Section 8

THE POTENTIAL IMPACT ON COMMERCIAL FISHERIES OF GROUND PRE-EMPTED BY PETROLEUM-RELATED STRUCTURES ON GEORGES BANK

Stephen Olsen
Coastal Resources Center

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FISHING AND PETROLEUM INTERACTIONS ON GEORGES BANK

VOLUME II: THE CHARACTERISTICS OF THE TWO INDUSTRIES, POTENTIAL FUTURE TRENDS, AND AN ASSESSMENT OF FORESEEABLE CONFLICTS

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INTRODUCTION

Volume I of this report presented charts (Plates 3 and 4) that quantified domestic fishing activity in the Georges Bank vicinity cumulatively for the years 1965-1974 as days fished and pounds landed. These data were collected by the National Marine Fisheries Service (NMFS). Information was also presented that was gathered by interviewing fishermen (Plates 5 and 6) on which areas they consider the best fishing grounds. Volume I also contains a brief description of the gear used by commercial fishermen on and near Georges Bank and estimates of what the area might produce as a maximum sustainable yield under proper resource management. In this volume (Section 2) statistics are presented showing the proportion of landings at major ports taken in the Georges Bank vicinity in 1975. In this season we again focus on the distribution of domestic fishing activity. Further discussions with fishermen have resulted in only one small change in the location of fishing grounds; the prime longline ground on the Cultivator Shoal has been extended. Much work has been done, however, refining the NMFS data and comparing it to the information gathered from fishermen and the areas most likely to be impacted by offshore oil and gas activities.

Since NMFS data have appeared in various forms over the last 18 months it is useful to summarize the content and accuracy of the three versions that are presently available.

(1) Data collected by NMFS in blocks measuring 10 x 10 minutes of latitude and longitude (10 x 8.3 nautical miles) showing catches in dollars and pounds at major ports for the years 1969-1970 were presented in the MIT Georges Bank Petroleum Study (1973). The data accounted only for reported catches not total catches.

(2) The entire NMFS data file for 1965-1974 showing days fished and catches landed was first organized and made available as a prepublication report released by the NMFS Northeast Fisheries Center at Woods Hole in August, 1975. The data showed only the "raw" information gathered in interviews and were not prorated to account for the total catches taken by all vessels and boats or for the whole weight (as opposed to gutted or shucked weight) of all species. Since more large vessels are interviewed than small vessels and boats, the data were biased toward landings by large vessels; scallop landings were included as meat weights and not as the weight of the whole animal, and corrections were not made for fish that had been gutted. Beside not being adjusted to account for total

New England landings, the data file had not been audited for errors in data tabulation. These data were used in the report on commercial fisheries and petroleum development prepared at the Woods Hole Oceanographic Institution and released in April, 1976.

(3) The first volume of this report was released in January, 1976. The NMFS data presented had been prorated to show total landings of whole fish and shellfish. The data file had also been audited and errors corrected. Cumulative data for days fished and pounds landed for all species and all gear during the period 1965-1974 were presented. It was recognized that data for some species (notably lobster and swordfish) and some gear (primarily off-bottom gear) were inaccurate since the sampling techniques used in gathering the data did not cover these adequately.

(4) In this volume, only data within the potential Georges Bank oil and gas lease area (15.8 million acres) are examined. Three years, 1965, 1969 and 1974, have been selected for detailed analysis. Data are presented in both dollars and pounds for five species groups and are prorated to account for total New England landings of whole fish and shellfish.

DESCRIPTION OF THE DATA BASE

Data on domestic landings by areas measuring 10 x 10 minutes latitude and longitude are gathered only in New England by agents of the Statistics and Market News Division of the NMFS. The NMFS data file does not include domestic catches landed outside the New England region but the volume and value of those landings is not considered significant. NMFS agents are based in major ports and they gather the information by interviewing a sample of skippers as they unload their catch. The data gathered are for the "hailed weight," which is the skipper's estimate of what he has caught. The agents also gather some information, especially in smaller ports, from buyers. The reason why data on swordfish and lobster do not adequately account for those fisheries is that a large proportion of the catches are landed in small outlying ports or are sold directly to retail markets.

There are many problems inherent in the interviewing procedure used. Fishermen are usually reluctant to tell anyone precisely where they fish and many see no reason why such information should be gathered by a government agency. Cooperation and accuracy vary widely from skipper to skipper. Many will give only a general area such as "along the northern edge" or cite a loran bearing that crosses the entire southern part of the Bank. It is then up to the agent to assign the catch to one, or at the most three, 10 x 10 blocks. In many cases it would not be possible to file accurate data even if fishermen were willing to tell exactly where they fished. Many trips last for several days and catches may have been taken from a great variety of places as the fishermen search for fish. Even if the skipper remembered how much he had caught in each place the interview form does not permit recording more than three blocks. In practice the entire catch is usually assigned to one or two blocks. Clearly, the accuracy of the data depends in good part upon the skill and knowledge of the agent. Unfortunately, there has been a complete turnover in the personnel performing the interviews during the study period and some port agents have needed more time to learn than others. All these problems are recognized by NMFS and those familiar with the data stress that undue credence should not be given to data for a single 10 x 10 block. Larger patterns of distribution should be evaluated.

METHODS USED IN THIS ANALYSIS

The amount of time required to manipulate the data file enabled us to examine in detail only three of the 10 years for which data are available. The years 1965, 1969 and 1974 promised to provide the best overview of trends in domestic fisheries over the decade. Since data on offbottom gear are very sketchy they were not included in the analysis. Large volume landings of industrial fish caught in Rhode Island Sound had influenced the intervals in the numerical code used to rate individual blocks in the data presented in Volume I; in this analysis only data for 10 x 10 blocks encompassed by the potential oil and lease area were examined. The data for the three years were arrayed into six species groups:

(1) pelagics and squid
(2) all flounders
(3) other groundfish
(4) crustaceans
(5) mollusks other than squid
(6) all species

Dollar values were assigned by prorating the values recorded in the interview data to account for total New England landings. Computer printouts were then generated that rated each 10 x 10 block on a scale of 1-9 by pounds and by dollars, separately, for each species group and for each of the three years.

Patterns of distribution were then examined in six subareas within the potential lease area (Figure 1). Since, for the purposes of this study, we wish to define areas where fishing tends to be concentrated over a long period, and not during a single year, the three years of detailed data were combined. It is well known that fishermen using a given kind of gear concentrate their activities in discrete areas known as fishing grounds. It was found that the areas delineated by the three highest of the nine intervals by the NMFS data came closest to the description of grounds compiled by interviewing fishermen. In some cases the area thus delineated varied slightly between the dollar and pound charts. This is because the unit value of some species is more than others; an area that produced large codfish might rate as a 6 on the pounds chart but as a 7 on the dollars chart. It was decided therefore to delineate "grounds" as those areas rated in the three highest intervals by dollars or pounds or both.

An examination of the "grounds" thus delineated for each individual year showed that the areas were relatively constant. For the purposes of this study, the area delineated as "grounds" by pounds and/or dollars for each species group for the three years combined was selected for study. The catches taken in each subarea in pounds and constant 1974 dollars during the three years was extracted from the data file and summed for "grounds" and "nongrounds". The results of this analysis are displayed in the Map Supplement to Volume II of this report.

Table 1 shows the three-year average catch for each species group from the entire potential gas and oil lease area both within and without "grounds" as defined above. Thus, an average 175 million pounds ($33.4 million) of fish and shellfish were taken annually in the Georges Bank lease area and landed in New England ports. Catches taken on "grounds" were 140 million pounds compared to 35 million pounds taken on "nongrounds". Table 2 gives the contribution of each subarea to the total average catch from the entire potential lease area. For example, 14 percent of the flounder in dollars ($1.8 million) were taken in subarea 3 where tracts under consideration for the first lease sale are concentrated.[1] Table 3 breaks down the data for each subarea into the average value and volume of catches inside and outside "grounds". Thus the area defined as "flounder ground" in subarea 3 produced an average of $1.2 million in flounder or $9,619 per lease tract. Areas defined as "non-ground" produced an average $0.5 million of flounder or $1,002 per tract. Data for pounds are also provided.

Table 4 gives the degree of overlap between "ground" as defined by the NMFS data and by fishermen in interviews with the lease tracts selected for study for the first lease sale and tracts considered of high and medium interest by the petroleum companies. If we continue to pursue the example of flounder ground, as defined by the NMFS data in subarea 3, we see that 3.9 percent of the ground overlaps with tracts selected for study for the first lease sale. However, the area delineated by fishermen as "prime trawling ground, especially for yellowtail flounder" overlaps 27.5 percent with the first sale tracts.

