that plant structures offer the shrimp. Field and laboratory predator-prey experiments with P. aztecus in vegetated and non-vegetated salt marsh habitats indicate that small juveniles hide among plant stems to escape predators (Minello and Zimmerman, 1983a,b; Zimmerman and Minello, 1984; Zimmerman et al., 1984; Minello and Zimmerman, 1985). The number of successful predator attacks on prey declines with increasing vegetation complexity. Thus wetland habitats appear to be favored sites for juvenile shrimp, which is consistent with observations of organism adaptation to resource depression in the presence of predators (Charnov et al., 1976). These responses are also observed for freshwater lakes with wetlands fringing their borders, coral reefs, seagrasses and rivers (Groen and Schmulbach, 1978; Johannes, 1978; Savino and Stein, 1982; Strange et al., 1982; Duroucher, 1984; Heck and Thomas, 1984; Holland and Huston, 1984; Robblee and Zieman, 1984; Hoyer et al., 1985; Risotto and Turner, 1985).

Mangrove Loss and Postlarvae and Adult Supply

Does decline in shrimp landings or postlarval supply follow the loss of mangroves due to mariculture pond construction? To address this question, it is worthwhile to determine the changes in mangrove areas since significant pond construction began in or about 1976.

The decline in mangrove area in Ecuador as a direct result of the construction of mariculture ponds in the mangrove zone is estimated at 10.6 percent by Alvarez (this volume). Valdiviezo (no date) estimated that there were a total of 175,219 hectares (ha) of mangroves and 89,368 ha of brackish water mariculture ponds (Table 4) in Ecuador as of 1982. One study of the Guayas River estuary (CLIRSEN, 1983) indicates that 16 percent of the pond growth from 1966 to 1982-83 occurred in mangroves (Table 5). Assuming that about 10 percent of the present mariculture ponds are in former mangrove zones, then about 9,000 ha of mangroves are no longer functioning as a forested wetland ecosystem.

Is this estimated 10.6 percent decline in mangrove matched by an equivalent decline in shrimp landings or postlarval supplies? This is a difficult question to address with present landings statistics for Ecuador. Although the trawl effort has remained somewhat constant for the last 15 years (Figure 9), the catch per unit effort (CPUE) has fluctuated; but natural variations in a variety of fisheries stocks, especially shrimp, fluctuate at least 20 percent in any one year.

Further, the 10.6 percent declines in mangrove are cumulative. In 1980 declines were only around 1.0 percent, so the impact of mangrove loss is relative to annual environmental fluctuations that affect stocks. Even so, the CPUE in the last several years is lower than average.

Another question is whether or not fishing effort in the last few years has remained constant. Without compensating for a changing effort, as well as vessel numbers, it is difficult to separate out the relative influences of climate, effort and mangrove decline. Certainly the effort has not been completely constant because the size of the boats (measured in horsepower) has changed since 1980 (Figure 10).

Effects of Climate on Annual Fluctuations of Penaeid Shrimp Stocks

Natural Variations in Stock Size

Adult stock harvests may vary as much as 100 percent from year to year. Table 6 shows the coefficient of variation for the Ecuadorian trawling fleet and several other world shrimp fisheries. The Ecuador fleet has a very low variation in CPUE of 20 percent compared to up to 90 percent elsewhere. Clearly there has been high stability in recruitment over the last 25 years in Ecuador. However, there is still much variation from year to year. Understanding the factors leading to this variation is important to the management of this fishery.

It is now well documented that these large annual variations are associated with changes in estuarine conditions. Variation in estuarine salinity and temperature are the best-documented climatic influences (Table 7), but the frequency and intensity of frontal passages, river discharges or substrate conditions may also be important. Numerous data on CPUE are available (e.g., Gulland and Rothschild, 1984; Kapetsky, 1981; Kapetsky and Lasserre, 1984 a,b), but there is no systematic and comparative analysis of climatic influences. Copeland and Bechtel (1974) analyzed the salinity and temperature preferences of several penaeid species in estuaries of the northern Gulf of Mexico. They clearly demonstrated the interactive optimal preferences by shrimp for temperature and salinity, rather than linear relationships dominated by one factor.

