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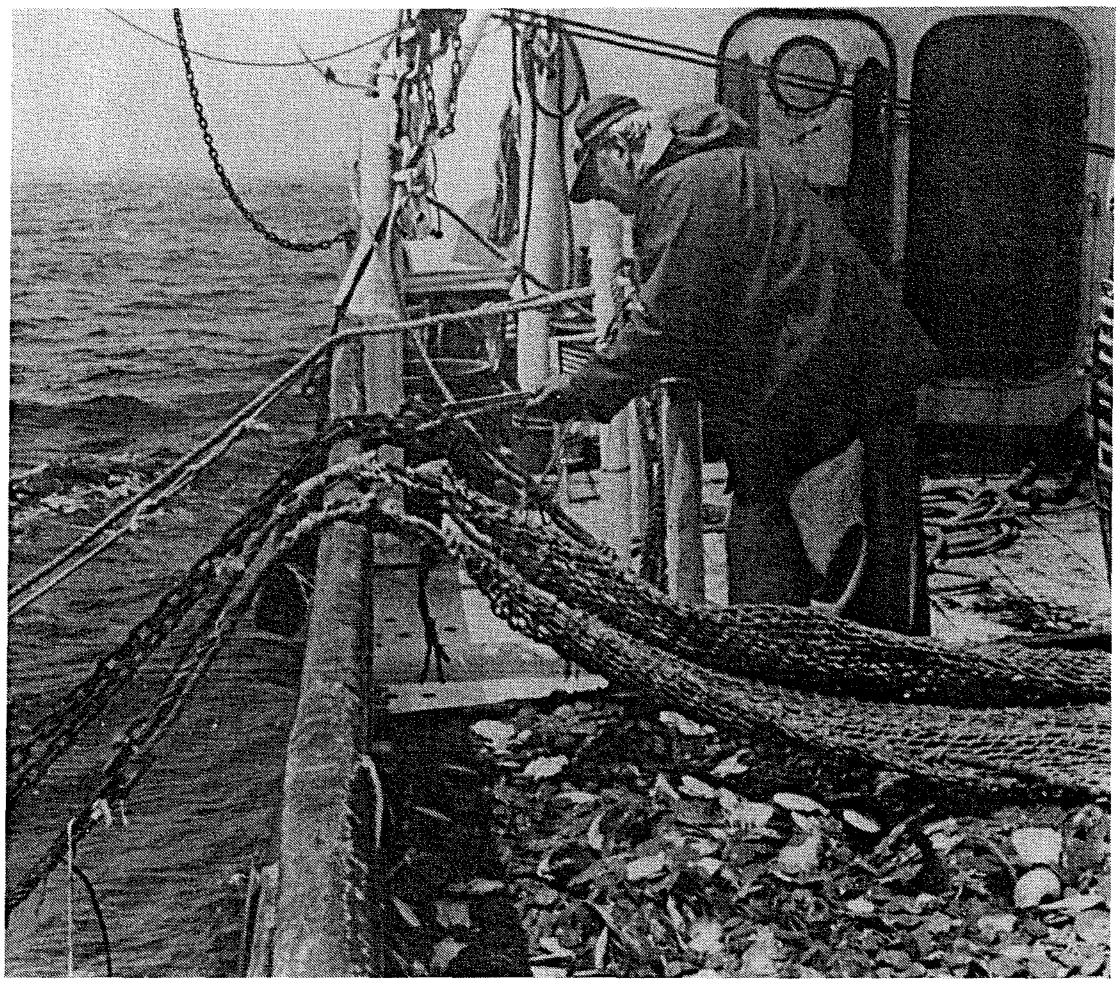

Participating Agencies and Supporting Organizations:
East Coast Fisheries Association
National Marine Fisheries Service
New England Fishery Management Council
Virginia Institute of Marine Science, College of William and Mary
Virginia Sea Grant Marine Advisory Program

A COMPARATIVE ANALYSIS OF THE EFFECTS ON TECHNICAL EFFICIENCY AND HARVEST OF SEA SCALLOPS (PLACOPECTEN MAGELLANICUS) BY OTTER TRAWLS OF VARIOUS MESH SIZES

EAST COAST FISHERIES ASSOCIATION*

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INTRODUCTION

Since 1983, the sea scallop, _Placopecten magellanicus_ (Gmelin), fishery has been regulated by the Fishery Management Plan for Sea Scallops (FMPSS) under the authority of the New England Fisheries Management Council (NEFMC, 1982). The regulations restrict vessels which land shucked meats to a maximum number of meats per pound; vessels which land shell-stock are subject to minimum shell size restriction. The current meat count and shell stock regulations are 30 meats per pound (MPP) with a 10% tolerance between February 1 and September 30 and 33 MPP with a 10% tolerance between October 1 and January 31, and a minimum shell size of 3.5-inches (88.9 mm) in which no more than 40 out of 400 scallops can be less than 3.5-inches.

The regulations have posed several problems. First, there is a possible problem of inequity between firms which shuck at sea and firms which shell stock or land whole scallops in the shell; the existence of the inequity has not been substantiated, but it likely occurs within both fleets. Second, it has been demonstrated that there is considerable variation in the meat count for scallops of given shell heights; this is believed to be related to spatial and temporal differences and the reproductive cycle (DuPaul and Kirkley, 1987, 1988; Shumway and Schick, 1988; DuPaul et al., 1988). Third, the meat count for landed product may be different than the meat count for harvested product due to shucking and at-sea handling practices.

As a result of these sources of variations and problems, the current regulations may be inadequate. Alternative forms of regulations need to be considered. This study analyzes the harvesting efficiency and size selectivity of various mesh sizes on vessels which trawl for scallops; these vessels typically land shell stock. If changes in mesh and ring size increase escapement of small scallops and have minimal effects on the harvesting efficiency, gear restrictions may offer a feasible alternative to the current set of regulations. However, it is stressed that the analysis of harvesting efficiency and size selectivity in this study is predicated on the resource conditions prevailing for the time and resource areas examined. Different resource conditions could yield different results; for example, size selectivity for an area comprised of mostly large scallops would be different than the size selectivity of an area comprised of mostly small scallops.

MATERIALS AND METHODS

Data collection

A nine-day sea scallop conservation engineering project was conducted aboard the F/V Miss Quality from the port of Wanchese, North Carolina. The vessel, a commercial sea scallop shell-stocker, departed at 0800 on 20 April and returned on 28 April, 1988. Fishing gear trials with sea scallop trawl nets were conducted in the mid-Atlantic area, adjacent to the New Jersey coast (NEFC Statistical Areas 614, 621, and 622, Figure 1). The trawl trials were conducted for the purpose of obtaining catch and length-frequency data necessary for analyzing harvesting efficiency and size selectivity of trawls.

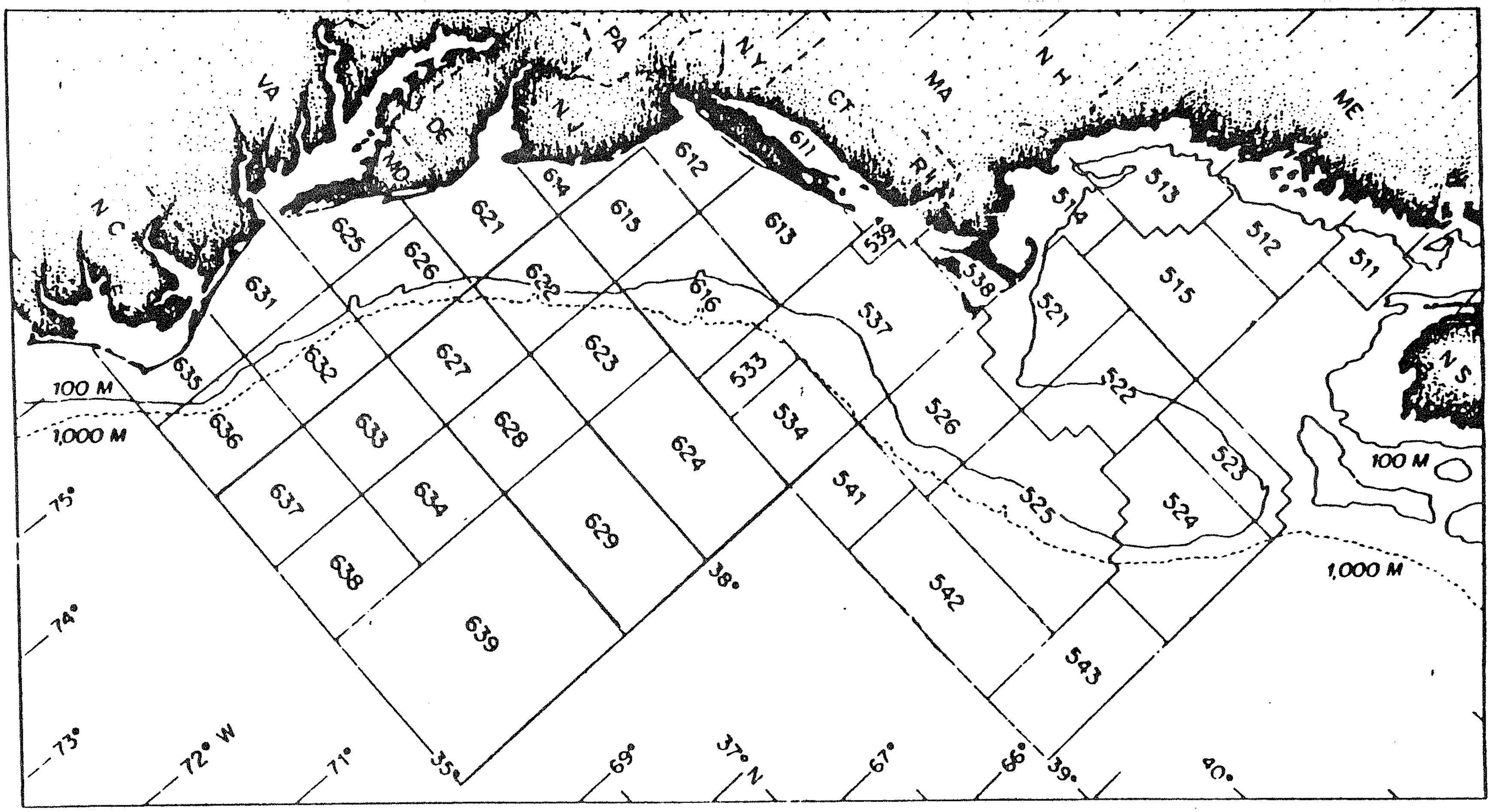
A second vessel, the F/V Lady Cheryl, a commercial dredge vessel from New Bedford, Massachusetts, conducted dredge hauls in the same area as the shell-stocking vessel. The dredge vessel fished concurrently an eight foot experimental survey dredge (2-inch rings) with a one and one-half inch (38 mm) liner and a standard 15-foot commercial scallop dredge (3-inch rings). These tows were made to compare size selectivity and catch rates of various gear configurations in the same resource area at the same time.

Experimental hauls for both vessels were made at depths ranging from 23 to 35.5 fathoms (41 to 64 meters). Average depth fished by the F/V Miss Quality was 33 fathoms (59 meters); average depth fished by the F/V Lady Cheryl was 26 fathoms (47 meters). Typically, 2 baskets of scallops from each net-mesh combination per tow were sampled for a total of four baskets of scallops per tow on the net boat; sample size for the dredge vessel was one basket per tow from each dredge for a total of two baskets per tow.

Scallops were measured by 5 mm intervals using measuring devices available from the National Marine Fisheries Service. Length of tow, time of day, depth, and baskets of

FIGURE 1. NATIONAL MARINE FISHERIES SERVICE (NMFS)

THREE-DIGIT STATISTICAL AREAS



scallops, fish, and trash were recorded for all tows. A total of 43 trawl tows were used to analyze size selectivity and harvesting efficiency; scallops from 15 tows by the dredge were used for analysis.

