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Abstract

Scallop dredges as those used by fishermen on the U.S. and Canadian East Coast and Alaska are large, heavy and unforgiving as a fishing gear with relatively poor species specific and size selectivity. Bycatch issues in the U.S. scallop fishery can be characterized accordingly: the harvest of undersized or juvenile scallops; the harvest of finfish that are either retained or discarded; the harvest of miscellaneous invertebrates some of which are retained; and the collateral damage of all bycatch animals resulting from either contact with the gear or from handling and exposure on deck. Significant reductions in the harvest of juvenile scallops, or discards, have been achieved by increasing scallop dredge ring sizes and by reducing or omitting chaffing gear. However, collateral damage to discards resulting from the handling of the scallop dredge, culling and deck operations can exceed 10%. The bycatch of finfish by scallop dredges can be significant and can pose serious problems if retention is not allowed nor desirable as mortality rates are high. Dredge rings ranging in size from 3.0 to 4.0 inches (76.2 -101.6 mm) are not conducive to the escapement of juvenile fish. Research to determine the effectiveness of scallop dredge modifications for the escapement of finfish has been limited. Modest success in finfish escapement has been reported by changing the mesh of the dredge twine top. The bycatch of crustaceans and other invertebrates by scallop dredges has been documented for the Alaskan scallop fishery but little has been done elsewhere. Quantities of bottom debris and substrate are often retained in the dredge bag along with bottom dwelling invertebrates. Potential solutions to scallop dredge bycatch include increasing dredge ring sizes, reducing chafing gear, modifications in dredge design, changes in fishing strategies and educational programs for the fishermen.

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*Introduction

The sea scallop (Placopecten magellanicus), supports a large and valuable commercial fishery throughout much of its distribution in the Exclusive Economic Zone (EEZ) of both the United States and Canada. It is found in commercial quantities from Belle Isle, Newfoundland to near Cape Hatteras, North Carolina (MacKenzie et al 1978). U.S. scallop meat landings for 1991-1993 totalled 33,301 MT valued at U.S. $427.1 million (New England Fishery Management Council, 1995); Canadian landings for 1992-1994 totalled 21,664 MT valued at Can. $312.1 million (pers. comm., C. G. Cooper, Department of Fisheries and Oceans; Sept. 1995).

Sea scallops are primarily harvested by dredges or drags which are towed across the bottom at speeds ranging from 4 to 5.5 knots. In the process of harvesting scallops, the dredges also capture a variety of finfish and invertebrates as bycatch. Unfortunately, dredges inherently have poor selection characteristics (Bourne 1966). Bycatch in the sea scallop dredge fishery can be significant in terms of quantity and landed value.

National Marine Fisheries Service (NMFS) data for 1991-1993 indicated that over 23,192 MT (whole weight) of finfish and invertebrates were landed as bycatch by the U.S. scallop dredge fishery. There is virtually no available information on the amount of bycatch discarded at sea. Recent changes in groundfish management strategies in the U.S. and Canada have focused considerable attention on bycatch in the scallop fishery. One concern is simply an allocation issue between the scallop dredge fishery and the groundfish trawl fishery; another is more of a conservation issue concerned with the mortality of finfish discards.

Attention, however, has increasingly focused on the harvest and potential for significant discard mortalities of small or juvenile sea scallops. The growth of scallops through age 5 is typically very rapid with gains in meat weight in excess of 200% between ages 2 and 4. The harvesting of small scallops is of substantial concern to management authorities because of the lost economic opportunities and the reduction of potential spawning stock biomass.

Issues surrounding the harvest and/or discarding of small scallops have been mostly addressed by an evaluation of larger scallop dredge rings as a conservation measure (Medcof 1952; Bourne 1966; DuPaul et al. 1989; DuPaul and Kirkley, 1994; Brust et al. 1995). Researchers have generally concluded that larger dredge rings offer a partial solution to the problem of the unintentional harvest of small or unwanted scallops.

In this paper, we present preliminary analysis of bycatch of finfish, invertebrates, and juvenile scallops in the dredge fishery. We initially explore sources of bycatch mortality. Subsequently, we discuss possible options for reducing bycatch in the scallop fishery. Our analyses and observations are based information obtained from several at sea experiments conducted between 1987 and 1995.

*The Standard Scallop Dredge

The most common gear in use for the offshore scallop fishery is the "New Bedford type" dredge or drag. This gear has been described in detail by Bourne (1965) and Posgay (1957). The standard dredge is constructed with a heavy metal frame from 12-17 ft. (3.7 - 5.2 meters) in width (Figure 1). Attached to the dredge frame is a bag constructed of steel rings connected together by chain links. The top of the bag is fitted with a "twine top" or "rope back."

As of March 1994, U.S. regulations for the northwest Atlantic sea scallop fishery restricted the total width or combined width of two dredges to 30 ft. (9.1 meters). Additional regulations also limited the mesh size of the twine top to a minimum of 5.5 inches (139 mm) and ring size--internal diameter--to 3.25 inches (82.6 mm). Prior to March 1994, there were no restrictions on dredge width but ring sizes could not be smaller than 3.0 inches (76.2 mm). Effective January 1996, the minimum ring size allowed in the U.S. northwest Atlantic sea scallop fishery will be 3.50 inches (88.9 mm). Canadian scallop dredges are constructed with 3.0 inch (76.2 mm) rings.

