Technical Report

Massachusetts Division of Marine Fisheries
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EXECUTIVE SUMMARY

In response to a request from the Massachusetts Legislature in July of 1993, a study of the Loligo squid fishery in Nantucket and Vineyard Sounds was conducted. The fishery consists of trawlers and weirs accounting for nearly all squid landings from the sounds with about one-quarter of the landings attributable to weirs. The squid fishery draws considerable attention when it begins close to the beach in late April since it is characterized by a "fleet" of trawlers up to 90' in length (vessel size limit), towing along the beach beginning during the early morning hours.

Study objectives were to: evaluate changes and trends in the fishery from 1978-1993 with emphasis on the trawl fishery; determine the effect of the inshore squid trawl fishery on other fisheries resources in state waters; describe the history and nature of squid fisheries in Massachusetts and federal waters; document the manner in which squid fisheries in Massachusetts waters have been managed; and evaluate the effect of offshore fisheries on squid and other fisheries resources in Massachusetts waters.

Squid is in danger of being overfished region-wide. Each year the spawning stock consists of only one cohort supporting inshore and offshore fisheries. The Mid-Atlantic Fishery Management Council, responsible for management of squid in federal waters, acknowledges the substantial potential for recruitment overfishing and the apparent negative relationship between offshore effort/catch and performance of the inshore squid fishery; i.e., a doubling of offshore effort since 1985 has been accompanied by a decrease in catch and catch per unit effort in inshore fisheries. Winter (January-April) 1993 landings reached an all-time high of about 29 million lbs. Of concern to local inshore fishermen, squid landings from Statistical Area 538 (primarily the sounds) have declined drastically. Area 538 landings in 1992 and 1993 were well below the 3.9 million lbs. average for the study period, and were only 2% and 4%, respectively, of U.S. landings. Preliminary 1994 landings indicate another dismal year for inshore fishermen.

In recent years the number of small trawlers (vessel classes 1&2) in Massachusetts' inshore squid fishery declined dramatically reaching its lowest point in 1993. Days fished and landings for these vessels decreased sharply as well. Involvement of small trawlers measured as percent of number of vessels, days fished, and pounds of squid landed reached its lowest point in 1993.

It will be unlikely that squid biomass arriving in the sounds each spring can continue to sustain the number and size of vessels participating in the May fishery. Catches by trawlers and weirs have declined. The fishery continues to shorten; i.e., since 1991, nearly all draggers departed the sounds before the fourth week of May after intense fishing during the first three weeks. A way to downsize the squid fleet is to reduce effort by larger vessels (class 3 & 4) that have greater catches of squid and by-catches of finfish than smaller vessels.

DMF sea sampling catch data were expanded to estimate trawlers' total catch and discard of commercially important species in 1993. Large vessels had higher winter flounder discards than small vessels (13.6 vs 2.2 lbs./hour). In 1993 effort of large vessels was almost three and one-half times the effort of small vessels (1,135 versus 3,758 hours). Most of this flounder catch and discard occurred towards the center of Nantucket Sound with most discard

being sublegal fish. This higher discard rate was expected since large vessels land a more mixed catch, tow more efficient gear, and fish longer in areas farther from shore where other species may be more abundant. High winds, typical during spring, are not as limiting for large vessels as they are for small vessels. Consequently, increased participation of large vessels (especially class 4) in the inshore squid fishery is a concern.

As a result, discarding of undersized flounders (and scup) during small-mesh fishing for squid especially in deeper waters of Nantucket and Vineyard Sounds poses a newly identified management problem for DMF and MFC. DMF analyses revealed that declines in abundance of some commercially valuable by-catch species (notably winter flounder) were consistent with regional abundance trends for these species. As regional abundance increases, by-catch increases; consequently, since large vessels have more by-catch than small vessels, large vessel by-catch could rise dramatically with increased regional abundance. Furthermore, with the recent collapse of important groundfish resources and expected tightening of New England Council Multispecies Plan regulations, large trawlers may turn some of their attention to squid in Massachusetts waters.

Besides downsizing the squid fleet in Massachusetts waters, small-mesh fishing for flounder and scup by all vessels should be minimized especially close to shore. This can be accomplished by prohibiting April squid fishing or extending the time of the existing DMF area closure in the sounds to April 23 unless or until a gear type can be developed to reduce or prevent by-catch.

Considering the impact of the offshore squid fishery on Massachusetts' inshore squid fishery, DMF must be adamant on the need for further restrictions offshore. For example, the Mid-Atlantic Council should curtail the expanding offshore fishery especially for very small squid by prohibiting squid fishing during the fall and early winter (in some or all areas) and/or by establishing a squid minimum size or a trawl mesh size to allow escapement of small squid. Other recommendations regarding Council management of squid (i.e. quotas) are provided.

The offshore fishery for squid and other species is problematic for Massachusetts. DMF analyses indicate that relationships between inshore spring trawling effort to local abundance of winter flounder, fluke, windowpane flounder, and black sea bass are weak or very weak. In contrast, relationships between offshore trawlers' effort is moderate to strong. Scup was the only species showing no relationship to inshore spring trawling effort or offshore effort. Consequently, actions such as prohibiting or seriously restricting the spring squid trawl fishery in Massachusetts waters may not increase finfish abundance if offshore effort remains high.

Other recommendations pertain to offshore squid fishery sea sampling, a continuation of DMF sea sampling of the inshore squid fishery, further research into squid spawning, and development of strategies to balance competing needs of trawlers and fish weirs in Massachusetts waters especially if federal management of squid involves a quota-based approach.

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INTRODUCTION

Purpose and objectives

Massachusetts Division of Marine Fisheries (DMF) and the Marine Fisheries Commission (MFC) have devoted considerable time to better management of the longfinned squid (Loligo peleai) fishery. From dealings with squid at-sea processing operations in Nantucket and Vineyard Sounds to setting a squid season with protection of small squid and reduced discard of juvenile finfish in mind, DMF and MFC have monitored and regulated the inshore squid fishery. This fishery is important to many inshore fishermen using weirs and draggers and to recreational fishermen who view squid as the bait that draws gamefish to Massachusetts waters.

This importance was highlighted by the 1993 legislative charge directing DMF to conduct a study of the effect of the squid trawl fishery on other fishery resources in state waters. This charge was accompanied by a public petition for a closure of Vineyard Sound to dragging -- a petition that eventually resulted in a MFC decision to seasonally close portions of Vineyard Sound to mobile gear fishing.

Both the charge to do a study and this petition occurred at about the same time as a Mid-Atlantic Fishery Management Council (MAFMC) decision to write a fifth amendment to its squid management plan. This Council is responsible for managing squid in federal waters. Since squid migrate between federal and state waters and any further attempts to improve management of squid in Massachusetts waters will be impacted by what occurs in federal waters, DMF decided to widen the scope of the study and to set the following objectives:

(1) Evaluate changes and trends in the fishery from 1978-1993 with emphasis on the trawl fishery;
(2) Determine the effect of the inshore squid trawl fishery on other fisheries resources in state waters, i.e., Nantucket and Vineyard Sounds;
(3) Describe the history and nature of squid fisheries in Massachusetts' and federal waters;
(4) Document the manner in which squid fisheries in Massachusetts' waters have been managed; and
(5) Evaluate the effect of offshore fisheries on squid and other fisheries resources in Massachusetts waters.

Information sources

To achieve these objectives, the following primary sources of information were used:

(1) DMF sea sampling data obtained on board squid fishing vessels in Nantucket and Vineyard Sounds especially during 1993;
(2) DMF Resource Assessment Project bottom trawl survey catches and a recent Project analysis of species distributions and abundance south of Cape Cod and in Buzzards Bay;

(3) National Marine Fisheries Service (NMFS) records of various species' landings and fishing effort from 1978 through 1993;
(4) Report of the 17th Northeast Regional Stock Assessment Workshop of January 1994;
(5) Draft 5th Amendment to the MAFMC Squid Management Plan;
(6) DMF records of fish weir landings of squid; and
(7) Previous Council management plans, DMF manuscripts, published research in scientific journals, and Commercial Fisheries News articles (see Literature Cited).

Responsible agencies/organizations

The following agencies/organizations affect Massachusetts marine fisheries management.

DMF — Massachusetts Division of Marine Fisheries regulates fishing within waters under the jurisdiction of the Commonwealth, including all of Nantucket Sound. DMF licenses commercial fishermen that fish in Massachusetts waters or land fish in the Commonwealth and collects statistics from commercial fishermen.

MFC — Massachusetts Marine Fisheries Commission is a 9-member board of citizens appointed by the Governor to vote on management proposals affecting fishing in waters under the jurisdiction of the Commonwealth.

NMFS — National Marine Fisheries Service, within the National Oceanic and Atmospheric Administration, conducts research, enforces regulations, collects landings data, advises the Councils, and protects habitat and threatened and endangered marine species.

MAFMC — Mid-Atlantic Fishery Management Council develops federal fishery management plans for selected species. Plans cover squid, mackerel, butterfish, surf clams, ocean quahogs, summer flounder, and bluefish. The Council includes state representatives from New York south to Virginia and representatives from relevant federal agencies.

NEFMC — The New England Fishery Management Council is similar to the Mid-Atlantic Council with state representatives from Maine south to Connecticut. There are Council plans for sea scallops, lobster, and groundfish (e.g., cod, haddock, flounders, and hakes).

ASMFC — Atlantic States Marine Fisheries Commission coordinates state regulations for those species caught primarily nearshore within states' territorial waters. Species include striped bass, northern shrimp, and winter flounder. ASMFC and the Councils have cooperated on a number of management plans such as summer flounder, bluefish, and lobster.

DMF concerns

Squid stock status

Squid is in danger of being overfished region-wide. For many years the MAFMC has had the benefit of a resource with a seemingly unreachable target, i.e., a maximum sustainable yield (MSY) of 44,000 metric tons (mt) (97.0 million lbs.). Landings averaged 17,800 mt just (39.2 million lbs.) during 1987-1992 (NEFSC 1994). Now, the Northeast Fisheries Science Center advises a MSY of 36,000 mt (79.3 million pounds), and the Council proposes this change for its new amendment. Using this assessment information to specify foreign fishery quotas for 1995 pursuant to the current fishery management plan, the Council already has established the 1995 optimum yield at 36,000 mt and has characterized the stock as being "probably fully exploited" at a "medium biomass level" (MAFMC 1994).

Moreover, squid biology suddenly has become clearer. Fishery scientists now believe squid don't live beyond one year, contrary to previous beliefs about a life history that spanned up to three years. Each year a single cohort supports both the fishery and spawning stock; consequently, as acknowledged by the Council, "The potential for recruitment overfishing is substantial since only one cohort exists at any one time."

This new assessment information combined with an expanding offshore fishery now has now made the Council's task quite challenging and made it necessary for the Commonwealth to be outspoken in its desire to ensure that offshore effort doesn't displace inshore fisheries such as those that exist in Massachusetts waters. For example, the report of the 17th SARC, stated:

> "...the 36,000 mt should not be viewed as an annual harvest target -- but more of an initial, rough upper bound on the sustainable yield from a cohort. In years of low Loligo biomass, however, this level of landings would likely result in severe reductions in spawning stock biomass...Failure to ensure an adequate annual level of spawning escapement can jeopardize both the stock and the fishery."

Regional and local management

Massachusetts seeks assurances that the inshore squid fishery will not be jeopardized by offshore fishing effort. As stated in the Council's draft management program:

> "...There appears to be a negative relationship between offshore effort/catch and performance of the inshore fishery. Recent increases in offshore effort (doubled since 1985) have been accompanied by a decrease in catch and catch per unit effort in the inshore fisheries..."

Since Massachusetts is at the northern edge of the Loligo squid fishery range, DMF and MFC are quite concerned about this possible relationship and fear that expanding offshore fisheries will displace inshore fisheries pursued by trawlers and weirs. Controls in the offshore fishery are necessary otherwise the inshore fishery will suffer. This year (1994) was

another dismal year for inshore squid fishermen whose ranks also have been joined by an increasing number of offshore squid fishermen pursuing squid wherever and whenever they are found.

Besides further controls in federal waters, DMF and MFC are aware that refinements in state management of inshore squid fisheries are necessary. Small-mesh fishing for squid, especially in deeper waters of Nantucket and Vineyard Sounds during April and May, can result in high catch and discard of undersized flounders and scup. Hence, DMF and MFC are concerned about new vessels coming to local waters to pursue squid -- vessels displaced from the groundfish fishery (cod, haddock, and flounders) by federal regulations mandating "days off" from groundfishing and by extensive area closures.

HISTORY OF U.S. AND FOREIGN SQUID FISHERIES

The U.S. fishery dating back to the late 1800's was dominated by weirs in inshore waters, especially in Massachusetts, with squid being sold primarily for bait. Landings were modest throughout the first half of the 20th century averaging about 4.4 million lbs. (2,000 mt) during 1928-1967 (Brodziak, 1994). These totals included some amounts of shortfinned squid, Illex illecebrosus.

A foreign fishery escalated in the late 1960's and dominated squid landings for two decades. This "directed" fishery began in 1967, and for the next 16 years through 1982, landings by foreign vessels exceeded the domestic fleet (Figure 1). Catches by foreign vessels reached a high of over 83 million lbs. (38,000 mt) in 1973. Domestic catches that year were a meager 2.4 million lbs., about 3% of total removals.

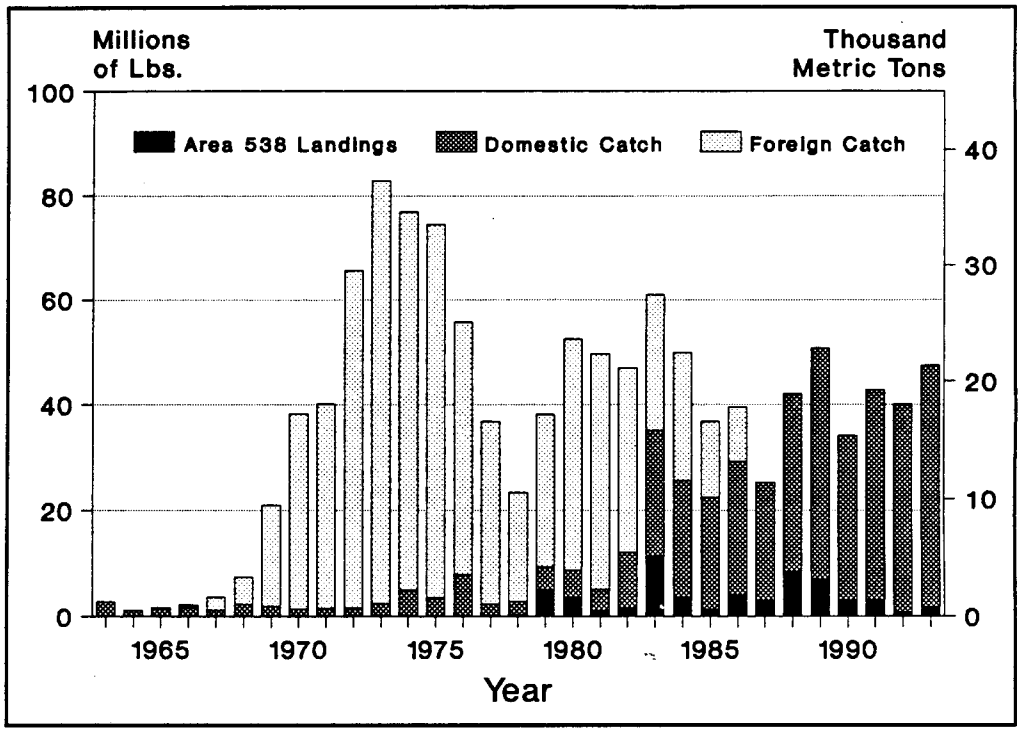

Figure 1. East Coast Loligo squid catch, 1963-1993. Area 538 component of catch prior to 1978 not highlighted. Data from Brodziak (1993).

The 1970's saw some growth in the inshore trawl fishery. For example, the 1978 MAFMC Squid Fishery Management Plan noted:

> "In 1974 and 1975, approximately 35-40 small and medium otter trawlers from Massachusetts ports conducted a short-term directed fishery for Loligo on spring spawning concentrations near Nantucket with catches processed for export..."

In 1976 after passage of the Fishery Conservation and Management Act (the Magnuson Act), the industry was given the opportunity to "Americanize" the fisheries by displacing foreign vessels catching squid (and other species) and building shoreside processing plants to accommodate expected increases in domestic landings.

However, displacement of foreign vessels took another decade to complete because

foreign nations were granted allocations to target squid within the newly established territorial sea that extended out to 200 miles. These allocations were phased out by 1986. In the interim, foreign vessels maintained their access to squid in the region through joint ventures. These arrangements allowed foreign vessels to purchase squid and some other underutilized species over-the-side from domestic trawlers.

Historical accounts of fishery management council meetings reveal a complicated and politically charged period for managing and allocating squid. For example, joint venture allocations became "the most time-consuming and controversial agenda item for the regional fishery management councils" (Stevens, 1983a). Shore-based processors seeking to boost the U.S. role in the foreign squid export market vehemently opposed participation by foreign trawlers fishing or accepting squid at sea, thus intercepting product that would have come ashore (Pierce 1982).

The domestic seafood processing industry increased its capacity for processing squid in the expectation of fully utilizing squid and other species caught in the expanded 200 mile territorial sea. Domestic fishing vessels that could process at sea were built or modified for processing "underutilized" species (squids, butterfish, and mackerel) that had been the targets of the foreign fleet (Stevens, 1985).

With increased targeting of squid, especially offshore in winter months, domestic landings grew dramatically through the 1980's and leveled off during 1990-1992, averaging 38.6 million pounds (17,500 mt). However, 1993 landings increased to over 49.0 million pounds (22,200 mt) -- the second highest year for domestic landings. Notably, these annual landings remained below peak years of 1973-1975 when the foreign fleet's landings averaged about 72 million pounds.

SQUID FISHERY IN MASSACHUSETTS WATERS

Squid distribution and movement

Long-finned squid are assumed to constitute a unit stock throughout their commercially exploited range from Nova Scotia south to Cape Hatteras. Squid overwinter offshore along the edge of the continental shelf and migrate inshore during spring.

Figure 2. *Squid egg mass commonly seen in local waters during spring and summer.*

In Massachusetts, squid are abundant along the southern shores of Massachusetts notably in Buzzards Bay and Vineyard and Nantucket Sounds during spring and summer. They usually are not found in commercially harvestable quantities in waters north of Cape Cod.

Larger squid arrive in Massachusetts waters in late April and early May and are followed by smaller individuals. Temperature affects squid distribution, so their arrival is likely advanced or delayed by spring water temperatures.

Locally, spawning begins during May and continues throughout summer. Evidence for this time of spawning are squid egg masses (mops) found in trawlers' catches in May as well as during the summer months, June-September (Figure 2), when trawlers target summer flounder.

Large numbers of young-of-the-year, 0.4-4.0" mantle length (1-10 cm) squid are observed during DMF's September bottom trawl survey in the sounds and Buzzards Bay (Howe et al. 1993).

A recent ageing study (Macy 1992) indicates that squid also hatch during fall and winter months -- presumably somewhere offshore.

Local abundance is highly variable as evidenced by annual squid landings of weirs and trawlers (Figure 3). Nevertheless, since 1991 both gear types have experienced below average landings, and it appears the downward trend continued in 1994 based on preliminary reports.

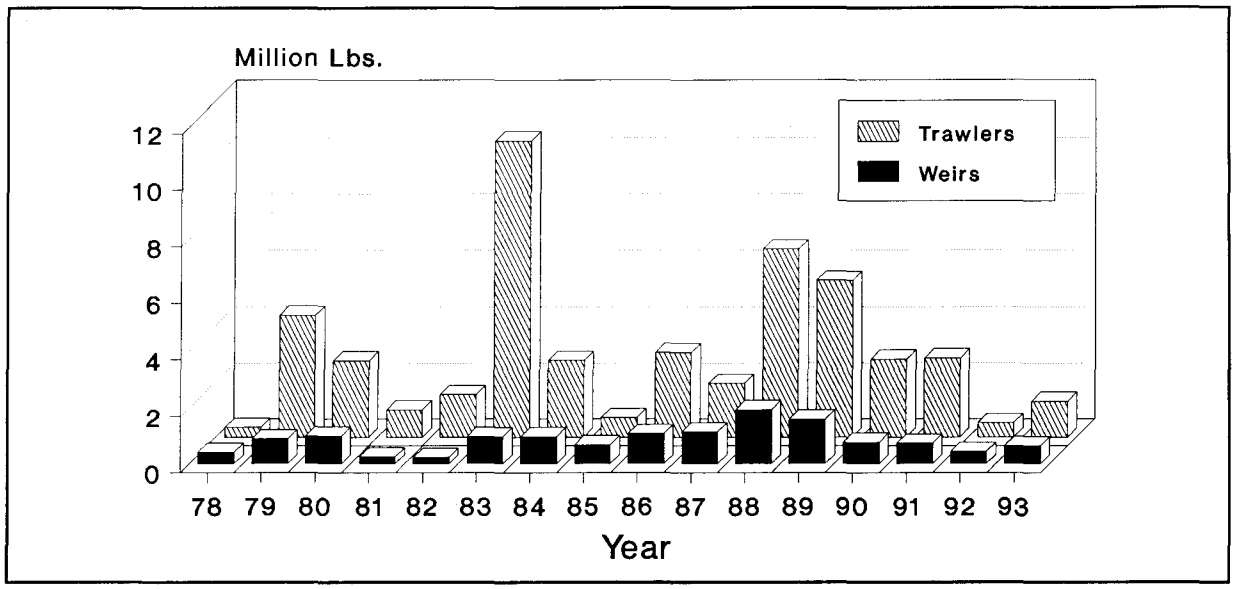

Figure 3. *Annual squid trawl landings from Area 538 compared to squid landings from weirs as reported to DMF, 1978-93.*

The spring-time seasonal surge in squid abundance is attributable to warming water temperatures. Squid catches in federal trawl surveys have been linked to water temperatures by Summers (1969b) and Serchuck and Rathjen (1974). They found catches greatly diminished in areas where bottom temperatures were less than 8°C (46°F). Largest catches were found in waters 10-12°C (50-54°F) in spring and 10-14°C (50-57°F) in fall.

Temperature records monitored by the NOAA National Ocean Survey, Woods Hole Station, show average sea water temperatures reach 10°C (50°F) during the first week of May. However, annual deviations in temperature are common as seen in Figures 4 and 5 depicting historical daily mean temperatures for 1978-1993 and each year's average temperature for the first week of May.

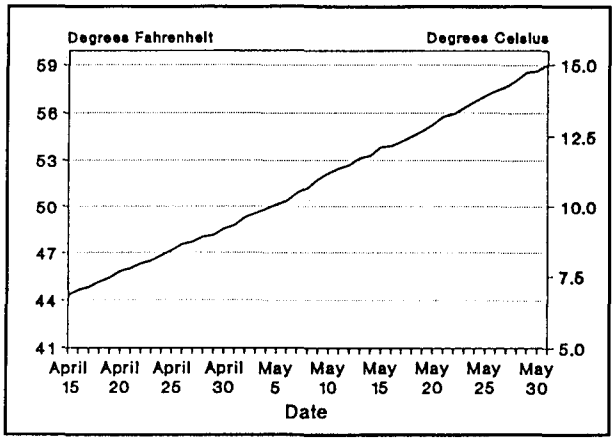

Figure 4. Average daily temperature at Woods Hole for the years 1978-1993

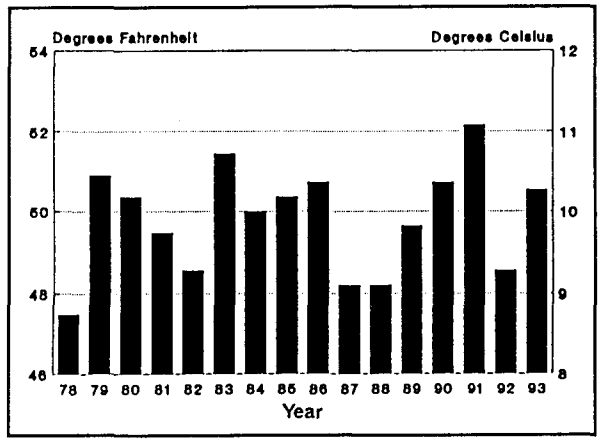

Figure 5. May 1-7 Average daily sea water temperature at Woods Hole, 1978-1993

Within Massachusetts waters nearly all squid landed are taken from Nantucket and Vineyard Sounds; mobile gear fishing and weirs are prohibited in Buzzards Bay. The sounds are primarily shallow (less than 60 ft.) with most nearshore waters less than 30 ft. Water temperatures in these shallow areas are much warmer than deeper waters to the south and east (Figure 6).