Cun and Marin (1982) examined fisheries landings data to determine the annual changes in the catch of P. stylirostris in the northern (zona de Golfo), central and southern parts (zona de Playas) of the Gulf of Guayaquil between 1965 and 1979 (Figure 11). The interannual variations were high and there were differences in species dominance between areas, though the reasons are not yet understood.

Data on the flow of the Jubones River, which enters the Guayas estuary (Table 8) was used as a surrogate for regional variations in rainfall and temperature, demonstrating an inverse relationship with riverflow and CPUE (see also Figure 12). Since El Nino usually brings wet and warm weather, these events seem to indicate that such events are unfavorable for shrimp recruitment. However, the most recent El Nino events of the 80s resulted in very high values of CPUE, but are not included here because of the lack of riverflow data. The major point of this figure is to encourage analysis of effects of climate on Ecuadorian shrimp CPUE (as well as other species). This approach has proven feasible elsewhere (e.g., Table 7).

Implications for Management of Penaeid Shrimp Stocks

The options available to penaeid shrimp managers might be described as being of three types: economic, or fleet and processing management; personnel, or socio-cultural management; and habitat management. Habitat management is emphasized here. The primary cause of changes in these wetlands are manmade activities and may, therefore, be manageable. Without more attention to habitat, the first two concerns will become less important and more difficult to implement. As the potential crop of both postlarvae and adults decreases with wetland losses, options to manage whatever remains become much more limited.

Penaeid shrimp managers should regard habitat management as their primary responsibility. Otherwise, they will be faced with trying to divide fewer and fewer stocks among more and more people, especially fishermen, while watching their well-designed but static management plans falter with changing environmental conditions.

Conclusions and Recommendations

Below are some conclusions and recommendations based on the review of penaeid shrimp biology and the present situation in the Ecuadorian fishery. These will necessarily be broadly stated since implementation must be flexible to reflect local variations in economies, personnel, politics and environment.

1. Conclusion: Penaeid shrimp recruitment from larvae to adult is strongly influenced by habitat quality and quantity. The hypothesis that habitat quantity determines adult stock sizes is supported by limited field observations following wetland removal from the ecosystem. Conservation of habitat quantity is of high significance to sustained stock recruitment success since it seems to be the final determinant of natural potential stock densities which climatic influences modify annually.

Recommendations: Mangrove zones must be conserved if the government wants to avoid major changes in stocks of postlarvae, juveniles and adults. Stock harvest is probably at its natural limit, and conservation, rather than further exploitation of the few remaining stocks, is in order.

- Where possible, mangroves should be restored through reestablishment of the natural hydrology.
- Mangrove buffer zones around cleared zones should be at least twice the levee width and include the levee.

2. Conclusion: The shrimp industry in Ecuador is expansive and intensive, and shows signs of increasing user-use conflict. Minimization of conflict is possible but all parties must be involved to optimize interactions. Accurate data is required for this interaction to succeed.

Recommendations: An integrated study plan which includes all users and all aspects of the environment should be developed. One agency must represent the ecosystem since resource conflicts are partially based on individual exploitation of the common resource, e.g., mangroves and water quality; the issues are complicated, involve multiple resource use and have long-lasting implications for a variety of social, political and natural resources.

- Determine if the decline in kg/ha of ponds is real. If not, determine where the data are incorrect. Can this situation be rectified? If the decline is real, what are the reasons behind it? Are they ecological, economic or political?
- Examine the existing data to see if there are any other data which could be summarized for long-term analysis.
- Develop a complete fisheries statistical analysis and continue data collection.
- Support the newly-established effort to formalize a captain's log book to summarize fishing effort: trips, hours, etc.