Unfortunately, the degree of agreement between "grounds" as defined by the NMFS data and by fishermen in interviews is consistently poor. This is illustrated by Table 5. There are many possible reasons for this discrepancy. An area that fishermen agree is a prime ground for a certain species, may not necessarily produce a large number of pounds and dollars when compared to the Bank as a whole. It is the author's opinion, however, that the problem rests primarily with the difficulties inherent in the collection of the NMFS data. It is the author's opinion that the values that can be attached to "grounds" and "non-grounds" in the subareas from the NMFS data are fairly good indications of the true values. However, the precise geographic location of those grounds and non-grounds is probably more accurately reflected in the charts compiled by interviewing fishermen. This information was presented in Volume I and is again reproduced in the charts attached to this volume.

Summary Results

Subarea 3, where tracts likely to be sold in the first lease sale are concentrated, is one of the least productive areas of the Bank when catches of all species are considered. According to the NMFS data, the average productivity of "grounds" per tract for all species is 77,179 pounds worth $20,890, compared to 164,410 pounds and $29,585 per tract in the most productive subarea 1. However, subarea 3 is of relatively high importance when flounder and scallop (mollusks excluding squid) grounds are considered. One of the conclusions that may be drawn from this is that the port of New Bedford, which is the center for flounder and scallop fisheries, could be more severely impacted than other ports by petroleum-related activities on Georges Bank.

The three principal potential sources of problems and conflicts between fishermen and petroleum-related activities on Georges Bank are traffic, debris on seafloor and pre-empted ground. The problem of debris is discussed in Section 9. Traffic problems can be minimized if supply boats travel in recognized lanes and the men running these vessels are educated to be familiar with the behavior of fishing vessels. In the North Sea, there have been a number of incidents between fishing vessels and supply boats, some of which have involved collisions. A major reason for these problems appears to be that the men operating the supply boats do not recognize the limited maneuverability of a fishing vessel that is towing gear and the necessity of keeping a careful lookout at all times. In bad weather, small, wooden-hulled fishing vessels may not show up on a radar screen.

The following discussion is an attempt to assess the amount of fishing ground that may be pre-empted from fishing by oil-related activities and structures.

AREA PRE-EMPTED FROM FISHING BY PETROLEUM-RELATED STRUCTURES

The problems caused by the loss of fishing grounds pre-empted by petroleum-related structures are of considerable concern. In the Gulf of Mexico, fishing is known to be especially good around platforms since these attract fish as an "artificial reef." Platforms are popular among hook and line fishermen. According to the MIT Georges Bank Petroleum Study (1973), however, trawlers in the Gulf generally operate no closer than one-half mile to platforms. In the North Sea, a 500-meter (1,650-foot) buffer zone around offshore structures is enforced within which fishing vessels may not operate. The 500-meter buffer zone was established by international law for all offshore structures at the Continental Shelf Convention held in Geneva in 1958 (Brownlie, 1972). Kowalski (1976) reports that a de-facto zone with a one-kilometer radius from which fishing vessels are excluded is enforced around some platforms in the North Sea. This takes place when activities around a structure are particularly intense. Since fishing operations on Georges Bank are similar to those in the North Sea it appears reasonable to assume that there will be at least a 500-meter exclusion zone around individual platforms on Georges Bank. Appendix A provides calculations showing that a 500-meter buffer is reasonable in light of the turning radii of fishing vessels operating towed gear. If we assume that the average platform has a diameter of 200 feet, the total excluded area for an individual platform would be 220 acres. A jack-up drilling rig would exclude a similar area. Semi-submersible drilling rigs, however, are held in place by a series of anchors (generally nine). The anchor lines may be assumed to extend out 1,500 feet (Draft Environmental Impact Statement, BLM, 1976). If a 1,650-foot (500-meter) buffer zone is included beyond the anchors, the total excluded area would be some 715 acres. However, if fishermen know the precise location of the anchors it is reasonable to assume that they could, at least in good weather, operate towed gear (trawl or scallop dredge) within 300 feet of the anchors. In this case the area excluded by each semisubmersible would be 233 acres. Since semisubmersibles are used only for exploratory drilling, the area pre-empted by them would be only temporarily withdrawn. Pipe-laying operations would also temporarily exclude a large area.

The oil and gas reserves on Georges Bank are expected to be relatively small. According to the Draft Environmental Impact Statement (BLM, 1976) it is likely that oil and gas will be brought to shore by tanker. Loading would probably take place at a buoy some 6,500 feet away from the platform. If a 1,650-foot buffer (500-meter) is established around the platform, the pipeline to the buoy and the tanker, some 686 acres would be pre-empted. If only a 300-foot buffer is extended around the pipeline and the loading area some 360 acres would be pre-empted.

At present (Draft EIS, BLM, 1976) it appears that pipelines on Georges Bank will be buried "where technically and economically feasible as determined by the USGS Area Oil and Gas Supervisor." It is unclear whether gathering lines among platforms and between platforms and loading buoys will be buried. It may be assumed that fishing will be permitted over buried pipelines but not over unburied pipelines and gathering lines. If a 1,650-foot or 300-foot buffer were enforced on either side of unburied pipelines and gathering lines the excluded area would total 364 acres or 73 acres per mile of pipe. The problems relating to towed fishing gear and pipelines are discussed in Appendix B.

The amount of area excluded by a cluster of offshore structures is much greater than the area excluded by isolated individual structures. A small North Sea oil field that is probably comparable to the size of fields that may be developed on Georges Bank is the Forties Field. There are four platforms on this field that are spaced two to three miles apart and linked to one another by gathering lines. According to a report prepared for the Department of Agriculture and Fisheries for Scotland (1975), fishermen are not prepared to risk fouling their gear on the trenched (not buried) gathering lines and the close proximity of the platforms makes maneuvering difficult when towing gear, especially in bad weather. The report estimates that the Forties Field excludes 6,400 acres (10 square miles) from fishing.

POTENTIAL AREA PRE-EMPTED ON GEORGES BANK

Exploratory drilling on Georges Bank may involve the operation of 6 to 10 semisubmersibles (see Section 7). The area temporarily pre-empted could be 1,400 to 2,330 acres if fishing vessels stand off 300 feet from the anchors. Estimates for a total of 25 to 50 platforms are cited in Section 7 for the high and low find scenarios. It is not possible at this time to foresee how many of these platforms will be clustered and how many will be associated with a loading buoy. However, the following gives an indication for the potential magnitude of the areas involved:[2]

	25 platforms	50 platforms
Individual platforms (1,650-foot buffer	8.6 sq. miles	17.2 sq. miles
Individual platforms with loading zone (300-ft. buffer around loading zone and pipe)	14.1 " "	28.2 " "
Individual platforms with loading zone (1,650 ft. with buffer around complex)	26.8 " "	53.6 " "
Clusters similar to Forties Field	62.5 " "	125.0 " "

A combination of clusters and individual platforms will probably be seen if development takes place. If we assume a hypothetical worst case, and the maximum amount of area is pre-empted by platforms and related structures under the high find scenario, some 125 square miles could be pre-empted by clustered platforms in small fields. This is equivalent to some 14 lease tracts. If, for a hypothetical worst case, all the pre-empted area was in the most valuable "ground" for all species in a subarea containing lease tracts being considered for the first sale (subarea 1), the loss suffered per year would total 2.3 million pounds worth $414,190. This is 1.3 percent of the pounds and 1.2 percent of the value of the average annual Georges Bank domestic catch.[3]

The above "worst case" is unrealistic for many reasons. First of all, not all platforms would be in subarea 1 nor would they be in clusters that exclude 10 square miles for every four platforms. Also, virtually all commercially important species on Georges Bank migrate and it is reasonable to assume that at least some of the fish temporarily out of reach to fishermen would be caught elsewhere at another time.