Coinciding with a single statistical area (Area 538) used by the NMFS commercial fisheries statistics program (Figure 7), nearly all this area is within waters under the jurisdiction of the Commonwealth except a small portion of the western edge that includes part of Rhode Island Sound (Figure 8). NMFS port agents (Susan Murphy, personal communication) report that squid landings from the Rhode Island portion of Area 538 are minimal.

Trawlers and stationary fish weirs account for nearly all squid landed from Massachusetts waters south of Cape Cod, with handlines contributing small, insignificant amounts. Annual landings for trawlers and weirs combined have fluctuated dramatically during 1978-1993 (study period) from less than one million pounds in both 1978 and 1992 to a high of over 11 million pounds in 1983 (Table 1, Figure 3). Catches for the two gear types track fairly well. When trawl catch rises, weir catch tends to rise as well, and vice versa.

Of note, Area 538 landings were adjusted to ensure that all weir landings were tallied. DMF weir landings were substituted for NMFS data. Weir owner/operators provide monthly reports to DMF. Some fishermen admit that because they do not hold federal permits, they provide landings data to DMF and do not report to NMFS port agents. See Appendix A for annual landings and adjusted totals.

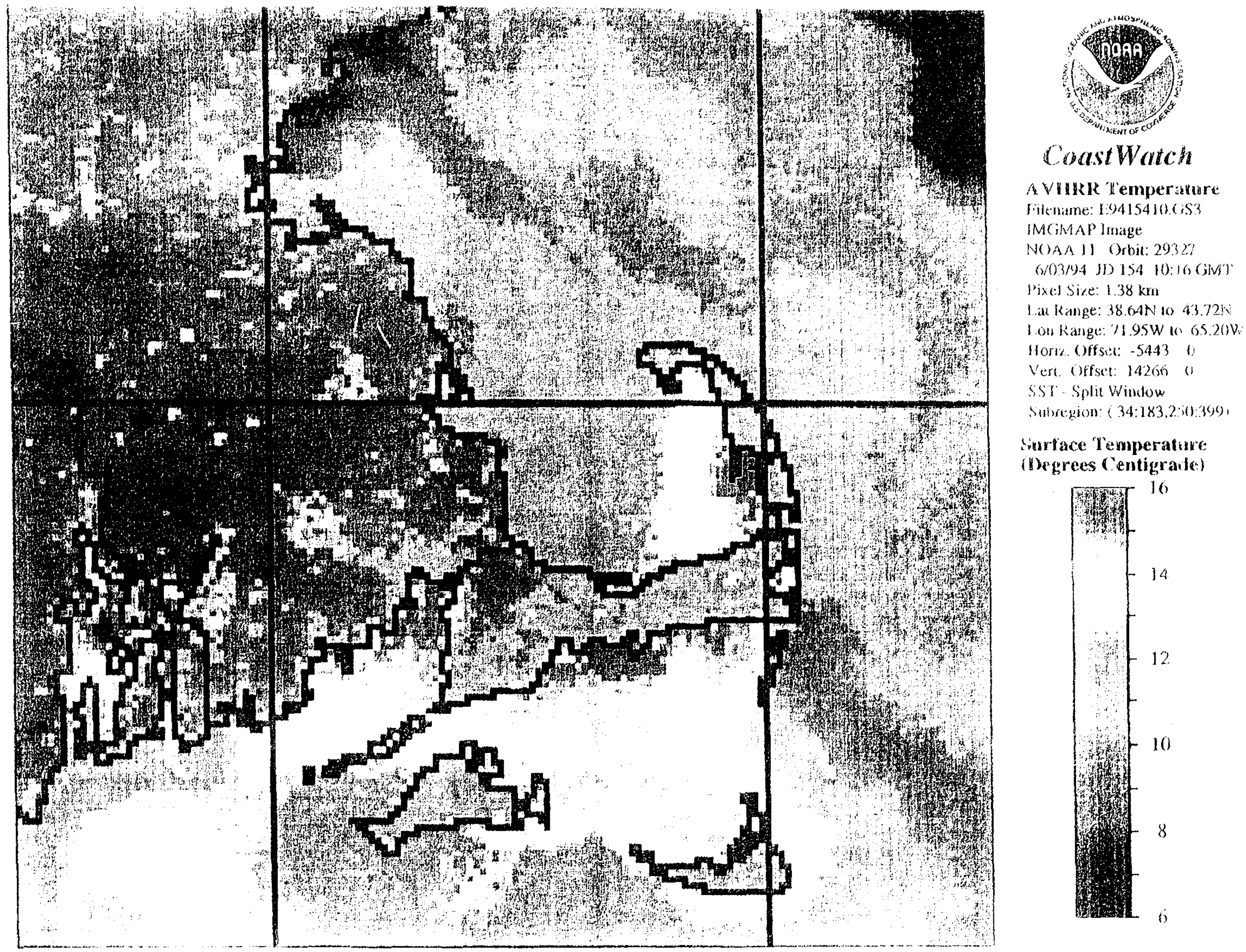

Figure 6. Sea surface temperatures in the Cape Cod region recorded on 6/3/94. Temperatures in Nantucket Sound are markedly warmer than those south of the islands and especially east of Cape Cod.

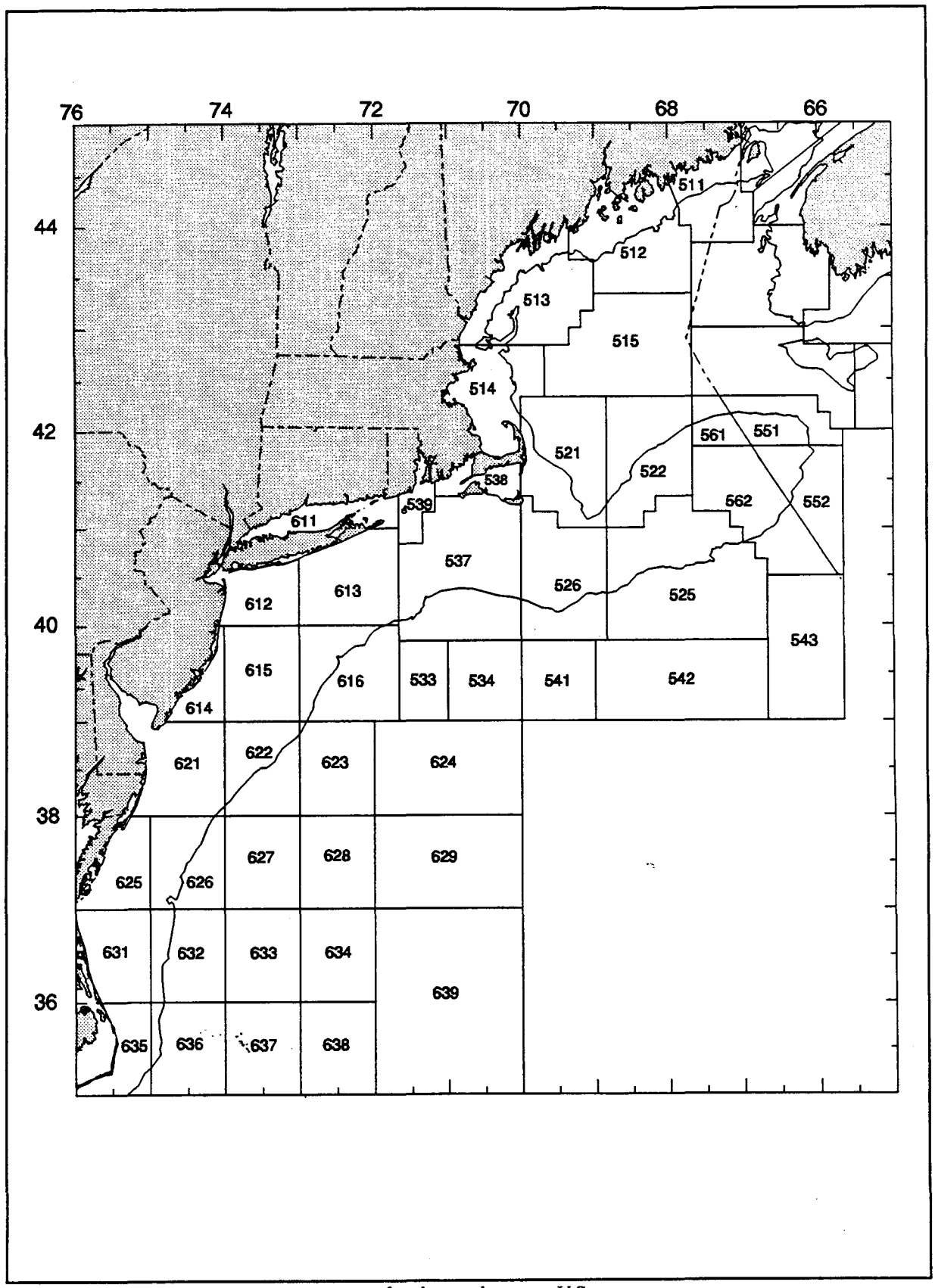

Figure 7. NMFS statistical reporting areas for the northeastern U.S.

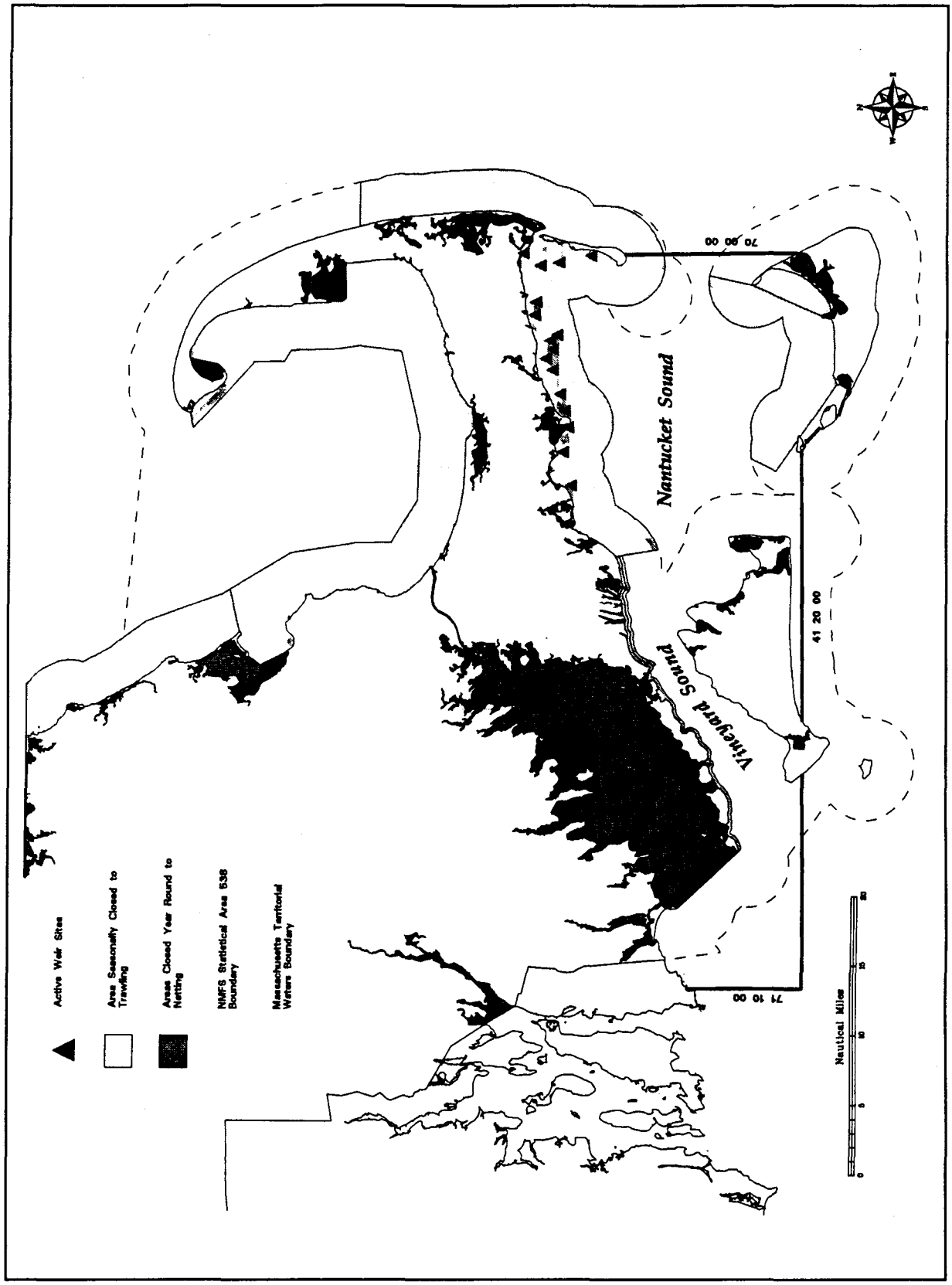

Figure 8. *Study Area: Southeastern Massachusetts areas with DMF mobile gear closures and fished weir sites. NMFS statistical Area 538 outlined.*

Trawl fishery

Landings

Trawlers dominated squid landings from 1978 through 1993 (Table 1). About 78% of total landings from Area 538 was attributed to trawlers. Annual trawl landings from Area 538 averaged 3 million pounds (1,361 mt) while weir landings averaged only about 0.8 million pounds (363 mt). However, in some years of low landings overall, weir landings approached trawl landings (1985 and 1992) and slightly exceeded trawl landings in 1978.

Table 1. Comparison of trawl* landings from Area 538 with Massachusetts weirs in Nantucket Sound.

Year	Trawls (Lbs.)	Pct	Weirs (Lbs.)	Pct	Total (Lbs.)
1978	348,708	46%	413,592	54%	762,300
1979	4,319,943	83%	887,058	17%	5,207,000
1980	2,716,382	73%	981,158	27%	3,697,539
1981	969,521	80%	245,222	20%	1,214,742
1982	1,497,148	87%	222,778	13%	1,719,925
1983	10,500,512	92%	937,307	8%	11,464,873
1984	2,729,557	74%	950,320	26%	3,694,117
1985	693,898	51%	665,490	49%	1,359,387
1986	3,000,478	75%	1,021,069	25%	4,062,330
1987	1,911,215	63%	1,117,880	37%	3,041,155
1988	6,661,561	78%	1,910,135	22%	8,571,695
1989	5,556,558	79%	1,497,521	21%	7,131,725
1990	2,753,120	78%	758,216	22%	3,511,335
1991	2,799,061	79%	727,854	21%	3,526,914
1992	510,957	55%	425,654	45%	936,610
1993	1,259,504	66%	639,921	34%	1,899,425
Totals	48,228,123	78%	13,401,176	22%	61,629,299
Average	3,014,258	72%	837,573	28%	3,851,831
Maximum	10,500,512	92%	1,910,135	54%	11,437,819
Minimum	348,708	46%	222,778	8%	762,301

* All trawl types including otter trawlers and paired midwater trawlers.

Trawl landings have the greatest variability. Dramatic increases from one year to the next have been seen, especially from 1978-79 and 1982-83. Landings reached a high of about 10,501,000 pounds (4,762 mt) in 1983 and a low of about 349,000 pounds (158 mt) in 1978.

Historically, fishing in Massachusetts waters for squid has spanned from a few days to a few months, based on availability of squid. However, recently implemented DMF regulations significantly shortened the season when small mesh is allowed to under six weeks (See following section on "History of trawl fisheries management within the sounds").

A review of NMFS weighout records of Area 538 trawl landings during the 16-year study period shows landings primarily in spring (April-June), coinciding with arrival of squid and warming of Massachusetts waters (Figure 4). Catches peak in May (Table 2). Relative contribution of May to annual trawl landings averaged 79% with highs of 93% and 96% in 1992 and 1993, respectively, to a low of just 50% in 1988 (Table 3). The 1988 season saw the highest June landings of the study period. Similarly, July and August landings were the highest of the period. The July high can be explained by DMF's allowing use of small mesh (less than 3½") beyond a June 30 deadline to July 15, at the request of fishermen delivering squid to an at-sea processor in late June. The August landings are difficult to explain since 3½" was the required legal minimum mesh. Either squid were being caught with this mesh, fishermen ignored the mesh restriction, or the catch location was incorrect.

For trawlermen, 1983 (with over 10 million pounds landed) was a remarkable year of

Table 2. Monthly Area 538 Otter Trawl Landings 1978-1993. Data does not include trawl types such as paired midwater trawlers, shrimp trawlers, and crab bottom trawlers. Therefore, totals are slightly less than the trawlers' totals in table 1.

	JAN lbs	FEB lbs	MARCH lbs	APRIL lbs	MAY lbs	JUNE lbs	JULY lbs	AUG lbs	SEPT lbs	OCT lbs	NOV lbs	DEC lbs	TOTAL
1978	-	-	-	-	203,753	119,691	11,644	970	183	8,982	2,720	-	347,943
1979	-	-	-	21,975	3,358,027	912,952	17,932	959	676	3,438	1,289	-	4,317,248
1980	-	-	-	97,179	2,349,037	225,999	15,416	2,790	3,726	7,303	1,438	4	2,702,892
1981	-	-	-	129,929	707,832	107,669	4,051	2,277	5,104	11,924	675	60	969,521
1982	-	-	-	10	1,186,047	298,185	4,159	4,123	1,581	1,000	155	48	1,495,308
1983	-	-	450	163,162	7,164,396	3,142,551	7,456	5,140	1,496	15,161	700	-	10,500,512
1984	-	-	-	161	1,819,229	861,556	10,196	7,027	10,539	19,383	1,387	79	2,729,557
1985	-	-	-	2,512	626,511	31,059	10,371	2,341	1,381	12,871	6,021	831	693,898
1986	-	-	-	18,500	2377316	534,629	30,202	4,813	7,540	13,491	13,607	-	3,000,098
1987	-	-	-	19,295	1,606,436	232,785	24,522	6,276	4,196	15,148	2,487	-	1,911,145
1988	-	-	-	4,789	3,250,413	2,108,867	704,041	370,392	4,696	20,165	1,461	3,730	6,468,554
1989	-	-	-	187,474	4,486,248	698,604	20,586	3,501	5,381	20,979	13,710	-	5,436,483
1990*	-	-	-	21,063	2,187,371	421,230	43,121	8,918	10,969	20,482	16,696	-	2,732,850
1991*	-	-	-	24,679	2,602,146	20,179	20,713	14,870	1,544	21,530	0	-	2,710,661
1992	-	-	-	8	445,643	3,239	3,740	965	728	5,719	2,505	-	462,547
1993**	-	-	-	-	1,112,015	87,759	N/A	N/A	N/A	N/A	N/A	N/A	1,199,774
AVERAGES			28	43,171	2,217,651	612,935	61,877	29,024	3,983	13,172	4,323	317	2,979,937

* 1990 and 1991 does not include 3,000 and 5,000 lbs where month was unknown.
** 1993 data are preliminary and landings after June not presented.

Table 3. Monthly Percent Contributions for Area 538 Otter Trawlers.

	JAN pct	FEB pct	MARCH pct	APRIL pct	MAY pct	JUNE pct	JULY pct	AUG pct	SEPT pct	OCT pct	NOV pct	DEC pct
1978	-	-	-	-	59%	34%	3%	0%	0%	3%	1%	-
1979	-	-	-	1%	78%	21%	0%	0%	0%	0%	0%	-
1980	-	-	-	4%	87%	8%	1%	0%	0%	0%	0%	0%
1981	-	-	-	13%	73%	11%	0%	0%	1%	1%	0%	0%
1982	-	-	-	0%	79%	20%	0%	0%	0%	0%	0%	0%
1983	-	-	0%	2%	68%	30%	0%	0%	0%	0%	0%	-
1984	-	-	-	0%	67%	32%	0%	0%	0%	1%	0%	0%
1985	-	-	-	0%	90%	4%	1%	0%	0%	2%	1%	0%
1986	-	-	-	1%	79%	18%	1%	0%	0%	0%	0%	-
1987	-	-	-	1%	84%	12%	1%	0%	0%	1%	0%	-
1988	-	-	-	0%	50%	33%	11%	6%	0%	0%	0%	0%
1989	-	-	-	3%	83%	13%	0%	0%	0%	0%	0%	-
1990*	-	-	-	1%	80%	15%	2%	0%	0%	1%	1%	-
1991*	-	-	-	1%	96%	1%	1%	1%	0%	1%	-	-
1992	-	-	-	0%	96%	1%	1%	0%	0%	1%	1%	-
1993**	-	-	-	-	93%	7%						
AVERAGES		0%	2%	79%	16%	1%	1%	0%	1%	0%	0%	

Note: dash (-) represents no catch for the month while 0% represents a percentage less than 0.5%, thus rounded to 0%.

record landings. However, in recent years, landings have declined to less than two million pounds with preliminary reports of similar low catches this 1994 season.

Time and location of fishing

By DMF regulation trawlers may begin fishing for squid in Vineyard and Nantucket Sounds on April 23. Late-April small-mesh fishing, with most fishermen using cod end liners of 1" - 2" inside a 3" - 5" cod-end, has been allowed since 1990 after fishermen convinced DMF and the Commission that a complete prohibition on April small-mesh fishing was unfair. At February 1990 public hearings, fishermen testified that some vessels caught squid with small-mesh nets (unlawfully) prior to May 1 (McKiernan 1990). With early arrival of squid that year, trawlermen were unwilling to wait for the May 1 opening. April 1989 high squid landings of 187,474 pounds helped make their point. Adding to the temptation to use illegal mesh, fish weirs are allowed to take squid in areas open to trawling, and many shallow areas are lost to draggers on May 1 when a band of water from the shore to about 3 miles is closed to trawling until November 1. A key reason for this DMF/MFC concession (April 23 opening) was inadequate at-sea enforcement.

In May, trawling is concentrated in two areas. The first area is along the Falmouth shore from Nobska Point in Woods Hole to Succonnesset Point in Mashpee -- the only area along the southern Cape Cod shore open to trawling during the squid season. Smaller vessels are confined to nearshore areas off Falmouth during days of strong winds and rough seas. Some of this area is now closed to mobile gear fishing out to ¼-mile -- a controversial 1994 MFC decision. The closure increases to ½-mile on June 1. (Figure 9)

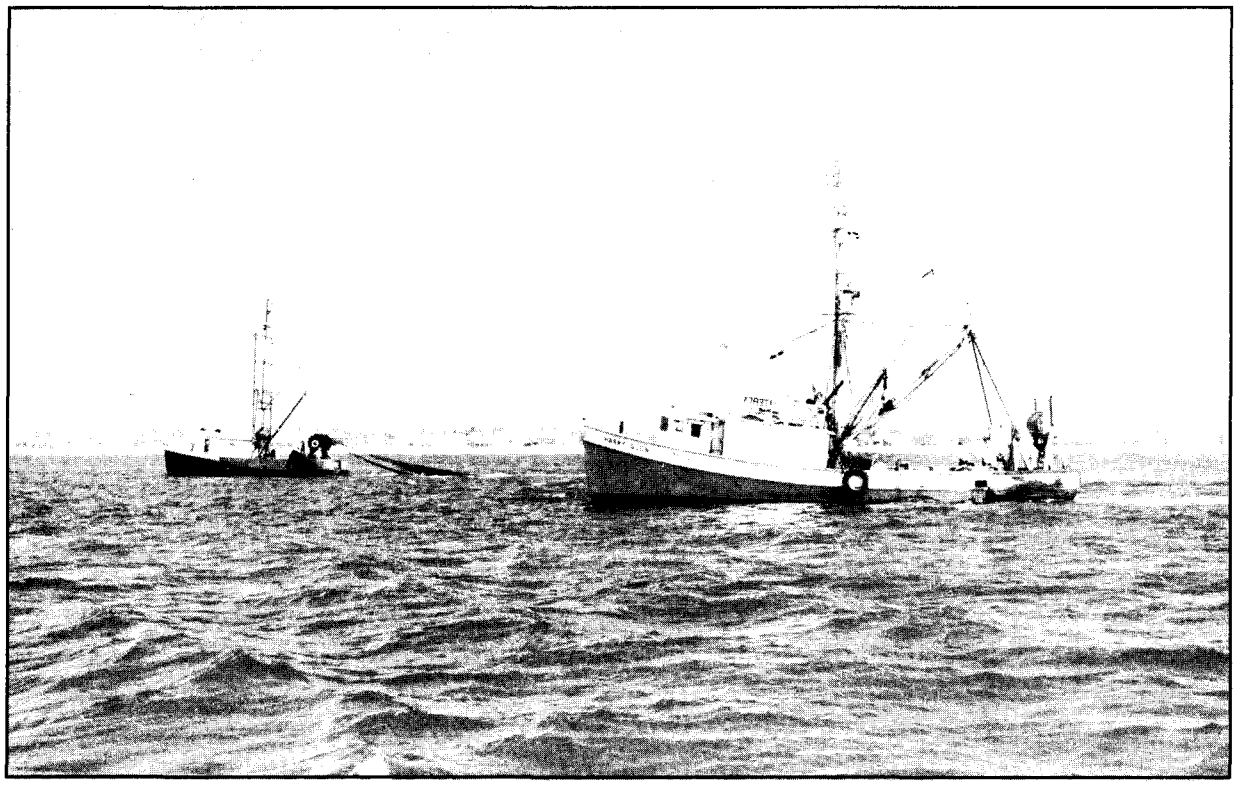

Figure 9. *Trawlers fishing near Falmouth shore in Vineyard Sound.*

The second most trawled area is a large portion of the center of Nantucket Sound near Horseshoe Shoal. This area is frequented by larger vessels in the fleet (greater than 50 gross registered tons - GRT). During 1989-1993, DMF observers noted that by mid-May most vessels abandoned Vineyard Sound off Falmouth and followed the "run" of squid east toward the center of Nantucket Sound (Figure 10).