3. Conclusion: The variations are high enough now to mask the relatively smaller changes in stock size due to present reductions in mangrove.
Recommendation: An analysis of the effects of climate on the annual variations in stocks should be completed. It would be especially useful to examine the effects of oceanic temperature anomalies on shrimp and on other stocks.

4. Conclusion: Postlarvae supplies can be increased without exploiting additional mangrove zones by reducing the loss of postlarvae after capture and before introduction into ponds.
Recommendation: Promulgate techniques to increase the supply of postlarvae by decreasing the mortality of those caught.

Table 1
List of Shrimp of Commercial Importance (McPadden, 1985)

Common Name	Family	Species
Blanco	*Penaidae*	*Penaeus vannamiei* *P. stylirostris* *P. occidentalis*
Cafe	*Penaidae*	*P. californiensis*
Rojo	*Penaidae*	*P. brevirostris*
Zebra	*Penaidae*	*Trachypenaeus byrdi* *T. pacificus* *T. face*
Pomada/Titi	*Penaidae*	*Xiphopenaeus riveti* *Protrachypenaeus precipua*
Carapachudo	*Solonoceridae*	*Solonocera spp.*
Camrones de Profundidad	*Pandalidae*	*Heterocarpus spp.*

Table 2
Distribution of Shrimp Species in Marine and Pond Harvests
(from M. Cobo, mimeo report)

Species	% Commercial Catch	% Pond Harvest
P. occidentalis	70	5
P. styliorstris	15 to 20	95
P. vannamei	2 to 3	0
P. californiensis	3	0
Trachypeneus byrdi	minor	0
T. faoea	"	0
T. similis pacificus	"	0
Xiphopeneus riveti	"	0
Protrachypene precipua	"	0
Solenocera florea	"	0

Table 3
Summary of Examples of Penaeid Shrimp Stock Changes Following Intertidal Wetland Changes

Area	Vegetation Changes	Stock Changes	Source
Louisiana	Quantity, quality	Quantity, quality	Turner unpub.
Kuwait and Saudi Arabia	Quantity	Quantity	Morgan and Garcia, 1982
Japan	None; mudflat reclamation	Quantity	Doi et al., 1973
El Salvador	Quantity	Quantity	Daugherty, 1975
Vietnam	Quantity	Quantity	Norman, 1983

Table 4
Area of Mangrove, Camaroneras and Salinas in Ecuador, circa 1982-1984 (Valdivieso, no date)

Province	Camaroneras	Manglares	Salinas
Guayas	52,912	119,526	17,340
El Oro	26,484	24,456	2,520
Manabi	8,377	12,416	164
Esmeraldas	1,595	30,153	–
TOTAL	89,368	186,551	20,024

Table 5
Changes (in hectares) from 1966 to 1982 in Mangrove, Salinas and Other Estuarine Zones in a Pilot Study Area in El Oro Province (from CLIRSEN, 1983)

Zone	1966	1977	1982
Urban	256.7	434.7	588.5
Mangrove	4,692.9	4,231.7	3,294.1
Camaroneas	0.0	834.0	2,330.6
Rivers	1,437.5	1,514.5	1,465.7
Salinas	466.3	333.8	139.4
High Land Vegetation	466.3	333.8	162.6
Agriculture	615.2	730.2	634.7
TOTAL	8,556.3	8,548.6	8,555.1

Table 6
Variation in the Catch per Effort of Several Developed Shrimp Fisheries
(from Gulland and Rothschild, 1984)

Country	Years (n)	Coefficient of Variation (%)	Species	Source Page
Australia	10	52	Single	42
Australia	11	19.5	Single	43
Brazil-Guiana	19	23.8	All	61
Kuwait	16	43.5	All	74
Saudi Arabia Bahrain	11	39.7	All	74
Iran	12	50.4	All	75
Indonesia	9	93.2	All	107
Senegal	14	31.6	All	133
U.S.A. Gulf of Mexico	12	29.8	Single	164
U.S.A. Gulf of Mexico	12	24.5	Single	164
Ecuador	25	20.0	All	---