The estimated worst case above, however, does not account for losses of ground due to unburied pipelines, debris and subsea completions. It also does not account for the potential recovery of stocks under 200-mile limit management practices or the gradual increase in the proportion of Georges Bank catches taken by domestic, rather than foreign, fishermen. In Volume I, it was hypothesized that, under good management Georges Bank could produce a maximum sustainable yield (MSY) of 420,000 metric tons (924 million pounds) of fish compared to the average yield of 175 million pounds ($33.4 million) taken by domestic fishermen in 1965, 1969 and 1974, according to NMFS data. If Georges Bank were harvested at the MSY level and all catches were taken by domestic fishermen, it is hypothesized that the total catch might be worth $142 million (this takes into account the low unit price of much of this catch). It may be further estimated that this would generate an annual total of $420 million in transactions of which $166 million would be personal income. If the area pre-empted in the hypothetical worst case above proportionally increased in productivity and value under these hypothetical MSY conditions, the area exempted could be valued at an annual $1.7 million. These landings could annually produce $5 million in transactions of which $2 million would be personal income.

Not considered in the above discussion is the potential impact of lost ground due to unburied pipelines, subsea completions and debris. There is at present no way in which one can estimate how much area these structures could pre-empt.

CONCLUSIONS

The impact of the pre-emption of fishing ground by petroleum-related structures could be significant. A large proportion of the Georges Bank scallop and flounder grounds lies within lease tracts being considered for the first lease sale. The impacts could be most noticeable in ports where these fisheries are important. Impacts may be softened if the number of structures are minimized and if fishermen are consulted before the precise location of a structure is decided upon. A small adjustment in the placement of a structure could mean the saving of one or several "tows" and thus reduce the impact of lost ground.

FOOTNOTES

[1] Data for crustaceans (lobster) are recognized by NMFS to be incomplete and should be used with caution.

[2] No estimate is made here of the area excluded by subsea completions or the number of subsea completions that may be placed on Georges Bank. The areas involved, however, could be sizable.

Table 1. New England Landings From Georges Bank Vicinity By Species Group; Three Year Average From NMFS Data

		Flounders	Other Groundfish	Pelagics and Squid	Crustaceans	Mollusks except Squid	All Species
Grounds	lbs	57,055,748	62,328,145	312,261	2,604,076	17,951,655	140,251,885
	$	10,716,701	9,642,097	182,392	3,207,495	3,078,953	26,827,638
Non-Grounds	lbs	11,337,062	18,513,410	38,526	442,169	4,867,095	35,198,262
	$	2,339,788	2,808,608	7,336	649,696	786,037	6,591,464
Total	lbs	68,392,810	80,841,555	350,787	3,046,245	22,818,751	175,450,147
	$	13,056,489	12,450,705	189,728	3,857,191	3,864,975	33,419,070

Table 2. Contribution of Each Subarea to Landings from the Georges Bank Area: Subarea 1 (Three Year Average from NMFS Data)

	Flounders	Other Groundfish	Pelagics and Squid	Crustaceans	Mollusks except Squid	All Species
lbs	15,508,809	26,440,899	8	330,614	2,142,493	44,422,823
% total lbs	22.7	32.7	<1	10.9	9.4	25.3
$	2,933,981	4,300,761	1.7	489,040	335,066	8,058,851
% total $	22.5	34.5	<1	12.7	8.7	24.1

Table 2 (con't.). Subarea 2.

	Flounders	Other Groundfish	Pelagics and Squid	Crustaceans	Mollusks except Squid	All Species
lbs	9,738,463	2,783,442	87,892	104,613	3,719,472	16,433,882
% total lbs	14.2	3.4	25.1	3.4	16.3	9.4
$	1,721,949	468,302	98,300	168,989	611,988	3,068,527
% total $	13.2	3.8	51.8	4.4	15.8	9.2

Table 2 (con't.). Subarea 3.

	Flounders	Other Groundfish	Pelagics and Squid	Crustaceans	Mollusks except Squid	All Species
lbs	8,351,259	5,315,983	35,326	1,220,256	4,493,356	19,416,181
% total lbs	12.2	6.6	10.1	40.1	19.7	11.1
$	1,781,835	922,471	37,849	1,442,373	740,080	4,924,941
% total $	13.6	7.4	19.9	37.4	19.1	14.7

Table 2 (con't.). Subarea 4.

	Flounders	Other Groundfish	Pelagics and Squid	Crustaceans	Mollusks except Squid	All Species
lbs	22,510,684	4,557,966	75,607	990,745	5,498,673	33,633,675
% total lbs	32.9	5.6	21.6	32.5	24.1	19.2
$	4,207,025	709,169	26,917	1,214,988	981,799	7,139,897
% total $	32.2	5.7	14.2	31.5	25.4	21.4

Table 2 (con't.). Subarea 5.

	Flounders	Other Groundfish	Pelagics and Squid	Crustaceans	Mollusks except Squid	All Species
lbs	1,544,769	3,053,023	146,456	378,037	---	5,122,285
% total lbs	2.3	3.8	41.8	12.4	---	2.9
$	293,273	113,826	25,914	507,916	---	940,929
% total $	2.2	<1	13.7	13.2	---	2.8

Table 2 (con't.). Subarea 6.

	Flounders	Other Groundfish	Pelagics and Squid	Crustaceans	Mollusks except Squid	All Species
lbs	10,738,826	38,690,241	5,497	21,979	6,964,757	56,421,301
% total lbs	15.7	47.9	1.6	<1	30.5	32.2
$	2,118,408	5,937,177	747	35,884	1,195,709	9,285,925
% total $	16.2	47.7	<1	<1	30.9	27.8

Table 3. Landings by Subarea and by Species Group: Subarea 1.
(Three Year Average from NMFS Data)

		Flounders	Other Groundfish	Pelagics and Squid	Crustaceans	Mollusks except Squid	All Species
Grounds	lbs	13,051,837	22,586,532	---	222,769	966,592	36,827,730
	lbs/tract	85,306	66,432	---	3,908	60,412	164,410
	$	2,453,862	3,707,436	---	315,471	150,349	6,627,118
	$/tract	16,038	10,904	---	5,535	9,397	29,585
Non-Grounds	lbs	2,456,972	3,854,367	8	107,845	1,175,901	7,595,093
	lbs/tract	5,741	15,993	<1	206	2,081	21,275
	$	480,136	593,325	1.7	173,569	184,718	1,431,749
	$/tract	1,122	2,462	<1	331	327	4,011
Total	lbs	15,508,809	26,440,899	8	330,614	2,142,493	44,422,823
	lbs/tract	26,693	45,509	<1	569	3,688	76,459
	$	2,933,981	4,300,761	1.7	489,040	335,066	8,058,857
	$/tract	5,050	7,402	<1	842	577	13,871

Table 3 (con't.). Subarea 2.

		Flounders	Other Groundfish	Pelagics and Squid	Crustaceans	Mollusks except Squid	All Species
Grounds	lbs	8,806,369	416,079	87,846	23,292	2,858,434	12,192,014
	lbs/tract	88,064	34,673	5,490	1,456	26,714	158,338
	$	1,519,642	82,466	98,293	42,186	471,810	2,214,396
	#/tract	15,196	6,872	6,143	2,637	4,409	28,758
Non-Grounds	lbs	932,094	2,367,363	52	81,321	861,038	4,241,868
	lbs/tract	4,460	7,971	<1	277	4,263	18,284
	$	202,308	384,836	7	126,803	140,178	854,131
	$/tract	967	1,296	<1	431	694	3,682
Total	lbs	9,738,403	2,783,442	87,892	104,613	3,719,472	16,433,882
	lbs/tract	31,516	9,008	284	339	12,037	53,184
	$	1,721,949	468,302	98,300	168,989	611,988	3,068,527
	$/tract	5,573	1,516	318	547	1,981	9,931

Table 3 (con't.). Subarea 3.

		Flounders	Other Groundfish	Pelagics and Squid	Crustaceans	Mollusks except Squid	All Species
Grounds	lbs	5,936,220	894,852	35,018	1,146,795	3,233,424	11,246,309
	lbs/tract	46,017	74,571	1,297	11,946	33,682	77,179
	$	1,240,911	158,383	37,762	1,324,669	538,938	3,300,663
	$/tract	9,619	13,199	1,399	13,799	5,614	20,890
Non-Grounds	lbs	2,415,039	4,421,131	308	73,461	1,259,932	8,169,871
	lbs/tract	4,472	6,729	<1	128	2,199	15,988
	$	540,924	764,087	87	117,704	201,476	1,624,279
	$/tract	1,002	1,163	<1	205	352	1,222
Total	lbs	8,351,259	5,315,983	35,324	1,220,256	4,493,356	19,416,178
	lbs/tract	12,483	7,946	55	1,824	6,717	29,023
	$	1,781,836	922,471	37,849	1,442,373	740,413	4,924,941
	$/tract	2,663	1,379	59	2,156	1,107	7,362

Table 3 (con't.). Subarea 4.