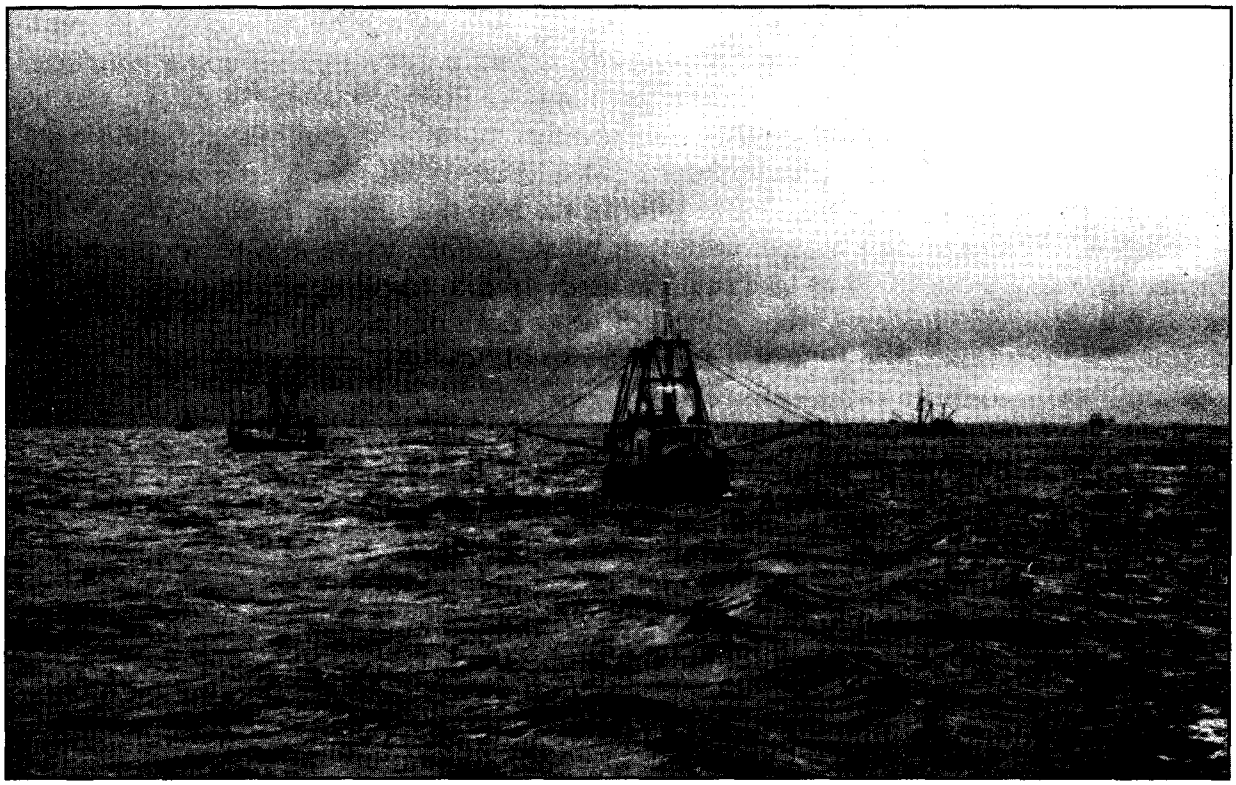

Figure 10. *Trawlers fishing in the center of Nantucket Sound near Horseshoe Shoal.*

Fleet composition and participation

During the 16-year study period, fleet composition of trawlers landing squid from Area 538 has varied. The fleet is classified according to trawler gross registered tons of displacement (U.S. Dept of Commerce, 1993). Class 1 vessels are less than 5 GRT. Class 2 vessels range from 5 to 50 GRT and comprise most "inshore" draggers -- vessels less than about 60 feet that fish nearshore and unload typically on a daily basis. Vessel classes 3 (51-150 GRT) and 4 (151-500 GRT) are larger vessels, typically fish multi-day trips, are capable of operating farther from shore, and are less weather-dependent (Figure 11).

In recent years the number of class 1&2 vessels in Massachusetts' inshore squid fishery declined dramatically reaching its lowest point in 1993. Days fished and landings for these vessels decreased sharply as well.

These vessel classes' gradual diminishing contribution, especially in 1993, is evident from an examination of number of vessels, days fished, and pounds of squid landed as a percent of the total each year from 1978 to 1993 (Figure 12). In 1993, percent contributions

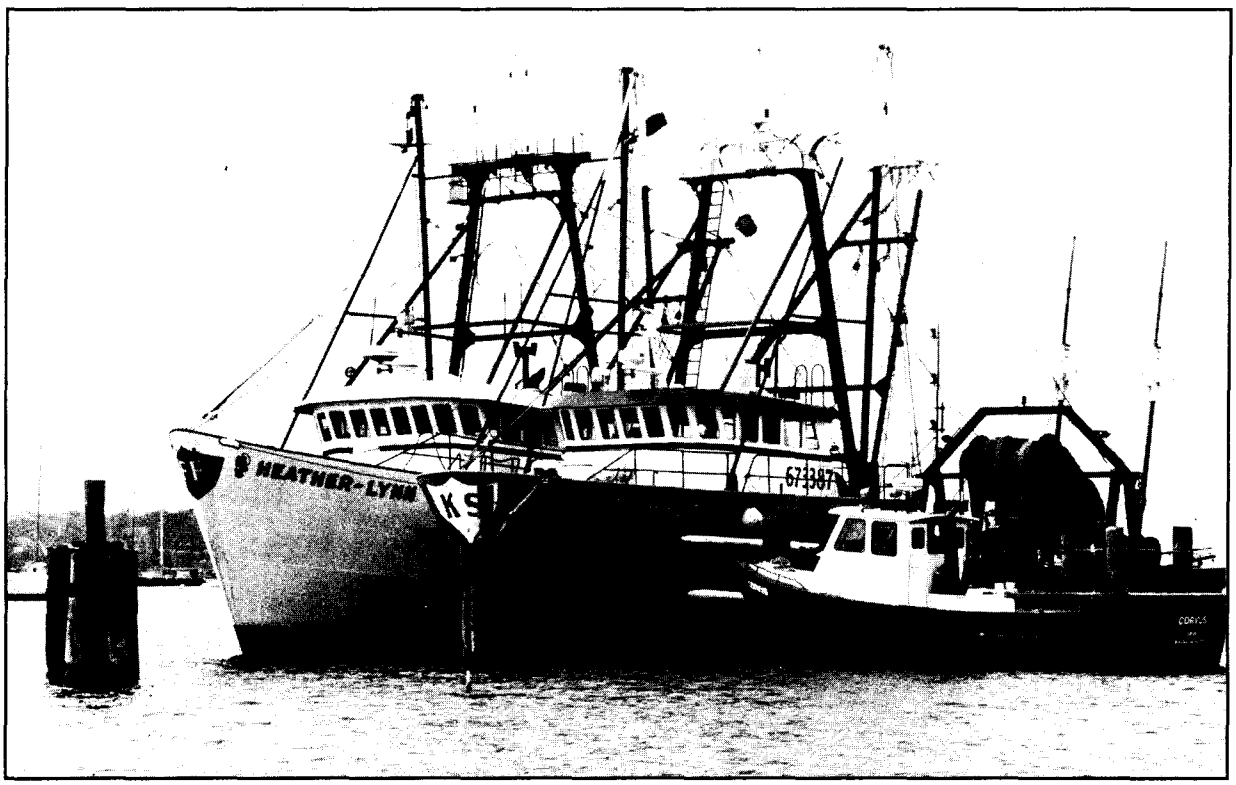

Figure 11. *Two large trawlers active in the Area 538 squid fishery docked in Vineyard Haven Harbor.*

for class 1&2 vessels reached their lowest point. In contrast, the gradual increase in percentages for vessel class 4 peaked in 1993. During the late 1970's percentages were less than 5%. Throughout most of the 1980's percentages were about 10%, and in 1993 rose to about 25%. Class 3 vessels' participation increased slightly during the period.

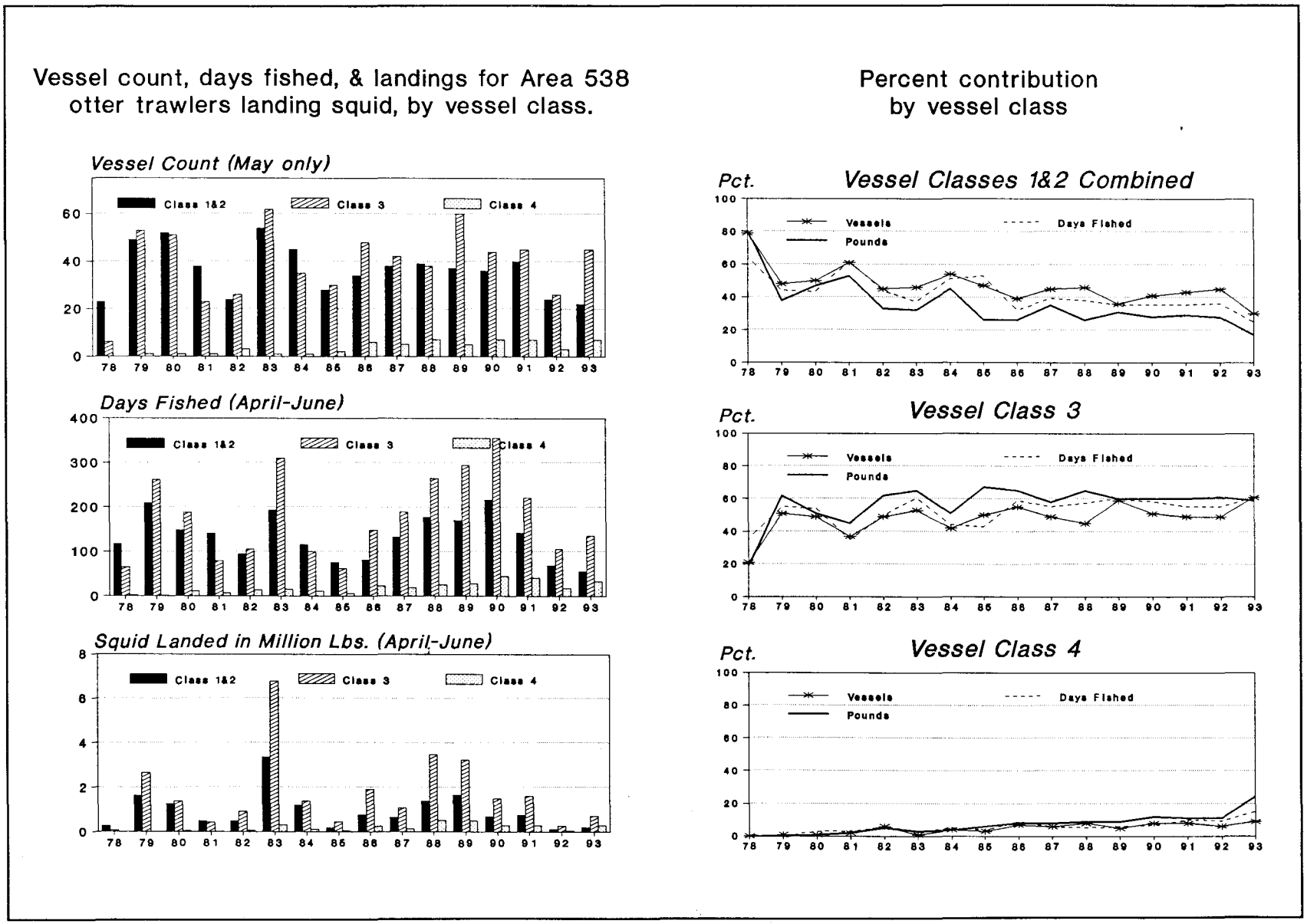

Figure 12. Changes in squid landings, effort and fleet composition.

States of landing for Area 538 trawl-caught squid

Of all squid landed by trawlers from Area 538 (all trawl types combined) during the 16-year study period, Massachusetts ports accounted for 45% with the remainder being landed in other states' ports (Tables 4 and 5). Annual percentages landed in Massachusetts ports ranged from a low of 25% in 1988 to a high of 85% in 1978. Rhode Island accounted for 46% of the Area 538 trawl-caught landings during the 16-year period with annual percentages ranging from 15% in 1978 to a high of 69% in 1986. The states of Maine, New York, Virginia and New Jersey accounted for the remaining 8% of landings during the period.

Table 4. States of landing and quantity of Area 538 trawl-caught squid, 1978-1993. Data include all trawl types.

Year	Mass.	R.I.	N.Y.	N.J.	ME.	VA.	Totals
1978	296,935	51,473	-	300	-	-	348,708
1979	2,711,666	1,608,277	-	-	-	-	4,319,943
1980	1,883,550	832,832	-	-	-	-	2,716,382
1981	684,490	285,031	-	-	-	-	969,521
1982	655,146	824,987	-	-	-	17,015	1,497,148
1983	4,902,955	5,272,240	-	-	-	325,317	10,500,512
1984	1,523,058	1,014,413	-	-	-	192,086	2,729,557
1985	281,441	412,457	-	-	-	-	693,898
1986	924,356	2,076,122	-	-	-	-	3,000,478
1987	588,028	1,254,617	1,400	-	67,170	-	1911215
1988	1,655,287	2,732,809	1,069,086	-	1,204,379	-	6,661,561
1989	2,283,317	2,473,525	-	-	799,716	-	5,556,558
1990	1,033,372	1,503,640	-	-	216,108	-	2,753,120
1991	1,446,093	1,352,968	-	-	-	-	2,799,061
1992	307,403	203,554	-	-	-	-	510,957
1993	684,079	490,227	85,298	-	-	-	1,259,604
Totals	21,861,176	22,389,172	1,155,784	300	2,287,373	534,418	48,228,223
%	45%	46%	2%	0%	5%	1%	100%

Note: Landings are irrespective of vessel's homeports; e.g., Rhode Island-based vessels often unload in Massachusetts' ports.

Table 5. Percentages of Area 538 trawl-caught squid landed in each state, 1978-1993.

Year	Mass.	R.I.	N.Y.	N.J.	Me.	Va.	Totals
1978	85%	15%	-	0%	-	-	100%
1979	63%	37%	-	-	-	-	100%
1980	69%	31%	-	-	-	-	100%
1981	71%	29%	-	-	-	-	100%
1982	44%	55%	-	-	-	1%	100%
1983	47%	50%	-	-	-	3%	100%
1984	56%	37%	-	-	-	7%	100%
1985	41%	59%	-	-	-	-	100%
1986	31%	69%	-	-	-	-	100%
1987	31%	66%	0%	-	4%	-	100%
1988	25%	41%	16%	-	18%	-	100%
1989	41%	45%	-	-	14%	-	100%
1990	38%	55%	-	-	8%	-	100%
1991	52%	48%	-	-	-	-	100%
1992	60%	40%	-	-	-	-	100%
1993	54%	39%	7%	-	-	-	100%
Average	50%	45%	1%	0%	3%	1%	100%

Note: Landings are irrespective of vessels' homeports; e.g., Rhode Island-based vessels often unload in Massachusetts' ports.

Growing participation of trawlers outfitted with freezing equipment, all of which hail from other states, contributed to the amount of squid removed from Area 538 and landed in distant ports. Vessels licensed as at-sea processors have hailed from Rhode Island, Maine, New York, and New Jersey. Vessels that freeze at sea do not unload at a local port on a daily basis. Rather, they wait until their holding capacity is reached which takes one or more weeks.

One notable recent event is the emergence of vessels less than 90' equipped with plate freezers. These vessels fish as well as freeze squid at sea and can choose to take squid over-the-side when their own catches are insufficient to maintain production among the crew sorting and freezing squid. Two such vessels were licensed to fish and buy over-the-side in 1993, but only one participated.

Weir fishery

Fishing practices

Fish weirs were among the earliest type of fishing gear utilized in Massachusetts. From the mid 1800's through the early 1950's, first the floating trap and then the fixed weir, became one of the most important gear types on Cape Cod.

Being a fixed or passive form of fishing gear, Nantucket Sound weir catch is affected by year-to-year and day-to-day migratory fish behavior which is also influenced by prevailing wind and current patterns. For example, during a spring of 'southwesterlies' (winds), squid catch may be enhanced. Fishing success of a weir ultimately depends on fish abundance and availability within nearshore waters.

The majority of weirs, fished from 1-2 miles from shore, are concentrated in the eastern portion of Nantucket Sound off Monomoy Island and Chatham and are set primarily along the 18' (5.5 meter) mean low water depth contour. Licensed sites extend from Barnstable east to Monomoy Island off Chatham (Figure 8).

Weir construction and design have changed little in 100 years. Up to 60 wooden poles, each as long as 75', are driven into the bottom to form the frame for hanging nets in a typical weir or pound net configuration of leader, heart, and bowl (Figure 13). The leader, an underwater wall of the largest mesh (usually 18") stretching perpendicular to the shoreline, may range from 900' to 3,600' to the weir's heart or entrance. Mesh size in the heart is smaller yet still large enough to allow fish escapement. The bowl has the smallest mesh (1 3/4"), with an entire net floor within which the fish are actually captured or held. The bowl is drawn or hauled to remove catch by long-handled dip nets (Figure 14).

The theory behind the success of fish weirs is explained by the behavior of schooling fish when they encounter or "hit" the leader. Fish react by swimming deeper to escape thereby following the net wall "offshore" into the heart. From the heart, fish may enter the bowl; there is nothing to prevent escapement from the bowl, except for the mouth passage-

way which is fashioned with a curved wing to direct schooling fish around, rather than back through the opening. Once inside the bowl, fish continue to school or swim in a circular/figure-eight pattern. When a weir is full of undesirable and/or unmarketable catch, such as sea robins, the bowl is lowered completely to release these fish alive. Likewise, undersized fish are released alive.

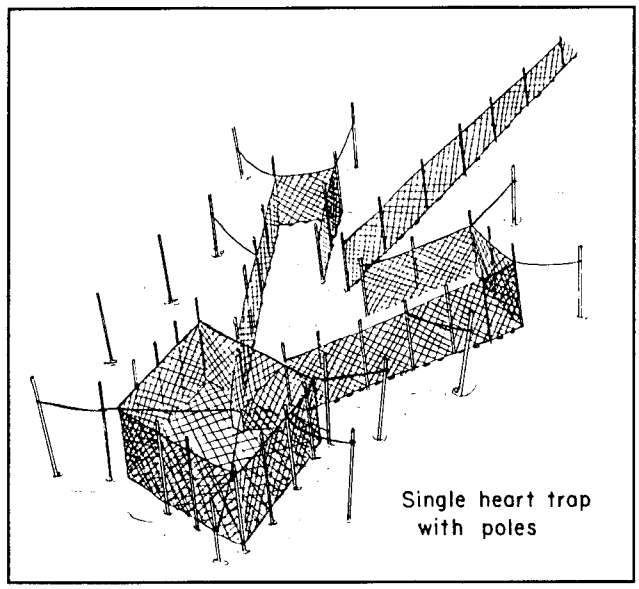

Figure 13. *Schematic drawing of a weir. Weirs in Nantucket Sound typically have a round heart and round bowl.*

Fishermen and gear

Forty weir sites south of Cape Cod have been granted to six weir owners/companies. These sites extend along the shore from Barnstable to Monomoy Point. Fishermen are able to shift their locations from areas where fishing may not have been good the previous year, perhaps as a result of shoaling or other factors, to more viable sites. For example, after a 1978 storm, Monomoy Island broke near Common Flat. Fishermen's catch reportedly decreased perhaps due to the cold water intrusion from east of the Island, and fishermen had to fish different sites. Spring water temperatures east of Monomoy Island are dramatically lower than those within the sound (Figure 6).

Fishermen are restricted to sites on their permit. The location of their first pole is defined by a latitude-longitude coordinate and a bearing describes the direction of the weir. The authorized distance along the bearing is from 600 to 1,000 yards.

Less than one-half of permitted sites are fished. For example, in 1990 six weir owner/companies fished 17 sites (Figure 8). All these weirs (as well as those not set in 1990) are found within DMF's Area 2 south of Cape Cod which is closed to mobile gear fishing from May 1 until October 31.

Management

Weirs are licensed or permitted under MGL, Chapter 130 - Marine Fisheries Section 29, within prescribed near-shore boundaries, clearly designated on all NOAA nautical charts. Application for a permit must first be submitted to the respective coastal town, through the Selectmen (or City Council) who must approve (or deny) a fish trap:

> "upon such conditions and subject to regulations as they (Selectmen) may impose; but no authority given shall be valid unless approved in writing as to location and construction by the Department of Public Works (presently DEP) and the Director (DMF), and subject to any appropriate conditions."

In other words, if approved by the town first, the 5-year permit also must be accepted by the Waterways Division of DEP and finally by DMF.

Figure 14. *Weir fishermen harvesting the catch.*

Weirs must be set in locations where no harbor lines exist and set within city and town limits. Towns may have additional regulations pertaining to inter-trap distance and gear marking. The minimum distance is mandated between trap sites in Harwich (3,000') and Dennis (4,500'). Yarmouth recently established a 6,000' distance. Barnstable does not have a distance requirement.

MFC established a weir buffer zone in 1991. Since fish tend to follow the weir's leader to the head (heart and bowl), they become concentrated and attract other fishermen to the weir where fish are available and more easily caught. This use of the weir's fish-attracting traits by other fishermen, notably handliners; for example, by fishing in the bowl or heart or alongside the leader, caused conflicts on the water between weir and other fishermen. Consequently, a reasonable buffer zone (Figure 15) within which no person can conduct commercial or recreational fishing -- except the weir owner or those with the owner's consent to remove fish and squid from the head(s) -- was established. The buffer zone is the area around the fish weir which is circumscribed by buoys attached to weir pole anchors.

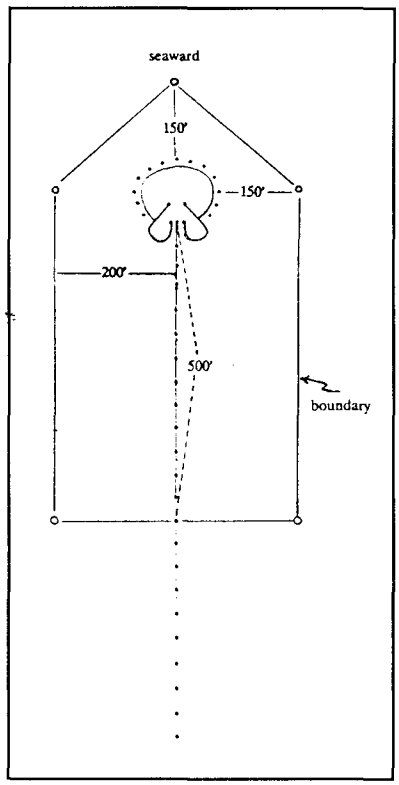

Figure 15. *Fish weir buffer zone.*

Landings

Annual changes in weir landings have not been as variable as that of the trawlers. Trawlermen react to reports of squid abundance by fishing more or less days in the fishery. In contrast, weir fishermen erect their gear along the shore in April and await the arrival of a suite of target species, including squid.

The most important species landed by weirs, in terms of tonnage, in recent years are

long-finned squid, scup, mackerel, bluefish, and butterfish (Table 6).

Table 6. Massachusetts fish weir landings (lbs.) from Nantucket Sounds for 1990 - 1992.

Species	1990	1991	1992
Albacore	6,955	5,273	5,005
Bluefish	57,865	43,342	38,580
Bonito	3,802	2,886	62,852
Butterfish	22,823	7,023	2,801
Fluke	1,123	4,303	2,532
Sea Herring	41,620	2,000	2,000
Atl. Mackerel	342,477	154,582	260,669
King Mackeral	562	1,214	107
Sp. Mackeral	22,039	19,698	278
Scup	199,184	77,633	330,057
Sea bass	2,681	361	160
Squid	755,495	727,768	424,806
Tautog	4,092	4,368	3,951

For squid, seasonal trends in weir landings are similar to that in the trawl fishery, according to fishermen's catch report data submitted to DMF's Fisheries Statistics Program. Most squid are caught during May (Table 7), accounting for an average of 89% of annual landings (Table 8). Since 1985, more than 99% of the annual weir landings accrued by the end of May.