Table 7
Examples of the Effect of Climate on
Coastal Penaeid Shrimp Stocks

Location	Species	Effect on Yield	Source
North Carolina (U.S.A.)	*P. duorarum*	Temperature (-)	Hettler and Chester (1982)
Louisiana (U.S.A.)	*P. setiferus*	Salinity (-)	Barrett and Gillespie (1973)
	P. aztecus	Riverflow (-)	
Louisiana	*P. setiferus*	Salinity (-) Temperature (+)	Turner (1979)
	P. aztecus	Salinity (+) Temperature (+)	
Northern Gulf of Mexico (U.S.A.)	*P. setiferus*	Salinity (-) Temperature (+)	Copeland and Bechtel (1974)
	P. aztecus	Salinity (+) Temperature (+)	
Florida (U.S.A.)	*P. durarum*	Water Level (+)	Browder (1986)
Laguna Madre, Texas (U.S.A.; hypersaline)	*P. fluviatilis* *P. aztecus*	Rainfall (+)	Gunter and Edwards (1969)
Australia	*P. merguiensis*	Rainfall (+)	Staples et al. (1984) Ruello (1973)
Indonesia	*P. merguiensis* *P. monodon*	Riverflow (+)	Turner (1975)
Senegal	*P. duorarum*	Salinity (+)	Le Reste (1980)

Table 8
Drainage Area and Percent of the Total for the Major Rivers
in the Vicinity of the Guayas estuary (from Stevenson, 1981)

River	Drainage Area (km2)	Percent Total Area
Guayas	32,800	64.00
Jubones	4,280	8.34
Naranjal	3,060	6.00
Boliche	1,300	2.50
Arenillas	550	1.07
		Total % = 81.91

Figure 1. The relative density of penaeid shrimp stocks off the coast of Ecuador by depth contour (adapted from data in Loesch and Cobo, 1972).

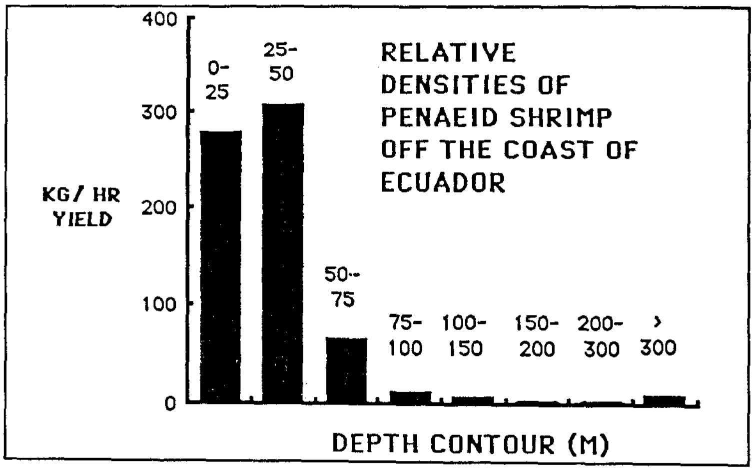


Figure 2. The relationship between intertidal vegetation and penaeid shrimp yields in Malaysia (adapted from data in Jothy, 1984).