*Bycatch of Undersized Scallops

The unintentional harvest of undersized scallops as bycatch is problematic for most scallop dredge configurations. If there are small scallops in the population, there will be some retention by most commercial dredges. Retention of small scallops is more pronounced when there is an unusually large pre-recruit year class. Retention may also increase in areas with substantial quantities of shells, sand dollars, starfish and crabs. In general, particular characteristics of the scallop fishery such as vessel size and power, bottom type and spatial distribution of the scallops influence the performance and selectivity of the gear.

During the latter part of 1993 in the mid-Atlantic resource area, large numbers of sea scallops from the strong 1990 year class were retained by 3 inch (76.2 mm) ring scallop dredges and subsequently discarded because they were too small to comply with the prevailing fishery regulations. Ninety percent of the scallops harvested in this resource area were 70 mm or less; the remaining 10% greater than 70 mm were retained for shucking.

Based on research data obtained from 42 tows comparing 3 (76.2 mm) and 3.25 (82.6 mm) inch rings in the mid-Atlantic in November 1993, it was observed that 154,538 scallop discards were harvested with the 76.2 mm ring dredge and 84,592 were harvested with the 82.6 mm ring dredge. The 82.6 mm ring dredge reduced the harvest of small scallops by 45% (Figure 2). If relative efficiency ratios for the 88.9 mm ring dredge were applied to these resource conditions, scallop discards would have been reduced to 50,306, a 67% reduction in scallop discards.

Irrespective of the particular aspects of the numerous studies on scallop gear selectivity, all reach a similar conclusion. As ring or size mesh increases, the escapement of smaller scallops increases. Consequently, changes in ring or mesh size have been used as a regulatory strategy to advance the age of scallops at first capture. For this purpose, minimum ring size regulations can be accompanied by minimum shell size or maximum meat count restrictions.

Size selectivity and subsequent quantities of discards, however, are not only based on gear characteristics. Selection or culling practices of the crew may also have important ramifications for the size and quantity of discards. During several gear experiments, it was observed that culling practices varied with the size and quantity of other scallop harvested, crew size, prices received, and production costs. Changes in gear characteristics, thus, offer only a partial solution to the problem of harvesting and discarding small scallops.

Brust et al. (1995) conducted an evaluation of 82.6 mm and 88.9 mm ring dredges in response to the scallop gear changes scheduled in Amendment #4 of the Sea Scallop Fishery Management Plan (SSFMP). During 1994-95, four commercial scallop trips were made in the mid-Atlantic region to evaluate the selectivity of 82.6 mm and 88.9 mm ring dredges. Data from 209 of 781 paired tows revealed that a total of 57,592 undersized scallops were left on deck as discards by the crew; 35,918 from the 82.6 mm ring dredge and 21,674 from the 88.9 mm ring dredge (Figure 3).

The size distribution of scallops in the resource area had changed significantly since November of 1993. From June 1994 through April 1995, there were always 2 or 3 year classes present in the population. By April 1995, scallops in the 1990 year class had grown to 90 to 95 mm and the 1991 year class, 75 to 80 mm; only 13% of the harvested scallops were less than 70 mm. If we apply efficiency ratios for the pre-Amendment #4 dredge with 76.2 mm rings and chaffing gear to this particular data set, the number of discards would be 73,464, 35,918 and 21,674, respectively. Consequently it can be concluded that increasing ring size can significantly decrease the number of scallops as discarded bycatch even with favorable resource conditions.

In the context of bycatch as currently defined, the harvest of small scallops are a consideration only if they are discarded by the crew. The primary problem and concern is the mortality associated with harvesting and the practices associated with culling and discarding.

**Changes in Culling Practices

As mentioned earlier in this paper, the culling of retainable scallops by the crew have a significant influence on the number and size of discarded scallops. This selection process is not necessarily influenced by regulatory constraints. Amendment #4 does not restrict the size of scallop meats which is the predominant product form of the dredge fishery. In the Canadian fishery, however, a maximum meat count per kilogram is currently enforced. A ring size constraint, as an age of entry control, is thus only partially successful in reducing the harvest of undersized scallops because of the poor selectivity characteristics of the dredge.

An increase in dredge ring size, however, can be successful in reducing fishing mortality in strong incoming year classes, and extend the age composition in the fishery until a year class is fully recruited by the gear with larger rings (Brust, et al. 1995). Size frequency distribution of scallops in commercial catches from June 1994 through April 1995 indicated that the 1990 year class continued to be a major portion of the catch. As a result, the size of scallops in the catch and those retained by the crew showed progressive increases in size. At the same time, the size at which 50% of the scallops were retained (or discarded) increased from 60-65 mm to 75-80 mm (Figure 4). These data indicated that the change in ring size from 80.6 to 88.9 mm not only changed the scallop size composition in the catch over time, but that in turn, changed the size composition of scallops discarded by the crew.

**Discard Mortality

When small or undersized scallops are harvested, they are discarded after the catch has been culled for larger, retainable scallops. Scallop discards can be damaged during the process of emptying the dredge, culling the catch and shoveling (or kicking) the trash and unwanted scallops overboard. Medcof and Bourne (1964) recognized that discard mortality, under certain conditions, could exceed 20%.