Vessel description

F/V Miss Quality

The F/V Miss Quality is a 78-foot (23.8 meters), 24-foot beam (7.3 meters), 9-foot (2.7 meters) draft, steel-hulled combination western (stern ramp and dual net reel) and southern rigged (port and starboard 50-foot outriggers) sea scallop trawler. The main engine is a Caterpillar 5.88 reduction turning a 7046 four blade propeller; gross-registered-tonnage is 159 tons with a fishhold capacity of 40 tons. The vessel can accommodate a crew of six.

Electronics for the F/V Miss Quality included: Furuno Echo Sounder Type FE-D813AF; EPSCO Chromascope Fish Finder, CVS-886; Northstar 7000, Remote Control equipped with Wood Freeman Automatic Pilot; EPSCO, C-Plot 2; Furuno-Radar Type FR-711 (72 mile range); Furuno-Radar Type FR-240, Mark-II (24 mile range); EPSCO C-Nav XL Plotter; and Sea Water Temperature, Dytek Laboratories, Model 703200.

Radio communications equipment included: Patterson Mfg. Co. Sideband, FCC Data-310-A (Call WYK4056); Regency Polaris VHS; three citizen band radios--Cobra 148GTL-OX CB, Horizon Maxi CB, and Realistic TRC-415.

F/V Lady Cheryl

The F/V Lady Cheryl is a 100-foot (30.5 meter), 12-foot draft (3.65 meter) steel-hulled western rigged sea scallop dredge vessel. The gross-registered-tonnage is 194 tons and the vessel can accommodate a crew of 14.

Fishing gear

Two sea scallop shell-stocking trawl nets, two modified trawl nets, and one typical calico scallop trawl net were evaluated during the fishing experiment. Simultaneous trawl hauls were conducted to test differences between nets. The trawl boards were attached directly to trawl wings, thereby maintaining the spread and "mouth" opening of the trawl net. Two identical sets of otter boards were used off the starboard and port outriggers. Board dimensions were 11-feet (3.35 meters) by 3.4-feet (1.12 meters). Fifty fathom (19.4 meters) bridle cables of 5/8-inches (16 mm) wire cable extended from both the 5/8-inch starboard and port main cable. The ratio of wire to water depth was maintained at 3 to 1; however, each main cable was alternately decreased by 25 fathoms (45.7 meters) to prevent the two nets from tangling during fishing operations.

Sea scallop shell-stocking trawl nets

The trawl configuration consisted of a two-seam, narrow 9:1 tapered trawl body with codend. Two similar sized shell-stocking trawl nets were tested: a 98 foot (29.9 meter) headrope and footrope, 5-inch mesh body (four mm polyethylene twine) with a 4 1/2-inch mesh codend; and a 100 foot (30.5 meter) headrope and footrope, 4-inch mesh body (three mm polyethylene twine) with a 4 1/2-inch mesh codend. The wing construction of the five-inch mesh trawl consisted of 90 dog wings with a 90 mesh belly; the wing construction of the 4-inch mesh trawl net consisted of 113 dog mesh with a 234 mesh belly. Headropes and footropes were 3/4-inch diameter (19 mm) with 1/2-inch diameter (13 mm) chain attached 12 links every 16-inches. The 100 foot, 4-inch mesh trawl net was constructed to minimize the difference of surface area between that of the five-inch net.

The codend of each of the above nets consisted of Number 120 nylon braided twine, 60 meshes in length. During the codend experiment, a 5-inch codend, 120 nylon braided twine, 50 meshes in length, was used.

Sea scallop shell-stocking nets were heavily equipped with chaffing gear to avoid wear. An approximate one-meter length of 3/16-inch (5 mm) diameter or Number 20 braided nylon was doubled and attached around the entire codend. From the terminus of the codend, working forward, a chaffing strand was attached to each mesh row for about half the length of the codend; thereafter, a strand was attached every other row for approximately 20 knots above the codend.

Calico scallop trawl net

A typical, two-seam, semi-ballon design, calico trawl net was tested with a sea scallop trawl net. The calico trawl net was constructed entirely of 3-inch mesh, No. 84 braided nylon. The 36 foot long (11 meters), 5/8-inch (16 mm) diameter combination rope/wire headrope and footrope, with identical top and bottom sections, was rigged with a "Texas drop chain". This consisted of 1/2-inch (13 mm) cable running the length of the footrope and fastened at regular intervals by 3-link chain drops. Both the codend and the trawl net body were protected with polyethylene chaffing gear, similar to the arrangement described above.

Fishing operations

Fishing operations were conducted in coastal waters, east of Virginia, Maryland, and New Jersey from approximately 39 24′ N, 74 01′ W to 37 04′ N, 74 55′ W in depths ranging from 27 to 35 fm. Fishing was conducted between April 21 and 27, 1988; 43 tows were completed. Two nets were simultaneously towed with towing times ranging from 10 to 182 minutes; towing speed was 2.8 knots. Net mesh size of the paired tows are presented in Table 1. Tows 1 through 5 were conducted to examine whether or not there were any port or starboard related differences.

TABLE 1

Paired tows and corresponding mesh sizes of trawl nets[a]

Tow #	Net	Mesh Size (inches)		
		Top Panel	Bottom Panel	Codend
1-5	1	5	5	4 1/2
	2	5	5	4 1/2
6-12	1	5	5	4 1/2
	2	4	4	4 1/2
13-24	1	5	5	5
	2	4	4	4 1/2
25-31[b]	1	3	3	3
	2	4	4	4 1/2
32-33	1	5	4	4 1/2
	2	4	4	4 1/2

[a]Side-by-side gear configurations were examined.

[b]Calico scallop trawl net.

The dredge vessel, Lady Cheryl, made corresponding tows on the same bearings as F/V Miss Quality a few hours after Miss Quality had fished. Table 2 provides the tow numbers for the dredge vessel comparable to the tows made by the trawl vessel.

Catch and length-frequency data

Catch data were collected for each tow and net (Table 1 of Appendix I). Catch and scallop size distribution for each grouping of tows for which data were obtained are presented and discussed in the results section of this study. The catch of scallops was recorded in baskets; the two handled plastic baskets often used on commercial fishing vessels measured 17-inches across the top, 13-inches at the bottom, and 15-inches high. Length-frequency data for 2 baskets per net per tow were obtained. The two baskets were a sub-sample from the total catch after debris and by-catch were separated from the scallops. The shell height of scallops was measured in 5 mm intervals.

Purposes of the study were to examine harvesting efficiency and size selectivity. Harvesting efficiency was examined by comparing seemingly unrelated regression estimates of catch-effort models for four of the mesh combinations; a conventional F-test was used to examine the efficiency of tows 32 and 33. Size selectivity was examined by graphical interpretation. Selection curves based on the methods of Beverton and Holt (1957), Pope et al. (1975),

TABLE 2

Matched tows involving F/V Lady Cheryl using scallop dredges and F/V Miss Quality using scallop trawl nets.

	F/V Lady Cheryl		F/V Miss Quality			
Tow #	Dredge Size (ft.)	Ring Size (in.)	Tow #	Mesh Size (inches) Top	Bottom	Codend
61-65	8	2[a]	6-12	5	5	4 1/2
	15	3		4	4	4 1/2
84-88	8	2	13-24	5	5	5
	15	3		4	4	4 1/2
106-110	8	2	25-31	3	3	3
	15	3		4	4	4 1/2

[a]All tows made with 8-foot dredge, 2-inch (50.8 mm) rings, and a 1.5-inch (38 mm) liner.

and Serchuk and Smolowitz (1980) were not used to examine selectivity for several reasons. First, grouping of data into 5 mm intervals caused heteroscedasticity. Second, truncation at 0 and 1 posed special estimation problems. Third, estimates of number of scallops that escaped harvest relative to the number of scallops actually retained in the net were imprecise. In essence, estimates of percent retention were inaccurate.

The statistical problems of heteroscedasticity and double truncation can be easily remedied. Procedures to correct for heteroscedasticity caused by grouping of data are summarized in Maddala(1977) and Bewley (1989). The problem of double truncation may be corrected by using a 'two limit probit' or 'two limit tobit' model (Rosett and Nelson 1975). These procedures, however, were not further pursued because it was not thought that estimates of size selectivity based on the data available were meaningful. That is, estimates of percent retention for closely similar mesh sizes are not indicative of actual size selectivity. Nevertheless, data for estimating relative size selectivity are presented in this report.

Size selectivity was inferred from the length-frequency and cumulative distribution graphs. However, the analysis of size selection is conditional on the prevailing resource conditions and areas fished. Different stock distributions, densities, and size compositions could yield different results (Bourne 1965). For example, selectivity would be different for an area characterized by a large concentration of small scallops vs. large scallops.

RESULTS

Harvesting efficiency

Although the experiment was primarily concerned with determining size selectivity of different mesh sizes, it was also important to determine the relative efficiency of different mesh sizes. That is, what was the difference between catch for a given level of fishing effort by one mesh size and catch for the same level of effort for a different mesh size. The possible difference between catches is important to know if mesh restrictions are to be implemented. It also was necessary to quantify differences in harvest levels to validate the trawl experiment. For example, if the same mesh trawl was towed on both sides of the vessel and there were differences in the catch levels, the analyses of harvesting efficiency and size selectivity would have to be modified to reflect port-starboard differences.

In this section, an analysis of the relative efficiency of different mesh sizes is presented. Analyses are based on the assumption that the traditional catch-effort model characterizes the relationship between catch and effort:

(1) $C_{it} = \beta_i \, Effort_{it}$

where C is catch per tow, effort is time per tow measured in minutes, i is the ith mesh size, and β is the coefficient to be estimated.

Model (1) is estimated for each combination of mesh size by seemingly unrelated regression or Zellner estimation. The relative efficiency is examined by imposing the restriction that β for one mesh size equals β for another mesh size; a likelihood ratio test is used to test for statistical differences. If the two estimated β coefficients are equal, there is no statistical difference in catch between the various gear combinations for a given level of effort.

The statistical results of the tests for differences between mesh size are presented in table 3. The first test was a test to determine if the 5-inch body, 4.5-inch codend mesh towed on one side of the vessel had the same effect on catch as the same mesh towed on the other side of the vessel. This was used as a 'ground truth' comparative test.

As indicated in table 3, catch for a given level of effort by the 5-inch body, 4.5-inch codend mesh towed on one side of the vessel was not statistically different than catch obtained by the same mesh towed on the other side of the vessel. However, there were substantial differences in between the catch and effort relationships for the other three mesh combinations.

A limited number of observations prevented testing the equality between the efficiency of a 4-inch body,

TABLE 3

Results for equality tests of coefficients

Structure tested[a] ($\beta_i = \beta_j$)	Chi-squared[b]	Critical-value 1-percent
5 inch body, 4.5 inch codend 5 inch body, 4.5 inch codend	4.88	6.64
4 inch body, 4.5 inch codend 5 inch body, 4.5 inch codend	12.77[c]	6.64
4 inch body, 4.5 inch codend 5 inch body, 5.0 inch codend	13.97[c]	6.64
calico trawl 4 inch body, 4.5 inch codend	15.18[c]	6.64

[a]Null hypothesis is that $\beta_i = \beta_j$ or that the effort coefficient is equal for the two catch-effort equations.

[b]Chi-squared is for one degree of freedom.

[c]Effort coefficients between pair of mesh sizes examined were statistically different.

4.5-inch codend vs. a 5-inch top panel, 4-inch bottom panel, and a 4 1/2-inch codend (tows 32 and 33). However, a regression of catch on effort of the two yielded coefficients of .194 and .1984, respectively. The correlation between catches for the two mesh sizes was .98; thus, indicating little difference between the two mesh combinations.

Additional tests were performed on the equivalency of the relationship between catch and effort with one mesh held constant and towed in conjuction with different mesh sizes. The 4-inch body, 4.5-inch codend towed with a 5-inch body, 4.5-inch codend was compared to the 4-inch body, 4.5-inch codend towed with a 5-inch body, 5-inch codend. Similarly, the 5-inch body, 4.5-inch codend was tested against the 4-inch body, 4.5-inch codend. Standard F-tests failed to reject any differences. The 4-inch body, 4.5-inch codend harvested the same regardless of the other two meshes towed; the same results were found for the 5-inch body, 4.5-inch codend mesh.