		Flounders	Other Groundfish	Pelagics and Squid	Crustaceans	Mollusks except Squid	All Species
Grounds	lbs	21,891,351	2,501,289	47,582	934,848	5,276,042	30,651,112
	lbs/tract	77,629	39,703	1,133	5,026	50,248	143,902
	$	4,064,300	76,568	21,822	1,138,713	943,003	6,577,739
	$/tract	14,412	1,215	520	6,122	8,981	30,881
Non-Grounds	lbs	619,333	2,056,677	28,025	55,897	222,631	2,982,563
	lbs/tract	3,479	5,181	67	204	627	12,075
	$	142,725	299,267	5,096	76,275	38,796	562,159
	$/tract	802	754	12	278	109	2,276
Total	lbs	22,510,684	4,557,966	75,607	990,745	5,498,673	3,363,675
	lbs/tract	48,936	9,909	164	2,154	11,954	73,117
	$	4,207,025	709,169	26,917	1,214,988	981,799	7,139,897
	$/tract	9,146	1,542	59	2,641	2,134	15,522

Table 3 (con't.). Subarea 5.

		Flounders	Other Groundfish	Pelagics and Squid	Crustaceans	Mollusks except Squid	All Species
Grounds	lbs	664,871	1,672,339	141,821	276,372	---	2,755,402
	lbs/tract	44,325	42,880	2,149	7,677	---	45,923
	$	121,195	38,168	24,516	386,456	---	570,334
	$/tract	8,080	977	371	10,735	---	9,506
Non-Grounds	lbs	879,898	1,380,685	4,635	101,665	---	2,366,866
	lbs/tract	3,911	6,869	27	498	---	13,149
	$	172,079	75,658	1,398	121,461	---	390,595
	$/tract	765	376	8	595	---	2,170
Total	lbs	1,544,769	3,053,023	146,456	378,037	---	5,122,285
	lbs/tract	6,437	12,721	610	1,575	---	21,343
	$	293,273	113,826	25,914	507,916	---	940,929
	$/tract	1,222	474	108	2,116	---	3,921

Table 3 (con't.). Subarea 6.

		Flounders	Other Groundfish	Pelagics and Squid	Crustaceans	Mollusks except Squid	All Species
Grounds	lbs	6,705,100	34,257,054	---	---	5,617,164	46,579,317
	lbs/tract	38,758	88,291	---	---	43,544	147,871
	$	1,316,792	5,245,742	---	---	974,854	7,537,388
	$/tract	7,612	13,520	---	---	7,557	23,928
Non-Grounds	lbs	4,033,726	4,433,187	5,497	21,979	1,347,593	9,841,983
	lbs/tract	9,696	22,056	9	37	2,230	35,920
	$	801,616	691,435	747	33,884	220,855	1,748,537
	$/tract	1,927	3,440	1.3	58	480	6,382
Total	lbs	10,378,826	38,690,241	5,497	21,972	6,964,757	56,421,301
	lbs/tract	17,621	65,688	9	37	11,825	95,792
	$	2,118,408	5,937,177	747	33,884	1,195,709	9,285,925
	$/tract	3,597	10,080	1.3	58	2,030	15,766

Table 4. Overlap of High and Medium Petroleum Company Interest and First Lease Sale with Fishing Grounds as Deliniated Through Interviews: Subarea 1.

	% OVERLAP		
	High Interest	Medium Interest	First Sale
Total Subarea	0.2	2.4	2.2
Domestic Fishing Grounds Prime Grd., Esp. Yellowtail	---	5.0	6.0
Prime Grd., Esp. Cod & Haddock	---	---	---
Inshore Mixed Groundfish	---	---	---
Lobster Ground	---	---	---
Prime Gray Sole Ground	---	---	---
Fluke & Butterfish Ground	---	---	---
Scallop Dredge Ground	---	36.0	32.0
NMFS Fishing Grounds Groundfish except Flounder	---	3.5	2.9
Flounder	---	7.8	6.5
Mollusks except Squid	---	---	---
Crustaceans	---	7.0	8.8
Pelagics and Squid	---	---	---
All Species	---	5.3	4.5

Table 4 (con't.). Subarea 2.

	% OVERLAP		
	High Interest	Medium Interest	First Sale
Total Subarea	8.4	17.5	10.8
Domestic Fishing Grounds Prime Grd., Esp. Yellowtail	21.0	20.0	26.3
Prime Grd., Esp. Cod & Haddock	---	---	---
Inshore Mixed Groundfish	---	---	---
Lobster Ground	---	---	---
Prime Gray Sole Ground	---	---	---
Fluke & Butterfish Ground	---	---	---
Scallop Dredge Ground	24.1	27.7	25.3
NMFS Fishing Grounds Groundfish except Flounder	---	---	---
Flounder	5.0	24.0	10.0
Mollusks except Squid	14.0	15.9	16.8
Crustaceans	---	18.7	---
Pelagics and Squid	31.2	31.2	37.5
All Species	6.5	27.3	13.0

Table 4 (con't.). Subarea 3.

	% OVERLAP		
	High Interest	Medium Interest	First Sale
Total Subarea	17.2	18.1	20.5
Domestic Fishing Grounds Prime Grd., Esp. Yellowtail	27.5	16.4	30.0
Prime Grd., Esp. Cod & Haddock	---	---	---
Inshore Mixed Groundfish	---	---	---
Lobster Ground	1.8	19.6	3.6
Prime Gray Sole Ground	7.0	4.2	9.8
Fluke & Butterfish Ground	---	---	---
Scallop Dredge Ground	34.1	25.3	35.2
NMFS Fishing Grounds Groundfish except Flounder	---	---	---
Flounder	3.9	10.8	4.6
Mollusks except Squid	36.5	22.9	37.5
Crustaceans	4.2	21.9	5.2
Pelagics and Squid	---	7.4	---
All Species	5.7	10.7	6.3

Table 4 (con't.). Subarea 4.

	% OVERLAP		
	High Interest	Medium Interest	First Sale
Total Subarea	2.4	7.6	3.5
Domestic Fishing Grounds Prime Grd., Esp. Yellowtail	---	21.1	---
Prime Grd., Esp. Cod & Haddock	6.0	24.0	6.0
Inshore Mixed Groundfish	3.9	5.2	4.8
Lobster Ground	---	---	---
Prime Gray Sole Ground	---	---	---
Fluke & Butterfish Ground	---	5.7	3.8
Scallop Dredge Ground	25.0	41.7	25.0
NMFS Fishing Grounds Groundfish except Flounder	---	6.3	---
Flounder	2.8	5.0	3.5
Mollusks except Squid	8.6	19.0	9.5
Crustaceans	---	6.4	2.7
Pelagics and Squid	4.8	---	4.8
All Species	0.9	10.3	1.9

Table 4 (con't.). Subarea 5.

	% OVERLAP		
	High Interest	Medium Interest	First Sale
Total Subarea	0.8	1.7	1.3
Domestic Fishing Grounds Prime Grd., Esp. Yellowtail	---	---	---
Prime Grd., Esp. Cod & Haddock	---	---	---
Inshore Mixed Groundfish	---	---	---
Lobster Ground	---	---	---
Prime Gray Sole Ground	---	---	---
Fluke & Butterfish Ground	---	---	---
Scallop Dredge Ground	---	---	---
NMFS Fishing Grounds Groundfish except Flounder	---	---	---
Flounder	---	---	---
Mollusks except Squid	---	---	---
Crustaceans	---	---	---
Pelagics and Squid	---	---	---
All Species	---	---	---