Data obtained from 42 tows indicated that in the process of emptying the dredge and culling the catch, 7.3% of the discards were fatally damaged (separated shells, broken shells, exposed mantle, crushed scallops; Figure 5). The percentage of fatally damaged discards was less for the 88.9 mm ring dredge when compared to the 82.6 mm ring dredge--5.4% and 8.1%

respectively. The advantage of the larger scallop dredge rings are compounded both by the decrease in the overall numbers of discards and the decrease in discard mortality.

*Finfish Bycatch

Finfish and some commercially valuable invertebrates, namely crabs and lobsters are often harvested as bycatch by the sea scallop dredge fishery. U.S. summary data for 1991-1993 bycatch species, in terms of landings and revenue, indicates that monkfish (Lophius americanus), yellowtail flounder, (Pleuronectes ferrugineus) and winter flounder, (Pleuronectes americanus) were most common (Table 1).

Total landings of bycatch for the period was over 51 million pounds (23,181 MT) valued at $28.7 million, or nearly 7% of sea scallop revenue. Although the reported revenue from bycatch appears minor, it can be considered important especially during certain times of the year and when scallop abundance is low.

Retained bycatch of finfish in the Canadian scallop fishery totalled for three years (1992-1994) was 2400 MT with monkfish, cod (Gadus morhua), and winter flounder comprising most of the bycatch (Table 2). The amount of bycatch for the Canadian fishery was significantly less than the U.S. totals. This may be due to fewer vessel days at sea and fishing company policies with regard to finfish bycatch being retained or discarded.

For both the U.S. and Canadian sea scallop fishery, little information is available on discarded bycatch of undersized finfish, damaged lobsters, crabs and other invertebrates. More importantly there is virtually no information relative to the mortality/survival rates of discarded bycatch. Most individuals who are familiar with the fishery indicate that mortality rates could be very high. Animals are often damaged in handling the dredge, when the catch is culled for retainable scallops and bycatch, and in the process of shoveling overboard sand, shells, rocks and unwanted animals.

The disposition of monkfish was examined during one commercial trip in the Southern New England/mid-Atlantic region (Figure 6). Analysis of data from 49 of 176 tows indicated that the culling size of monkfish was about 380 mm total length. It was observed that out of 1321 monkfish harvested, 1047 were discarded (Carnegie and DuPaul, 1995). On a cautionary note, it must be recognized that monkfish distribution, both in size and numbers, are greatly influenced by season and geography. However, this data was obtained on traditional scallop fishing grounds with significant fishing vessel activity.

**Reduction of Finfish Bycatch

There apparently has been little published on methods for reducing finfish bycatch in the sea scallop dredge fishery. In the U.S., research will begin soon to evaluate gear modifications in an attempt to reduce bycatch. In Canada, gear modifications to reduce bycatch have been tested by the scallop industry with some modest success (pers. comm., C. G. Cooper, Department of Fisheries and Oceans, Canada; Sept., 1995).

The Canadian work found that the use of large square mesh in the twine top resulted in a decrease in the catch of roundfish (cod, haddock) but not in flatfish (winter flounder, yellowtail flounder). Windows or open squares in the back of the twine top and tickler chains attached to the forward frame of the dredge resulted in similar decreases in the catch of roundfish by approximately 25%. Dredge modifications to reduce the harvest of flatfish may be problematic; it is clearly an area of needed research.

While a modest but welcomed reduction of cod and haddock has been achieved, questions remain about strategies to reduce the bycatch of small and undersized monkfish and flatfish. Bycatch mortality of discarded fish appears to be high as many small monkfish and flatfish are dead by the time they are discarded overboard. Additional research is needed to evaluate gear modifications and changes in fishing strategies to reduce finfish bycatch mortalities

*Deck Management

Another potentially important, but undocumented source of discard mortality is poor deck management. Finfish, scallops, crabs and other invertebrates are often left on deck for extended periods of time after the catch has been culled. When this occurs, mortality occurs either because of prolonged absence from the water or damage inflicted by the crew while working. Immediate steps could be taken to discard live, but unwanted animals overboard. In addition, fish, undersized scallops and crabs should not be left on deck between haul-backs. With a very modest effort, the crew could minimize discard mortality by cleaning the deck of the vessel immediately after culling retainable scallops. Although deck management may or may not make a significant difference in discard mortality rates, it is something the crew could accomplish with minimal effort.

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Figure 1.

Standard sea scallop dredge with two tickler chains, sweep chain and rubber chaffing gear on bottom portion of bag. Modifications for hard bottom fishing include the use of rock chains in the mouth of the bag.