Table 4 presents the estimated coefficients of the catch-effort equations for the different mesh sizes (i.e., final form estimates). As indicated by the coefficient estimates, the 4-inch body with a 4.5-inch codend is considerably more efficient than the other mesh sizes. That is, a unit effort with this mesh yields a larger catch response than any other mesh size.

Relative harvesting efficiency was examined in terms of the technical relationship between catch and effort.

TABLE 4

Estimated coefficients of catch-effort equations

Mesh combination examined/tested	Coefficient[a] (β_i)	t-statistic[b]
5 inch body, 4.5 inch codend	.018	3.06
5 inch body, 4.5 inch codend	.018	3.06
4 inch body, 4.5 inch codend	.228	5.59
5 inch body, 4.5 inch codend	.103	4.97
4 inch body, 4.5 inch codend	.192	6.90
5 inch body, 5.0 inch codend	.090	6.16
Calico trawl	.027	6.65
4 inch body, 4.5 inch codend	.181	24.55

[a]Final form coefficient estimates reflect results of statistical tests of the equality of coefficients (See Table 3 for explanation of structures tested).

[b]All parameters were statistically different than zero ($p \leq 0.05$).

The estimated β coefficients in Table 4 are indicative of the relative efficiency of the various meshes (e.g., the coefficient for the calico trawl is .027 and that for the 4-inch body, 4 1/2 codend is .181; thus, the standard 4-inch body, 4 1/2-inch codend is more than six times as efficient as the calico trawl (.181/.027)). Overall, the 4-inch body, 4.5-inch codend was considerably more efficient in terms of total catch for given levels of effort. Harvest levels for the 4-inch body, 4.5-inch codend were approximately double the harvest levels of the 5-inch body, 4.5-inch codend and 5-inch body, 5-inch codend.

In conclusion, the 4-inch body, 4.5-inch codend mesh was considerably more efficient than the other mesh size combinations. Furthermore, of the mesh sizes tested, the 4-inch body, 4.5 inch codend yielded equivalent results regardless of the other gear with which it was towed.

<u>Size selection</u>

A primary purpose of the study was to examine whether or not an increase in the mesh size would result in reduced catches of small scallops. Additional purposes were to determine (1) if changes in mesh would result in escapement of smaller scallops with no appreciable change in the catch of larger scallops, and (2) size selectivity. Several methods were used to estimate size selection curves for the 3" rings on the dredge and the various mesh sizes.

Using the alternate haul method of Serchuk and

Smolowitz (1980), the calculated the mean (50%) size selection was 75 to 85 mm for the dredge. The 25 to 75% range was between 70 and 90 mm. However, the estimated size selection was found to be extremely sensitive to the method used to calculate an adjustment factor. The closely similar mesh method of Davis (1934) and Beverton and Holt(1957) failed to yield adequate estimates of size selectivity for the various mesh sizes.

Although the various methods yielded conflicting results, they all appeared to suggest approximately 100% retention of scallops larger than 95 mm. (3.7-inches) for the 3" rings. The Beverton and Holt method indicated 100% retention of scallops between 115 (4.5-inches) and 120 mm. (4.7-inches) for the 5" body-4.5" codend and 4" body-4.5" codend. However, the estimated retention factors for the mesh combination appeared to be very unstable.

Additional problems prevented accurate estimation of size selection curves. First, grouping of the data into 5 mm intervals posed a problem of heteroscedasticity and masked the size selection. Second, retention rates of 0 and 100% resulted in double censored values; a two-limit probit or two-limit tobit model is necessary to estimate size selection. This approach was used to estimate size selection without correcting for heteroscedasticity, but the results appeared to be inadequate. Moreover, Beverton and Holt (1957) have demonstrated that estimates of size selectivity using the alternate haul method applied to data obtained from closely similar meshes are incorrect. Simply, they do not yield accurate and unbiased estimates of true retention.

It was concluded that while estimates of relative size selectivity were possible, these estimates would not be meaningful or useful for assessing size selectivity. As a result of the various problems, the analysis of size selection was restricted to analyzing the corresponding length-frequency and cumulative distribution information. The analyses, however, were primarily in terms of graphical interpretation. These are subsequently described with respect to the grouped net tows and matched dredge tows.

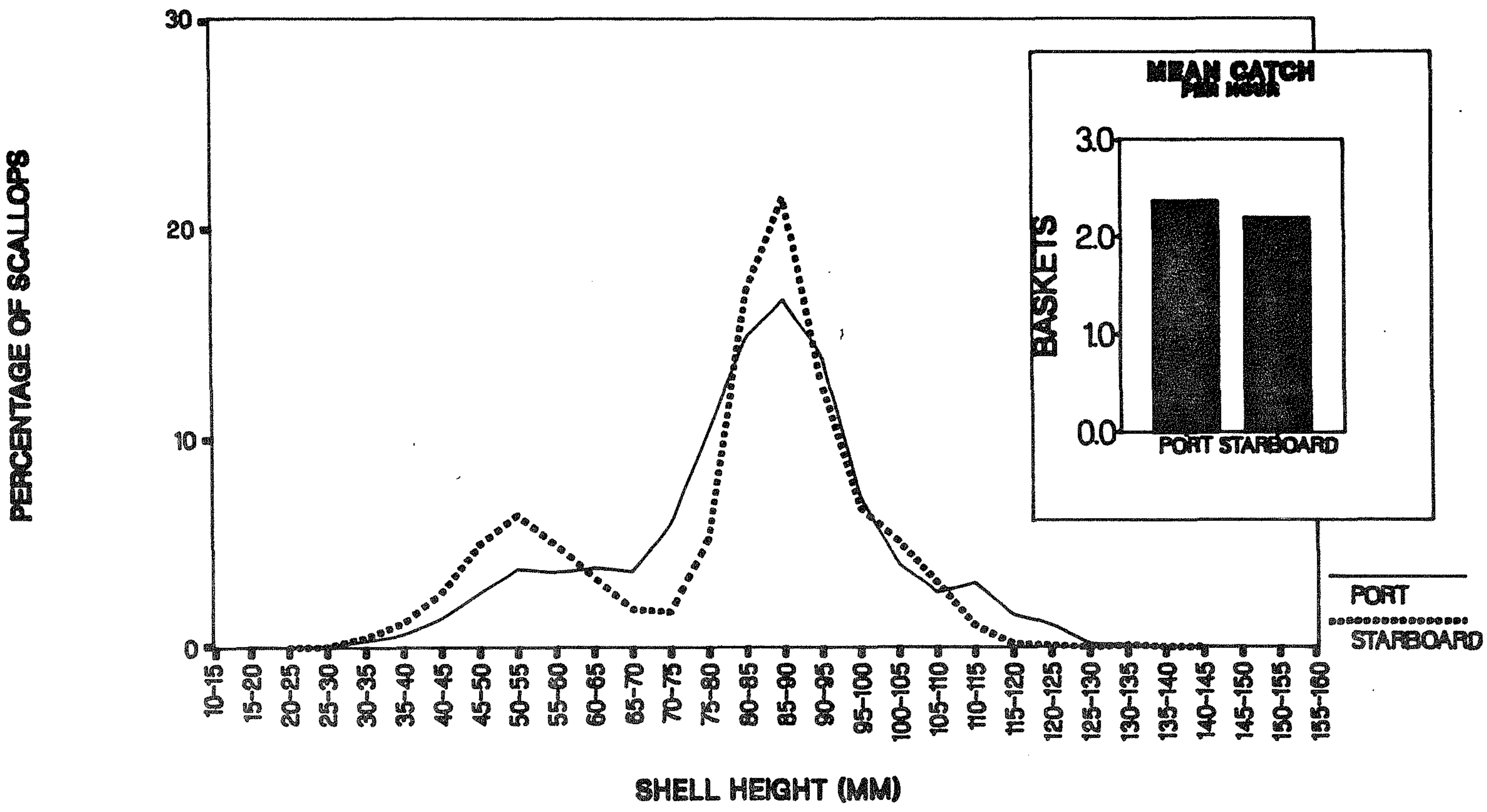
Tows 1-5 (5" body-4.5" codend: identical nets)

As previously indicated, the purpose of tows 1-5 was to examine possible port-starboard differences. The nets were identical in configuration and mesh sizes, but one of the net was new. Harvesting efficiency appeared to be nearly equal (Table 4). The size distributions, though, displayed minor differences (Figure 2). The starboard net had more scallops in the 85-90 mm and 50-55 mm size ranges. Since these were the first 5 tows, during which time the scientific and commercial fishing crew were becoming familiar with operations, the length frequency data may be subject to measurement error. Catch and tow data for tows 1-5 are presented in Appendix I. There were no matched tows by the scallop dredge vessel.

FIGURE 2

SIZE DISTRIBUTION OF SEA SCALLOPS CAPTURED BY ONE MESH SIZE ON EITHER SIDE OF THE TRAWLER

AGGREGATE OF FIRST FIVE TOWS



5-INCH BODY, 4.5-INCH CODEND

Tows 6-12 (5" body-4.5" codend vs. 4" body-4.5" codend)

Tows 6-12 were conducted to examine whether or not an increase in the size of the mesh of the body would reduce catch and allow greater escapement of smaller scallops. Corresponding matched tows by the dredge vessel were 61-65. The number of scallops per 5 mm size interval are presented in Table 5; the catch per tow information is presented in Appendix I.

As indicated by the numbers of scallops by size in Table 5, there does not appear to be any size selection for scallops less than 80 mm in size. This is further illustrated in Figure 3; comparisons of size distributions for individual tows appear in Appendix II. Minor size selection may occur between 80 and 90 mm; the 4" body-4.5" codend had proportionately more scallops between 80 and 90 mm (51.7 vs. 46.6%). Beyond 90 mm, the 5" body-4.5" codend harvested proportionately more scallops.

In comparison, the dredges with 3" and 2" rings indicated considerable differences in size selectivity. As expected, the 2" ring had proportionately more small scallops. If the size distribution of the 2" ring is indicative of the size distribution of the resource available, the 3" ring and the two meshes allow considerable escapement of smaller scallops.

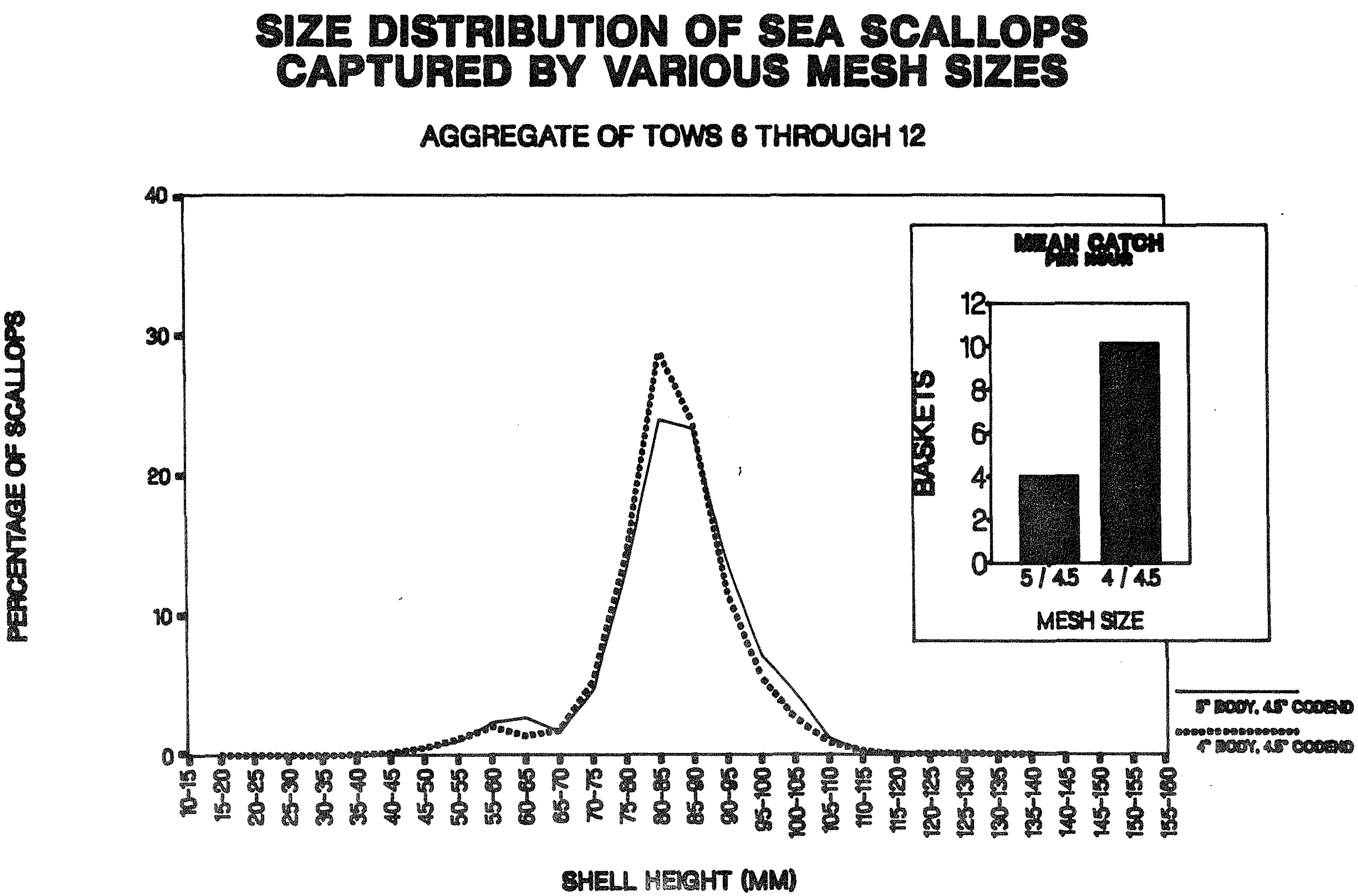
A comparison of the size distribution and mean catch per hour of the four gear combinations indicates that the 4"