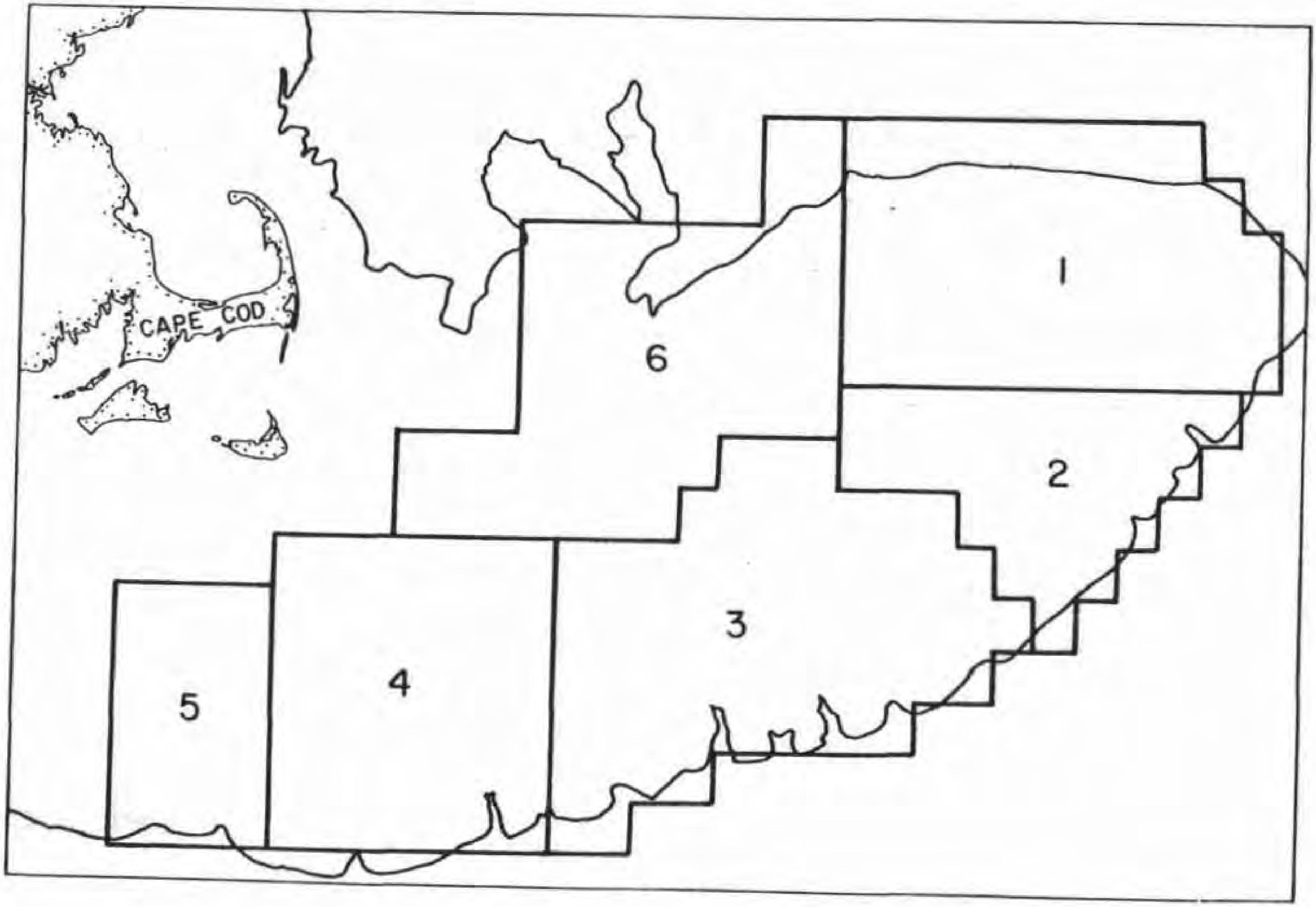
Table 4 (con't.). Subarea 6.

	% OVERLAP		
	High Interest	Medium Interest	First Sale
Total Subarea	---	4.1	0.8
Domestic Fishing Grounds Prime Grd., Esp. Yellowtail	---	20.4	---
Prime Grd., Esp. Cod & Haddock	---	8.4	2.3
Inshore Mixed Groundfish	---	---	---
Lobster Ground	---	---	---
Prime Gray Sole Ground	---	---	---
Fluke & Butterfish Ground	---	---	---
Scallop Dredge Ground	---	3.8	---
NMFS Fishing Grounds Groundfish except Flounder	---	5.7	1.3
Flounder	---	10.4	2.3
Mollusks except Squid	---	9.3	0.8
Crustaceans	---	---	---
Pelagics and Squid	---	---	---
All Species	---	7.0	1.6

Table 5. Agreement Between Grounds as Deliniated Through NMFS Landing Data and Interviews Conducted For This Study

TRAWL		SCALLOP DREDGE	
Subarea	% Agreement	Subarea	% Agreement
1	38.5	1	0
2	0	2	17.9
3	0	3	8.5
4	9.5	4	2.0
5	15.0	5	0
6	52.9	6	10.0

Fig. 1. Subareas Within the Georges Bank Potential Lease Area



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Section 8

Appendix A

FISHING VESSEL MANEUVERABILITY STUDIES

Saul B. Saila
Graduate School of Oceanography

Tadeusz Kowalski
Department of Ocean Engineering

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Section 8

Appendix A

FISHING VESSEL MANEUVERABILITY STUDIES

Saul B. Saila
Graduate School of Oceanography

Tadeusz Kowalski
Department of Ocean Engineering

INTRODUCTION

The ability of fishing boats that are towing nets to maneuver around and between obstructions has a bearing on the safety zones that should be extended around obstructions and on calculating the amount of fishing ground that is removed from operational fishing due to the presence of the obstruction(s).

The simplest way to define the maneuverability of a trawler is by means of a radius R which describes the steady turning circle for that particular vessel. When a trawler is in a continuous turn with a constant rudder angle and speed the final stages of motion become a circle of radius R. When the trawler is towing a trawl net while turning in a circle the trawl will describe another circle of radius r. If the trawler is trawling in an area where there is a uniform current, then the whole system has a maximum possible drift equal to the speed of the current added to the circular motion.

This section outlines a very simplified method for calculation of the two radii described above. The object of these calculations is to produce a rapid and simple way to estimate the turning radii of the trawler-trawl system.

The analysis is based on the method of estimating the turning radius of a trawler as described by Rossel and Chapman (1947) and the method for determining the trajectory of a midwater trawl as given by Karapuzov (1966).

A number of assumptions had to be made in order to develop simple methods for these calculations. They include the following: the speed of trawling is assumed to be between 2 and 4 knots. No account is taken of current effects on the net alone. In spite of these assumptions the methodology developed in this manner seems reasonable for certain types of decisions.

The following information is required for estimating the turning radius of the trawler and the trawl net.

∇ = volume of displacement of the trawler (ft^3). This is approximately equal to 35x displacement in tons if the vessel is floating in salt water.

L = length of the trawler at the waterline (ft).

T = draft amidships of the trawler (ft).

α = rudder angle, degrees.

l = horizontal projection of the warp length (ft).