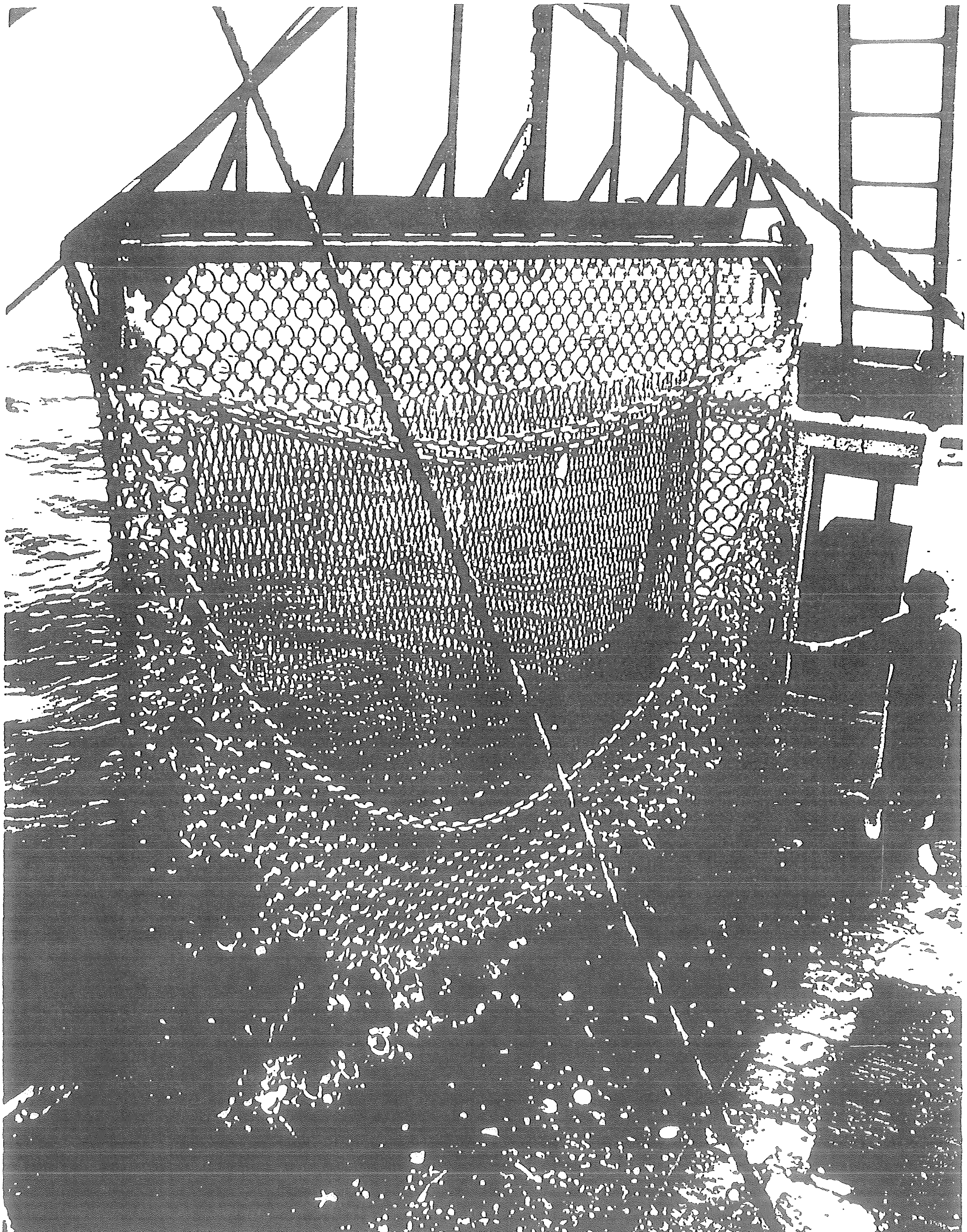
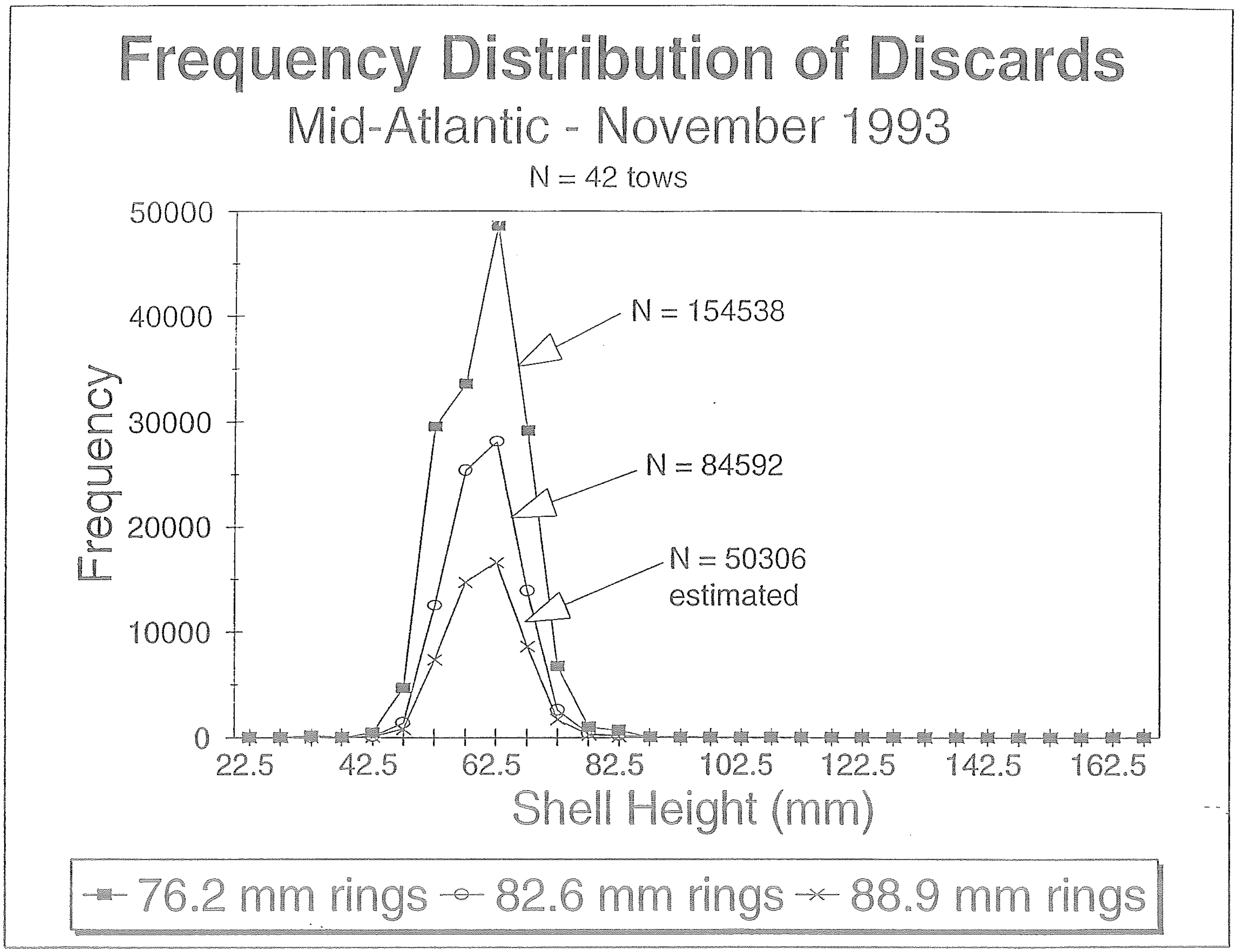