TABLE 5

Length-frequency distribution of sea scallops captured by tow two different mesh combinations (tows 6-12) and ring diameters (tows 61-65)

Shell Height	Mesh Sizes				Ring Sizes			
	4/4.5 inch		5/4.5 inch		3 inch		2 inch	
	Number	%	Number	%	Number	%	Number	%
20-25	0		0		0		0	
25-30	0		0		0		0	
30-35	0		0		0		3	.14
35-40	1	.02	0		0		16	.74
40-45	9	.18	9	.19	0		58	2.67
45-50	29	.58	26	.55	5	.28	123	5.66
50-55	63	1.26	52	1.10	23	1.28	165	7.59
55-60	101	2.03	116	2.45	21	1.17	153	7.04
60-65	73	1.47	123	2.59	19	1.06	172	7.91
65-70	92	1.85	81	1.71	31	1.72	105	4.83
70-75	281	5.64	228	4.81	24	1.33	217	9.98
75-80	701	14.07	605	12.76	114	6.34	285	13.11
80-85	1406	28.22	1099	23.19	347	19.29	323	14.86
85-90	1170	23.48	1110	23.42	409	22.73	258	11.87
90-95	595	11.94	663	13.99	305	16.95	150	6.90
95-100	278	5.58	348	7.34	210	11.67	82	3.77
100-105	129	2.59	215	4.54	180	10.01	46	2.12
105-110	43	.86	58	1.22	69	3.84	13	.60
110-115	9	.18	5	1.10	31	1.72	4	.18
115-120	1	.02	2	.04	10	.56	1	.05
120-125	0		0		1	.06	0	
125-130	1	.02	0		0		0	
130-135	0		0		0		0	
135-140	0		0		0		0	
140-145	0		0		0		0	
145-150	0		0		0		0	
150-155	0		0		0		0	
155-160	0		0		0		0	
Total	4982		4740		1799		2174	

FIGURE 3


SIZE DISTRIBUTION OF SEA SCALLOPS
CAPTURED BY VARIOUS MESH SIZES
AGGREGATE OF TOWS 6 THROUGH 12
PERCENTAGE OF SCALLOPS
40
30
20
10
0
10-15
15-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
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150-155
155-160
SHELL HEIGHT (MM)
MEAN CATCH
PER HOUR
BASKETS
12
10
8
6
4
2
0
5 / 4.5
4 / 4.5
MESH SIZE
5" BODY, 4.5" CODEND
4" BODY, 4.5" CODEND

body-4.5" codend harvested more scallops between 80 and 85 mm (Figure 4). At the 85-90 mm range, all gear except the 2" ring harvested nearly equal proportions of sea scallops. Beyond 90 mm, the dredge with the 3" rings harvested proportionately more large scallops. The relative efficiency of the 4" body-4.5" codend, however, may result in higher total catches of scallops larger than 90 mm.

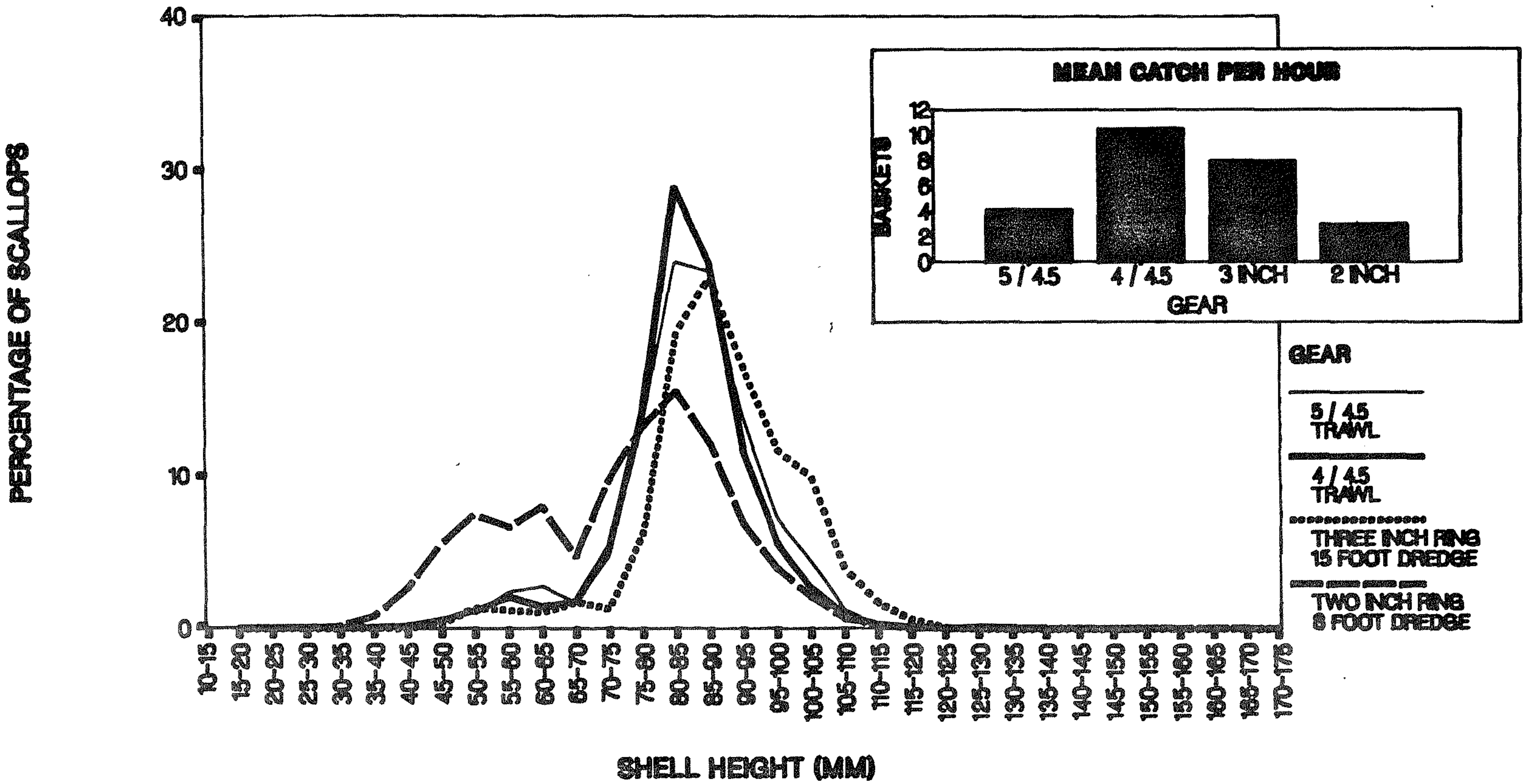
Scallops of 70 mm in size are considered to be recruited into the commercial dredge fishery which shucks scallops. Scallops smaller than 70 mm (approximately 2.75 inches) are typically not shucked. In comparison, 90 mm scallops represent the recruitment size in the shell-stock fishery; the regulation restrictions shell stock to a minimum shell size of 3.5 inches (88.9 mm). Scallops less than 70 mm accounted for approximately 7.4, 8.6, and 5.5% of the total catch by the 4" body-4.5" codend, 5" body-4.5" codend, and the dredge with the 3" rings (Figure 5). In comparison, scallops less than or equal to 90 mm accounted for 78.8, 72.8, and 55.2% of the respective gear harvests. Alternatively, nearly 45% of the scallops caught by the dredge using a 3" ring were greater than 90 mm; 21 to 27% of the scallops caught, respectively, by the 4" body-4.5" codend and 5" body-4.5" codend were greater than 90 mm.

Information on the cumulative size distribution and mean catch per hour fishing indicates that although the 4" body-4.5" codend had a higher total mean catch per hour, it had a lower catch per hour of scallops > 90 mm than did the