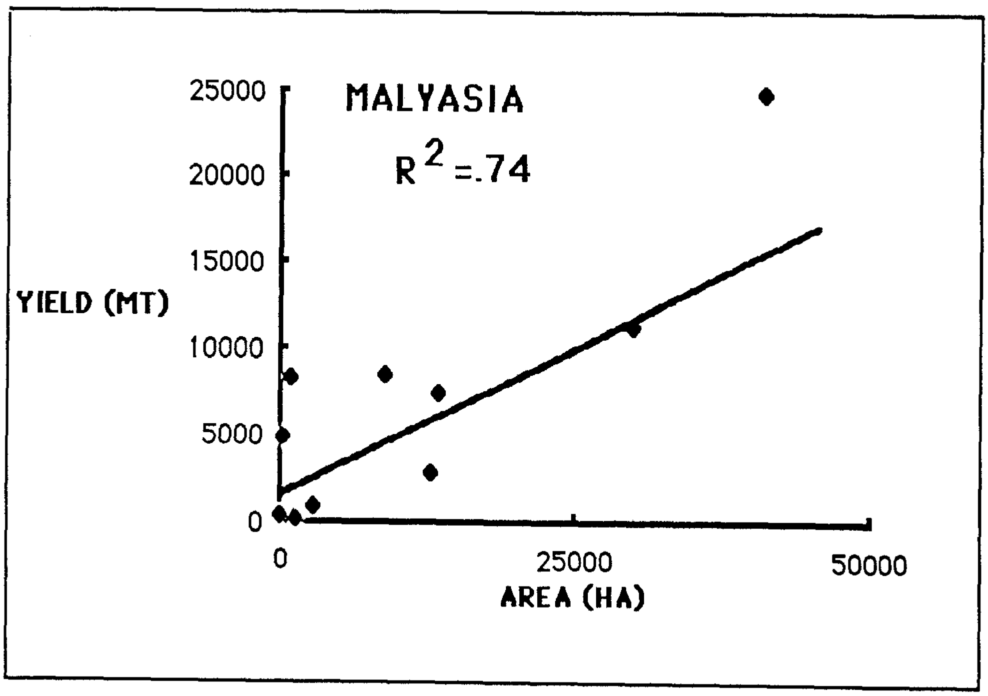


Figure 7. The percent of brown shrimp (P. aztecus) caught in the inshore waters of Louisiana from 1963-1976 (NMFS statistics).

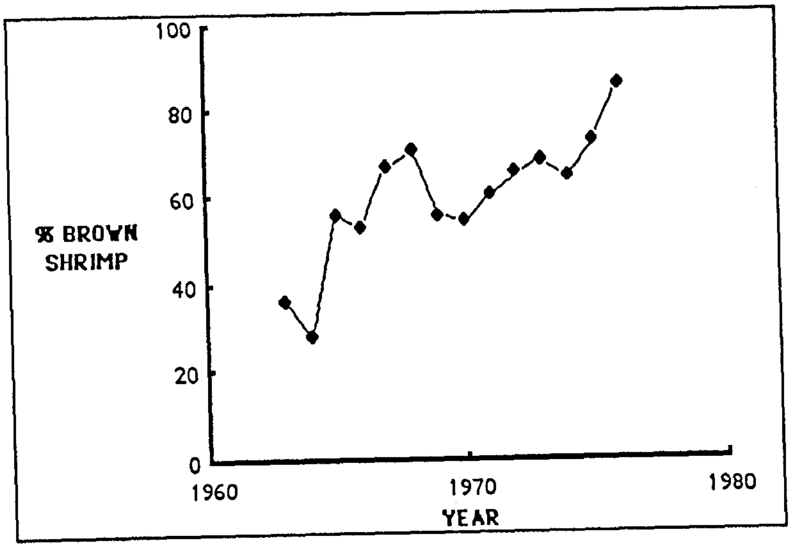


Figure 8. The decline of shrimp yields in Japan as related to reclamation of intertidal lands in Japan (from Doi, 1983).