Figure 2.

Size frequency of sea scallop discards during November 1993 in the mid-Atlantic region (Del-Mar-Va) for three dredge ring sizes. Data for 88.9 mm rings were estimated using efficiency ratios derived from gear trials conducted in 1988 and 1994-1995.



Frequency Distribution of Discards
Mid-Atlantic - November 1993
N = 42 tows
50000
40000
30000
20000
10000
0
Frequency
N = 154538
N = 84592
N = 50306
estimated
22.5
42.5
62.5
82.5
102.5
122.5
142.5
162.5
Shell Height (mm)
76.2 mm rings
82.6 mm rings
88.9 mm rings

Figure 3.

Size frequency distribution of sea scallop discards during four commercial trips from June 1994 - April 1995 in the mid-Atlantic region (Del-Mar-Va) for three dredge ring sizes. Data for 76.2 mm rings were estimated using efficiency ratios derived from gear trials conducted in 1988 and 1993.

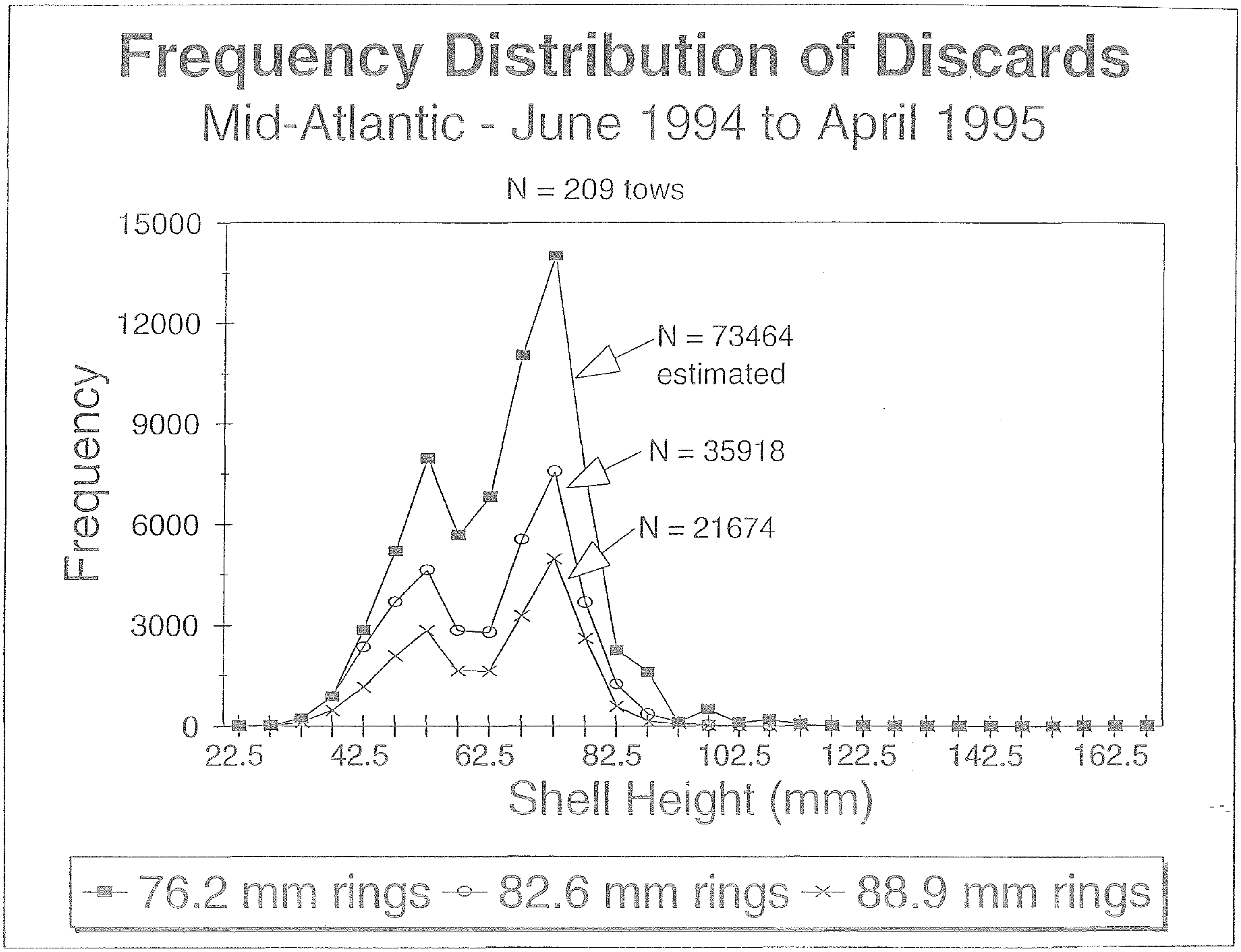

Frequency Distribution of Discards
Mid-Atlantic - June 1994 to April 1995
N = 209 tows
15000
12000
9000
6000
3000
0
Frequency
N = 73464
estimated
N = 35918
N = 21674
22.5
42.5
62.5
82.5
102.5
122.5
142.5
162.5
Shell Height (mm)
76.2 mm rings
82.6 mm rings
88.9 mm rings

Figure 4.

Size distribution of sea scallops retained by crew for four commercial trips in the mid-Atlantic region (Del-Mar-Va). There were no significant differences in crew selection between 88.9 and 82.6 mm ring dredges. Size at 50% retention were significantly different for August 1994 and April 1995.