FIGURE 4

SIZE DISTRIBUTION OF SEA SCALLOPS CAPTURED BY VARIOUS GEAR

TOWS 6 THROUGH 12 AND 61 THROUGH 65

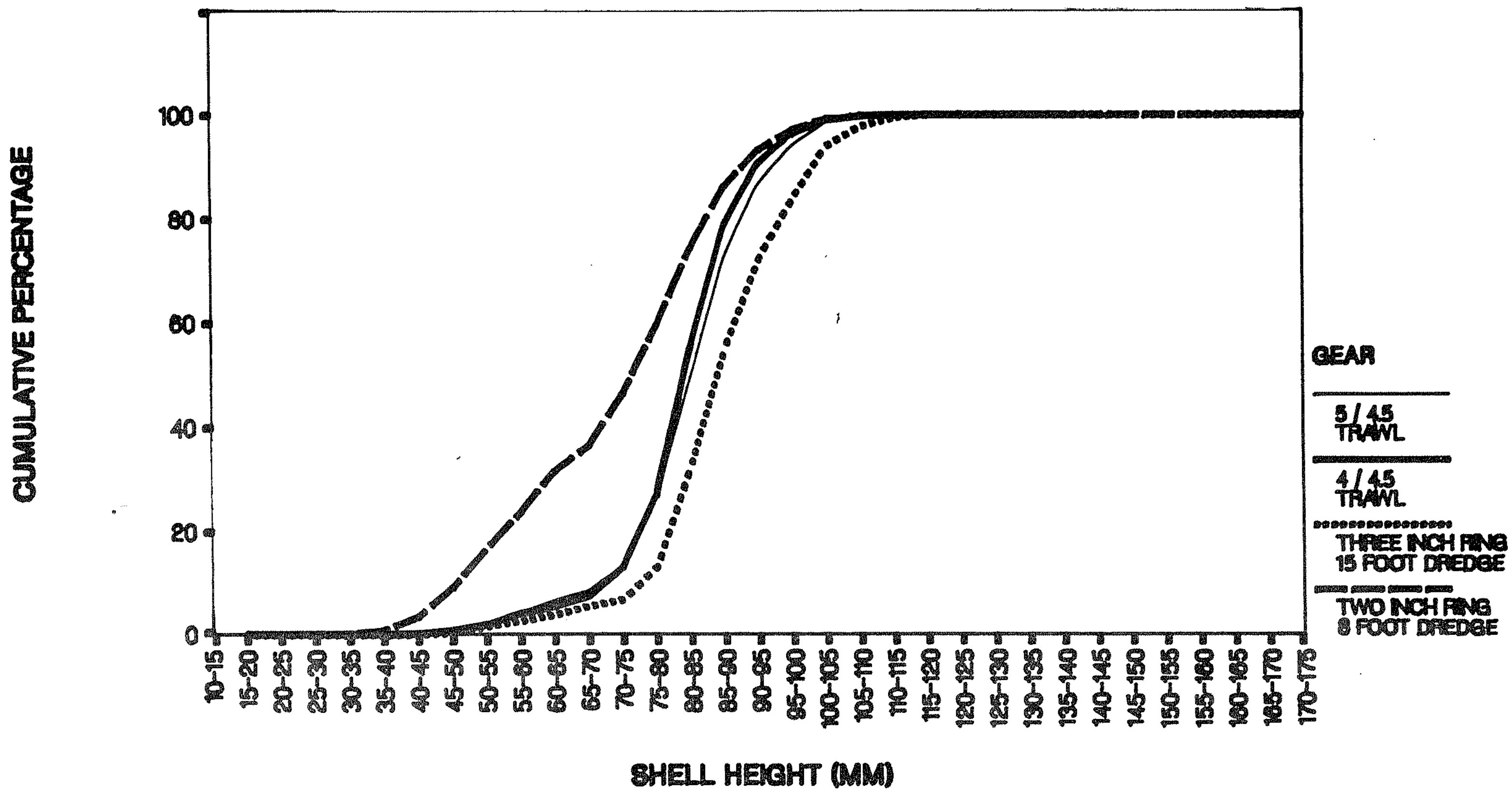


6 THROUGH 12 = TRAWL NET
61 THROUGH 65 = DREDGE

FIGURE 5

SIZE DISTRIBUTION OF SEA SCALLOPS CAPTURED BY VARIOUS GEAR

TOWS 6 THROUGH 12 AND 61 THROUGH 65



6 THROUGH 12 = TRAWL NET
61 THROUGH 65 = DREDGE

dredge using the 3" rings (Table 6). Equivalent catches per hour between the 4" body-4.5" codend and the 3" ring appear to occur for a cull size range of 80-85 mm. It is important to realize, however, these comparisons may be biased because size distribution does not equate to volume (i.e., number of baskets).

Tows 13-24 (4" body-4.5" codend vs. 5" body-5" codend)

Tows 13-24 were made to obtain information about changes in catch and size distribution with a larger body mesh and codend. Specifically, these twos were made to obtain information for the purpose of testing the standard shell-stocking net with a 4" body and 4.5" codend against a 5" body and 5" codend. Twelve tows were completed; length and frequency data were obtained for 7 tows (13,15,16,17,18,19, and 24). Total catch ranged from 8.3 to 61 baskets per tow (Appendix I). Length frequency data are summarized in Table 7 and depicted in Figures 6-7. Corresponding matched tows by the dredge vessel were 84-88 (Table 7 and Figure 7). Percent length-frequency data per tow are depicted in Appendix II.

In comparison to tows (6-12), relative size selectivity was more pronounced for the 4" body-4.5" codend evaluated against the 5" body-5.0" codend. The smaller mesh took considerably more scallops between 20 and 80 mm. Moreover, the size distribution from tows 13-24 for the 4" body-4.5" codend was comparable to the distribution for tows 6-12.

TABLE 6

Comparison of mean catch per hour by selected cull sizes (tows 6-12 and 61-65)

Gear	Mean catch per hour	Estimated mean baskets per hour for cull sizes			
		Selected cull sizes			
		70mm	80mm	85mm	90mm
	Baskets per hour				
4" body-4.5" codend	10.49	9.71	7.65	4.69	2.22
5" body-4.5" codend	4.19	3.83	3.09	2.12	1.14
3" ring	8.00	7.56	6.94	5.40	3.58

TABLE 7

Length-frequency distribution of sea scallops captured by tow two different mesh combinations (tows 13-24) and ring diameters (tows 84-88)

Shell Height	Mesh Sizes				Ring Sizes			
	4/4.5 inch		5/5 inch		3 inch		2 inch	
	Number	%	Number	%	Number	%	Number	%
20-25	1	.02	0		0		1	.05
25-30	3	.05	0		1	.06	2	.10
30-35	3	.05	0		0		13	.66
35-40	1	.02	0		1	.06	37	1.89
40-45	5	.09	0		2	.11	103	5.26
45-50	8	.14	2	.04	11	.62	173	8.84
50-55	45	.77	8	.15	17	.95	236	12.05
55-60	96	1.63	21	.40	13	.73	217	11.08
60-65	151	2.57	56	1.07	29	1.62	177	9.04
65-70	102	1.74	56	1.07	21	1.18	84	4.29
70-75	307	5.23	194	3.70	42	2.35	117	5.98
75-80	850	14.47	690	13.15	112	6.27	164	8.38
80-85	1779	30.28	1794	34.18	301	16.86	188	9.60
85-90	1492	24.40	1456	27.74	391	21.90	185	9.45
90-95	566	9.63	508	9.68	355	19.89	136	6.95
95-100	211	3.59	222	4.23	227	12.72	55	2.81
100-105	133	2.26	152	2.90	129	7.23	29	1.48
105-110	75	1.28	61	1.16	81	4.54	26	1.33
110-115	26	.44	8	.15	37	2.07	10	.51
115-120	12	.20	10	.19	12	.67	5	.26
120-125	4	.07	2	.04	2	.11	0	
125-130	1	.02	3	.06	1	.06	0	
130-135	0		2	.04	0		0	
135-140	2	.03	1	.02	0		0	
140-145	2	.03	0		0		0	
145-150	0		1	.02	0		0	
150-155	0		1	.02	0		0	
155-160	0		0		0		0	
Total	5875		5248		1785		1958	

FIGURE 6

SIZE DISTRIBUTION OF SEA SCALLOPS CAPTURED BY VARIOUS MESH SIZES

AGGREGATE OF TOWS 13, 15, 16, 17, 18, 19, AND 24

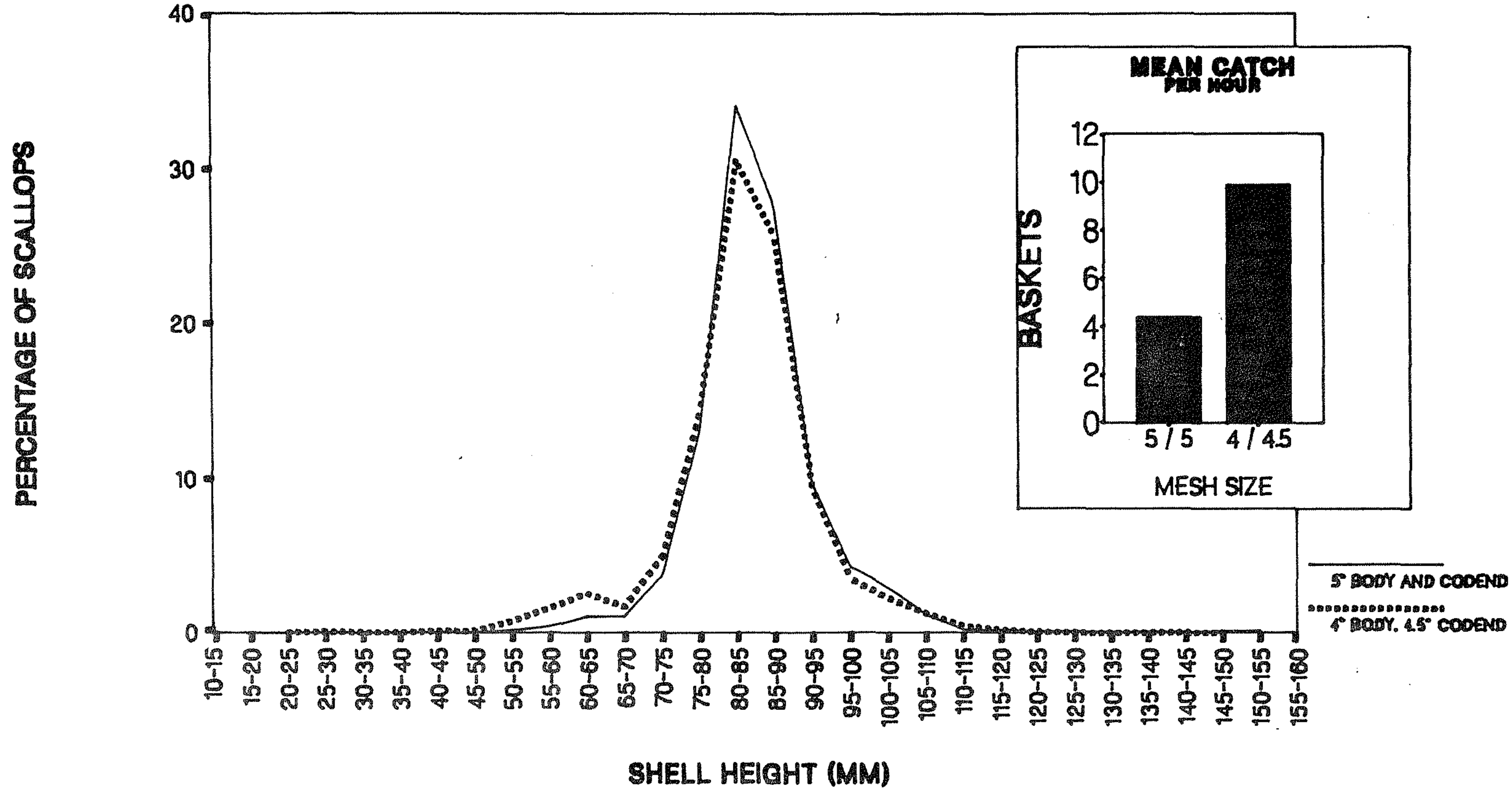
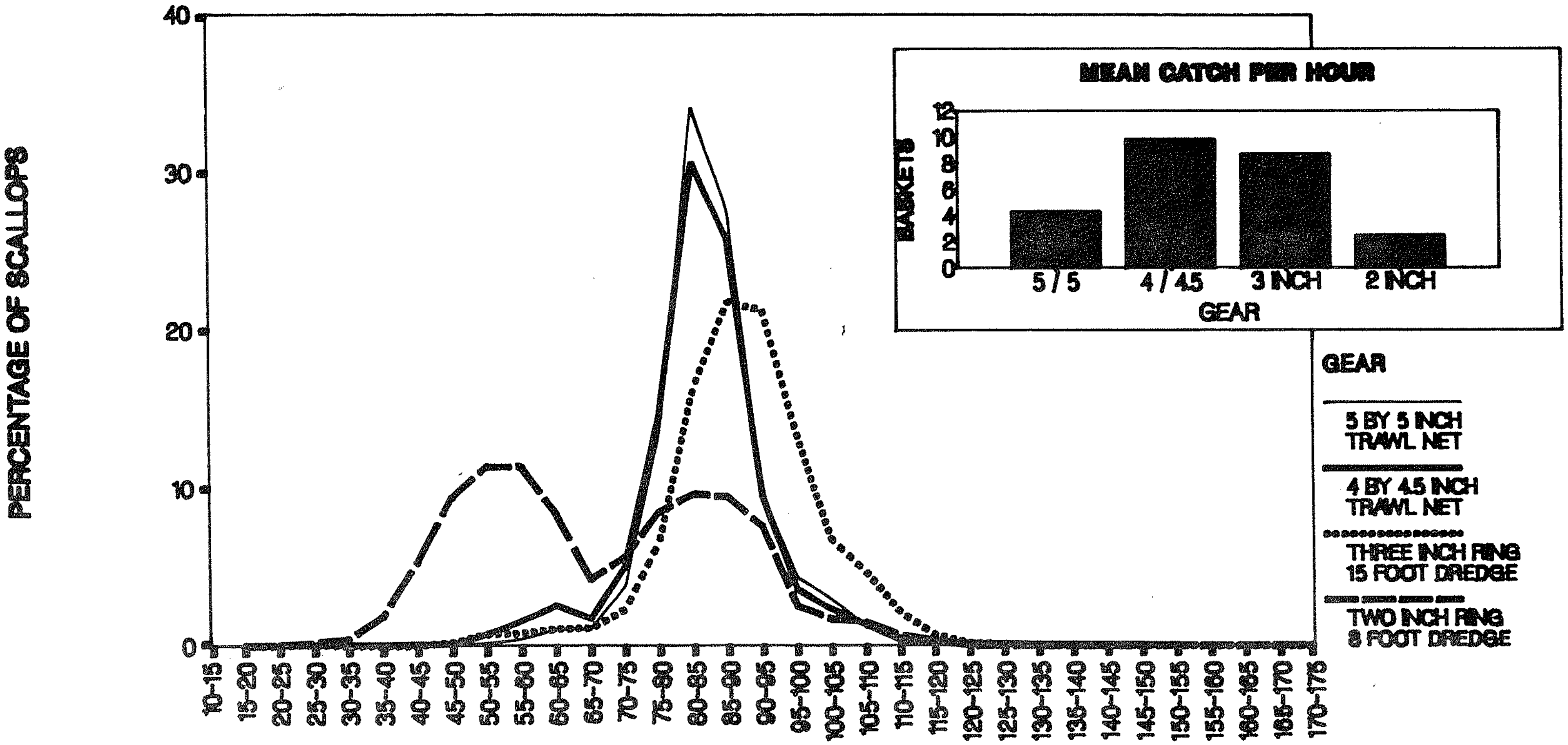