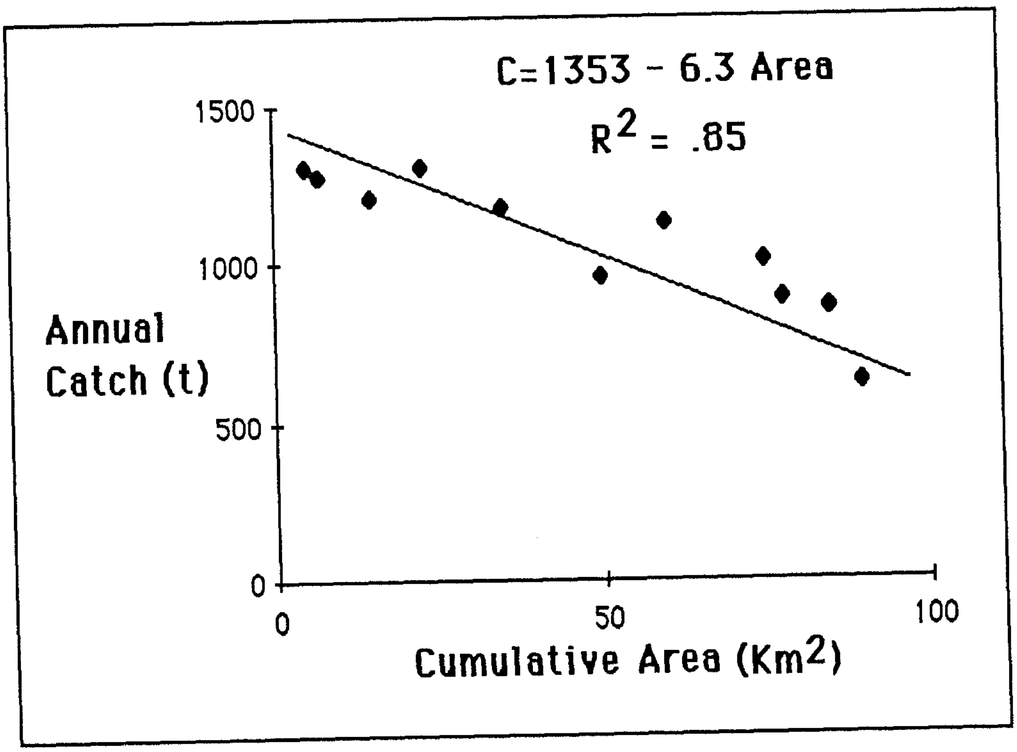


Figure 9. The number of trawling vessels in the industrial shrimp fleet and the catch per vessel from 1954 to 1984.

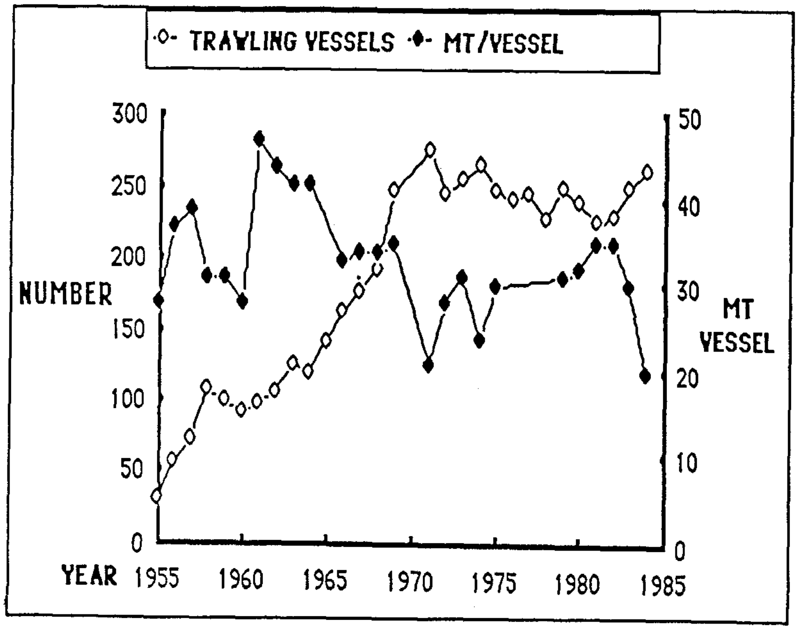


Figure 10. The distribution of horsepower in the offshore trawling fleet.