Weirs accounted for 28% of annual Area 538 landings during the 16-year study period with annual contributions ranging from 8 to 54% (Table 1). Landings ranged from 222,777 pounds in 1985 to a high of 1,910,134 in 1988 (average 850,750 pounds).

For weir fishermen, peak years of landings were 1986 through 1989 when landings exceeded 1 million pounds each year. Landings were below average for the past four years, 1990-1993, and based on fishermen's reports, 1994 landings declined again, down at least 50% from last year.

It is notable that weir catches in 1983 were only slightly above average, not nearly the record year experienced by trawlers. Weir fishermen recalled that strong southwest winds were common, and they suggested that nearshore waters became silty causing squid to migrate away from the weirs to the deeper waters of Nantucket Sound - an area open to trawlers.

Table 7. Monthly Massachusetts squid landings (lbs) from weirs as reported to the DMF Statistics Program, 1978-92.

	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTAL
1978	-	-	-	4,895	377,450	28,259	1,620	1,218	150	-	-	-	413,593
1979	-	-	-	43,298	776,353	32,116	33,627	1,518	145	-	-	-	887,058
1980	-	-	-	12,105	926,162	5,251	27,748	9,033	858	-	-	-	981,158
1981	-	-	-	22,235	215,921	4,363	1,890	812	-	-	-	-	245,222
1982	-	-	-	61	207,489	9,545	5,664	18	-	-	-	-	222,778
1983	-	-	-	106,610	725,053	99,845	5,741	57	-	-	-	-	937,307
1984	-	-	-	843	867,601	58,517	7,487	15,708	163	-	-	-	950,320
1985	-	-	-	70,188	593,502	1,550	249	-	-	-	-	-	665,490
1986	-	-	-	137,130	881,195	2,460	246	35	2	-	-	-	1,021,069
1987	-	-	-	39,305	1,075,727	2,552	283	9	3	-	-	-	1,117,880
1988	-	-	-	125,335	1,772,069	9,750	2,115	500	365	-	-	-	1,910,135
1989	-	-	-	158,575	1,323,475	6,100	9,370	-	-	-	-	-	1,497,521
1990	-	-	-	157,035	596,235	4,365	580	-	-	-	-	-	758,216
1991	-	-	-	112,355	615,375	116	7	-	-	-	-	-	727,854
1992	-	-	-	1,851	421,160	1,200	252	1,190	-	-	-	-	425,654
Averages				66,121	758,318	17,733	6,459	2,007	112				850,750

Table 8. Monthly percent contributions for Massachusetts weirs as reported to the DMF statistics program.

	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTAL
1978	-	-	-	1%	91%	7%	0%	0%	0%	-	-	-	100%
1979	-	-	-	5%	88%	4%	4%	0%	0%	-	-	-	100%
1980	-	-	-	1%	94%	1%	3%	1%	0%	-	-	-	100%
1981	-	-	-	9%	88%	2%	1%	0%	-	-	-	-	100%
1982	-	-	-	0%	93%	4%	3%	0%	-	-	-	-	100%
1983	-	-	-	11%	77%	11%	1%	0%	-	-	-	-	100%
1984	-	-	-	0%	91%	6%	1%	2%	0%	-	-	-	100%
1985	-	-	-	11%	89%	0%	0%	-	-	-	-	-	100%
1986	-	-	-	13%	86%	0%	0%	0%	0%	-	-	-	100%
1987	-	-	-	4%	96%	0%	0%	0%	0%	-	-	-	100%
1988	-	-	-	7%	93%	1%	0%	0%	0%	-	-	-	100%
1989	-	-	-	11%	88%	0%	1%	-	-	-	-	-	100%
1990	-	-	-	21%	79%	1%	0%	-	-	-	-	-	100%
1991	-	-	-	15%	85%	0%	0%	-	-	-	-	-	100%
1992	-	-	-	0%	99%	0%	0%	0%	-	-	-	-	100%
Averages				7%	89%	2%	1%	0%	0%				100%

Value of squid landings

Squid value generally has seen an increase with largest increases in price occurring during the last six years when ex-vessel price increased from $0.34 in 1989 to $0.62 per pound in 1993. This recent increase in ex-vessel value (price paid to fishermen) can be attributed to a number of factors. Domestic demand for east coast Loligo pealei exceeds supply, and there is growing competition between domestic producers and firms packing for the export market (Ross 1994). Increased domestic use of squid has increased demand, especially since several major domestic processors have upgraded plants and equipment to produce more consumer acceptable products (cleaned tubes, squid rings, stuffed squid, etc.).

Table 9. Squid landings and ex-vessel value for Area 538 trawlers (all types) 1978-1993.

Year	Pounds	Value	Per lb.
1978	348,708	$140,958	$0.40
1979	4,319,943	$1,576,085	$0.36
1980	2,716,382	$824,607	$0.30
1981	969,521	$335,850	$0.35
1982	1,497,148	$561,121	$0.37
1983	10,500,512	$3,175,151	$0.30
1984	2,729,557	$530,018	$0.19
1985	693,898	$170,224	$0.25
1986	3,000,478	$995,784	$0.33
1987	1,911,215	$613,605	$0.32
1988	6,661,561	$1,911,121	$0.29
1989	5,556,558	$1,913,446	$0.34
1990	2,753,120	$1,120,559	$0.41
1991	2,799,061	$1,437,289	$0.51
1992	510,957	$308,091	$0.60
1993	1,259,604	$786,306	$0.62
Averages	3,014,258	$1,025,013	$0.37

Ross (1994) also reported that foreign demand for U.S frozen squid was strong in 1993 due to reduced spring squid landings off the Falkland Islands and California. Furthermore, an international ban on drift gillnetting for squid has decreased landings in Japan, Korea, and Thailand.

However, as seen in Table 9, recent increases in ex-vessel price have not prevented a decline in overall value of landings. Value of local trawl landings during the past two seasons (1992 and 1993) has declined compared to the years 1988-1991.

The 1994 price will likely be even higher as fishermen were reportedly paid from $0.80 to $1.10 this past season.

Contributions of Area 538 to east coast Loligo production

Area 538 has been one of the most productive single statistical areas for the domestic Loligo fishery in the past two decades (Table 10). Brodziak and Rosenberg (1993) reported Area 538 accounted for an average of 48% of total annual U.S. landings from 1970 to 1990, but noted the decline in relative importance during the 1980's due to expansion of the offshore fishery.

It should be noted that during years of foreign fishing and foreign/domestic joint ventures, U.S. landings were only a small percentage of total squid removals. The majority was either caught by foreign trawlers offshore or delivered by U.S. trawlers over-the-side.

Percent of total catch ranged from 10-20% in 1979, 1983, and 1986-1990. The period 1991-1993 was similar to 1978-1985, except for 1979 and 1983. The elevated percent contributions of 1986-1989 may be attributable to a brief respite in the offshore fishery. Notably, foreign landings were negligible during 1987-1989 (11,000 pounds or less).

As percentage of U.S. squid landings, the recent decline of Area 538's contribution is dramatic (Table 10). Area 538 produced only 2% and 4% of the east coast squid landings during the past two years, 1992 and 1993. Offshore landings taken during autumn and winter (October-April) now dominate production (Brodziak 1994). In 1992, nearly half of the annual squid landings was taken from one statistical area, 616 -- along the edge of the continental shelf off New Jersey (Figure 7).

Table 10. Area 538 Loligo landings expressed as percent of both U.S. landings and total catches (including foreign catches and joint ventures) 1978-1993.

Year	Area 538 Landings*	As pct of US Landings	As pct of Total Catch
1978	762,301	39%	3%
1979	5,207,001	77%	14%
1980	3,697,540	64%	7%
1981	1,214,743	43%	2%
1982	1,723,926	31%	4%
1983	11,437,819	60%	19%
1984	3,679,877	23%	7%
1985	1,359,388	9%	4%
1986	4,021,812	16%	10%
1987	3,029,095	13%	12%
1988	8,571,696	21%	20%
1989	7,054,079	14%	14%
1990	3,511,336	11%	10%
1991	3,526,937	8%	7%
1992	939,514	2%	2%
1993	1,899,425**	4%	4%

** Area 538 landings data includes NMFS squid landings data for all gear types except fish traps, pound nets and weirs, and Mass. weir landings figures were substituted. U.S. landings and adjusted for the changes in the Area 538 component.*

*** 1993 area 538 data are preliminary, including all Mass. weir landings but only*

Landings figures for 1993 indicate continued growth in offshore fisheries. Winter 1993 landings (January-April) reached an all-time high at nearly 29 million pounds (Table 11). However, inshore fishermen did not enjoy a similar increase during the Massachusetts spring fishery. Area 538 landings were only about 1.9 million pounds in 1993, well below the 3.9 million lbs. average for the study period - and only 4% of the U.S. total.

Table 11. Winter (January - April) U.S. loligo squid landings as percent of annual total, 1978-1993.

Year	U.S Landings* Annual	Jan-April	Pct.
1978	1,929,914	253,265	13%
1979	6,787,320	602,910	9%
1980	5,819,393	677,529	12%
1981	2,847,042	550,038	19%
1982	5,623,006	626,395	11%
1983	19,221,899	1,843,641	10%
1984	15,765,823	2,864,881	18%
1985	15,178,615	3,263,034	21%
1986	25,339,785	4,739,096	19%
1987	22,790,470	7,786,615	34%
1988	40,949,358	9,975,445	24%
1989	52,061,726	25,092,348	48%
1990	33,358,209	11,134,901	33%
1991	43,177,500	10,623,434	25%
1992	40,147,025	19,349,280	48%
1993**	47,400,000	28,739,134	61%

** U.S. landings data adjusted with corrections for the Mass. vs. NMFS weir landings data discrepancies. Landings do not include squid caught by domestic vessels and delivered to foreign processors through joint ventures. During the late 1970's and early 1980's most squid catches were attributed to foreign trawlers catching or accepting and processing squid at-sea through joint ventures.*

*** 1993 data preliminary.*

HISTORY OF TRAWL FISHERIES MANAGEMENT WITHIN THE SOUNDS

Significant restrictions on trawlers working in Nantucket and Vineyard Sounds were implemented from 1978-1992. At the outset, the fishery was practically unrestricted: no net mesh minimum sizes, few fish minimum sizes, no gear limits, and no limit on vessel size. Only the seasonal approximate 3-mile, May 1 through October 31 closure established in 1938 from Mashpee to Chatham was in effect. Most important, however, was the Commonwealth's inability to regulate fishing beyond the three mile limit in the sounds.

A report submitted by then-Director Frederick C. Wilbour (1963) to the Massachusetts Legislature concerning trawling in the territorial waters of Nantucket and Vineyard Sounds recommended a night closure to mobile gear and minimum mesh sizes of 4 1/2" to 5 1/2" to reduce mortality of small fish. The authors concluded:

> "The future of the small draggers fishing in these sounds is dubious; if the larger draggers continue to fish in the territorial waters of the sounds both night and day, the small draggers will probably go out of business."

These actions were accomplished over 25 years later. In 1983, DMF obtained the authority needed to regulate fishing in the sounds: state jurisdiction throughout Nantucket Sound. Congress amended the Magnuson Act in 1983 and granted the Commonwealth fisheries jurisdiction throughout Nantucket Sound in waters west of the 70° line. Prior to this time, waters in the center of Nantucket Sound beyond three miles from shore were under federal jurisdiction. Any state regulations would have been weakened by unrestricted fishing in the unregulated area.

DMF and the Commission began to regulate fishing in the area after obtaining this necessary jurisdiction. The most controversial decision was the 90-foot vessel length limit adopted in 1985, thus preventing vessels larger than 90 feet (registered length) from fishing in state waters. This action was taken to thwart an anticipated shift inshore by large vessels displaced from fishing portions of George's Bank by the 1984 World Court decision which gave important Georges Bank fishing grounds to Canada. Also, eight new domestic freezer-trawlers ranging in length from 100 to 219 ft were being built to take advantage of the reduced foreign vessel allocations of Loligo and Illex squids, mackerel, and butterfish both for the directed foreign fishery and joint ventures (Stevens, 1985). This size limit reduction was intended to be a stop-gap measure until other strategies could be adopted. Other rules adopted in 1985 included:

- permit required for domestic vessel processing at sea or accepting fish over the side;
- ban on night fishing by mobile gear (repealed that year, but adopted again in 1992).
- trawl gear limits of 18" diameter discs, rollers, and rockhoppers.
- minimum fish sizes for scup (7") and sea bass (8") for both commercial and

recreational fishermen (scup and bass later increased to 9" and 12", respectively).

The "squid season" is not established by regulation directly. Rather, it is set indirectly by trawl net minimum mesh size regulations. Current regulations allow use of small mesh (no minimum specified) for 41 days from April 23 - May 31 with the potential for a 15 day extension based on sea sampling results. Thus, large-mesh regulations "frame" the spring squid fishery.

Current rules have evolved over the past nine years and have shortened the squid season:

- In 1985, trawl net minimum mesh of 5" was first implemented for state waters, and in waters south of Cape Cod was required from November 1 through April 30. No minimum mesh was mandated from May - October.

- In 1987, at the request of the Massachusetts Inshore Draggerman's Association, 3½" trawl mesh was required from July through October. Notably, in 1988 at the request of fishermen delivering squid to a freezer/trawler in Nantucket Sound, DMF allowed squid mesh to be used beyond the June 30 deadline into July.

- In 1990, squid mesh season was shifted from May 1-June 30 to April 15-June 15 to protect juvenile scup and sea bass.

- In 1992, the squid season was shortened again to the current 41 days, April 23 - May 31 with a provision to allow squid fishing to continue until June 15 if catches remain free of undersized finfish, and squid size remains large.

Other restrictions affecting trawlers working in Vineyard and Nantucket Sounds include:

- Trawlers targeting squid are limited to 100 pounds of flounders in possession. Also in 1992, mandatory mesh size south of Cape Cod during June-October was increased to 4½" (up from 3½"). Any vessel possessing more than 100 pounds of flounders (any species) must possess only 5½" mesh or larger year round. For vessels unloading each day, this translates to 100 pounds per day, but for vessels fishing a multi-day trip, vessels are capped at the 100-pound limit for the trip, unless they offloaded their flounder catch at shore then resumed their fishing for squid the following day.

- In 1992 a night closure to mobile gear fishing was established for Vineyard and Nantucket Sounds for April through October. In November 1992 the closure was extended to all state waters and all months of the year. Trawlers that could formerly direct their efforts on other species after dark (when squid are generally less catchable) with no mesh size restrictions were now forced to cease their operations from one-half hour after sunset to one-half hour before sunrise. This timing of the night closure extends from March 1 through October 31. The closure extends from 6:00 p.m. to 6:00 a.m. from November 1 through the last day of February.

Trawlers fishing outside of Massachusetts waters have not been similarly regulated. In nearby Rhode Island Sound (including areas under the jurisdiction of Rhode Island), trawlers were not subjected to mesh size regulations. But this past year, Rhode Island trawlers were required to use large mesh to catch flounders. However, mesh size is not regulated for vessels targeting non-flounder species, e.g. squid, scup, butterfish, and black sea bass.

In federal waters beyond three miles south of Martha's Vineyard and Nantucket Island and west to 72°30' W Longitude (near Hudson Canyon), specially-permitted trawlers are exempted from the MAFMC Fluke Management Plan 5½" cod end minimum mesh size restriction (or 6" square mesh) from November 1 through April 30 if 200 pounds or less of fluke is in possession. For the rest of the year and in all areas east and west of the line, a minimum of 5½" (or 6" square) is required when more than 100 pounds of fluke is in possession.

Similarly, in federal waters south of the Islands and west throughout the southern New England area, trawlers may fish with or possess nets less than 5½" (diamond or square mesh) throughout the entire net provided that trawlers do not possess or land per trip more than 500 pounds of regulated species (e.g., cod, haddock, and flounders in total). In 1995 the same provision will apply except that the square mesh minimum size will increase to 6."

MANAGING SQUID PROCESSING AT SEA, 1984-1993

History

Most of DMF's and MFC's management attention paid to the squid fishery has been spent regulating opportunities to process squid at-sea. In 1983 local companies tried to arrange for foreign vessels to accept squid at sea from domestic vessels fishing in Nantucket Sound. By 1985 domestic freezer-trawler owners displaced foreign vessels seeking opportunities to buy squid over-the-side in the sounds.

The 1982 amendment to the Magnuson Act known as the Internal Waters Joint Venture Amendment (Marine Law Institute, September 1984), permitted over-the-side fish transfers to foreign vessels in a state's internal waters based on a governor's determination that the state's processing facilities cannot handle catch of domestic harvesters.

In 1983, the Commission recommended that the Governor not approve a joint venture arranged by Agro Marine of New Bedford for a Spanish processing vessel (freezer-trawler) to accept and process squid in Nantucket Sound. The MFC based its decision on an informal survey of local processors and determined there was ample processing capability given the available harvesting capacity. Also, the issue of state vs. federal jurisdiction in the center of Nantucket Sound had yet to be fully resolved.

However, in spring 1983 squid catches in Vineyard & Nantucket Sound were so large they overwhelmed fishermen and processors (Stevens 1983b). Some processors placed quotas on individual fishermen, and some fishermen were "shut off" for up to five days.

This "glut" factored into the MFC's 1984 decision to recommend that the Governor approve one of two requests for foreign vessels to process squid in Massachusetts internal waters. The MFC recommended one operation involving a Spanish processing vessel be approved for 5.5 million pounds (2,500 mt). Furthermore, the Commission was swayed by a lack of response to a DMF questionnaire concerning processing capacity and intent for the upcoming season.

Controversy erupted when seafood dealers, many of whom had not responded to MFC and DMF requests for information, lobbied the Governor to deny the venture. The Governor initially indicated support for an "experimental fishery" at about 2.8 million pounds (1,250 mt), but opted to withhold approval pending an economic impact analysis. Consequently, squid arrived in 1984 without the extra processing capacity of the foreign processor. However, squid were not nearly as abundant as the previous year, and ex-vessel prices were reduced as well.

From 1985-1991, DMF received annual requests from owners (or representatives) of domestic freezer-trawlers to buy squid over-the-side. Public meetings were held each year in late winter to determine the number of processors to be permitted to operate in the fishery and the squid weight limits each vessel would be allowed.

Figure 16. *Small trawler (21 GRT, 41 ft. long) offloads squid to large freezer-trawler (197 GRT, 112 ft) in Vineyard Sound near the Falmouth shore in May 1988.*

Each year DMF tried to balance needs of fishermen, processors, and the resource. Some fishermen enjoyed the convenience of delivering squid at sea since it allowed more hours fishing, negated the need and cost for ice, and provided extra processing capacity in the event of a 1983 type of "glut" when dealers could not handle all the available supply. Also, larger vessels were limited by available docking space in the harbors bordering Nantucket and Vineyard Sound. Squid typically are caught during daylight hours, and most vessels head shoreside in the evening to unload.

For the owners of freezer-trawlers over 90 feet that targeted squid through the winter months in offshore waters, the at-sea processing provided income when squid were inshore, when Massachusetts regulation prevented them from fishing in the sounds. The at-sea processing arrangements provided access to valuable quantities of "extra large" squid (tube length over 12"), common to the sounds. Price per pound increases with squid size.

Opponents of at-sea processing included shoreside processors and dealers who were concerned about losing product when squid were transferred at sea. Also, commercial and recreational fishermen feared floating processors created a "magnet effect" attracting new vessels to the squid fishery or allowing existing participants to fish longer and harder.

Weir operators believed their landings would suffer due to increased trawling in the

sounds intercepting squid before reaching nearshore, stationary traps. Furthermore, gear conflicts were anticipated by weir operators and other fixed gear fishermen such as conch and fish potters -- conflicts caused by trawlers drawn to the sounds by the freezer trawlers and unfamiliar with Nantucket Sound or local fixed gear setting patterns.

DMF and MFC expressed concern about potential squid overharvest in this known squid spawning area and the cumulative effects of by-catch and discard mortality on important species such as striped bass, winter flounder, and scup.

Despite receiving up to six requests for permits each spring, DMF issued only one to three at-sea processing permits each year. DMF attempted to keep the number of operations to a minimum due to the need to monitor the catch composition, especially by-catch and discard of juvenile fish and potential impacts on shore-based processors in Massachusetts, Rhode Island, and elsewhere. In addition, weight limits were placed on each permit (Table 12).

Legal challenge to at-sea processing limits and vessel size limit

After 1991, DMF no longer placed limits on amounts of squid that processors were allowed to purchase. In 1990 Davrod Corporation and Deep Sea Fish of Rhode Island, after being denied an at-sea processing permit (for the F/V Huntress, a 90'6" freezer-trawler), brought a federal suit against DMF to overturn two regulations: the limits placed on at-sea processing permits and the vessel length limit.

Table 12. Summary of permits issued by DMF to process squid at-sea with totals landed as a percent of all trawl-caught squid from Area 538.

Year	Permits Issued	Per permit Limits	Amount Processed at-sea	Trawl-caught Squid Total	Squid Processed At-sea as percent of all Trawl-Caught Squid
1985	1	2000 MT	Unavailable	314 MT	-
1986	1	2000 MT	Unavailable	1361 MT	-
1987	1	1000 MT	6 MT	867 MT	1
1988	1	1000 MT	471 MT	3021 MT	16
1989	3	1000 MT	660 MT	2520 MT	26
1990	2	500 MT	155 MT	1249 MT	12
1991	2	250 MT	276 MT	1269 MT	22
1992	3	NONE	4 MT	232 MT	2
1993	4	NONE	85 MT	571 MT	15

U.S. District Court Judge Walter J. Skinner upheld the vessel size limit along with the rule that at-sea processors accept catches sorted free of finfish by-catch. However he ruled that DMF should not "impose any restriction on the amount of Loligo squid which may be processed annually by at-sea processors" (Davrod v. Coates, No. 90-11345S). A subsequent appeal to Judge Skinner's decision to the U.S. Court of Appeals upheld the vessel size regulation but overturned the lower court's ruling that DMF could not restrict the amount of squid processed by at-sea processors. On remand, Judge Skinner ruled that the total amount

processed at sea was so low that there was no effect interstate commerce.

Since 1992, DMF has opted not to limit the number of permits or place weight limits on permits. Low squid catches in the sounds in recent years (1992-94) have made it infeasible for at-sea processors to purchase the amounts approaching squid poundage limits for at-sea processors that were applied in the past. Furthermore, many of DMF's concerns have been addressed through regulations affecting all trawlers in the squid fishery such as the shortened squid trawl mesh season and the requirement that at-sea processors only accept squid free of by-catch (undersized or illegal).

The proportion of trawl-caught squid in Area 538 landed by at-sea processors peaked at 26% in 1989 (Table 12). In contrast, 1992 squid catches were so low that freezer-trawlers left after a few disappointing days, and some never participated in the fishery. In 1993, with squid abundance and landings up only slightly from the disappointing 1992 level, only three of the five permitted freezer-trawlers participated in the fishery, all for less than two weeks during mid-May.

CATCHES IN THE SQUID TRAWL FISHERY

Squid

Size composition

Early spring arrival of squid inshore is dominated by larger squid followed by a shift toward smaller individuals. Squid size composition, examined by DMF sea samplers on trawlers for the past four seasons (Figure 17), has been similar except for 1990 due to the presence of 2-4" (5-10 cm) squid. These small squid were seen only on the season's last sampling date (May 23) when of the five samples taken, only one sample measured more than 25% of the total weight under 5" mantle length -- the standard DMF established to end at-sea processing of squid. The remaining four samples ranged from 15.4% down to 2.3%.