FIGURE 7

SIZE DISTRIBUTION OF SEA SCALLOPS CAPTURED BY VARIOUS GEAR

TOWS 13 THROUGH 24 AND 84 THROUGH 88



13 THROUGH 24 = TRAWL NET
84 THROUGH 88 = DREDGE

Relative size selectivity between the two nets appeared to be complete at 80 mm. Beyond 80 mm, the 5" body-5" codend caught proportionately more scallops than did the 4" body-4.5" codend. Relative size selection between the 3" and 2" rings also appeared to be complete by 80 mm. The 3" ring caught proportionately more scallops larger than 80 mm than did the 2" ring; the 3" ring also caught proportionately more scallops larger than 90 mm than did all the other gear combinations.

A comparison of the average number of baskets per hour indicates that the 4" body-4.5" codend was the most technically efficient gear in terms of baskets per hour (Table 8). However, the dredge using 3" rings was more efficient for cull sizes greater than 80 mm. The 5" body-5" codend was half as efficient as the 4" body-4.5" codend for scallops greater than 90 mm. Figure 8 indicates that the two meshes harvested nearly equal proportions of scallops smaller than 85 mm and scallops greater than 85 mm; however, the smaller mesh harvested more than double the number of scallops smaller or larger than 85 mm.

Tows 25-31 (4" body-4.5" codend vs. 3" body-3" codend)

Tow 25-31 were made to obtain information on catch and size selectivity for a calico trawl (3" body-3" codend) relative to the typical trawl (4" body-4.5" codend) used by shell-stockers or net vessels. Seven tows were made, but excessive clogging of the calico trawl with mud, sand, and

TABLE 8

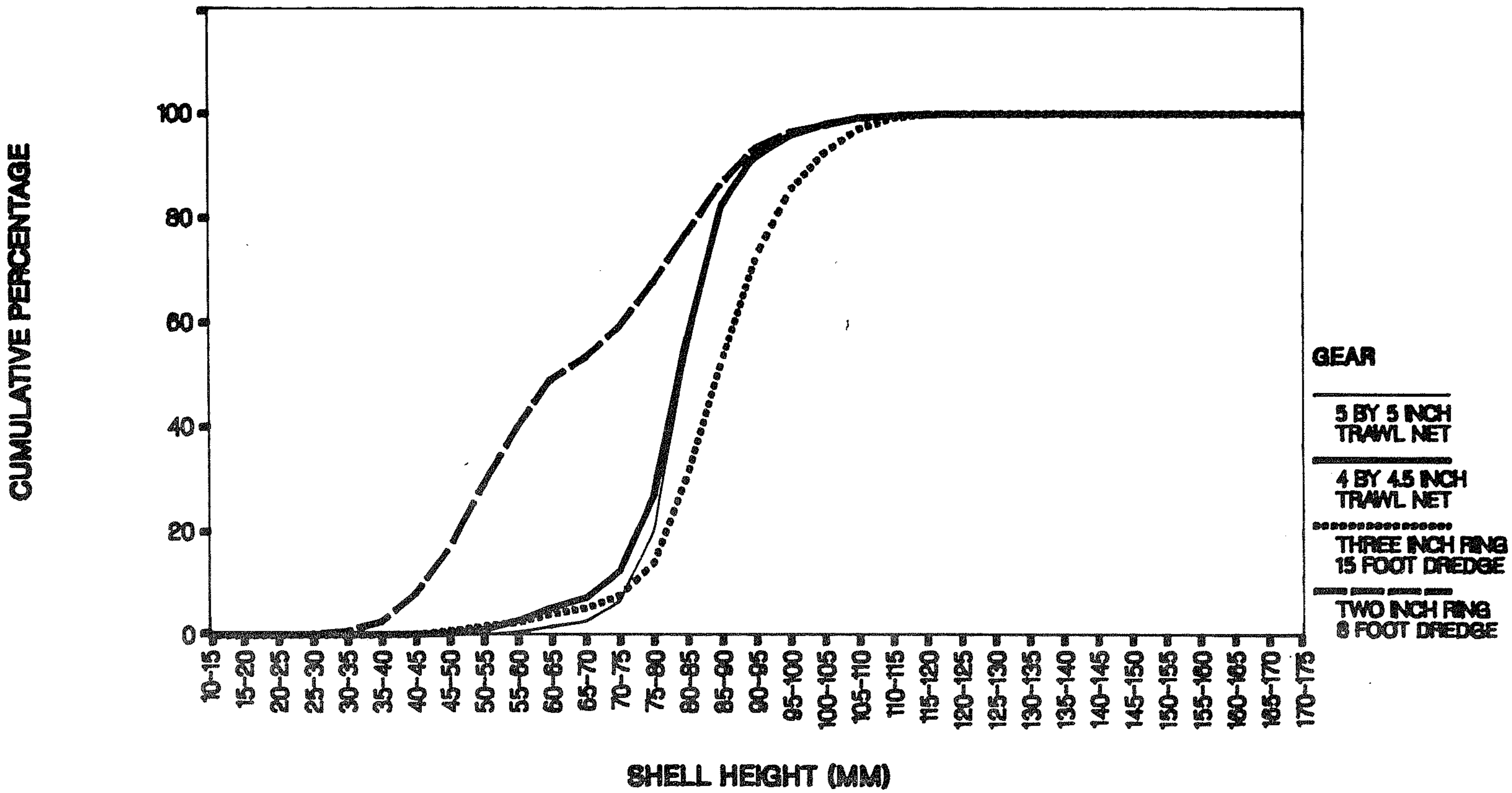
Catch and distribution at various cull sizes by selected gear (tows 13-24 and 84-88)

Gear	Mean catch per hour	Average number of scallops per basket	Cull sizes			
			70	80	85	90
4" body-4.5" codend	10.16	420				
Size distribution-%			92.9	73.2	43.0	17.6
Number of scallops per basket			390	307	181	74
Number of scallops per hour			3962	3119	1839	752
5" body-5" codend	5.24	375				
Size distribution-%			97.3	80.4	46.2	18.5
Number of scallops per basket			365	302	173	69
Number of scallops per hour			1913	1582	907	362
3" ring	9.63	357				
Size distribution-%			94.7	86.1	69.2	47.3
Number of scallops per basket			338	307	247	169
Number of scallops per hour			3255	2956	2379	1627
2" ring	2.55	435				
Size distribution-%			46.7	32.4	22.8	13.3
Number of scallops per basket			103	141	99	58
Number of scallops per hour			518	360	252	148

FIGURE 8

SIZE DISTRIBUTION OF SEA SCALLOPS CAPTURED BY VARIOUS GEAR

TOWS 13 THROUGH 24 AND 84 THROUGH 88



13 THROUGH 24 = TRAWL NET
84 THROUGH 88 = DREDGE

other debris permitted only three successful tows; matching dredge tows were 106-110. Shorter tow times failed to alleviate the clogging problem. Catch data are presented in Appendix I. Length frequency data are presented in Table 9 and depicted in Figure 9.

Size selectivity for the 4" body-4.5" codend and the calico trawl appeared to be complete by the 80-85 mm size range. As would be expected, the smaller mesh calico trawl harvested proportionately more small scallops (Figure 10). Scallops less than 85 mm accounted for 75.8% of the calico catch and 58.6% of the 4" body-4.5" codend catch. In terms of relative harvesting efficiency, the 4" body-4.5" codend was approximately 8.2 times as efficient as the calico trawl (10.95 vs. 1.33 baskets per hour of fishing).

In comparison, size selectivity for the 3" ring appeared to be complete for scallops between 80 and 90 mm. Scallops smaller than 85 mm accounted for only 29.5% of the 3" ring catch (Figure 10). The same size scallops (< 85 mm) accounted for 47.7% of the 2" ring catch. Interestingly, the calico trawl harvested a larger proportion of small scallops than did the 2" ring dredge with a liner.

A comparison of the relative technical efficiency indicates that the 3" ring used by the dredge vessel was the most technically efficient in terms of baskets per hour (13.23 baskets per hour). The 3" ring was also the most technically efficient gear for various cull sizes (Table 10). Scallops larger than 90 mm accounted for 13 and 41.2% of the

TABLE 9

Length-frequency distribution of sea scallops captured by tow two different mesh combinations (tows 25-31) and ring diameters (tows 106-110)

Shell Height	Mesh Sizes				Ring Sizes			
	4/4.5 inch		Calico		3 inch		2 inch	
	Number	%	Number	%	Number	%	Number	%
15-20	0		2	.13	0		0	
20-25	0		34	2.20	0		2	.11
25-30	0		84	5.46	1	.05	1	.05
30-35	0		28	1.82	0		3	.16
35-40	0		11	.71	1	.05	1	.05
40-45	0		15	.97	0		1	.05
45-50	0		23	1.49	0		5	.26
50-55	0		58	3.77	2	.11	19	.98
55-60	7	.60	103	6.69	2	.11	29	1.50
60-65	14	1.20	79	5.13	6	.33	62	3.21
65-70	13	1.12	23	1.49	2	.11	31	1.60
70-75	41	3.52	73	4.74	14	.77	51	2.64
75-80	172	14.78	202	13.13	126	6.92	186	9.62
80-85	435	37.37	431	28.00	383	21.04	531	27.47
85-90	331	28.44	265	17.22	533	29.29	575	29.75
90-95	86	7.39	63	4.09	292	16.04	254	13.14
95-100	34	2.92	14	.91	92	5.05	54	2.79
100-105	15	1.29	15	.97	93	5.11	45	2.33
105-110	8	.69	10	.65	102	5.60	42	2.17
110-115	2	.17	0		52	2.86	18	.93
115-120	3	.26	3	.19	73	4.01	8	.41
120-125	2	.17	0		37	2.03	8	.41
125-130	0		2	.13	4	.22	2	.11
130-135	0		0		2	.11	4	.21
135-140	1		0		2	.11	1	.05
140-145	0		0		0		0	
145-150	0		1	.06	0		0	
150-155	0		0	.02	0		0	
155-160	0		0		1	.05	0	
Total	1164		1539		1820		1933	