CALCULATION METHODS

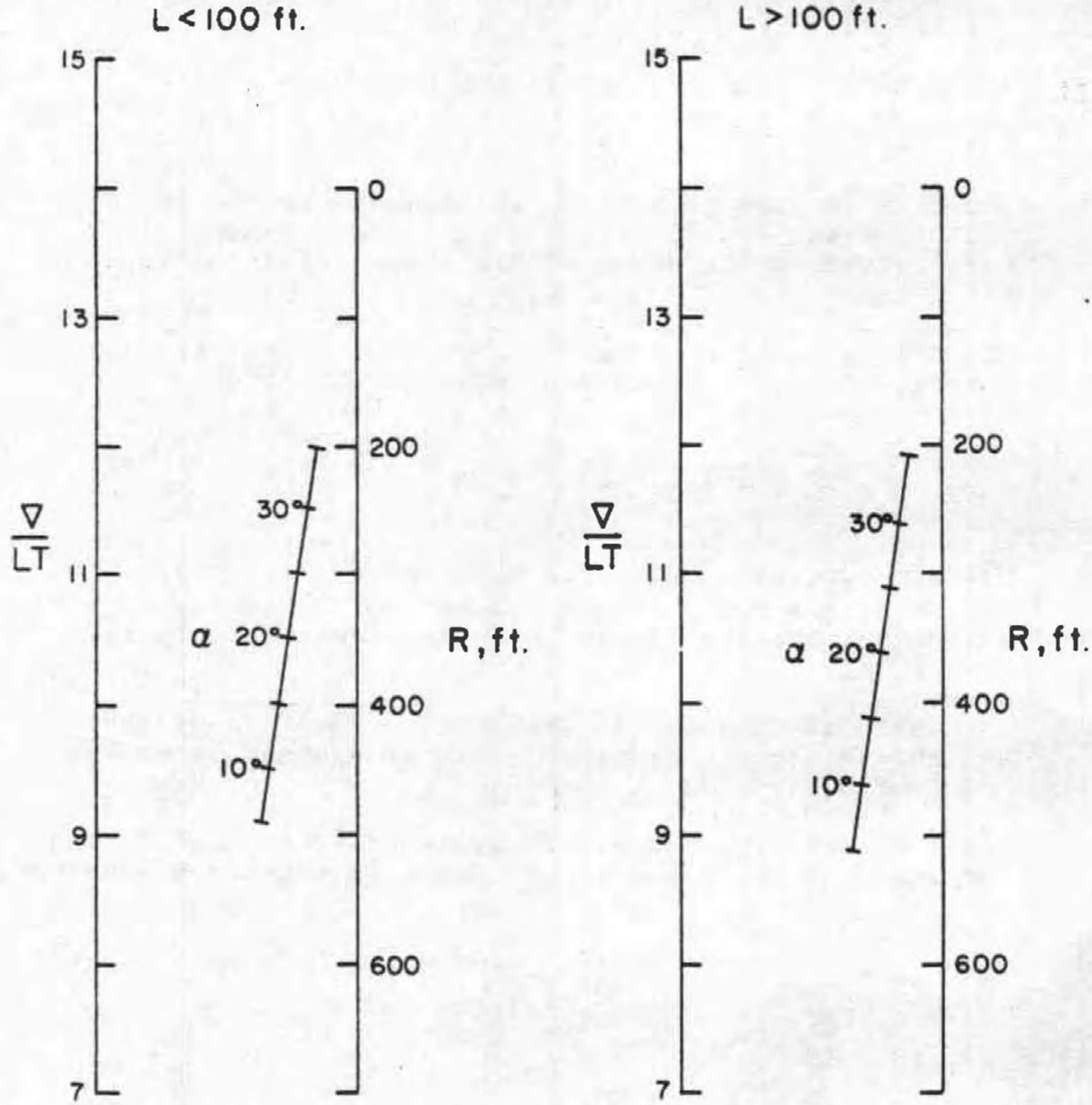
Figure 1 is used to estimate the turning radius of the trawler in the following manner. A straight line drawn through points on the ∇/LT and α scales, and the intersection of this line on the R line gives the turning radius. There are two nomographs in Figure 1. One is for trawlers shorter than 100 feet (for example, most trawlers of the current Point Judith, Rhode Island fleet) and the second for trawlers longer than 100 feet, such as those fishing from Boston and Gloucester as well as the current foreign fleet. The range of Figure 1 data includes values for the Point Judith fleet. Thus:

Alliance and Ocean State	∇/LT = 10.1	At a rudder angle of 15° this radius is about 400 ft.
For the John and Cindy	∇/LT = 7.7.	At a similar rudder angle of 15° this radius is 300 ft.

Alternatively, the following formula (Eqn. 1) can be used for the same calculation:

$$R = K \frac{\nabla (0.195 + 0.305 \sin \alpha)}{A(0.811 \sin\alpha \cos\alpha)} \qquad (1)$$

Fig. 1. Nomograph for determining the turning radius (R) of a fishing trawler.



∇ = VOLUME OF DISPLACEMENT, ft^3

L = LENGTH ON WATERLINE, ft.

T = DRAFT, ft.

α = RUDDER ANGLE, degs.

R = TURNING RADIUS, ft.

where:

A = rudder area, ft^2. This can be approximated by $A = 0.021\ LT$, when L and T are as defined previously. Suitable values of K for substitution are indicated below.

$K = 0.38$ for $L < 100$ ft.

$K = 0.40$ for $L > 100$ ft.

Figure 2 is used to provide an estimate of the turning radius of the trawl. After finding the trawler's turning radius the value of R/L gives r/R for a known R/l ratio.

The calculations of r can also be made using the following method. The angle of drift of the trawl δ is first calculated from:

$$\delta = \frac{1 + 0.75\ L}{R}\ \psi\,(1 - e^{-R/l\psi}). \qquad (2)$$

Optimum turning results are obtained for $1.3 \leq R/L \leq 1.5$. Values of R/l smaller than 1.3 may result in severe interaction between the trawler and the trawl net. In Equation 2 let:

ψ = angle of turn of the trawler ($\psi = 360°$ means that the trawler turned completely around and is on the same heading as at $\psi = 0°$).

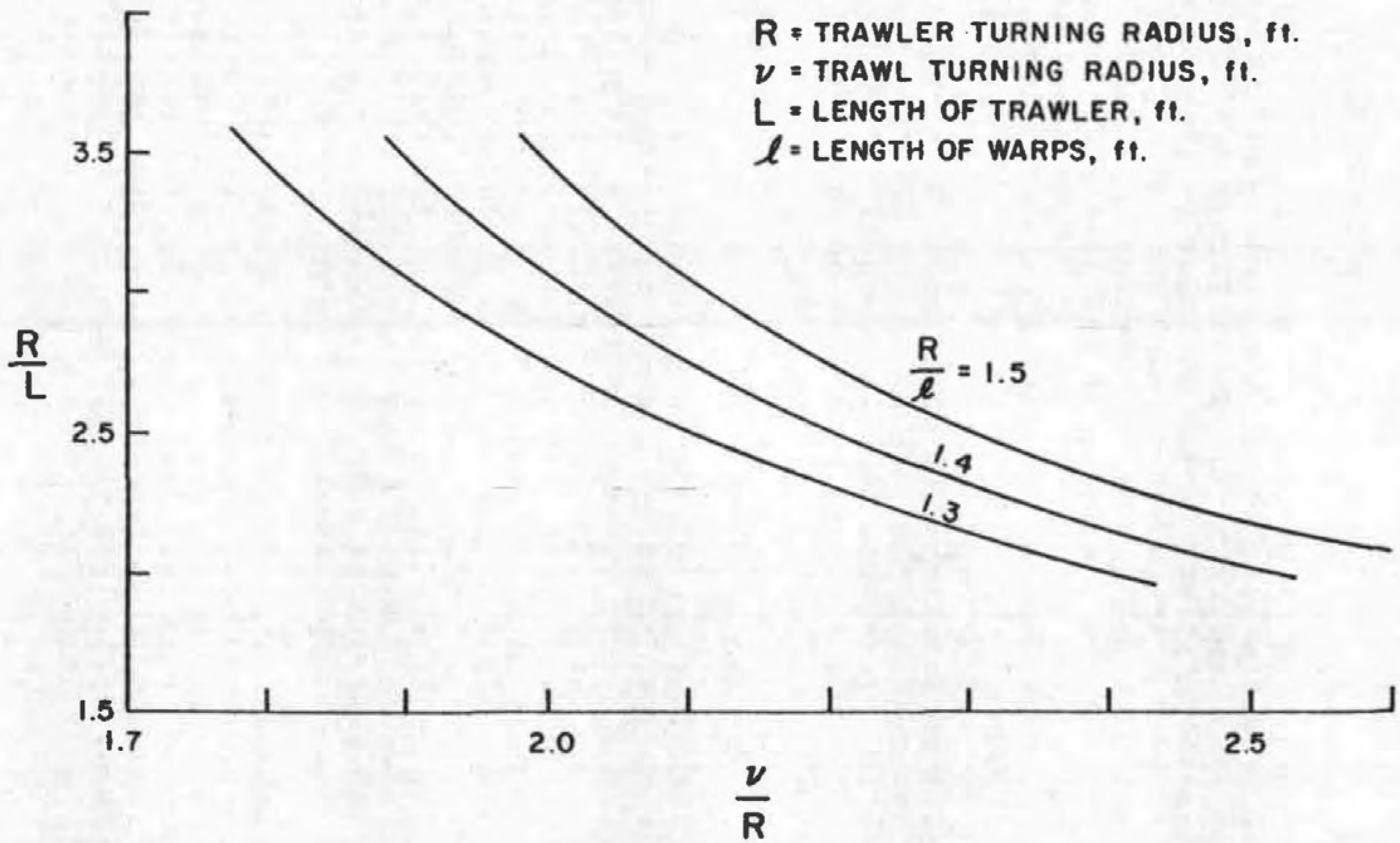
After calculating angles δ corresponding to angles ψ an average $\bar{\delta}$ is obtained for a number of R/L and R/l values. Then

$$\frac{r}{R} = \frac{l}{L}\ \frac{\sin\beta}{\sin(\bar{\delta} - \beta)} \qquad (3)$$

where:

$$\sin\beta = \frac{0.75\ L}{R}\ .$$

Fig. 2. Nomograph for calculating the turning radius (r) of the trawl net.