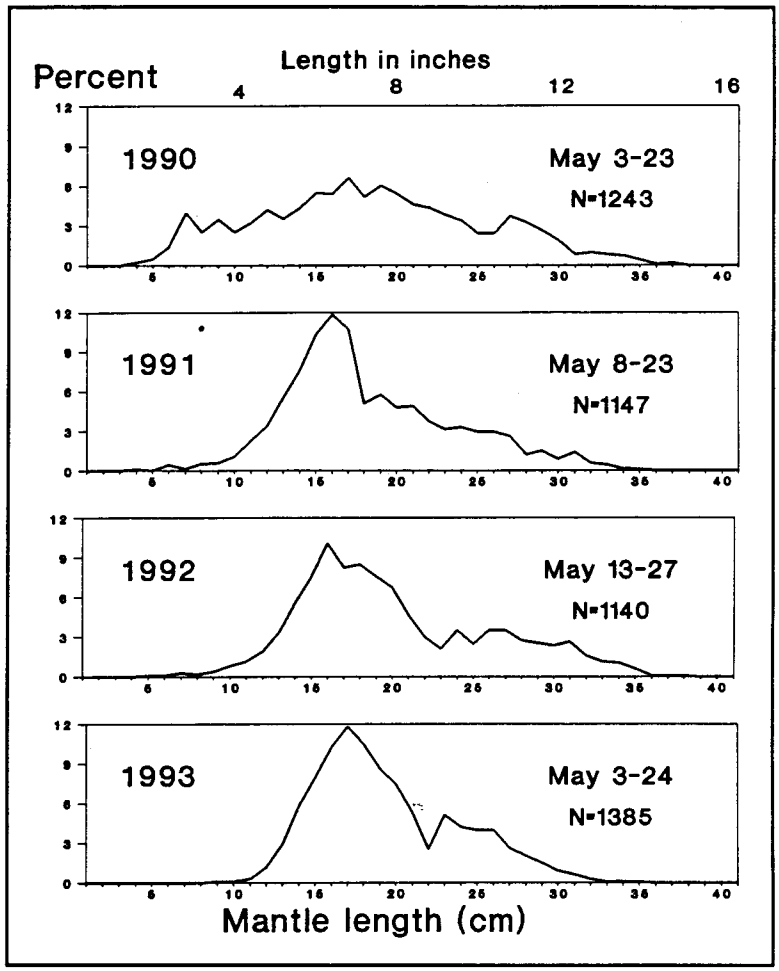

Figure 17. Squid size composition sampled by DMF observers during 1990-1993.

While sea samplers did not measure squid in 1989, data gathered from a permitted freezer-trawler demonstrated the shift in squid size during late May and June. Percent of squid packed in the 4-6" (10-15 cm) category ranged from 27% to 39% during May 4-May 24 but subsequently, during May 25-June 16, 61% of the squid packed were 4-6" (McKiernan and Bugley, 1989).

DMF amended regulations in 1991 to end the annual squid fishing season after May 31 with a possible extension into June based on sea sampling. Vessels have responded by leaving Nantucket Sound and pursuing squid south of Nantucket Island and Martha's Vineyard. These trips are normally beyond Massachusetts territorial waters, are outside of Area 538, and are not sampled by DMF at sea.

In light of new ageing research (Macy 1992), most squid observed in trawler catches were hatched the previous summer. According to Macy (1992), large squid 7" (17 cm) and

greater found inshore in spring were hatched primarily during the previous summer, and smaller squid were hatched after October of the previous year indicating late summer spawning. DMF's fall trawl survey encounters young-of-the-year (YOY) squid measuring less than 3½" (9 cm) annually each September. Squid encountered in DMF's fall survey grow to sizes seen in the following year's inshore spring fishery. Therefore, a measure of abundance of YOY in September might be the best predictor of next spring's abundance of large squid, assuming squid are not intercepted by offshore fisheries prior to their inshore migration. To predict the level of recruitment of small squid -- less than 5" (13 cm), the size that historically has dominated the catches in June and later months -- an offshore survey would be needed after the fall and winter hatching period.

Sex composition

The 1993 spring catch size frequency of 1,385 individuals is separated by sex in Figure 18. The mode in numbers of squid at length fell between 5½-8¼" (14-21 cm) in 1993. Very few females were greater than 8¾" (22 cm). For example, only 6% of females were above 8" while 63% of males exceeded 8." Similar results were seen in 1992 when DMF observers began noting squid sex during the season's final sampling trip on May 27.

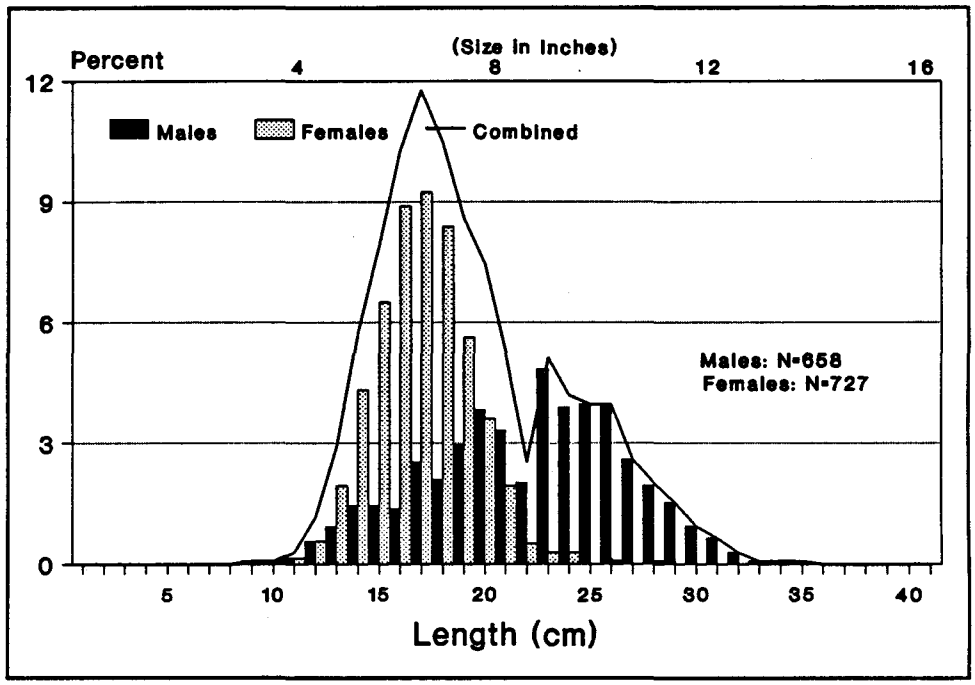

Figure 18. Squid size composition observed during 1993 partitioned by sex.

This lack of females at larger sizes may be explained by different growth rates. Females are smaller than males and restricted in length. Males and females grow at the same rate until females reach sexual maturity and shift their energy from body to reproductive growth; females increase in girth instead of length; and reproductive organs and eggs can comprise up to 30% of the weight of mature female squid (Macy 1992).

Catch composition

Catch composition in the Massachusetts squid trawl fishery can be described through

two data sources: reports of DMF sea samplers aboard commercial vessels and landings data collected by NMFS port agents.

Reported landings

Otter trawl trips from Area 538 landing any squid in May from 1978-1993 were selected from the NMFS commercial fisheries weigh-out system (Tables 13 and 14). May is the dominant month for squid landings by both trawlers and weirs (Tables 2, 3, 7, & 8), and squid is the primary target species of trawlers fishing in the sounds in May. A complete list of all species landed is provided in Appendix B.

Table 13. Summary of May Area 538 otter trawl landings for vessels landing squid. Top 7 species listed. Complete landings list is presented in Appendix A.

YEAR	SQUID	SCUP	WINTER FLOUNDER	WINDOWPANE FLOUNDER	TAUTOG	SUMMER FLOUNDER	BLACK SEA BASS	REMAINING SPECIES	TOTALS
1978	203,753	35,339	110,229	52,025	6,105	4,181	2,054	2,764	416,450
1979	3,358,027	578,143	206,358	43,684	8,660	18,075	12,848	107,470	4,333,265
1980	2,358,862	395,933	371,937	24,461	14,725	8,700	10,095	1,650,350	4,835,063
1981	823,682	292,673	253,941	47,279	2,745	10,176	22,698	44,202	1,497,396
1982	1,186,047	243,539	114,775	17,255	3,700	10,125	18,340	41,157	1,634,938
1983	7,164,396	430,375	205,357	39,672	10,956	24,932	39,236	62,696	7,977,620
1984	1,819,229	218,784	179,849	54,299	49,990	17,275	42,313	60,868	2,442,607
1985	626,511	69,694	155,130	61,682	40,881	15,115	15,494	37,935	1,022,442
1986	2,377,316	239,883	107,430	45,148	36,246	29,118	24,831	42,454	2,902,426
1987	1,606,436	332,824	131,089	108,268	34,168	19,041	7,067	162,446	2,401,339
1988	3,250,413	49,082	78,597	62,494	19,588	49,347	6,883	39,613	3,556,017
1989	4,486,248	257,944	83,524	32,075	25,511	42,715	8,073	54,668	4,990,758
1990	2,187,371	314,528	84,708	41,591	26,335	9,604	13,020	46,800	2,723,957
1991	2,602,146	113,802	55,957	14,293	19,367	19,076	2,241	33,694	2,860,576
1992	445,643	139,993	27,018	10,333	14,992	17,937	1,025	12,976	669,917
1993	1,115,955	103,924	50,256	14,851	4,740	5,373	264	65,380	1,360,743
MEAN	2,299,739	247,502	144,393	43,637	20,931	19,694	15,081	160,006	2,950,985

Note: In 1980, 1,589,882 pounds of "Other Fish" was recorded by NMFS. This category includes unidentified species used for reduction (i.e. fish meal). No species information is available.

Table 14. Percentages for each species listed in Table 13.

YEAR	SQUID	SCUP	WINTER FLOUNDER	WINDOWPANE FLOUNDER	TAUTOG	SUMMER FLOUNDER	BLACK SEA BASS	REMAINING SPECIES
1978	49%	8%	26%	12%	1%	1%	0%	1%
1979	77%	13%	5%	1%	0%	0%	0%	2%
1980	49%	8%	8%	1%	0%	0%	0%	34%
1981	55%	20%	17%	3%	0%	1%	2%	3%
1982	73%	15%	7%	1%	0%	1%	1%	3%
1983	90%	5%	3%	0%	0%	0%	0%	1%
1984	74%	9%	7%	2%	2%	1%	2%	2%
1985	61%	7%	15%	6%	4%	1%	2%	4%
1986	82%	8%	4%	2%	1%	1%	1%	1%
1987	67%	14%	5%	5%	1%	1%	0%	7%
1988	91%	1%	2%	2%	1%	1%	0%	1%
1989	90%	5%	2%	1%	1%	1%	0%	1%
1990	80%	12%	3%	2%	1%	0%	0%	2%
1991	91%	4%	2%	0%	1%	1%	0%	1%
1992	67%	21%	4%	2%	2%	3%	0%	2%
1993	82%	8%	4%	1%	0%	0%	0%	5%
MEAN	73.1%	10.0%	7.3%	2.6%	1.1%	0.9%	0.6%	4.3%

Note: The 34% for 1980 is due to very large landings of unidentified species used for reduction.

This data set was chosen because there weren't any state minimum net mesh requirements in May before 1992 when flounder possession was limited to 100 pounds for vessels possessing small mesh. It is assumed that most trips were conducted with small-mesh nets.

Squid was the predominant component of each year's May landings, averaging 73.1% by weight with annual percentages ranging from a low of 49% in 1978 to a high of 91% in 1991 (Table 14). The 49% in 1980 was due to unusually high, unidentified landings of "other" species with 1,589,882 pounds (33% of total 1980 Area 538 landings) of species such as sea herring used for reduction (i.e., fish meal).

Scup ranked as the most common "by-catch" species. Some of this scup by-catch may have resulted from directed small-mesh fishing for scup and squid together. This is a reason why another criterion was not used to define the data base (e.g., trips with landings 50% or greater squid). With a 50% criterion, many small-mesh trips with large amounts of squid would have been missed. Furthermore, before 1992 when night fishing was allowed in Massachusetts waters, vessels would have landed mixed catches of squid and flounders, perhaps caught at night and taken with small mesh. Squid landings from these trips also would have been missed.

Scup dominated the non-squid component of the landings' tally in 12 of the 16 years (Tables 13 and 14). Landings of scup in the May otter trawl fishery (trips landing squid) has accounted for an average of 12% of all Area 538 scup commercial landings. Scup landings per day fished in the squid fishery have been variable but have shown a steady decline since the early 1980's. There have been similar declines in overall annual Area 538 landings for all gear types (Figure 19). (Note: for trends plotted in Figure 19, "Trawl landings per day" and "Trawl landings/day in May" are based on May otter trawl trips landing squid. While "Annual 538 landings" represents annual commercial landings for the named species taken by all gear types).

Winter flounder has been the second ranking May by-catch species over the study period and ranked above scup in 1978, 1985, and 1988 (Tables 13 and 14). Landings of flounder in the May trawl fishery have accounted for an average of 16% of all commercial Area 538 annual winter flounder landings during 1978-1993. Flounder low landings of the past three years (1991-93) averaged just 44,410 lbs. and represented just 32% of the study period average. Furthermore, there has been an 88% decline from the peak year landings in 1980. Landings of flounder per day fished, quite variable during the earlier years of 1978-86, declined steadily during the past seven years. Similar declines in winter flounder abundance have been documented for Massachusetts waters south and east of Cape Cod (Howe et. al 1993).

Two other commercially important species commonly landed include windowpane flounder and tautog, and both species have increased in value during the 1980's. Increases in landings during the period are likely attributable to developing markets and increased ex-vessel price (personal communication, seafood processor Frank Sylvia of New Bedford).

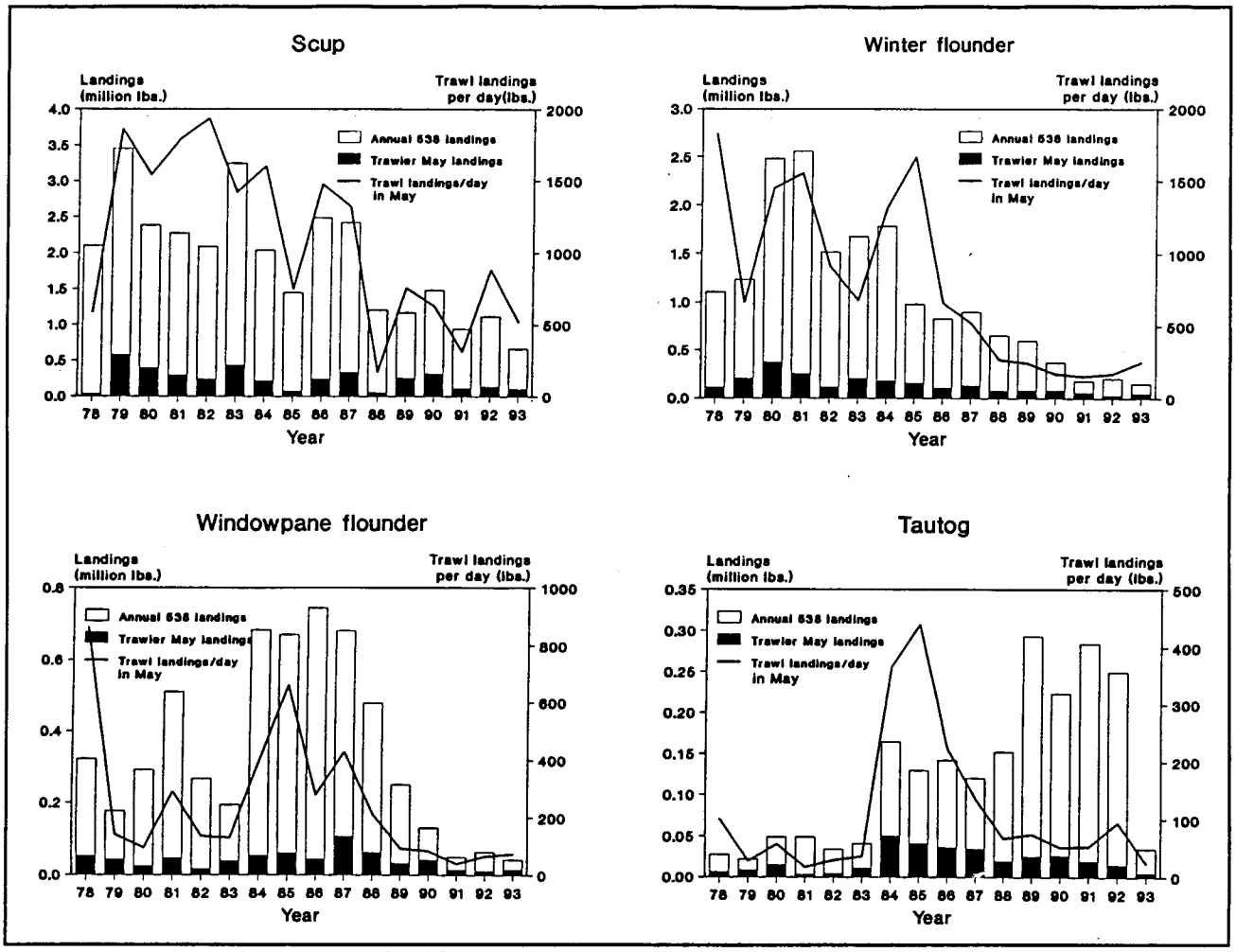

Figure 19. Area 538 landings trends of four by-catch species.

Windowpane flounder landings peaked during the mid 1980's and since 1987 have declined from a high of over 100,000 lbs. Landings during the past three years have been under 15,000 lbs., just one third of the long term average. Similar to winter flounder, landings of windowpane flounder in the May trawl fishery have accounted for an average of 16% of all commercial Area 538 windowpane flounder landings during 1978-1993.

Tautog landings in the squid fishery have seen a decline since 1984. However overall tautog annual landings in Area 538 increased during the period. Increased demand for tautog as well as a developing market for live fish fueled landings with increases primarily attributable to fishermen using pots, or rod and reel.

Summer flounder (fluke) and black sea bass also are commonly reported in small quantities. Each species represented less than 1% of the landed catch of the squid fishery (Table 14). Landings in the squid trawl fishery for these species accounted for a minor portion of the overall annual commercial landings (all gear types) from the region. For summer flounder, May trawl landings averaged 2% (18,799 lbs.) of the overall commercial (all gear types) landings from Area 538 of 814,082 lbs. For sea bass, May trawl landings

averaged 4% or 14,155 lbs. of annual commercial landings from Area 538 that averaged 324,749 lbs.

Declines depicted in catch rates of squid, winter flounder, windowpane, and scup are probably worse than portrayed since effort was not "standardized", to account for the increased number of fishing days by large vessels and fishing power attributable to increased numbers of largest vessels during the study period. Diminishing contribution of small vessels (Class 1 & 2) and increasing contribution of large vessels (Class 4) are depicted in Figure 12.

Larger trawlers (classes 3&4) land more of the top four by-catch species both on a per-day basis (not surprising given their greater horsepower and ability to tow larger nets) and on a per-unit squid basis, suggesting larger vessels land more of a "mixed catch". Figure 20

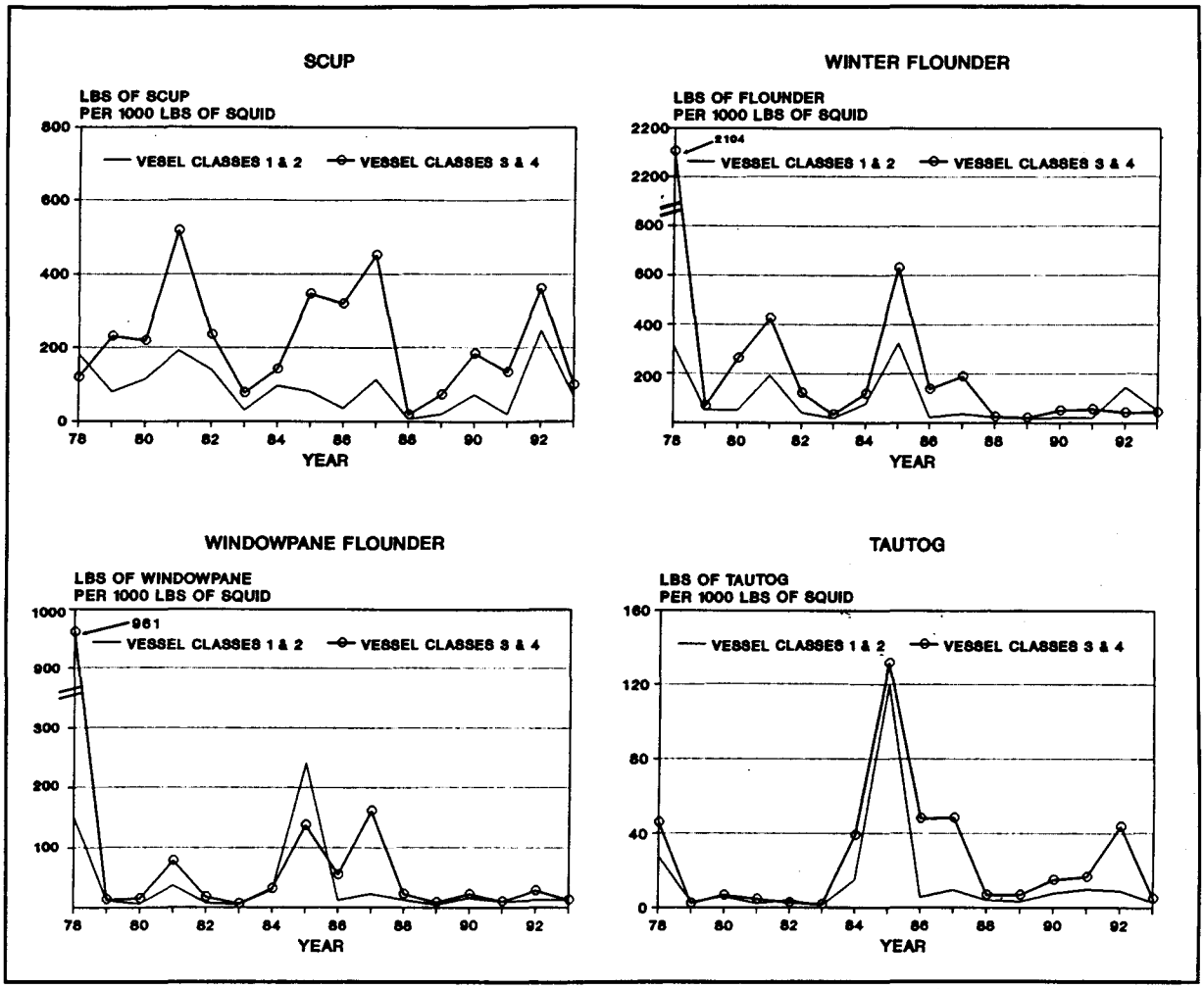

Figure 20. Comparisons of combined vessel classes' by-catch landed per unit (1000 lbs.) squid.

depicts the ratio of landings of the four primary by-catch species per 1000 lbs. of squid landed. Combined landings per 1000 lbs. of squid for class 1 and 2 vessels were significantly less than that for vessel classes 3 and 4 combined. Data were tested using a nonparametric

test, Wilcoxon Matched Pairs Signed Ranks Test (Nie, 1983).

DMF sea sampling

DMF squid fishery sea sampling began in 1989 on both commercial trawlers and at-sea processing vessels accepting catch over-the-side. In 1989, DMF biologists were stationed aboard the processor and documented contents of numerous tows. Vessels delivered detached trawl cod-ends to the processor; therefore, catches from many different vessels were observed in a short period of time. However, reliable information on location or tow time was not obtained. Furthermore, samplers were uncertain if fishermen removed any by-catch species from the catch before catch was transferred.

Since 1990, after observing dead fish in catches that were later discarded by processing vessel crews, DMF prohibited transfer of unsorted catch. All permits issued to processing vessels accepting squid at sea include a ban on transfer of sublegal fish and species prohibited to be taken by trawl gear. Permits read:

Table 15. Summary of DMF Sampling Efforts for Squid Trawl Fishery, 1989-1993.

Year	Trips	Time Period	Vessel Classes (GRT) Sampled
1989	3	May 13 - June 12	Samplers only stationed on processing vessel at-sea
1990	5	May 3 - 23	4 trips on Class 2 1 trips on Class 3
1991	3	May 8 - 23	2 trips on Class 2 1 trips on Class 3
1992	3	May 13 - 27	3 trips on Class 2
1993	8	May 3 - 24	4 trips on Class 2 3 trips on Class 3 1 trip on Class 4

> "Unsorted catches in detached cod-ends may not be accepted from fishing vessels. Striped bass, lobster, coho salmon, Atlantic salmon, smelt and shad may not be accepted in the transfer of the catches. All transfers shall be free of sublegal finfish."

During 1990, 1991, and 1992 sea sampling was conducted on an ad hoc basis, and a total of 11 trips were sampled during those years (Table 15). Samplers focused on finfish bycatch and squid size composition. After reports in 1989 that freezer-trawlers licensed as at-sea processors were discarding up to half of some vessels' squid catch due to small size, DMF mandated for 1990 and 1991 that at-sea processing cease when the "run" of squid became small, i.e., when 25% of the catch (by weight) measured below 5" mantle length. There were no reports of small squid dominating 1990 or 1991 catches. By late May, harvestable quantities of squid were no longer available, and the fleet departed the sounds.