FIGURE 9

SIZE DISTRIBUTION OF SEA SCALLOPS CAPTURED BY VARIOUS GEAR

TOWS 29 THROUGH 31 AND 106 THROUGH 110

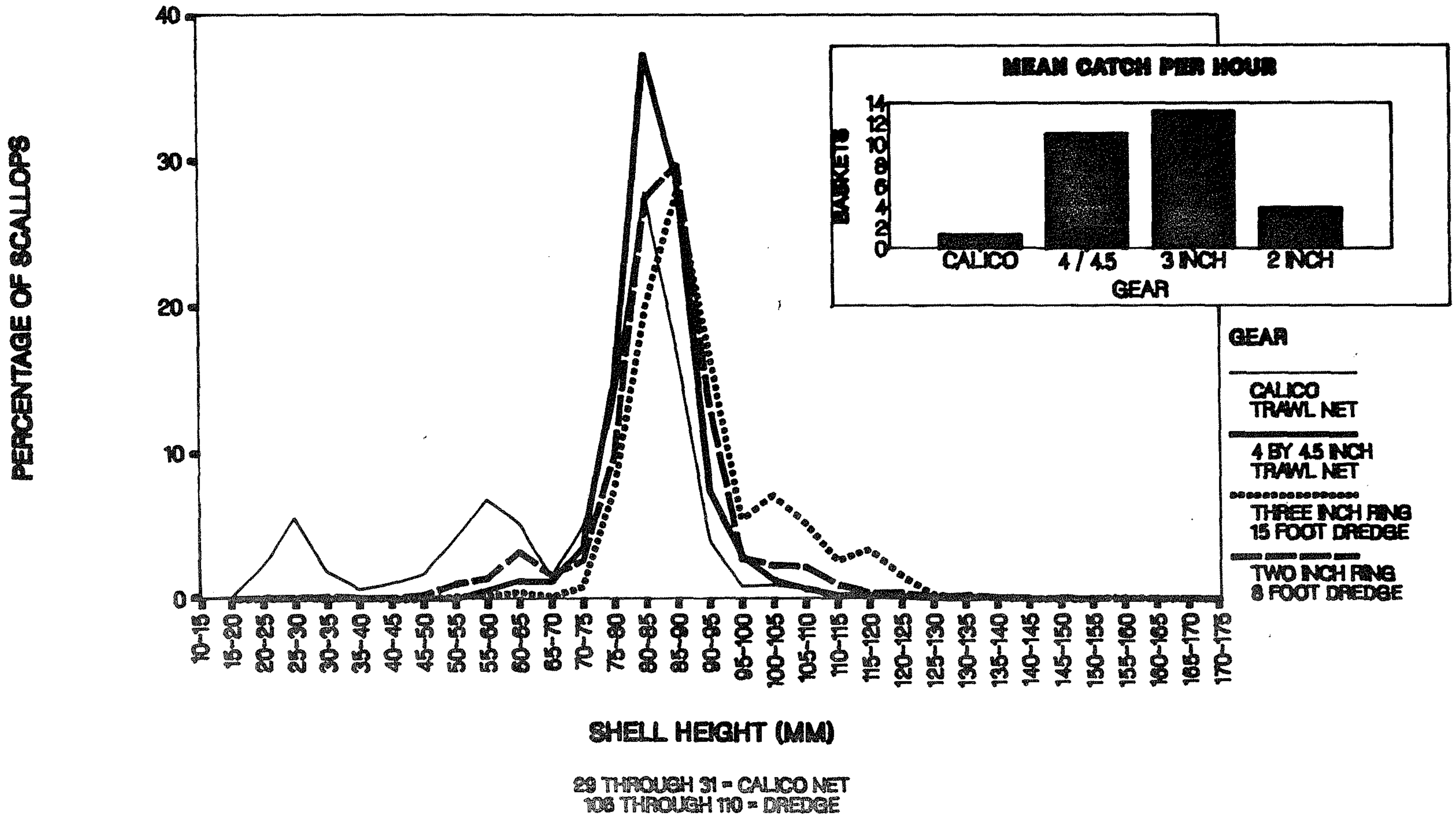


FIGURE 10

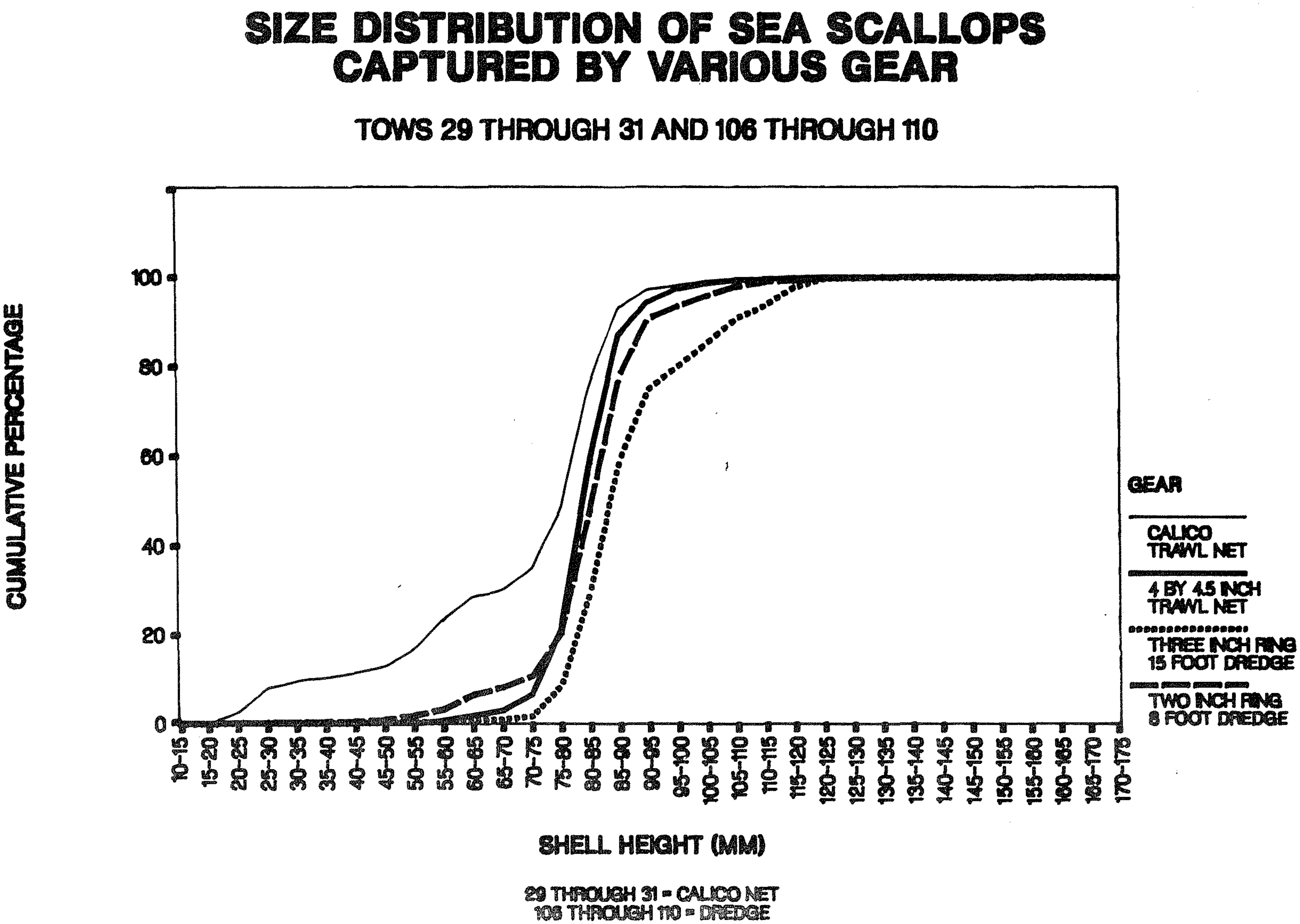

SIZE DISTRIBUTION OF SEA SCALLOPS
CAPTURED BY VARIOUS GEAR
TOWS 29 THROUGH 31 AND 106 THROUGH 110
CUMULATIVE PERCENTAGE
100
80
60
40
20
0
10-15
15-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-95
95-100
100-105
105-110
110-115
115-120
120-125
125-130
130-135
135-140
140-145
145-150
150-155
155-160
160-165
165-170
170-175
SHELL HEIGHT (MM)
GEAR
CALICO TRAWL NET
4 BY 4.5 INCH TRAWL NET
THREE INCH RING 15 FOOT DREDGE
TWO INCH RING 8 FOOT DREDGE
29 THROUGH 31 = CALICO NET
106 THROUGH 110 = DREDGE

TABLE 10

Catch and distribution at various cull sizes by selected gear (tows 29-31 and 106-110)

Gear	Mean catch per hour	Average number of scallops per basket	Cull sizes			
			70	80	85	90
4" body- 4.5" codend	10.95	388				
Size distribution-%			97.1	79.4	41.4	13.0
Number of scallops per basket			377	308	167	50
Number of scallops per hour			4128	3373	1763	548
3" calico	1.33	661				
Size distribution-%			70.1	52.2	24.2	7.0
Number of scallops per basket			463	345	160	46
Number of scallops per hour			616	459	213	61
3" ring	13.23	364				
Size distribution-%			99.2	91.5	70.5	41.2
Number of scallops per basket			361	333	257	150
Number of scallops per hour			4776	4406	3400	1985
2" ring (with liner)	3.95	407				
Size distribution-%			92.0	79.8	52.3	22.6
Number of scallops per basket			374	325	213	92
Number of scallops per hour			1477	1284	841	363

total catch by the 4" body-4.5" codend and 3" ring dredge; 93% of the scallops by the calico trawl were less than 90 mm.

Tows 32-33 (4" top panel, 4" bottom panel, 4.5" codend vs. 5" top panel, 4" bottom panel, 4.5" codend).

Tows 32-33 were made to determine whether or not size selection and technical efficiency would vary depending on the size of the top panel. For these two tows, only the size of the top panel was different. No matching tows by the dredge vessel were made. The number of baskets per tow displayed little variation between sides or over tows (23-25 baskets per tow) (Appendix I). Baskets per hour were nearly equal. The length frequency data are summarized in Table 11 and depicted in Figure 11.

As indicated in Table 11 and Figure 11, size selectivity was approximately the same for both gear configurations. Scallops between 75 and 90 mm accounted for nearly equal proportions of the total catches by the two gear configurations (75.2 vs. 75.6% for the 4" bottom and 5" bottom, respectively). A comparison of the cumulative percentage of the total catch by the two configurations also indicates nearly identical proportions (Figure 12). Scallops larger than 90 mm accounted for 12.8 and 11.8% of the total catch by the 4" top panel, 4" bottom panel, 4.5" codend and 5" top panel, 4" bottom panel, 4.5" codend gear configurations, respectively.

TABLE 11

Length-frequency distribution of sea scallops captured by tow two different mesh combinations (tows 32-33)

Shell Height	Mesh Sizes: 4/4/4.5 inch Number	%	5/4/4.5 inch Number	%
20-25	0		1	.06
25-30	2	.14	2	.12
30-35	0		0	
35-40	0		0	
40-45	0		2	.12
45-50	1	.07	6	.36
50-55	17	1.15	21	1.26
55-60	30	2.03	40	2.40
60-65	37	2.51	51	3.06
65-70	22	1.49	27	1.62
70-75	68	4.61	60	3.60
75-80	249	16.88	294	17.65
80-85	472	32.00	556	33.37
85-90	388	26.31	409	24.55
90-95	90	6.10	114	6.84
95-100	36	2.44	34	2.04
100-105	30	2.03	27	1.62
105-110	13	.88	12	.72
110-115	6	.41	5	.30
115-120	5	.34	1	.06
120-125	1	.07	1	.06
125-130	4	.27	0	
130-135	1	.07	1	.06
135-140	2	.14	1	.06
140-145	1	.07	0	
145-150	0		0	
150-155	0		1	.06
155-160	0		0	
Total	1475		1666	