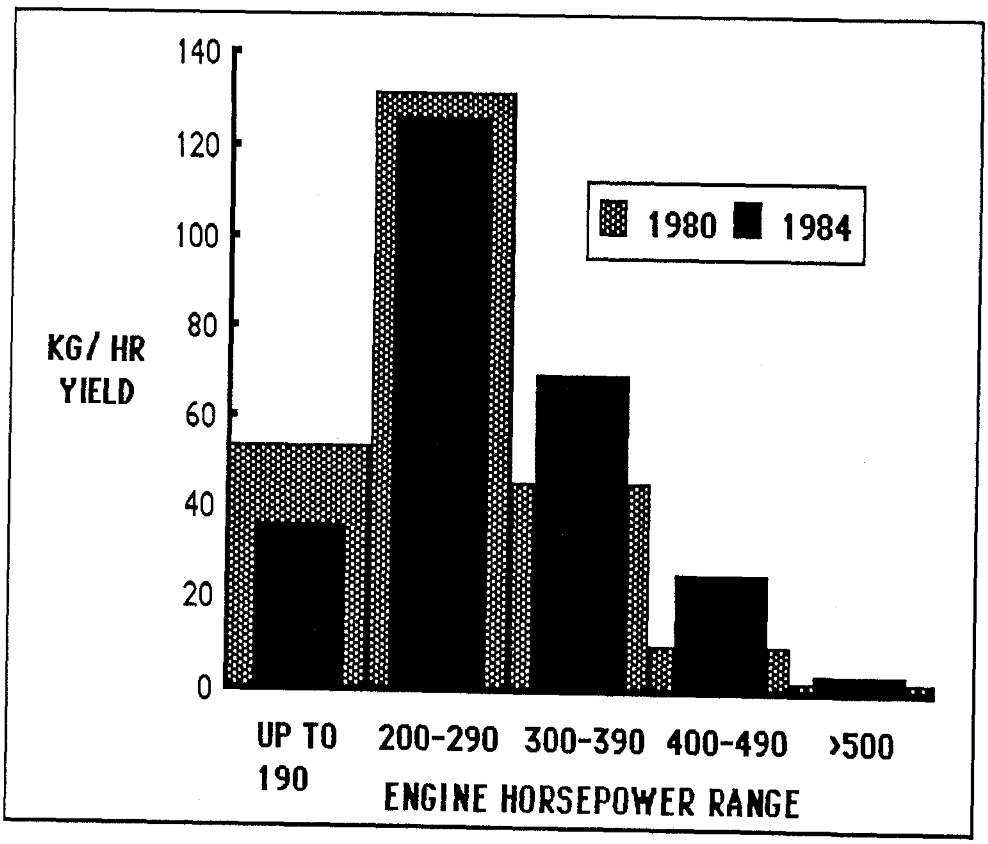


Figure 11. Annual changes in the percent catch which is P. vannamei within the Gulf of Guayaquil at the northern part of the Gulf (zona de Golfo) and the central and southern part (zona de Playas) (from Cun and Marin, 1982).