After obtaining the value of r for a given set of conditions the center about which the trawler-trawl system is rotating can be found from the following equation which is calculated for a radius R_c away from the stern of the trawler.

$$R_c = r \text{ secant } (\bar{\delta} - \beta). \quad (4)$$

Hence, Eqn. 4 provides an estimate of the turning radius R_c required for the trawler-trawl net system to clear a fixed obstruction. It is highly desirable that a suitable safety factor be added to this to allow for drift due to currents, wind and human errors which were not included in the calculations. A factor of 50 percent has been chosen for the safety factor above the calculated turning radius R_c. This new system turning radius is termed R_T after the safety factor has been applied.

For computational purposes some values of $\bar{\delta}$ are provided in Table 1. These values are considered reasonable for computations, and linear interpolation can be applied for values which lie between the tabulated terms.

Example Calculations

Illustrations of the data and all the computations necessary to estimate the trawler-trawl system turning radii are provided. The trawler Alliance is considered to be representative of the smaller size class of trawlers which can safely fish the Georges Banks area on a reasonably regular basis. Thus, it is considered as a lower limit on the size vessels which might encounter obstructions on the New England outer Continental Shelf. The details of the computations for this vessel are shown in Table 2. From this table it is evident that the safe system turning radius is on the order of 650 feet or approximately 200 meters.

Table 3 illustrates the details of similar computations performed for the largest vessel type currently encountered on the New England outer Continental Shelf area. From this table it is evident that the turning radius of this type of trawler-trawl net system is about 1,425 feet or approximately 435 meters. The rudder angles for these two examples are not identical so that these two computations are not exactly comparable. However, these data do provide some indication of the system turning radius, and this is believed to have an important bearing on the size of safety zones to be established around oil industry structures. Thus calculated safe turning radii range from about 650 to 1,500 feet, depending on the size of the fishing vessel. It should be pointed out that the USSR has recently placed an order in Poland for even larger vessels, the B-690 class which will be 178.3 meters long and 11,500 tons deadweight.

Table 1. Average trawl drift angles δ which are suggested for the calculation of R_c, the trawler-trawl net system turning radius.

	"R/L"			
"r/R"	1.5	3	2.5	3
1.3	27.5	32.5	36.0	39
1.4	24.5	29.5	33.6	37
1.5	21.5	27.0	31.0	34

DISCUSSION AND CONCLUSIONS

The results of these studies demonstrated that a safety zone with a radius of 500 meters around fixed objects in the sea seems reasonable. This suggests that the 500-meter radius safety zone established by international law should be applied in the New England outer Continental Shelf area as well.

The 500-meter safety zone also seems reasonalbe based on the accuracy and precision of navigational equipment now in use. It is believed that Loran C will permit navigation within a distance of ± 100 meters almost anywhere on the New England outer Continental Shelf. It is believed that the accuracy and percision of navigational equipment will improve in the relatively near future. Thus, it is concluded that vessels should be able to stay away from all obstructions clearly indicated on navigational charts if a safety zone of 500 meters is employed. There may be extremely rare exceptions to this case when a vessel attempts a turn under very adverse weather and tide conditions.

It is anticipated that the average size of fishing trawlers will decrease somewhat from the present average size. Indeed, it is suggested that the expected size of the U.S. trawler fleet on the New England outer Continental Shelf will not exceed 150 feet in the foreseeable future, because the large refrigerated factory type of vessel used by the foreign fleets will not be cost-effective for such short steaming distances. The estimated size of the largest U.S. fishing vessels on the New England outer Continental Shelf is expected to be approximately 130 feet in length with about a 13-foot draft and a displacement weight of about 200 tons.

In summary, a 500-meter safety zone around major obstructions seems reasonable from a consideration of both turning radii and navigational accuracy. The actual loss of fishing grounds and the possible conflicts with fishermen will depend upon the intensity of oil-number and gas-related activity, the spacing and number of obstructions, and the degree of collaboration between the two industries. However, for first approximation calculations an area with a radius of 500 meters around each obstruction seems reasonable.

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Table 2

Trawler-trawl System Turning Radius Calculations for Trawler <u>Alliance</u> from the Pt. Judith, Rhode Island Fleet.

Input Data:

Δ = tons displacement = 302 tons

L = length of waterline = 83.8 feet

T = draft amid ships = 12.5 feet

∇ = volume of displacement = 35 x 302 = 10570 ft^3

Calculations:

$$\frac{\nabla}{LT} = \frac{10570}{(83.8)\ (12.5)} = 10.1$$

For a rudder angle α of 35° and a value of 10.1 for $\frac{\nabla}{LT}$, from Figure 1 a value of R = 170 ft. is found.

$\frac{R}{L} = \frac{170}{83.3} = 2.0$, and for $\frac{R}{1} = 1.4$, from Figure 2

$\frac{r}{R} = 2.5$. Thus, from $\frac{r}{170} = 2.5$, r = 425 ft.

From Eqn. (4) which states that $R_c = r$ secant $(\delta - \beta)$ and from $\sin \beta = \frac{0.75L}{R}$ we find:

$$\sin \beta = \frac{(0.75)\ (83.8)}{170} = 0.3697 \text{ and } \beta = 21.7$$

From Table 3 $\delta = 33.6°$. Thus,

$$R_c = 425 \sec 11.9° = 434 \text{ ft.}$$

Using a safety factor of 50 percent, R_T, the calculated safe system turning radius = 651 ft. or approximately 200 meters.

Table 3

Trawler-trawl System Turning Radius Calculations for the Longest Size-Class of USSR Production Regrigerated Trawlers - Steam Type, to be Found in the Georges Bank Area

Input Data:

Δ = tons displacement = 2800 tons

L = length at water line = 340 feet

T = draft amid ships = 19 feet

∇ = volume of displacement = 35 x 2800 = 98,000 ft^3

Calculations:

$$\frac{\nabla}{LT} = \frac{98000}{(340)(19)} = 15.2$$

For a rudder angle of $\alpha = 15°$ and a value of 15.2 for $\frac{\nabla}{LT}$, from Figure 1 a value of R = 600 ft. is found.

$\frac{R}{L} = \frac{600}{340} = 1.76$, and for $\frac{R}{1} = 1.4$, from Figure 2.

$\frac{r}{R} = 2.75$, thus for $\frac{r}{340} = 2.75$, r = 935 ft.

From Eqn. (4) which states that $R_c = r \text{ secant } (\delta - \beta)$ and from $\sin \beta = \frac{0.75L}{R}$ we find:

$$\sin \beta = \frac{(0.75)(340)}{600} = 0.425 \quad \beta = 25.15°$$

From Table 3, $\delta = 35.3$. Thus,

R_c = 935 sec 10.10° = 950 ft.

Using a safety factor of 50 percent, R_T, the calculated safe system turning radius = 1425 ft. or approximately 434 meters.

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Section 8

Appendix B

SUBMARINE PIPELINE STUDIES

Tadeusz Kowalski

Department of Ocean Engineering

Saul B. Saila

Graduate School of Oceanography

INTRODUCTION

This appendix is based largely on a document entitled "Foundation Stability of Buried Offshore Pipelines. A Survey of Published Literature," by R. N. Manley and J. B. Herbich, TAMU-SG-76-204, Feb. 1976. The reader is referred to this document for further details.

In general the stability of a pipeline on the sea bed is dependent upon the magnitude of various hydrodynamic forces acting upon it. If the pipeline is unburied and on the sea floor, currents can scour out areas, causing a spanning between points on the sea bed. This will induce bending stresses of varying magnitude. In addition rapid currents may induce vortices which are shed at frequencies dependent upon flow conditions and pipe dimensions. Under some conditions, this vortex shedding can induce structural resonance, which will cause the pipeline to oscillate, and then further stresses may be induced. Finally, the exposed pipeline in a span area is vulnerable to being hooked by an otter board (trawl door) of a fishing vessel or by some anchoring device.

The stability of pipelines buried in the sea bed is also dependent upon the magnitude of several forces acting upon it, and these include the weight and apparent shear force of the overburdening soil as well as the weight, diameter and buoyance of the pipeline. If the currents are great enough in the vicinity of a pipeline to cause scour, the overburden can be washed away, exposing the pipeline to hydrodynamic forces. If the soil overburden is natural backfill, the sediment load can sometimes liquefy and lose its shear strength. It will then not be able to exert a downward force on the pipeline, and the pipeline may float to the soil-water interface, where it will be exposed to hydrodynamic forces.