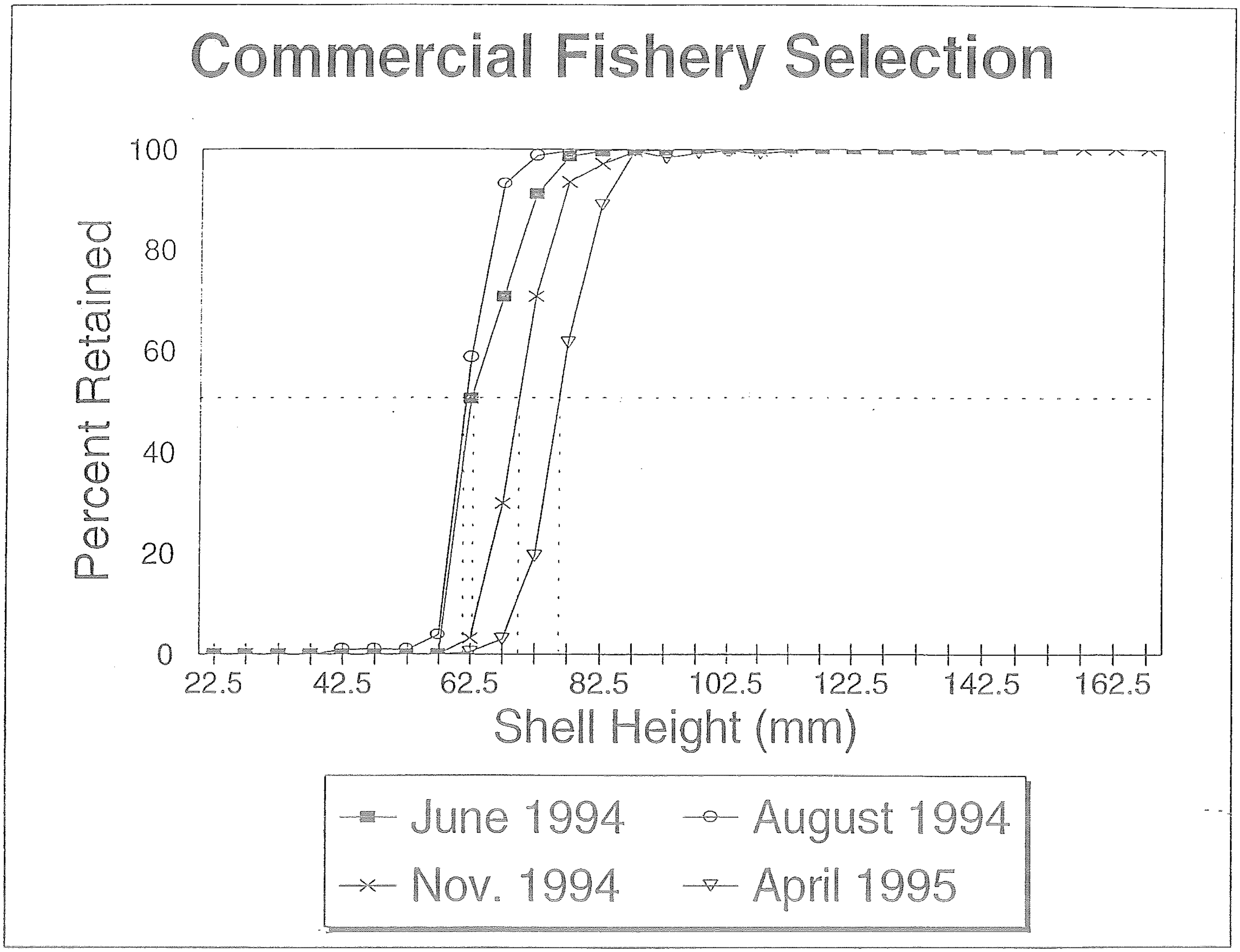
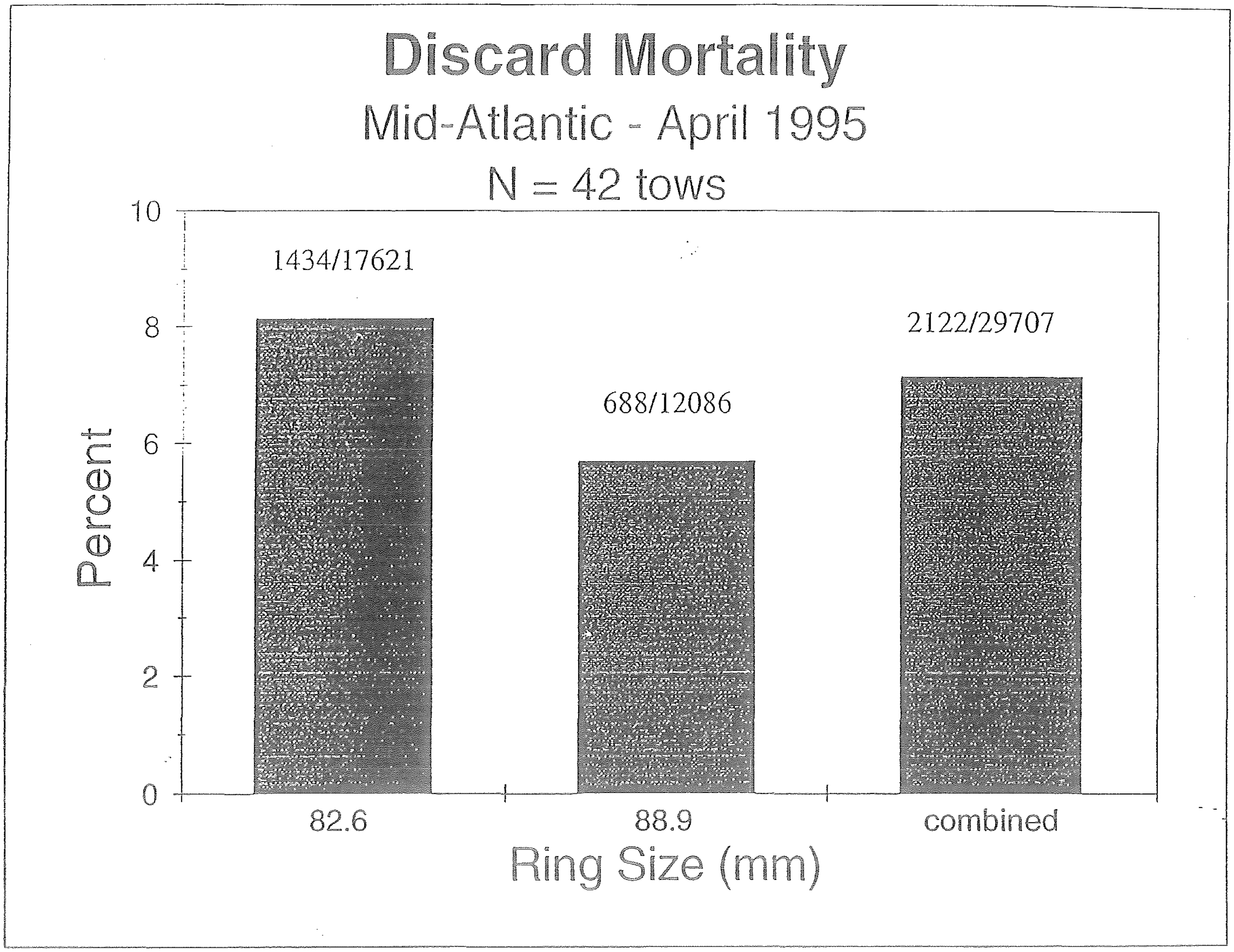

Commercial Fishery Selection
Percent Retained
100
80
60
40
20
0
22.5
42.5
62.5
82.5
102.5
122.5
142.5
162.5
Shell Height (mm)
June 1994
August 1994
Nov. 1994
April 1995

Figure 5.

Sea scallop discard mortalities observed for 82.6 and 88.9 mm dredge rings. Quantity harvested and percent mortality for the 88.9 mm ring dredge were substantially lower.



Discard Mortality
Mid-Atlantic - April 1995
N = 42 tows
Percent
10
8
6
4
2
0
1434/17621
688/12086
2122/29707
82.6
88.9
combined
Ring Size (mm)

Figure 6.

Size frequency distribution of monkfish (Lophius americanus) harvested by a commercial sea scallop dredge vessel in the Southern New England/mid-Atlantic region, November 1993. Data is from 49 of 176 tows. Culling size was determined to be approximately 380 mm total length (Carnegie and DuPaul, 1995).