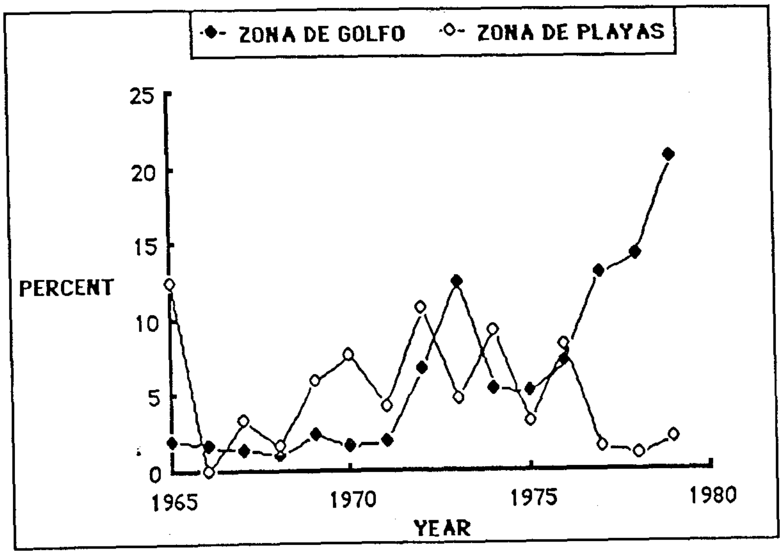
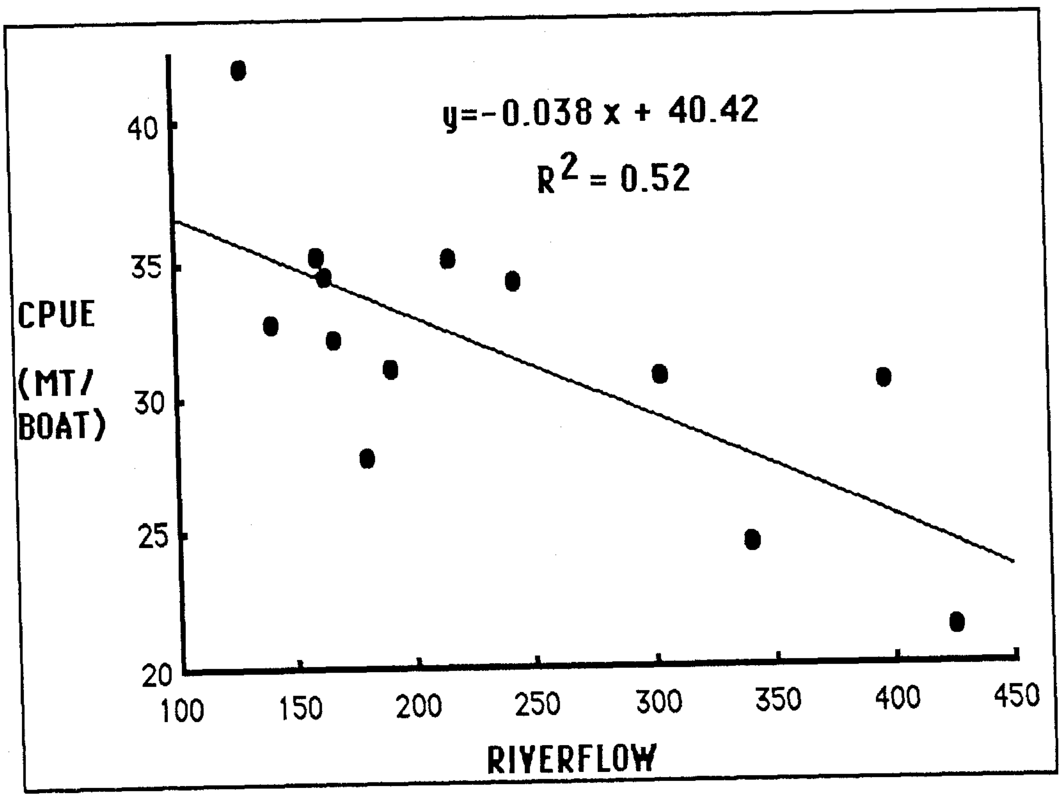


Figure 12. An example of climatic relationships with shrimp landings. Shown here is the relationship between winter riverflow (January through March) and trawl fisheries' catch per vessel for Ecuador from 1965 to 1979. The unofficial record of catch in the latest El Nino year resulted in a very high value for CPUE (not shown), suggesting that the curve rises steeply to the right, beyond the riverflow shown in this graph.



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