Several considerations are important in routing pipelines. The pipeline should be aligned with minimal orthogonality to prevailing currents and wave direction. The surface of the sea bed must be such that the maximum allowable radius of curvature of the line is not exceeded. Soft areas should be avoided to minimize floating or spanning, or areas of probable scour and active transport should also be avoided. It is very important to measure and to evaluate seasonal wave heights and scour limits when considering pipeline routing.

In general, because of possible flotation problems, it does not seem reasonable to permit natural backfilling of buried pipelines. Trench-filling by mechanical devices is highly desirable.

There are several unresolved problems with respect to routing offshore pipelines. These include the requirement of more detailed surveys which include studies of scouring from storm conditions, seasonal wave measurements, bottom current measurements and bottom sediment sampling and testing.

FORCES EXERTED ON A SUBMARINE PIPELINE BY A TRAWL DOOR

The problem of the effect of trawl doors dragging across submerged pipeline is being investigated by the River and Harbour Laboratory of the Technical University of Norway, Trondheim. The research has been following the standard route of theory, model tests and full scale tests. The work is being done under a grant from the Norwegian and British governments and some of the oil companies. This means that the public release of the research results is being delayed by at least one year. As of this time (April, 1976) the following work has been accomplished:

1. Theoretical analysis

2. Model scale tests

3. Equivalent half scale open sea tests

4. Full scale open sea tests

A report has been released of items 1 and 2 "Influences of Bottom Trawl Gear on Submarine Pipelines" Phase 1, dated April, 1974.

Tests of item 3 have been described in a paper given at the Offshore Technology Conference, Houston, Texas, May 1975. No numerical or even qualitative results are given. The release of these results is planned at a forthcoming conference in Stavanger, Norway, in September, 1976.

The following analysis is extracted from "Influences of Bottom Trawl Gear on Submarine Pipelines" Phase 1.

The direction of motion of the doors with respect to the pipeline produces different characteristic situations as described on pp. 29-33 of the above mentioned report.

The forces are analyzed individually although some combination of them may occur in certain situations.

The forces exterted on a pipeline by the trawl doors as the trawler pulls the bottom trawl across the pipe can be identified as follows:

1. Impact forces.
2. Pipeline reaction forces to the friction of the doors as they are pulled over the pipe.
3. Hooking forces.
4. Towing warp bending forces.

IMPACT FORCES

These are based on the kinetic energy available. The worst possible case will occur when the total kinetic energy is absorbed by the pipe during the impact and will be equal to K.E. - $1/2\ m\ V^2$. Values for a range of door weights and towing speeds are given in the following table in units of energy expressed as foot pounds.

	Speed, knts				
Door Weight, lbs.	2	2.5	3	3.5	4
			FT. LBS.		
500	89	139	200	272	355
1000	178	278	400	544	710
2000	355	556	800	1088	1420
4000	710	1112	1500	2176	2840

FRICTION FORCES ON THE PIPE AS THE TRAWL SLIDES OVER THE PIPE

These were obtained from model experiments. Only the speed and the angle of incidence are of importance. The results are averages of five runs. A factor of 0.5 was used in scaling these forces up to full size, to account for scale effect due to surface roughness differences.

Towing Speed Knots	Angle of Incidence Degrees	Friction Force Lbs.
2	65	6477
2	55	6969
5	65	6793
5	55	7110

FORCES ON A PIPELINE DUE TO HOOKING BY THE TRAWL DOOR

Under very specific conditions hooking of the trawl doors may occur. The forces imposed on the pipeline depend, after the first impact, on the power of the engines of the trawler, specifically on the so-called "bollard pull" of the trawler. The bollard pull of a trawler is defined as the thrust developed at maximum power at zero forward speed, a situation arising when the doors are hooked on the pipe and the trawler is stopped in its forward motion with the engines still fully on. If the pipe is strong enough and the warp line does not part the trawler will eventually be pulled back over the pipe and then unhooking of the doors will begin.

The hooking force will be modified by the elasticity of the warp cable and by the catenary of the warp.

Taking the most pessimistic set of circumstances the hooking force

$$F_H = \frac{M_V V_T^2}{\delta} \quad \text{and} \quad \delta = \sqrt{\frac{M_V L}{EF}}\, V_T \quad \therefore \quad F_H = V_T \sqrt{\frac{M_V EF}{L}}$$

where M_V = Mass of the trawler

V_T = Towing speed

δ = Elastic elongation of towing warp

E = Young's modulus of warp wire

F = Cross section of warp wire

L = Length of warp

F_H = Hooking force

F_T = Towing pull

In actual fact there are two modifying circumstances that considerably reduce the calculated hooking force F_H. They are:

1. The straightening of the catenary and the elasticity (elongation of the line) of the warp reduce the speed of the trawler V_T so that at the moment when the warp line is straight and the full hooking force is applied the velocity is much reduced. Hence F_T is is also reduced.

2. The trawling winches are equipped with a slipping clutch which is set to slip at about 10 percent - 20 percent above the towing pull F_T.

   The hooking force F_H therefore can be taken at 1.2 F_T from full scale test results.

For a typical North Sea Trawl door of about one ton weight (in air) the average forces will be:

(V) knots	2	2.5	3	3.5	4
(F_T) tons	2.8	4.0	5.0	6.4	8.0
(F_H) tons	3.4	4.8	6.0	7.6	9.6
(F_H) lbs.	7616	10752	13440	17024	21504

The above values compare favorably with the available bollard pull of 8 to 9 tons for trawlers of 85 to 120 feet with 500 horsepower-engines.

FORCES ON A PIPELINE DUE TO THE BENDING OF THE TOWING WARPS

This is a downward directed force occurring as the warps slide over the pipeline and happens only if the pipe diameter is greater than the height of the point of attachment of the warp line to the door (above the sea bed). The value of this force with a towing pull of 4 tons amounts to a maximum of 1800 pounds.

Further discussions with the personnel involved in the trawl gear-pipeline interference investigations disclosed the following qualitative results:

1. The power of the trawler is most important parameter.

2. The speed of the trawling (within the range of trawling speeds 2 to 5 knots) is not critical.

3. Hooking of the doors on a pipe occurs only under extremely unfavorable circumstances.

4. Since the hooking forces seem to be the maximum extered on a pipeline during the interaction between the trawl gear and the pipeline, the weight of the doors is not as important as the bollard pull of the trawler (which is proportional to the power of the trawler).

Comparing the values of the four separate forces that the trawler gear can exert on the pipeline, it is seen that the hooking force is the greatest. It is approximately equal to the bollard pull of the trawler. Hence, a very easy and quick estimate of the maximum force exterted on a submarine pipe is the bollard pull of the trawler.

CONCLUSIONS

Based on the theoretical and model test results of the River and Harbour Laboratory, Trondheim, the following conclusions have been obtained:

There is a definite problem of interference between the submarine pipelines and the bottom trawls operating over the pipelines.

The only safe situation is provided by burying the pipelines.

However, scouring and unsuitable bottom geology may leave the pipeline exposed on the bottom of the sea and interaction will occur.

The danger is to both the fishing gear and to the pipeline.

Since the damage or fracture of the pipeline is substantially more dangerous from the point of view of oil pollution and the expense of repair than the damage to the trawl gear, the solution to the problem of interference must be based on the protection of the pipe and sacrifice of the trawl gear when interaction occurs.

Protection of the submarine pipelines can be achieved by:

1. Burying the pipe and instituting a system of periodic visual inspections to check that the pipe stays buried. If scour occurs, the pipe should be trenched and covered again.

2. Requiring the trawlers to incorporate a tension release device in the warplines to slip the lines at, say, 20 percent above the towing pull. Alternately the winch clutch should be required to be set to slip at that tension.

3. Requiring the fishermen to deliberately abandon the trawl gear if it cannot be released from the pipeline without exerting more than 20 percent extra pull. Compensation will have to be provided for this deliberate sacrifice of the gear.

4. Designing the pipelines to withstand 120 percent of the towing pull of the largest trawler that is expected to use bottom trawl in the area. Conversely, restricting fishing rights in the area to trawlers of the specified engine power is also possible but not as attractive for the fishing industry.

The maximum force that the bottom trawl can exert on the submarine pipeline happens when hooking occurs and is approximately equal to the bollard pull of the trawler.

The above conclusions may be modified when the River and Harbour Laboratory releases the full scale experimental results.

In general, it is believed that further research on various types of protective coatings on pipelines and research designed to minimize the hooking properties of trawl doors are required for a better understanding and resolution of some of the existing problems.