In 1992, regulations were amended to close the fishery after May 31, with a provision to extend the season up to June 15 if squid size was still large and discards of fish and squid remained low. This shortening of the season reduced the need to monitor squid size since small squid 4-6" mantle length historically dominate catches in June, not in May. DMF extended the squid season for one week in June at the request of fishermen who hoped the

run was "late", but catches never increased.

With the hiring of sea sampling personnel in late 1992, DMF increased its sea sampling capabilities and sampled eight trips from May 3-24 during the 1993 squid season with an emphasis on sampling all vessel classes in the fishery, especially vessel classes 3&4.

The 1993 "squid season" ended on May 31. DMF was not requested to extend the season into June. Summer flounder possession limits were increased from 100 to 500 pounds on June 1, and fishermen who remained in the sounds switched to large mesh (5½") as required by regulation.

Observed catches compared to NMFS reported Area 538 landings

DMF observed catches on otter trawlers from 1990-1993 were compared to May Area 538 otter trawl landings for vessels landing squid as reported to NMFS (Table 16). Data from 1989 were not included since 10 of 12 samples were acquired aboard a processing vessel, and it was unknown if by-catch species were kept by vessels delivering catches to the processor.

Squid was the dominant species in both DMF sampled catches and reported NMFS landings. With few exceptions, the dominant species of landed catch and sampled catch are the same, as seen in the rankings. Species totals from observed catches for each sampling year are listed in Appendix C. However, some species with schooling behavior, such as mackerel and dogfish, comprising large amounts of Area 538 landings, don't appear in observed catch retained on sea sampling trips. For example, NMFS reported 1993 mackerel 538 landings of about 35,000 pounds placing this species in fourth position. Dogfish was in 6th position. Clearly, DMF samplers did not happen to sample a trawler catching large amounts of mackerel or dogfish, or alternatively, these trips may have targeted these species and caught some squid; hence, otter trawl trips that may have been primarily for mackerel and dogfish were included in the tally. Furthermore, some species such as Illex squid, cod, American plaice, witch flounder, and silver hake -- observed in the sampled catch in small quantities -- might have been incorrectly reported to NMFS as Area 538 catch. Some tows in the NMFS database recorded as Area 538 catch might actually have occurred outside Area 538 for all or at least part of the trip.

Regarding increased sampling in 1993, considerable effort was expended to cover all size classes of vessels. DMF samplers had not sampled any Class 4 vessels in prior years due to difficulty of contacting these vessels. In contrast to smaller vessels under 50 GRT (classes 1&2), larger vessels in the fishery in excess of 50 GRT (class 3&4) fished multi-day trips and typically did not tie-up in port overnight but remained anchored on fishing grounds. As a result, they were not well represented in DMF sampling. DMF's focus during the earlier years was on monitoring at-sea processing operations and squid size. Sampling was expanded in 1993 to address increased public concern about trawling in the sounds.

Table 16. Observed catch retained on sea sampling trips compared to NMFS landings for all otter trawl trips landing squid in May from area 538.

YEAR: 1993

SPECIES	SEA SAMPLING LBS.	PCT	RANK	NMFS LANDINGS LBS.	PCT	RANK
LOLIGO	6,703	87%	1	1,115,955	82%	1
BLUEFISH	319	4%	2	6,691	0%	7
SCUP	279	4%	3	103,924	8%	2
TAUTOG	133	2%	4	4,740	0%	8
WINTER FL	128	2%	5	50,256	4%	3
SKATEWINGS	66	1%	6	0	-	
FLUKE	47	1%	7	5,373	0%	7
SKATE	20	0%	8	2,664	0%	10
BUTTERFISH	9	0%	9	2,017	0%	
WINDOWPANE	7	0%	10	14,851	1%	5
LOBSTER	7	0%		0	-	
BLACK SEA BASS	4	0%		264	0%	
MACKEREL	3	0%		35,028	3%	4
COD	0	-		2,995	0%	9
AMERICAN PLAICE	0	-		2,506	0%	
RED HAKE	0	-		38	0%	
MONKFISH	0	-		742	0%	
CONCH	0	-		1,958	0%	
SHAD	0	-		10	0%	
YELLOWTAIL FL.	0	-		664	0%	
SILVER HAKE	0	-		798	0%	
WHITE HAKE	0	-		107	0%	
STRIPED BASS	0	-		24	0%	
SPINY DOG	0	-		7,620	1%	6
WITCH FLOUNDER	0	-		577	0%	
POLLOCK	0	-		34	0%	
HADDOCK	0	-		3	0%	
WOLFFISH	0	-		26	0%	
CRAB	0	-		0	-	
ILEX SQUID	0	-		280	0%	
OTHER FISH	0	-		102	0%	
WEAKFISH	0	-		0	-	
SMALL TUNA	0	-		40	0%	
CONGER EEL	0	-		456	0%	
ATL HERRING	0	-		0	-	
SEA ROBIN	0	-		0	-	
HALIBUT	0	-		0	-	
TOTALS	7,725	100%		1,360,743	100%	

Year: 1992

SPECIES	SEA SAMPLING LBS.	PCT	RANK	NMFS LANDINGS LBS.	PCT	RANK
LOLIGO	2,572	86%	1	445,643	67%	1
BLUEFISH	0	-		5,157	1%	7
SCUP	406	14%	2	139,993	21%	2
TAUTOG	0	-		14,992	2%	5
WINTER FL	16	1%	3	27,018	4%	3
SKATEWINGS	0	-		0	-	
FLUKE	0	-		17,937	3%	4
SKATE	0	-		997	0%	10
BUTTERFISH	0	-		594	0%	
WINDOWPANE	0	-		10,333	2%	6
LOBSTER	0	-		0	-	
BLACK SEA BASS	0	-		1,025	0%	9
MACKEREL	0	-		3,615	1%	8
COD	0	-		46	0%	
AMERICAN PLAICE	0	-		15	0%	
RED HAKE	0	-		374	0%	
MONKFISH	0	-		646	0%	
CONCH	0	-		50	0%	
SHAD	0	-		0	-	
YELLOWTAIL FL.	0	-		95	0%	
SILVER HAKE	0	-		444	0%	
WHITE HAKE	0	-		5	0%	
STRIPED BASS	0	-		22	0%	
SPINY DOG	0	-		0	-	
WITCH FLOUNDER	0	-		35	0%	
POLLOCK	0	-		0	-	
HADDOCK	0	-		0	-	
WOLFFISH	0	-		0	-	
CRAB	0	-		240	0%	
ILLEX	0	-		0	-	
OTHER FISH	0	-		550	0%	
WEAKFISH	0	-		74	0%	
SMALL TUNA	0	-		0	-	
CONGER EEL	0	-		17	0%	
ATL HERRING	0	-		0	-	
SEA ROBIN	0	-		0	-	
HALIBUT	0	-		0	-	
TOTALS	2,994	100%		669,917	100%	

YEAR: 1991

SPECIES	SEA SAMPLING LBS.	PCT	RANK	NMFS LANDINGS LBS.	PCT	RANK
LOLIGO	11,939	98%	1	2,602,146	91%	1
BLUEFISH	0	-		4,678	0%	8
SCUP	30	0%	5	113,802	4%	2
TAUTOG	43	0%	3	19,367	1%	4
WINTER FL	105	1%	2	55,957	2%	3
SKATEWINGS	0	-		0	-	
FLUKE	39	0%	4	19,076	1%	5
SKATE	0	-		4,053	0%	9
BUTTERFISH	0	-		2,309	0%	
WINDOWPANE	0	-		14,293	0%	6
LOBSTER	0	-		108	0%	
BLACK SEA BASS	25	0%	6	2,241	0%	
MACKEREL	0	-		2,930	0%	
COD	0	-		3,214	0%	10
AMERICAN PLAICE	0	-		0	-	
RED HAKE	0	-		2,031	0%	
MONKFISH	0	-		1,913	0%	
CONCH	0	-		77	0%	
SHAD	0	-		38	0%	
YELLOWTAIL FL.	0	-		2,374	0%	
SILVER HAKE	0	-		9,146	0%	7
WHITE HAKE	0	-		41	0%	
STRIPED BASS	0	-		0	-	
SPINY DOG	0	-		0	-	
WITCH FLOUNDER	0	-		629	0%	
POLLOCK	0	-		6	0%	
HADDOCK	0	-		0	-	
WOLFFISH	0	-		0	-	
CRAB	0	-		0	-	
ILLEX	0	-		0	-	
OTHER FISH	0	-		0	-	
WEAKFISH	0	-		134	0%	
SMALL TUNA	0	-		0	-	
CONGER EEL	0	-		13	0%	
ATL HERRING	0	-		0	-	
SEA ROBIN	0	-		0	-	
HALIBUT	0	-		0	-	
TOTALS	12,181	100%		2,860,576	100%	

Year: 1990

SPECIES	SEA SAMPLING LBS.	PCT	RANK	NMFS LANDINGS LBS.	PCT	RANK
LOLIGO	3,940	65%	1	2,187,371	80%	1
BLUEFISH	0	-		5,605	0%	9
SCUP	2,068	34%	2	314,528	12%	2
TAUTOG	42	1%	3	26,335	1%	5
WINTER FL	2	0%		84,708	3%	3
SKATEWINGS	0	-		0	-	
FLUKE	0	-		9,604	0%	8
SKATE	0	-		4,339	0%	
BUTTERFISH	0	-		19,969	1%	6
WINDOWPANE	0	-		41,591	2%	4
LOBSTER	0	-		0	-	
BLACK SEA BASS	8	0%	4	13,020	0%	7
MACKEREL	0	-		6,351	0%	8
COD	0	-		1,786	0%	
AMERICAN PLAICE	0	-		0	-	
RED HAKE	0	-		0	-	
MONKFISH	0	-		1,498	0%	
CONCH	0	-		0	-	
SHAD	0	-		187	0%	
YELLOWTAIL FL.	0	-		1,259	0%	
SILVER HAKE	0	-		5,475	0%	10
WHITE HAKE	0	-		81	0%	
STRIPED BASS	0	-		0	-	
SPINY DOG	0	-		0	-	
WITCH FLOUNDER	0	-		157	0%	
POLLOCK	0	-		9	0%	
HADDOCK	0	-		4	0%	
WOLFFISH	0	-		0	-	
CRAB	0	-		0	-	
ILLEX	0	-		0	-	
OTHER FISH	0	-		0	-	
WEAKFISH	0	-		0	-	
SMALL TUNA	0	-		0	-	
CONGER EEL	0	-		47	0%	
ATL HERRING	0	-		5	0%	
SEA ROBIN	0	-		43	0%	
HALIBUT	0	-		5	0%	
TOTALS	6,060	100%		2,723,957	100%	

Expansion of sea sampling results

To estimate total discard by trawlers catching squid, catch rates were expanded using NMFS effort data (days fished) (Table 17). NMFS reported landings for 1993 are provided also. Refer to Appendix C1 for a list of all eight trips with sums of tow time, and catch and discard of all species.

For each of the eight sea-sampled trips in 1993, catch of seven species retained (and discarded) as pounds per hour were calculated by summing total catch retained (or discarded) and dividing the total by hours of towing for each trip. This method provided eight observations of catch and discard per hour which were then partitioned into two categories of vessel class (1&2 versus 3&4), each with four trips. This partitioning was based on the distinction between class two and three vessels -- the former averaging about one day for their trips and the latter averaging about 3-4 days -- based on NMFS 1988-1992 data for all New England otter trawl trips (U.S. Dept. of Commerce 1993).

Mean values for catch and discard were calculated for each category. Ideally, for this type of analysis, trips should be randomly selected by time and area with assumed homogeneity among vessels in each vessel class category. Achieving this randomness and homogeneity was hindered by personnel constraints, fleet unpredictability, and the difficult logistics of sampling highly mobile vessels that may not return to the same port after a day's fishing. For example, to sample the class 4 vessel, the DMF observer worked over 30 hours including traveling to Martha's Vineyard to meet the vessel, remaining on the vessel overnight anchored on fishing grounds, and sampling catches when fishing resumed at daybreak. Most large vessels fish multi-day trips and are either unwilling or unable to pick up and drop off sea sampling staff at convenient harbors such as Woods Hole, Falmouth, or Hyannis.

Nevertheless, this expansion of sea sampling results helps DMF accomplish the task set by the Legislature in 1993 by providing a better appreciation of the nature of 1993 catch and discard in Massachusetts' inshore squid fishery -- a fishery prosecuted in few areas during a relatively short period of time in contrast to other fisheries, especially in the EEZ, that occur day and night for many months from New England through the mid-Atlantic.

Squid

Catch retained

Total amount of squid retained was estimated by multiplying mean daily amounts (pounds per hour) retained for the four trips in each vessel category by number of hours (days fished X 24 hours) for all vessels in Class 1&2 and then for all vessels in Class 3&4. Effort data were provided by NMFS. Estimated total amount retained was then compared to NMFS reported landings from Area 538.

For squid, the target species, estimated totals from expanded sea sampling observations were underestimated for both vessel categories. For small vessels, the difference was 43%, while for larger vessels, the difference was only 5%.

Differences between expanded estimates and actual reported landings were expected since the four trips with 15.1 hrs. of towing by small vessels represented 1.3% of total fishing effort by small vessels. The four trips with 21.2 hrs. of towing by large vessels represented 0.6% of total effort by large vessels. Nevertheless, at least for the larger vessels the difference was surprisingly small.

Discard

Sea sampling discard rate multiplied by total effort in hours (NMFS data) resulted in very low estimates of squid discard. In 1993 for both vessel class categories discard was less than 1 pound per hour of towing, and estimated total discard was only about 1,500 pounds in contrast to reported landings of 1,115,955 pounds.

This low discard rate is understandable since trawling is prohibited after May 31 when squid tend to be smaller and of less value. Furthermore, with a market for small squid, there is incentive for most fishermen to land whatever squid they catch.

Table 17. Observed catch rates for selected species from 1993 sea sampling data expanded for estimating total catches and discards by vessel category.

		Vessels LT 50 GRT				Vessels GT 50 GRT			
Sampling Period		May 3-12				May 17-23			
Number of trips		4				4			
Total Hours Towing		15.1				21.2			
Total Effort in Hrs. (from NMFS)		1135.2				3758.4			
Species	Catch	Mean Lbs/hr	Expanded Estimate	NMFS Landings	Difference	Mean Lbs/hr	Expanded Estimate	NMFS Landings	Difference
Squid	Kept	102.0	115,790	204,243	-88,453	230.3	865,560	911,712	-46,152
	Discard	0.7	794			0.2	752		
Scup	Kept	2.0	2,270	13,802	-11,532	11.0	41,342	90,122	-48,780
	Discard	1.0	1,135			3.3	12,403		
Winter-Flounder	Kept	1.2	1,362	10,138	-8,776	5.4	20,295	40,118	-19,823
	Discard	2.2	2,497			13.6	51,114		
Tautog	Kept	1.3	1,476	552	924	5.3	19,920	4,188	15,732
	Discard	1.1	1,249			0.3	1,128		
Summer-Flounder	Kept	0.3	341	806	-465	1.9	7,141	4,567	2,574
	Discard	0.0	0			0.3	1,128		
Striped-Bass	Kept	0.0	0	0	N/A	0	0	N/A	
	Discard	3.1	3,519			44.9	168,752		
Windowpane-Flounder	Kept	0.0	0	2,560	-2,560	0.4	1,503	12,291	-10,788
	Discard	0.8	908			2.8	10,524		

Winter flounder

Catch retained

Forty-two pounds of winter flounder were caught during four trips on small vessels. These 42 pounds (16 kept and 26 discarded) were caught during 15.1 hrs. of towing. All 14

tows occurred in Vineyard Sound off Falmouth. Estimated total retained of 1,362 pounds was lower than NMFS reported Area 538 landings of 10,138 pounds for small vessels.

For the four trips on large vessels (21.2 hours of towing) 389 pounds (112 kept and 277 discarded) were caught. Trips were primarily in the center of Nantucket Sound, but two of 15 tows were off Falmouth. Estimated catch retained of 20,295 pounds was lower than the NMFS reported Area 538 landings of 40,118 pounds. As with squid, expanded catch retained was calculated by multiplying NMFS effort data by mean daily rate of catch.

Combined estimated flounder catch retained for small and large vessels was 21,657 pounds, just 40% of reported Area 538 May, 1993 trawl landings of 50,256 pounds. This estimate is a reasonable approximation of reported landings as it is within the range of recent May flounder landings for vessels targeting squid. For example, since 1978, May squid fishery winter flounder landings peaked at about 372,000 pounds in 1980, but have shown a downward trend since that time. Landings were lowest at only about 27,000 pounds in 1992. Landings in 1993 were only slightly higher at about 50,300 pounds.

Both small and large vessel estimated landings were lower than reported landings, and may be attributed to:

- Sampling error caused by insufficient number of trips, especially for small vessels for which sampling was limited to nearshore Vineyard Sound areas.

- Possible non-compliance with the 100-pound restriction on flounder catch during squid fishing could have had a major effect. Without sea samplers on board, and despite state environmental police officers patrolling fishing grounds, some fishermen might have ignored the restriction. If so, NMFS's May flounder landings from Area 538 would have been greater than what sea sampling would have suggested.

- NMFS's reports were for trips with some catch of squid. Therefore, trips targeting flounder with 5½" mesh or illegally with small mesh, but with some catch of squid, could have been included in the tally. However during the May fishery, DMF observers spoke with dozens of captains to arrange sea sampling trips and did not receive any reports of fishermen opting to target any species other than squid.

Discard

DMF sea sampling has shown that discard rate (mean lbs/hr) varies greatly for the squid fleet with small vessels having lower discards than large vessels (2.2 versus 13.6 lbs/hr). This higher discard rate attributable to larger vessels is expected since large vessels fish longer and in areas farther from shore where other species may be more abundant, land a more "mixed catch" (Figure 20), and are capable of towing larger, more efficient nets. High winds, typical during spring, are not as limiting for large vessels as they are for small vessels.

Most sampling of large vessels in 1993 occurred near the center of Nantucket Sound on Horseshoe Shoals where winter flounder are more abundant in May. Sampling on small

vessels occurred only off Falmouth where winter flounder abundance was relatively low for two possible reasons: (a) flounder already had begun to move from south Cape estuaries and shallow waters of the sounds to deeper waters in response to rising water temperatures and (b) flounder abundance off Falmouth during the time of sea sampling already had been lowered substantially due to April trawling prior to May 1.

Finally, larger vessels that do not unload their catch daily would be expected to discard more winter flounder because trawlers using small mesh are limited to 100 pounds or more of winter flounder (in combination with other flounder species). Figure 21 depicts the length frequency of winter flounder sampled at sea in 1993 (as well as in 1989 and 1991).

Total estimated amount discarded by large vessels (about 51,100 pounds) was calculated by multiplying sea sampling discard rate (mean pounds per hour) by total effort in hours provided by NMFS (Table 17). The same procedure for estimating winter flounder discard of smaller vessels resulted in a discard of about 2,500 pounds, probably a low estimate since small vessel sea sampling was restricted to the nearshore areas off Falmouth.

Another method to estimate total discards is an application of the catch/discard ratio - mean pounds per hour kept/discard ratio (5.4/13.6) - to total NMFS landings of winter flounder (Table 17). This method yields a higher estimate of flounder discards since NMFS landings were higher than estimated flounder catches based on sea sampling.

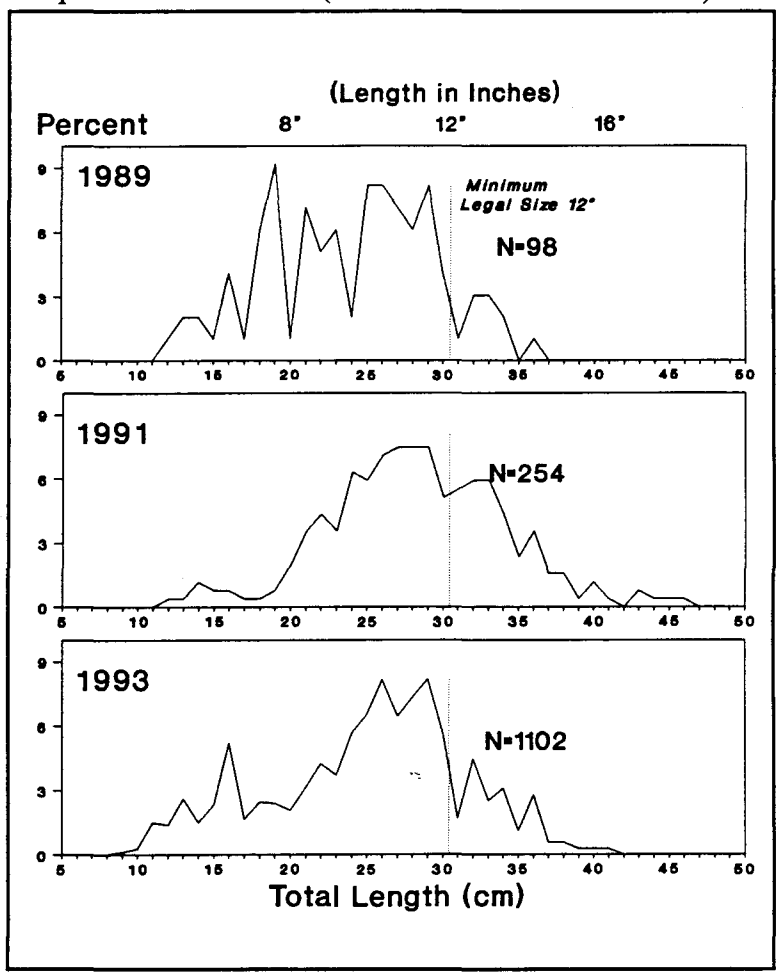

Figure 21. Winter flounder size composition measured during sea sampling 1989, 1991 and 1993.

For large vessels about 2.5 times more flounder was observed discarded than retained, so it is possible that flounder discards by large vessels could have been as high as 100,000 lbs. (e.g. 40,118 lbs. times 2.5). For small vessels the kept/discard ratio was 1.2/2.2 and reported flounder landings for these vessels were 10,138 lbs. With 1.8 times more flounder discarded than retained, discard could have been about 18,200 lbs. for a total discard of 118,200 lbs. Most flounder discard is sublegal fish (<12"); discard of legal-sized flounder is caused by the imposed limit of 100 pounds of flounder when small-mesh fishing.

The conservative winter flounder discard estimate of about 53,600 lbs. compared to 1993 winter flounder annual landings in Area 538 is high. About 153,000 pounds were landed, so discard during the spring squid fishery may have been 1/3 as much as was landed for Area 538 - or much higher if one employs the alternative catch/discard ratio estimators.

Increased participation of large vessels (especially Class 4) is troubling if discards of winter flounder increase commensurate with fishing power. Moreover, longer tows and repeat catch/discard of the same fish may also worsen discard mortality, a supposition that merits further DMF research. Previous DMF research found short tows (½-hour) and short exposure on deck (10 minutes) resulted in a minimum discard mortality of 14% (Carr 1993).

This potential substantial flounder discard and mortality could hinder Massachusetts' future compliance with the ASMFC Winter Flounder Management Plan. As of January 1995, DMF current regulations will have prevented winter flounder fishing mortality from exceeding the plan's target of 0.80 (about 55% annual exploitation). However, the target for January 1999 is 0.50 (about 39%). Minimizing the wastage of flounder during small-mesh fishing will reduce fishing mortality and help DMF reach the next ASMFC fishing mortality goal. Notwithstanding the need for further EEZ winter flounder restrictions, additional restrictions on directed fishing for winter flounder in Massachusetts waters might not be necessary or at least be less severe.

Of note, flounder discards likely will increase in the near future as the stocks rebound. DMF bottom trawl survey catches have increased during the past 3 years (1992-1994) and should continue to rise in response to region-wide conservation efforts of the ASMFC Winter Flounder Management Plan. Consequently, trawl designs that minimize flatfish catch in the small-mesh squid fishery are need. Draggers tow repeatedly for squid over the same relatively small areas of Nantucket Sound. To what extent flounder are repeatedly caught and discarded and whether their survival decreases, are unknown. Also, long tows may cause increased mortality; squid tows typically are 1-1½ hours long.

Scup

Catch retained

Migrating inshore in spring in response to increasing water temperature with larger individuals arriving first in late April and early May, scup were the predominant by-catch species landed during most years in the study period. Unfortunately, impact of the squid fishery on scup is difficult to assess. In contrast to winter flounder, scup are a schooling species representing a "hit or miss" catch for the squid fishery.

Most of the scup observed in the tows were retained (larger than 9" minimum size). Overall, observed catches were quite low. Total legal-sized scup observed on four small vessel trips was 38 pounds while just 241 pounds were seen on larger vessels. Catch retained averaged 2.0 and 11.0 pounds per hour for the small and larger vessels, respectively (Table 17).