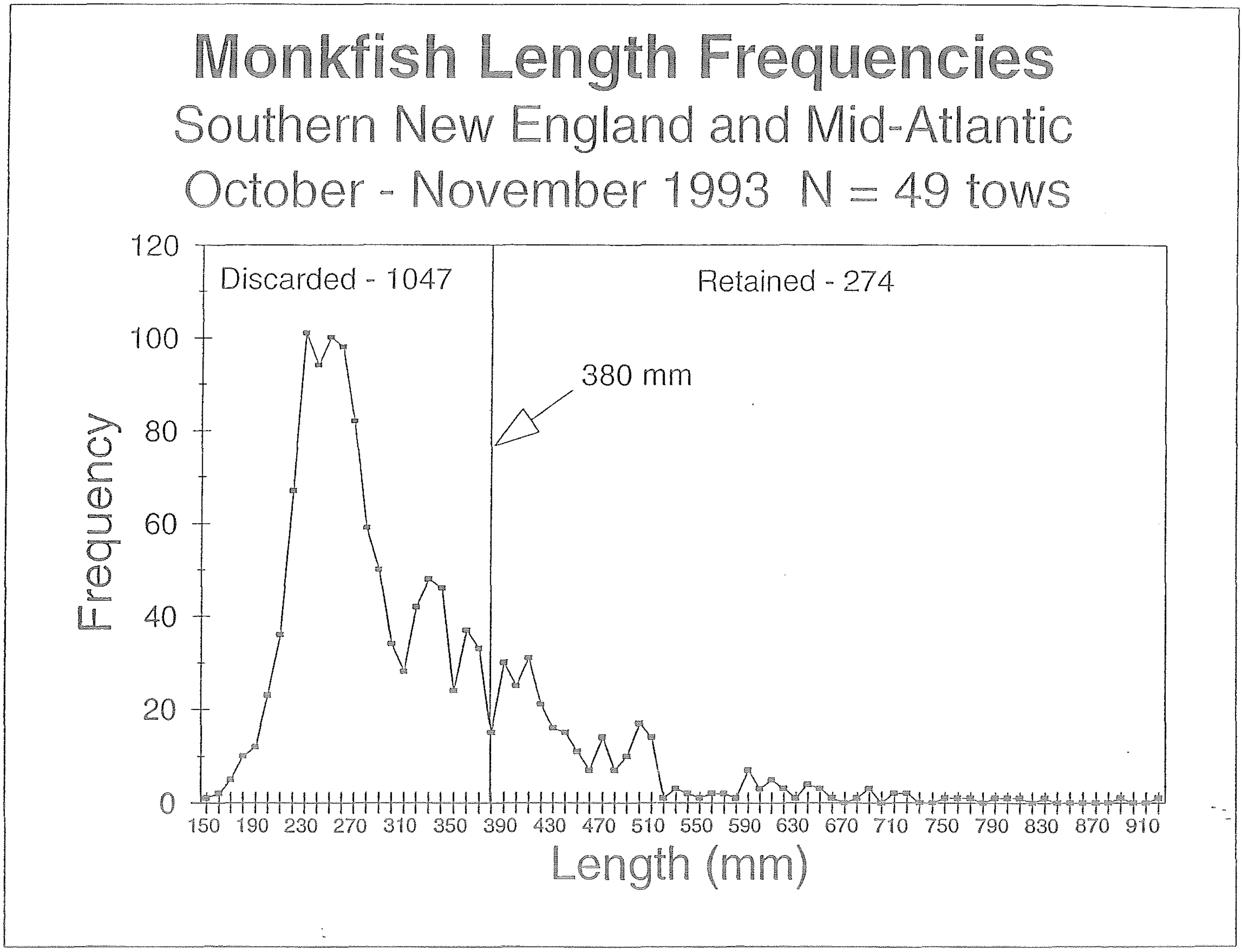

Monkfish Length Frequencies
Southern New England and Mid-Atlantic
October - November 1993 N = 49 tows
Discarded - 1047
Retained - 274
380 mm
Frequency
Length (mm)
0
20
40
60
80
100
120
150
190
230
270
310
350
390
430
470
510
550
590
630
670
710
750
790
830
870
910

Table 1. Bycatch landings and ex-vessel value for U.S. sea scallop dredge vessels; 1991-1993. NMFS data summarized by the New England Fishery Management Council (A. Applegate, personal communication.)

Species	Catch (kgs.)	Revenue ($)	Percent % Scallop Revenue
Scallops	33,301,542	427,071,875	
Monkfish	18,880,112*	17,528,659**	4.1
Cod	258,480	506,195	0.1
Summer Flounder	571,268	1,842,842,215	0.4
Yellowtail Fl.	1,473,677	4,225,889	1.0
Winter Flounder	911,839	2,409,555	0.6
Other flounder	550,720	1,455,289	0.3
Other species	545,720	771,553	0.2
TOTAL	23,192,380	28,739,355	6.7

* Whole weight
** Tails

Table 2. Bycatch landings for Canadian sea scallop dredge vessels; 1992-1994. Department of Fisheries and Oceans, Canada; C. G. Cooper, personal communication.

Species	Catch (kgs)	Revenue (C $)
Scallops	**21,664,000**	**$312,081,000**
Monkfish	1,568,106*	--
Yellowtail Flounder	88,448	--
Winter Flounder	96,650	--
Cod	256,858	--
Other	384,837	--
TOTAL	2,400,618	--

* Whole weight