Estimated catch retained for both vessel classes (1&2 and 3&4) was about 43,600 pounds in 1993 -- 42% of actual reported landings of scup by trawlers landing squid from Area 538 in May. Catch retained estimate for large vessels was about 41,300 pounds and 2,300 pounds for small vessels. As with winter flounder, estimates of catch retained were lower than reported landings perhaps because NMFS data includes vessels targeting scup with small-mesh nets but landing some squid.

Unlike flounder species, no limits have been placed on retention of scup with small mesh during the squid season because many legal-sized scup are caught in the squid fishery. After May 31, vessels targeting scup are required to use 4½" mesh; all others are required to use 5½" mesh. Another reason for lower estimates of catch could be, as already noted, the "hit or miss" catch of scup.

Discard

The current DMF management regime appears to protect age 1 scup (10-13 cm or 4-5 in.) that arrive on the grounds well after older and larger scup. Only during June sampling (1989) did this age class dominate the size composition (Figure 22). Since June squid fishing has been prohibited by regulation, protection has been afforded these small scup.

Discard estimate for small and large vessels was about 1,100 and 12,400 pounds respectively. As with winter flounder, this total was estimated by multiplying sea sampling discard rate (mean pounds per hour) by total effort in hours provided by NMFS. Higher discard estimates would result if calculated using the kept/discard ratio method. About 666,000 pounds of scup were landed from Area 538 in 1993 by all gear types.

Scup availability to squid trawlers varies greatly. While scup were commonly observed in squid fishery catches, appearing in 65 of 84 observed tows, 1993 catches of this schooling, migratory species were sporadic with fishermen reporting best catches at daybreak and sundown. Consequently, time of tows is important to know when applying sea sampling data to total catch for an estimate of squid fishery discards and none of the tows sampled occurred at or after sundown.

Furthermore, scup by-catch appears to be a function of the strength of a year-class and its availability in the sounds during May each year. For example, 1989, 1990, and 1991 year-classes in Massachusetts waters were below average, hence low discard (as age 2 fish primarily) in the 1991, 1992, and 1993 squid fishery. Sea sampling results supported DMF Resource Assessment Project expectations for discard based on anticipated scup spring abundance in the sounds -- average for 1991 and below average for 1992 and 1993 (Howe et. al 1994). Observed catches (both kept and discarded) during the following three years were much lower. In 1991, three trips produced only 99 lbs. with 30 lbs. retained; in 1992, three trips produced 489 lbs. with 406 lbs. retained; and in 1993 eight trips produced 371 lbs. with 279 lbs. retained. In 1993, 55 lbs. of scup was observed caught during four trips by small vessels off Falmouth (38 lbs. kept versus 17 lbs. discarded). Large vessels caught 316 lbs. mostly near the center of Nantucket Sound (241 lbs. kept versus 75 lbs. discarded).

Infrequent, large catches of scup suggest a potential discard problem. For example, DMF observers witnessed a 1990 trip where scup catch exceeded squid catch. Two tows off Falmouth resulted in 4,000 and 1,500 pounds of scup with a total discard of 3,500 pounds. Size frequency for 1990 (Figure 22) showed most scup exceeding the legal minimum size of 7" total length, but only the larger fish (9" or more) were retained (legal size is now 9" total length). In 1990 and 1991 weight of discards exceeded the marketable portion of the scup catch, while in 1992 and 1993 marketable scup dominated the catches (Appendix 3). Size compositions for 1993 were not presented in Figure 21 since observers did not obtain sufficient observations of scup "kept" sizes. The focus was primarily on discards. The remaining 14 of 16 tows in 1990 contained less than 50 pounds. Most of the catch appeared to be the 1988 year-class which was the largest in DMF's bottom trawl survey time series, 1978-1993.

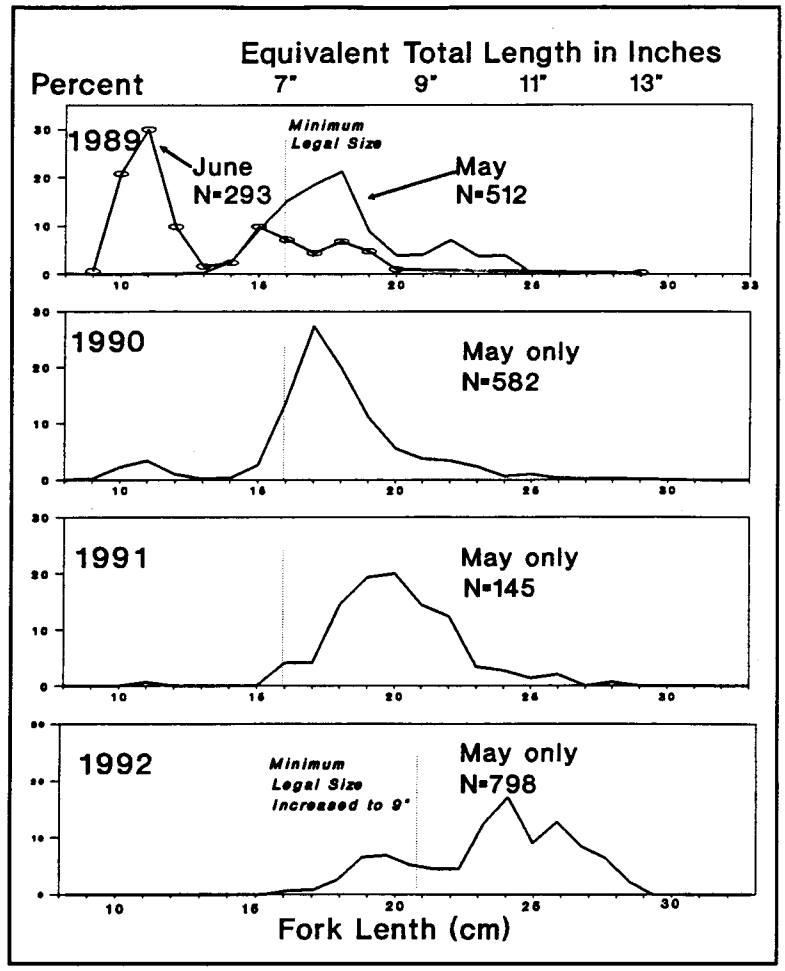

Figure 22. Scup size composition sampled at sea, 1989-1992.

How this amount of scup discard for all squid trawlers compares with discard by trawlers targeting scup with larger mesh (4½") or by other gears (pots, handlines, weirs) is unknown. This information is important since catch of scup landed by the squid fishery in May (Area 538 otter trawl trips landing squid) represents a fraction (average of 12% for 1978-1993) of annual commercial scup landings for the area. Scup discard in the squid fishery should be compared with discard in the directed scup trawl fishery in the sounds -- as well as offshore. Unfortunately, this information is unavailable. Mesh selectivity for scup is not sharp or "knife-edged" indicating that reliance on mesh regulations as the primary means to manage the trawl scup fishery is inadequate.

Striped bass

Striped bass discard also warrants attention. All striped bass caught by trawlers must be discarded because, by law, bass must be released. Bass can be taken only by hook and line in the Commonwealth.

Like scup, striped bass are commonly caught in the squid fishery as they migrate to Massachusetts southern shores and likely pursue squid as forage. Towing speed also contributes to bass catch. Most trawlers tow at relatively rapid speeds of 3-4 knots because they tow in the direction of the prevailing tides which are strong, especially in nearshore areas of Vineyard Sound.

At times, large catches of striped bass in the squid fishery were observed. For example, 590 of the 992 pounds observed in 1993 were caught in a single 1½-hour tow by a large vessel (84 GRT) fishing near Horseshoe Shoal. All fish were released apparently in fairly good condition. Other catches for large vessels were 33, 207, and 8 pounds, respectively, for all tows combined for each vessel. Smaller vessels fishing off Falmouth had catches of 14, 2, 59, and 0 pounds.

Of importance, total striped bass discard in the squid fishery must be seen in context of other fisheries. Only 3% by number and 1.2% by weight of the total Massachusetts striped bass "loss" (by-catch in squid and menhaden fisheries and commercial/recreational fisheries legal harvest and release legal/sublegal mortality) was due to the squid trawl fishery. Most of this by-catch appears to be released alive as evidenced by sea sampling.

In a recent DMF report, DMF biologist Paul Diodati (1994) estimated striped bass removals attributable to the squid trawl fishery to be about 4,727 fish or 27,130 pounds using 1993 sea sampling information. Average weight of bass observed was estimated at 5.7 pounds. For comparison, total removals of bass due to the 1993 Massachusetts recreational fishery was about 136,000 fish or 1,945,000 pounds.

Diodati cautioned that these trawler mortality estimates likely were high since they were based on a release mortality rate of 18% estimated for Hudson River trawl fisheries. Diodati felt the mortality rate for the Nantucket and Vineyard Sound trawl fishery was an overestimate since the sounds' trawl fishery is in open ocean areas during spring, and DMF samplers did not observe on-board mortalities. In comparison to the sounds, the Hudson River study was conducted in higher water temperature and lower salinity. Furthermore, DMF samplers have handled hundreds of bass over the 5-year sea sampling period and witnessed dead fish only on the processing vessel in 1989. Most fish handled have been lively and in good condition.

The frequency of bass catch in the squid trawl fishery of Nantucket and Vineyard Sounds should increase with the concurrent bass recovery. Bass abundance should surge beyond the historic highs of the 1970's. Shorter tows would likely minimize release mortality.

EFFECTS OF INSHORE SQUID TRAWL FISHERY ON FISH ABUNDANCE IN MASSACHUSETTS WATERS

The question of the effect of the inshore squid trawl fishery on state waters' fisheries resources is not new. Neither is the larger issue of how otter trawling should be regulated in Nantucket and Vineyard Sounds. For example, in the spring of 1979 Falmouth

sportfishermen petitioned DMF to limit or halt dragging for squid in Vineyard Sound. Local sport fishermen claimed tourism and their own fishing pleasure were threatened by commercial fishermen's overfishing of the sound. Earlier, in 1963, DMF was directed by the Legislature to investigate the need for restrictions on use of otter trawls in the sounds.

The most recent attempt to restrict trawling in the sounds was in 1993 when once again Falmouth area sportfishermen asked DMF and the Commission to ban dragging year-round out to 1½ miles from shore extending from Mashpee to Cuttyhunk Island. These fishermen made several allegations including: (1) closing the area would restore the abundance of fish local fishermen enjoyed 10-20 years ago; (2) removals of finfish species as by-catch impacted recreational fishing; and (3) intense trawling for squid off Falmouth resulted in a "broken food chain" with predator species leaving the area when their prey (squid) were removed.

To investigate these fishermen's claims and to contribute to the debate on effects of inshore squid trawling on other fisheries resources, DMF Resource Assessment Project biologists used their research trawl catches, landings and effort data from 1978-1993 for an assessment of effects of this inshore fishery on local abundance of finfish. They expanded their investigation by also examining the effect of offshore fishing effort. They concluded:

> "...Decreased local density of finfish in open areas (to trawling) was not related to inshore spring squid trawling effort or landings. Regional trawl effort occurring on Georges Bank and in southern New England did have significantly negative effects on local finfish density. Inferences of causal relationships between the inshore squid fishery and decreased local abundance of finfish were not supported. These results suggest that inshore abundance of these species is more related to total regional trawl effort." (Cadrin et al. 1994)

This conclusion was based on a statistical analysis of local annual abundance (measured by the DMF trawl survey) in the area of eastern Vineyard Sound and Nantucket Sound open to mobile gear fishing and six separate annual predictors: inshore spring squid landings, inshore spring squid effort by days fished (df) and standardized days fished (sdf), southern New England trawl effort (SNE), southern New England and Georges Bank effort (SNE-GB), and total northeast effort. Table 18 shows the strengths of the relationships, measured by "R-values" which are measures of association ranging from 0 (no relationship) to 1.00 (perfect relationship). To interpret the table, use the following criteria (Rowntree 1981) to determine strength of association. These criteria are almost the same as those of Milton et al. (1986) who are a bit more conservative; i.e., a weak correlation ranges from 0.0 to 0.5, moderate from 0.5 to 0.9, and strong from 0.9 to 1.0.

The relationships of inshore spring trawling effort to local abundance of winter flounder, fluke, windowpane flounder, and black sea bass are "very weak" to "weak." In contrast, relationships between offshore effort, characterized in three different ways and local abundance of these species were all "moderate" to "strong." Scup was the only species showing no relationship to inshore spring trawling effort or offshore effort, probably because abundance of this species is difficult to characterize by bottom trawl survey data due to the

"hit or miss" nature of the catch of this schooling species.

Table 18. Strengths of relationships between species' abundance (as measured by DMF trawl survey) and trawling effort. No statistically significant relationships were found between fish abundance and inshore squid trawlers' effort or landings. However, offshore trawlers' effort was correlated with species abundance. Significant results are boldfaced.

R-value	Strength of Relationship
0.00 to 0.20	very weak, negligible
0.21 to 0.40	weak, low
0.41 to 0.70	moderate
0.71 to 0.90	strong, high
0.91 to 1.00	very strong, very high

Species Abundance (survey wt. per tow)	Inshore spring trawling effort (df)	(sdf)	SNE effort (df)	SNE & GB effort (df)	Northeast effort (df)
Winter Flounder	0.18	0.24	**0.77**	**0.84**	**0.82**
Windowpane	0.24	0.29	**0.73**	**0.82**	**0.83**
Black Sea Bass	0.08	0.04	**0.55**	**0.47**	**0.47**
Fluke	0.00	0.06	**0.51**	**0.64**	**0.60**
Scup	0.04	0.04	**0.09**	**0.07**	**0.03**

These results are consistent with the fact that commercial landings of these species from Massachusetts waters are a relatively small fraction of total removals from each stock. While there are other removals caused by fisheries within Massachusetts waters, even more significant is the mortality caused by fisheries beyond Massachusetts' jurisdiction. Prohibiting the spring squid trawl fishery in Massachusetts waters may not increase finfish abundance if offshore effort remains high.

However, regarding local effects of the trawl fishery, notably to Falmouth area anglers, intensive trawling in a confined area, such as that off Falmouth probably reduces local abundance of fish available to recreational fishermen. The area trawled in Vineyard Sound along the Falmouth and Mashpee shores measures about four miles long and less than one mile wide. Up to 40 vessels fish the area for one or more weeks. Most vessels tow with the tidal current for the entire four-mile distance, then return to the beginning of the tow before re-setting the trawl. Abundance of finfish in this area is likely reduced. Furthermore, some species that are released (e.g. all striped bass as well as sublegal individuals of other species) probably are displaced to either end of the towing area.

While in Massachusetts, the squid inshore fishery has captured the attention of local fishermen, especially in Falmouth, the squid offshore fishery from October through April has escaped scrutiny by the public and most inshore commercial and recreational fishermen with the exception of some inshore draggermen and weir operators. State and federal assessment scientists and fisheries managers realize: (1) squid is in danger of being overfished region-wide and (2) there appears to be a negative relationship between squid offshore effort/catch and the performance of the inshore squid fishery; i.e., recent increases in offshore effort have been accompanied by a decrease in catch and catch per unit effort in the inshore fisheries. Fortunately, the Mid-Atlantic Fishery Management Council has adopted this position. Of note, Area 538 landings in 1992 (385 mt) represented only 2% of total landings (18,171.9

mt). Ninety-five (95%) percent of the total was from waters greater than three miles from shore (the Exclusive Economic Zone or EEZ). Historically (1983-1992) the EEZ share averaged 81% (Mid Atlantic Fishery Management Council, 1994).

Unfortunately, the Council's proposed Amendment #5 to its Squid, Mackerel, and Butterfish Management Plan will far short of insuring that sufficient escapement from the winter offshore Loligo fishery will occur to allow for traditional inshore fisheries and provide adequate spawning stock biomass. DMF has urged the Council rethink its strategies and consider other ways to protect small squid which are important recruits to the spring inshore fishery and the spawners that will produce the squid on which the offshore fishery depends.

RECOMMENDATIONS

(1) DMF and MFC should (a) prohibit April squid fishing thereby reestablishing the former May 1 opening of the squid season or (b) extend the area closure to April 23.

The purpose of this prohibition would be to minimize small-mesh fishing for flounder and scup especially close to shore. April landings of squid have been low since 1990.

The area/season closure in the sounds has remained the same despite changes in the seasonal opening of the squid-mesh season (May 1 to April 15 and then April 23). This has led to small-mesh trawling each year in late April within three miles of shore from Succonnessett Point in Mashpee east to Monomoy. In retrospect, because squid April landings in recent years have been low (less than 25,000 lbs.), the early opening is unjustifiable.

An argument in favor of this return to a May 1 opening, are recent increases in DELE funding and personnel which have boosted the level of enforcement at sea in the sounds. In 1990 many local draggermen urged an earlier opening for the squid season. They claimed they targeted squid illegally with small mesh in late April 1989 because without enforcement it made little sense to comply and stand idly by when other vessels were fishing illegally for squid without penalty. In 1989 and 1990 DELE's at-sea enforcement capabilities were inadequate to provide patrols and inspections necessary to prevent illegal small-mesh fishing. The situation has changed.

Nevertheless, there always will be some chance that in late April squid might be very available in Massachusetts waters. For example, in April 1989 otter trawl Area 538 landings were about 187,500 pounds. If and when the Mid-Atlantic Fishery Management Council effectively controls offshore fishing effort leading to increased abundance of squid inshore in the spring, April fishing could improve. A complete prohibition on small-mesh fishing in April would be inadvisable. An alternative approach would be an extension of the area closure to April 23. Of importance, late April squid fishing potentially will not be possible if the Council adopts a bimonthly quota management approach. March and early April squid fishing might cause a late April closure of the fishery, thus impacting trawlers and weir fishermen in Massachusetts waters -- fishermen awaiting the arrival of squid in the spring.

(2) DMF and MFC should downsize the trawler fleet fishing in the sounds for squid.

The available squid biomass that arrives in the sounds each spring cannot support the number and size of vessels participating in the May fishery. Catches by trawlers and weirs have declined. The fishery continues to shorten; i.e., since 1991, nearly all draggers have departed the sounds before the fourth week of May after intense fishing during the first three weeks.

Downsizing should entail reducing effort by larger vessels (class 3 & 4) that have greater catches of squid and by-catches of finfish than smaller vessels. Downsizing especially will be necessary if the Mid-Atlantic Fishery Management Council adopts a quota-based management strategy for its new Squid-Mackerel-Butterfish Management Plan. With quotas, the inshore fishery for squid in the spring could be over quickly as vessels hasten to rapidly catch as

much as they can before the quota is reached. This is a consequence of quota management. Fishermen will attempt to become more efficient and maximize their performance since quotas promote competition. Larger vessels which participate in the offshore fishery such as freezer-trawlers and other vessels capable of fishing multi-day trips and not seriously constrained by high winds and heavy seas, will cause a quick end to the inshore fishery especially when quotas become restrictive. This problem might worsen as large groundfish trawlers fish for other species due to a lack of groundfish caused by "collapsed" Georges Bank stocks and low abundance elsewhere.

A lower vessel size limit should be dovetailed with the limit that would be appropriate for the Massachusetts inshore fluke fishery since tightening of Massachusetts fluke quota (percent share of coastwide ASMFC fluke quotas), low landing/possession limits and early closures of the fishery have caused for two consecutive years a loss of most of September and all of October for fluke commercial fishing in Massachusetts waters.

(3) DMF should design a trawl to harvest squid but exclude flatfish and minimize by-catch.

Investigations should begin with studies of squid and by-catch fish behavior. Once designed, this trawl should be a required condition of DMF's squid regulated fishery permit and could result in resumed late April squid fishing by a downsized fleet. Similar by-catch reductions have been accomplished for the northern shrimp fishery. Work in progress by DMF and URI on a trawl for whiting (silver hake) to exclude flatfish may have application for the squid fishery.

(4) DMF should adopt the following positions on the new amendment to the Mid-Atlantic Fishery Management Council's squid management plan.

(a) Massachusetts should not support a Mid-Atlantic Council proposed option of an annual quota for the entire U.S. domestic fishery, unless the option is designed to ensure that Massachusetts' approximate one-month squid season (by DMF regulation) is not jeopardized. Quotas should not be based on recent years' catches which have shifted in favor of the offshore fishery to the disadvantage of the inshore fishery. Such a strategy potentially will reward that segment of the squid fishery primarily responsible for the imposition of quotas and one which focuses on small squid.

A quota (or seasonal quotas) is being proposed as an option "to insure that sufficient escapement from the winter offshore fishery occurs to allow for traditional inshore fisheries and to provide adequate spawning stock biomass." Massachusetts' squid inshore fishery is extremely short -- in most years, just the month of May! The offshore fishery occurs over many months so a quota-based management program could jeopardize the Massachusetts' inshore fishery. Bimonthly quotas will not be the answer to this problem since they will promote a "gold-rush" mentality and potentially draw more vessels to the squid fishery to take advantage of the beginning of a new quota period in the spring (i.e., May-June bimonthly quota).

(b) Massachusetts should not support a Mid-Atlantic Council proposed strategy of closing the U.S. fishery for Loligo when U.S. fishermen have harvested 80% of the allowable domestic harvest.

This option potentially will devastate the Massachusetts inshore squid fishery. If U.S. fishermen harvest 80% of the allowable domestic harvest before May so the proposed 10% by-catch then will apply, inshore fishermen in Massachusetts' waters will have a serious dilemma. During Massachusetts' very brief squid season, small mesh can be used provided no more than 100 pounds of winter flounder, yellowtail flounder, fluke, or windowpane flounder, in any combination, is in possession. Otherwise, 5 1/2" mesh or greater must be the only mesh size on the vessel. Consequently, the Council's proposed 10% by-catch would force inshore dragger fishermen to catch scup and other finfish with small mesh to reach the 10% -- a fishing strategy completely at odds with DMF's objective of reducing by-catch and discard of flounders in the small-mesh squid fishery. Furthermore, weir fishermen would have to land sea robins and any other fish they might have in their nets to reach the 10% figure -- an impossible task.

(c) The Mid-Atlantic Council should curtail the expanding offshore fishery especially for very small squid by prohibiting squid fishing during the fall and early winter (in some or all areas) and/or by establishing a squid minimum size or a trawl mesh size to allow escapement of small squid. However, William Macy (personal communication) reported that squid escaping through the mesh of trawl nets have low survival perhaps because the fragile, mantle skin is damaged when squid squeeze through net mesh. If survival is low, mesh size management strategies will be compromised. DMF has made a conscious effort to ease fishing pressure on small squid in our waters. The Council should reciprocate.

(5) DMF should develop strategies to balance competing needs of trawlers and fish weirs in Massachusetts waters if the Mid-Atlantic Council chooses a quota-based management strategy, an option the Council might prefer.

Since 1978, Massachusetts weir fishermen have accounted for about 28% of total squid landings attributable to catches in Area 538. This percent rose to 45% in 1992 and 34% in 1993 after averaging about 21% from 1988-1991. An annual Council quota will increase competition between the two gear types. Since weirs are fixed to the bottom, trawlers have the advantage of being able to pursue squid wherever and whenever they are found (except in DMF closed areas). DMF/MFC strategies to prevent the weir fishery from being seriously impacted by in-state competition for a quota potentially will oblige DMF to closely monitor both fisheries; however, monitoring cannot be timely and effective since the squid fishery is of short duration. Monitoring of this fishery will place an additional burden on DMF's Statistics Program which is already hard-pressed to perform other monitoring responsibilities (e.g., fluke and bluefish quotas). An additional consideration will have to be weir fishermen's advantage over mobile gear fishermen since the former can fish within the mobile gear closed area (May 1 through October 31). Squid are abundant in this area during the end of April and in May.

(6) DMF (and the Council) must urge that the offshore squid fishery be sampled at sea to determine catch and discard of small squid and by-catch species such as scup.

The impact of offshore small-mesh fishing on small squid and by-catch species is uncertain. This uncertainty disadvantages effective management of squid and by-catch species. The offshore fishery has doubled since 1985, and the potential for recruitment fishing is substantial since squid have a one-year life cycle. Consequently, the Council must get more information on the nature of these offshore squid catches and by-catch. This is especially important since the Council states in its draft management program:

> "...There appears to be a negative relationship between offshore effort/catch and performance of the inshore fishery. Recent increases in offshore effort (doubled since 1985) have been accompanied by a decrease in catch and catch per unit effort in the inshore fisheries..."

Because Massachusetts is the northern extent of the Loligo fishery, DMF is quite concerned about the possible contraction of the range of Loligo and that expanding offshore fisheries are displacing inshore fisheries.

(7) DMF should encourage research into squid spawning in Massachusetts waters and elsewhere, including location, timing, and duration of spawning.

This research will assist an evaluation of impacts of inshore fishing on squid before they spawn after their arrival to shoal, warm waters of Nantucket and Vineyard Sounds, Buzzards Bay, and other southeastern Massachusetts waters.

Spawning squid already have some protection afforded by our ban on mobile gear fishing from May 1 through October 31 within a 3-mile band along about two-thirds of the southern coast of Cape Cod and a similar 1/4 to 1/2-mile band along the northern portion of Vineyard Sound from its western end to Nantucket Sound. Squid spawn in many of these areas. Nevertheless, arguments have been made by offshore fishermen that their effort should not be cut until spawning squid are protected. This is the "chicken or the egg" argument that tends to lose its edge when offered up by fishermen involved in inshore and offshore squid trawl fisheries. Still, the issue needs to be addressed further by DMF.

Offshore spawning also needs further investigation. Loligo have the capacity to spawn throughout the year (Brodziak and Macy 1994), and they do. These researchers suggest Loligo populations "can be composed of numerous broods or micro-cohorts that may experience different growth and survival rates..." Examinations of peak periods of hatching through ageing research indicate significant amounts of spawning throughout the fall and winter when squid are on or moving to and from offshore wintering grounds. URI and NEFSC researchers should continue their characterization of the inshore and offshore squid fisheries by determining the age (month) composition of squid.

(8) DMF sea sampling of this fishery should be continued until we have DMF-approved gear that ensures minimal by-catch in the squid fishery.

Sea sampling is especially important when there are expectations that a good or better year-class of winter flounder and/or scup will be on spring fishing grounds. Furthermore, federal squid assessments use DMF samples of size and sex composition of squid catches -- a dependency that has grown since NMFS has reduced the amount of biological sampling by federal port agents.

(9) DMF's Resource Assessment Project and federal fisheries scientists should continue to refine the method for predicting abundance of squid.

Working through the NEFSC Stock Assessment Review Committee, DMF and NEFSC scientists should continue to refine and define methods for assessing squid abundance and predicting the success of the spring squid fishery especially since when squid abundance is low, reduced fishing pressure on squid in Massachusetts waters may be warranted. Similarly, reduced fishing pressure on squid in the EEZ will be required when spawning stock biomass is low. The challenge will be to determine when abundance is low. Since the Mid-Atlantic Fishery Management Council appears to favor quotas for restricting catch, improved and timely assessments will be critical.

ACKNOWLEDGEMENTS

Harvesting and processing industries: Cooperating trawler captains accommodated DMF observers upon request and provided transportation to shore from at-sea processing vessels as well as from other fishing vessels. Weir operators Ernest Eldredge and Mark Simonitsch offered insights and documentation about their unique fishery. Seafood dealers Warren Doty and Bob Mone of Martha's Vineyard, Frank Sylvia of New Bedford, and Noah Clark of Town Dock Fisheries of Point Judith readily shared their insights on this changing fishery. At-sea processing permit holders supplied annual reports of vessels delivering squid at-sea as well as reports of squid packed by size class.

Division of Marine Fisheries: Intensive 1993 sea sampling was accomplished by DMF's Peter Burns and Jeremy King. Their work was often strenuous and their days long, especially when sampling vessels fishing in the center of Nantucket Sound. Peter and Jeremy also contributed to analyses and research. From 1989-1993 many DMF staff "volunteered" to assist sampling at sea and measuring squid shoreside. Contributing staff included biologists Karen Bugley-Rypka, Paul Caruso, Greg Skomal, Kevin Johnson, Mike Syslo, and Information officer Chuck Connor. Data analysis support, technical advice, and reviews of the report were provided by the Resource Assessment Project led by Arnold Howe and staffed by Tom Currier, Steven Correia, and Steven Cadrin. Fisheries Economist David McCarron contributed analyses of landings data.

Massachusetts Division of Environmental Law Enforcement: Officers assigned to the patrol boat EVELYN provided real-time reports of vessels fishing the study area and transported DMF observers to commercial vessels for sampling in calm and not-so-calm seas.

Massachusetts Department of Fisheries Wildlife and Environmental Law Enforcement: Graphic artist David Gabriel assisted in graphics layout and production. Dorothy Graaskamp provided GIS maps depicting the study area (Figure 8). Game Biologist Bill Byrne of the Division of Fisheries and Wildlife provided photo development support.

National Marine Fisheries Service: Dr. Jon Brodziak of the Northeast Fisheries Science Center provided landings and effort data from the federal weighout system. He also provided advice on analyses, and he reviewed the report. Bob Ross, from the Trade Section, Fisheries Analysis Division, provided market analyses and insights. Sue Murphy, former port agent assigned to Pt. Judith (now in the Regional Office in Gloucester) provided contacts with fishermen, insights on fishing activity, and accurate, up to date reports on the inshore and offshore squid fishery. April Valleire, Karen Green, and Eric Hutchins, her fellow port agents, also were very helpful.

NOAA COASTWATCH: Grayson Wood provided satellite images of sea surface temperatures seen in Figure 6.

University of Rhode Island: Dr. William Macy provided insights about his recent squid age and growth studies.

Media: Loreli Stevens of Commercial Fisheries News provided much perspective and access to historical copies of CFN. Alan Stewart of Falmouth, formerly of the Falmouth Enterprise, contributed photographs taken during May of 1988. Mark Lovewell of the Vineyard Gazette also contributed a recent photograph of trawlers.

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APPENDICES

APPENDIX A. List of annual landings adjusted for discrepancies in the Nantucket Sound weirs landings figures. All "adjusted" landings figures used in this study.

Year	Mass. DMF Statistics Weir Catches	NMFS totals for weirs*	Difference	Area 538 Landings	Adjusted 538 Landings	U.S. landings	Adjusted U.S. Landings	Total catches	Adjusted Total catches
1978	413,593	188	413,405	348,896	762,301	1,516,509	1,929,914	23,474,430	23,887,835
1979	887,058	812,313	74,745	5,132,256	5,207,001	6,712,575	6,787,320	38,190,600	38,265,345
1980	981,158	961,441	19,717	3,677,823	3,697,540	5,799,676	5,819,393	52,359,930	52,379,647
1981	245,222	163,785	81,437	1,133,306	1,214,743	2,765,605	2,847,042	49,674,240	49,755,677
1982	222,778	164,308	58,470	1,665,456	1,723,926	5,564,536	5,623,006	46,898,145	46,956,615
1983	937,307	964,361	-27,054	11,464,873	11,437,819	19,248,953	19,221,899	60,996,915	60,969,861
1984	950,320	964,560	-14,240	3,694,117	3,679,877	15,780,063	15,765,823	49,883,715	49,869,475
1985	665,490	619,710	45,780	1,313,608	1,359,388	15,132,835	15,178,615	36,832,320	36,878,100
1986	1,021,069	1,061,852	-40,783	4,062,595	4,021,812	25,380,568	25,339,785	39,447,450	39,406,667
1987	1,117,880	1,129,940	-12,060	3,041,155	3,029,095	22,802,530	22,790,470	25,306,785	25,294,725
1988	1,910,135	1,882,830	27,305	8,544,391	8,571,696	40,922,053	40,949,358	42,060,375	42,087,680
1989	1,497,521	1,575,167	-77,646	7,131,725	7,054,079	52,139,372	52,061,726	50,741,460	50,663,814
1990	758,216	366,940	391,276	3,120,060	3,511,336	32,966,933	33,358,209	34,109,145	34,500,421
1991	727,854	339,453	388,401	3,138,536	3,526,937	42,789,099	43,177,500	42,759,360	43,147,761
1992	425,654	340,923	84,731	854,783	939,514	40,062,294	40,147,025	40,069,260	40,153,991

* *NMFS Totals include catches reported for weirs, pound nets and fish traps.*

APPENDIX B. Catch composition by species for all otter trawler trips landing squid during May from Area 538, 1978-1993

SPECIES	1978	1979	1980	1981	1982	1983	1984	1985	1986
SQUID	203,753	3,358,027	2,358,862	823,682	1,186,047	7,164,396	1,819,229	626,511	2,377,316
SCUP	35,339	578,143	395,933	292,673	243,539	430,375	218,784	69,694	239,883
WINTER FL.	110,229	206,358	371,937	253,941	114,775	205,357	179,849	155,130	107,430
WINDOWPANE FL.	52,025	43,684	24,461	47,279	17,255	39,672	54,299	61,682	45,148
TAUTOG	6,105	8,660	14,725	2,745	3,700	10,956	49,990	40,881	36,246
SUMMER FL.	4,181	18,075	8,700	10,176	10,125	24,932	17,275	15,115	29,118
SEA BASS	2,054	12,848	10,095	22,698	18,340	39,236	42,313	15,494	24,831
SILVER HAKE	-	6,225	27,261	3,658	150	1,231	12,491	12,085	3,994
BLUE FISH	206	1,099	2,247	2,626	5,152	146	952	4,568	26,843
BUTTERFISH	1,055	10,253	6,610	2,364	555	10,782	13,168	16,092	2,248
MACKEREL	11	814	1,153	156	1,973	5,004	8,317	1,324	399
COD	253	2,071	7,736	381	12,610	1,281	2,282	152	871
YELLOWTAIL FL.	124	1,141	4,295	656	3,840	5,828	11,933	1,416	3,642
SKATE	525	200	75	373	-	56	1,620	600	-
GOOSEFISH	110	1,231	5,234	653	515	1,110	2,603	1,089	2,260
RED HAKE	-	600	2,495	-	-	-	104	32	20
STRIPED BASS	-	1,262	547	5,017	136	154	-	17	-
OCEAN POUT	-	-	-	-	-	-	-	-	-
AMERICAN PLAICE	-	875	1,163	225	-	1,211	512	34	110
WITCH FL.	-	840	30	3	16	89	1,098	196	983
CONCH	-	421	345	-	-	-	150	75	157
TILEFISH	-	1,140	103	-	-	-	25	13	117
WHITE HAKE	-	-	139	16	1,375	122	624	13	163
CRAB	-	-	-	-	-	-	-	-	-
SHRIMP	-	-	-	-	-	-	-	-	310
POLLOCK	-	40	818	-	20	100	173	22	-
WOLFFISH	-	260	-	-	-	-	30	-	-
CUNNER	-	-	-	-	-	-	-	-	80
SP.DOGFISH	-	-	-	-	-	-	-	100	-
ATL.HERRING	-	-	193	-	-	-	-	-	-
HADDOCK	-	185	4	-	6	-	270	-	-
SHAD	-	-	-	-	-	-	33	14	26
STURGEON	-	-	-	2	-	15	-	-	65
PUFFER	-	-	-	-	-	-	-	-	-
SEA ROBIN	-	-	-	-	-	-	-	-	-
WEAKFISH	15	120	15	23	-	10	27	39	87
LOBSTER	-	-	5	-	102	-	3	-	-
CONGER EEL	-	-	-	-	-	-	-	17	60
HOGCHOKER	-	-	-	-	-	25	-	-	-
SMALL TUNA	-	-	-	-	-	0	-	15	-
SM. DOGFISH	-	-	-	-	-	15	-	-	-
HALIBUT	-	-	-	-	-	-	-	-	-
SCALLOP	-	-	-	-	-	-	4	-	-
ILEX SQUID	-	-	-	-	-	-	-	-	-
OTHER FISH*	465	78,693	1,589,882	28,049	14,707	35,517	4,449	22	19
ALL SPECIES	416,450	4,333,265	4,835,063	1,497,396	1,634,938	7,977,620	2,442,607	1,022,442	2,902,426

"OTHER FISH" includes unidentified species (e.g. sea herring) used for reduction. No species information is available.

APPENDIX B (Continued).

SPECIES	1987	1988	1989	1990	1991	1992	1993	MEAN
SQUID	1,606,436	3,250,413	4,486,248	2,187,371	2,602,146	445,643	1,115,955	2,225,752
SCUP	332,824	49,082	257,944	314,528	113,802	139,993	103,924	238,529
WINTER FL.	131,089	78,597	83,524	84,708	55,957	27,018	50,256	138,510
WINDOWPANE FL.	108,268	62,494	32,075	41,591	14,293	10,333	14,851	41,838
TAUTOG	34,168	19,588	25,511	26,335	19,367	14,992	4,740	19,919
SUMMER FL.	19,041	49,347	42,715	9,604	19,076	17,937	5,373	18,799
SEA BASS	7,067	6,883	8,073	13,020	2,241	1,025	264	14,155
SILVER HAKE	82,164	3,893	9,711	5,475	9,146	444	798	11,170
BLUE FISH	42,499	19,146	9,835	5,605	4,678	5,157	6,691	8,591
BUTTERFISH	5,259	1,427	3,920	19,949	2,309	594	2,017	6,163
MACKEREL	8,843	1,983	11,194	6,351	2,930	3,615	35,028	5,568
COD	520	4,367	5,012	1,786	3,214	46	2,995	2,849
YELLOWTAIL FL.	4,764	52	302	1,259	2,374	95	664	2,649
SKATE	9,968	2,538	10,726	4,339	4,053	997	2,664	2,421
GOOSEFISH	731	1,152	2,763	1,498	1,913	646	742	1,516
RED HAKE	4,111	4,363	70	-	2,031	374	38	890
STRIPED BASS	-	-	-	-	-	22	24	449
OCEAN POUT	1,009	-	5	-	-	-	-	63
AMERICAN PL.	-	63	-	-	-	15	2,506	420
WITCH FL.	375	73	345	157	629	35	577	340
CONCH	879	235	404	-	77	50	1,958	297
TILEFISH	139	-	-	-	-	-	-	96
WHITE HAKE	549	16	8	81	41	5	107	204
CRAB	-	-	-	-	-	240	-	15
SHRIMP	100	-	15	-	-	-	-	27
POLLOCK	5	5	82	9	6	-	34	82
WOLFFISH	35	-	-	-	-	-	26	22
CUNNER	-	-	128	-	-	-	-	13
SP.DOGFISH	-	-	-	-	-	-	7,620	483
ATL.HERRING	-	-	-	5	-	-	-	12
HADDOCK	-	-	-	4	-	-	3	30
SHAD	217	162	43	187	38	-	10	46
STURGEON	207	-	-	-	-	-	-	18
PUFFER	-	72	-	-	-	-	-	5
SEA ROBIN	-	-	66	43	-	-	-	7
WEAKFISH	28	35	9	-	134	74	-	39
LOBSTER	-	-	5	-	108	-	-	14
CONGER EEL	37	31	25	47	13	17	456	44
HOGCHOKER	-	-	-	-	-	-	-	2
SMALL TUNA	-	-	-	-	-	-	40	3
SM. DOGFISH	-	-	-	-	-	-	-	1
HALIBUT	-	-	-	5	-	-	-	0
SCALLOP	-	-	-	-	-	-	-	0
ILEX SQUID	-	-	-	-	-	-	280	18
OTHER FISH*	7	-	-	-	-	550	102	109,529
ALL SPECIES	2,401,339	3,556,017	4,990,758	2,723,957	2,860,576	669,917	1,360,743	2,851,595

* "OTHER FISH" includes unidentified species (e.g. sea herring) used for reduction. No species information is available.

APPENDIX C1.

1993 TRIP SUMMARIES FROM SQUID FISHERY SAMPLING.
ALL WEIGHTS IN POUNDS.

SAMPLING DATE	MAY 3		MAY 10		MAY 11		MAY 12		MAY 17		MAY 19		MAY 20		MAY 24					
VESSEL CLASS	Class 2		Class 2		Class 2		Class 2		Class 3		Class 3		Class 4		Class 3					
HOURS TOWING	4.4		2.3		1.4		7.2		4.9		4.7		7.2		4.4					
SPECIES	KEPT	DISC	KEPT	DISC	KEPT	DISC	KEPT	DISC	KEPT	DISC	KEPT	DISC	KEPT	DISC	KEPT	DISC	TOTAL KEPT	TOTAL DISC	GRAND TOTAL	SPECIES
LOLIGO SQUID	451	0	63	11	120	0	1360	0	3110	0	554	1	763	6	282	0	6703	18	6721	LOLIGO SQUID
STRIPED BASS	0	14	0	2	0	0	0	59	0	33	0	669	0	207	0	8	0	992	992	STRIPED BASS
SKATE	0	91	0	47	0	23	0	15	20	29	0	6	0	52	0	412	20	675	695	SKATE
SKATEWINGS	0	0	0	0	0	0	0	0	16	0	0	0	0	0	50	0	66	0	66	SKATEWINGS
WINTER FL.	14	13	0	5	2	4	0	4	65	170	14	8	23	49	10	50	128	303	431	WINTER FL.
SPIDER CRAB	0	69	0	3	0	3	0	8	0	0	0	110	0	31	0	155	0	379	379	SPIDER CRAB
SCUP	32	7	0	0	0	2	6	8	130	23	18	9	84	35	9	8	279	92	371	SCUP
BLUEFISH	0	0	0	0	0	0	0	0	0	0	48	0	266	0	5	0	319	0	319	BLUEFISH
TAUTOG	21	0	0	0	0	5	2	7	90	5	0	0	20	2	0	0	133	19	152	TAUTOG
LOBSTER	0	18	0	3	0	1	0	14	0	19	0	9	0	4	7	8	7	76	83	LOBSTER
WINDOWPANE	0	12	0	0	0	0	0	2	0	5	0	12	0	13	7	26	7	70	77	WINDOWPANE
FLUKE	6	0	0	0	0	0	0	0	9	0	5	0	14	2	13	4	47	6	53	FLUKE
HORSESHOE CRAB	0	37	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	43	43	HORSESHOE CRAB
LADY CRAB	0	4	0	3	0	1	0	7	0	2	0	9	0	12	0	5	0	43	43	LADY CRAB
ALEWIFE	0	14	0	0	0	0	0	2	0	1	0	3	0	1	0	16	0	37	37	ALEWIFE
SMOOTH DOG	0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	5	0	26	26	SMOOTH DOG
BUTTERFISH	0	2	0	0	0	1	0	3	2	1	6	2	1	2	0	1	9	12	21	BUTTERFISH
SCULPIN	0	7	0	0	0	0	0	0	0	12	0	0	0	1	0	0	0	20	20	SCULPIN
SEA HERRING	0	11	0	1	0	0	0	0	0	0	0	1	0	1	0	5	0	19	19	SEA HERRING
SEAROBIN	0	6	0	0	0	0	0	3	0	1	0	1	0	3	0	3	0	17	17	SEAROBIN
ROCK CRAB	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	5	0	6	6	ROCK CRAB
MENHADEN	0	2	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	5	5	MENHADEN
BLACK SEA BASS	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	4	0	4	BLACK SEA BASS
MACKEREL	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	3	MACKEREL
SHAD	0	1	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	4	4	SHAD
SEA RAVEN	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	3	3	SEA RAVEN
4SPOT FLOUNDER	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	2	2	4SPOT FLOUNDER
CONCH	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	2	2	CONCH
COD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	COD
TOTALS	527	308	63	75	122	40	1368	133	3442	306	645	845	1175	444	383	713	7725	2870	10595	

APPENDIX C2.

1992 TRIP SUMMARIES FROM SQUID FISHERY SAMPLING.
ALL WEIGHTS IN POUNDS.

SAMPLING DATE	MAY 13		MAY 22		MAY 27		TOTAL	TOTAL	GRAND	
SPECIES	KEPT	DISC	KEPT	DISC	KEPT	DISC	KEPT	DISC	TOTAL	SPECIES
LOLIGO SQUID	1100	0	562	0	910	0	2572	0	2572	LOLIGO SQUID
SCUP	344	75	2	1	60	7	406	83	489	SCUP
SKATE	0	8	0	38	0	211	0	257	257	SKATE
SMOOTH DOG	0	0	0	0	0	25	0	25	25	SMOOTH DOG
WINTER FL.	0	1	5	1	11	3	16	5	21	WINTER FL.
LOBSTER	0	11	0	4	0	0	0	15	15	LOBSTER
ALEWIFE	0	5	0	2	0	0	0	7	7	ALEWIFE
SEAROBIN	0	6	0	0	0	0	0	6	6	SEAROBIN
BUTTERFISH	0	4	0	0	0	0	0	4	4	BUTTERFISH
MENHADEN	0	3	0	0	0	0	0	3	3	MENHADEN
WINDOWPANE	0	0	0	0	0	2	0	2	2	WINDOWPANE
STRIPED BASS	0	2	0	0	0	0	0	2	2	STRIPED BASS
FLUKE	0	0	0	1	0	0	0	1	1	FLUKE
SHAD	0	1	0	0	0	0	0	1	1	SHAD
BLUEBACK	0	1	0	0	0	0	0	1	1	BLUEBACK
COD	0	0	0	0	0	1	0	1	1	COD
TOTALS	1444	117	569	47	981	249	2994	413	3407	

APPENDIX C3.
1991 TRIP SUMMARIES FROM SQUID FISHERY SAMPLING.
ALL WEIGHTS IN POUNDS.

SAMPLING DATE	MAY 8		MAY 14		MAY 23		TOTAL	TOTAL	GRAND	
SPECIES	KEPT	DISC	KEPT	DISC	KEPT	DISC	KEPT	DISC	TOTAL	SPECIES
LOLIGO SQUID	7950	0	2600	0	1389	0	11939	0	11939	LOLIGO SQUID
WINTER FL.	96	55	6	10	3	6	105	71	176	WINTER FL.
SCUP	8	9	10	29	12	31	30	69	99	SCUP
L. SCULPIN	0	67	0	0	0	0	0	67	67	L. SCULPIN
TAUTOG	43	2	0	0	0	0	43	2	45	TAUTOG
FLUKE	20	0	6	0	13	0	39	0	39	FLUKE
WINDOWPANE	0	21	0	6	0	2	0	29	29	WINDOWPANE
SEA BASS	16	1	0	0	9	0	25	1	26	SEA BASS
STRIPED BASS	0	17	0	0	0	8	0	25	25	STRIPED BASS
SEA HERRING	0	21	0	2	0	0	0	23	23	SEA HERRING
SEA RAVEN	0	17	0	1	0	4	0	22	22	SEA RAVEN
LOBSTER	0	9	0	3	0	1	0	13	13	LOBSTER
BLUEFISH	0	0	0	0	0	8	0	8	8	BLUEFISH
BUTTERFISH	0	1	0	7	0	2	0	10	10	BUTTERFSH
SEAROBIN	0	4	0	0	0	2	0	6	6	SEAROBIN
ALEWIFE	0	2	0	2	0	0	0	4	4	ALEWIFE
MACKERAL	0	1	0	0	0	0	0	1	1	MACKERAL
CUNNER	0	1	0	0	0	0	0	1	1	CUNNER
TOTALS	8133	228	2622	60	1426	64	12181	352	12533	

APPENDIX C4.
1990 TRIP SUMMARIES FROM SQUID FISHERY SAMPLING.
ALL WEIGHTS IN POUNDS.

SAMPLING DATE	MAY 3		MAY 8		MAY 14		MAY 21		MAY 23		TOTAL KEPT	TOTAL DISC	GRAND TOTAL	SPECIES
SPECIES	KEPT	DISC	KEPT	DISC	KEPT	DISC	KEPT	DISC	KEPT	DISC				
LOLIGO SQUID	160	0	200	0	1950	0	135	0	1495	0	3940	0	3940	LOLIGO SQUID
SCUP	29	10	2000	3500	7	12	9	23	23	90	2068	3635	5703	SCUP
ALEWIFE	0	9	0	0	0	0	0	0	0	0	0	9	9	ALEWIFE
BUTTERFISH	0	1	0	1	0	2	0	0	0	5	0	9	9	BUTTERFISH
WINDOWPANE	0	1	0	0	0	0	0	1	0	6	0	8	8	WINDOWPANE
TAUTOG	14	0	9	0	19	2	0	0	0	0	42	2	44	TAUTOG
LOBSTER	0	1	0	2	0	0	0	2	0	2	0	7	7	LOBSTER
STRIPED BASS	0	4	0	0	0	14	0	0	0	0	0	18	18	STRIPED BASS
WINTER FL.	0	2	0	1	1	0	0	1	1	1	2	5	7	WINTER FL.
SEABASS	0	0	2	0	0	0	0	0	6	0	8	0	8	SEABASS
BLUEFISH	0	0	0	0	0	0	0	0	0	25	0	25	25	BLUEFISH
MENHADEN	0	0	0	0	0	1	0	0	0	1	0	2	2	MENHADEN
L. SCULPIN	0	1	0	0	0	0	0	0	0	1	0	2	2	L. SCULPIN
SEA HERRING	0	1	0	0	0	0	0	0	0	1	0	2	2	SEA HERRING
SEA RAVEN	0	0	0	0	0	0	0	0	0	1	0	1	1	SEA RAVEN
4-SPOT FL	0	0	0	0	0	0	0	0	0	1	0	1	1	4-SPOT FL.
SEAROBIN	0	0	0	0	0	0	0	0	0	1	0	1	1	SEAROBIN
CUNNER	0	0	0	0	0	1	0	0	0	0	0	1	1	CUNNER
TOTALS	203	30	2211	3504	1977	32	144	27	1525	135	6060	3728	9788	