FIGURE 11

SIZE DISTRIBUTION OF SEA SCALLOPS CAPTURED BY VARIOUS MESH SIZES

AGGREGATE OF TOWS 32 AND 33

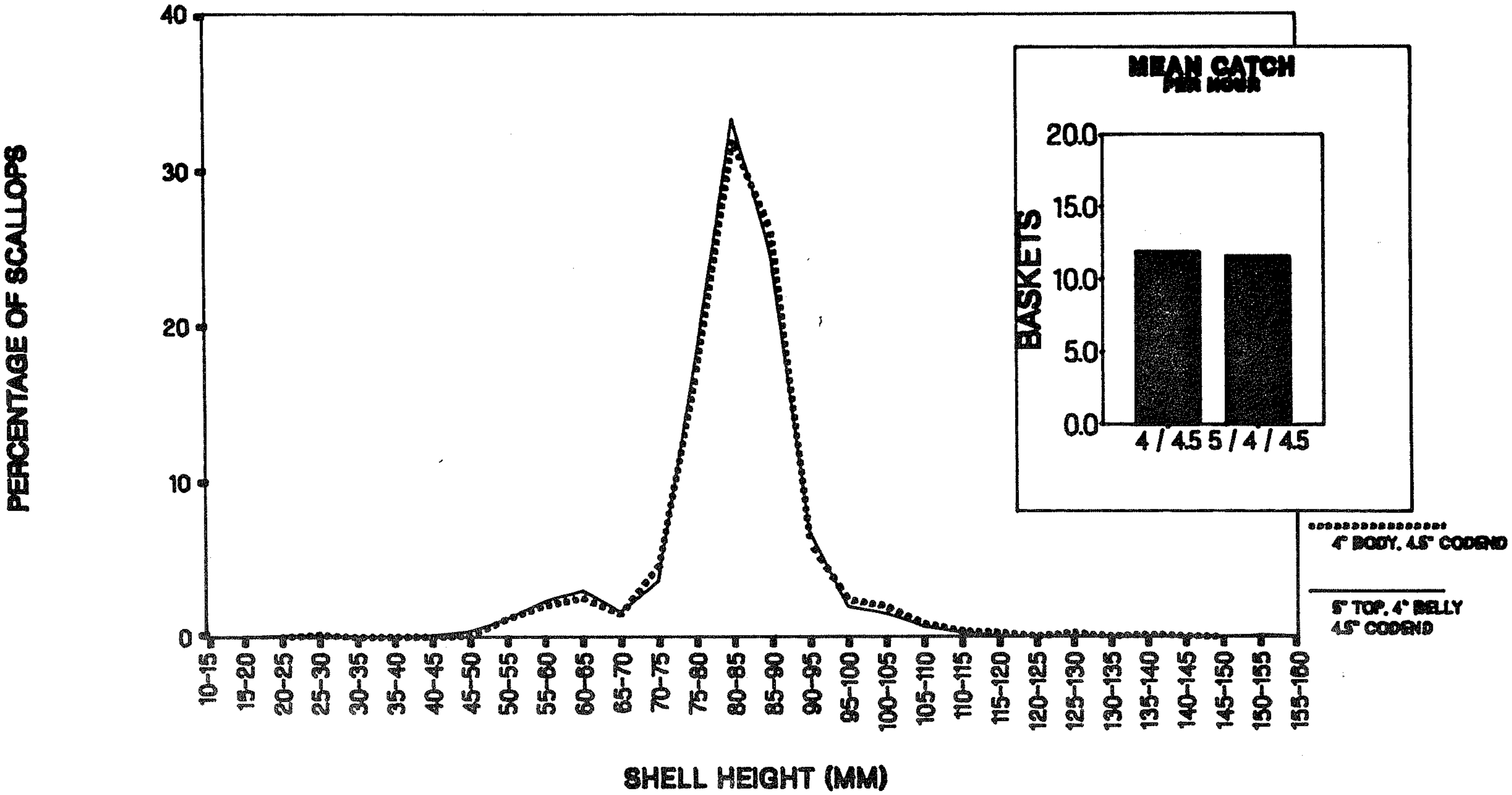
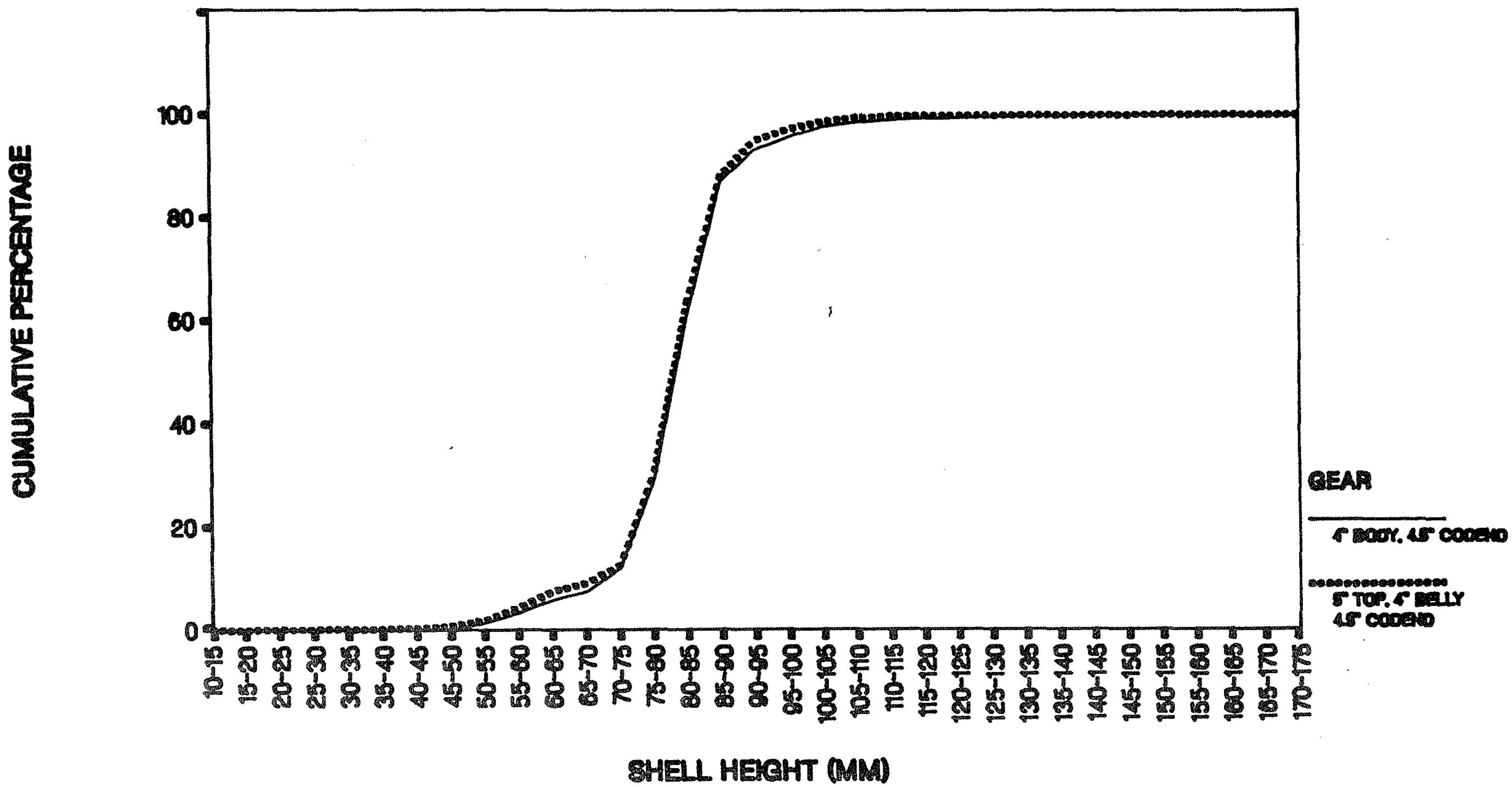


FIGURE 12

SIZE DISTRIBUTION OF SEA SCALLOPS CAPTURED BY VARIOUS GEAR

TOWS 32 AND 33



CONCLUSIONS

A major objective of the study was to examine size selectivity. The purpose of examining size selectivity was to determine the feasibility of imposing mesh regulations on trawlers to reduce mortality of small scallops. If larger meshes or other changes in the gear reduce the harvest of small scallops without affecting the harvest of large scallops, gear restrictions would likely be feasible and acceptable to industry.

Although size selection curves could be estimated with the available data, they were not used to examine size selection. This was because estimates were for relative size selectivity between two similar mesh sizes and statistically biased. Thus, the accuracy and usefulness of the estimates to assess size selectivity are questionable. Instead, size selectivity was inferred via other data analyses.

Analyses of the data indicated that larger meshes resulted in reduced catches of smaller scallops. Larger meshes generally caused reduced catches of all scallops. The major effect of increasing mesh size appeared to be on harvesting efficiency rather than on size selection (Table 12). For example, scallops smaller than 90 mm accounted for approximately 81.5% of the total catch by both the 4" body-4.5" codend and 5" body-4.5" codend for tows 13-24. However, the harvest rate of the 4" body-4.5" codend was approximately double the rate of the 5" body-5" codend. The

TABLE 12

Baskets per hour and size distribution by selected tows, gear, and shell size intervals

Tows/ Gear configuration	Baskets per hour	Selected shell size ranges			
		< 75	75-95	> 90	> 95
		----------Percent of sample----------			
6-12					
4/4.5	10.49	13.03	77.10	21.81	9.87
5/4.5	4.19	13.40	73.36	27.23	13.24
3" ring	8.00	6.84	65.31	44.80	27.85
2" ring	3.00	46.56	46.74	13.60	6.70
13-24					
4/4.5	10.16	12.31	78.78	18.54	8.91
5/5.0	5.24	6.43	84.75	18.50	8.82
3" ring	9.63	7.68	64.92	47.29	27.40
2" ring	2.55	59.24	34.38	13.33	6.38
29-31					
4/4.5	10.95	6.44	87.98	12.97	5.58
Calico	1.33	34.60	62.45	7.04	2.95
3" ring	13.23	1.53	73.29	41.22	25.18
2" ring	3.95	10.60	79.98	22.56	9.42

smaller mesh did harvest proportionately more small (< 75 mm) scallops.

It is important to realize that all results presented in this study reflect specific resource conditions. In terms of numbers of scallops available for harvest, the resource appeared to be dominated by scallops between 75 and 95 mm (Table 12). Scallops larger than 95 mm appeared to account for a relatively small proportion of the resource available for harvest.

An analysis of equity between trawl vessels and dredge vessels was not an objective of this study, but available data permit a preliminary examination of the equity of the regulations. In terms of numbers of scallops and baskets per hour, the standard 4" body-4.5" codend, trawl generally had a relative advantage. However, the 3" ring generally harvested more scallops larger than 90 mm. These results suggest that minimum shell size restrictions on shell stock more adversely affect shell-stockers than would an equivalent minimum shell size on scallops which are shucked at sea. These conclusions, however, only apply to resource conditions prevailing during this particular experiment.

In conclusion, the major effect on catches of small scallops of increased mesh sizes appears to be a reduction in harvesting efficiency. Escapement of smaller scallops because of larger meshes appears to be minimal. However, larger meshes compared to the 3" calico trawl appear to suggest considerable escapement. In terms of implementing mesh restrictions, larger meshes do not appear to be feasible if industry support is a concern to management authorities. Increasing the mesh to a 5" body with a 4.5" codend or a 5" body with a 5" codend would reduce catch, given prevailing conditions during this experiment, by 40 and 52%, respectively. Alternatively, restricting the size of top body panel to 5" would not be feasible since there was no difference in catch between a 4" body with 4.5" codend and 4" bottom panel with a 5" top body panel and 4.5" codend. In essence, restrictions on the top panel would not appear to adequately control mortality. However, if management is only concerned with reducing the catch of smaller scallops, increasing the mesh size offers an alternative to accomplish this objective.

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APPENDIX I

TOW #	DATE	TIME	TOW LENGTH (MIN.)	STARTING LORAN(X)	ENDING LORAN(X)	STARTING LORAN(Y)	ENDING LORAN(Y)	SHIP SIDE	MESH SIZE (")	BASKETS OF SCALLOPS	BASKETS OF TRASH
1	4/21	1036	064	26745.2	26746.5	42411.3	42418.0	P	5/4.5	00.8	
1	4/21	1036	064	26745.2	26746.5	42411.3	42418.0	S	5/4.5	00.8	03.5
2	4/21	1157	065	26745.1	26764.1	42419.5	42412.9	P	5/4.5	00.8	03.2
2	4/21	1157	065	26745.1	26764.1	42419.5	42412.9	S	5/4.5	00.8	04.8
3	4/21	1334	063	26775.1	26778.5	42408.5	42381.0	P	5/4.5	04.0	00.5
3	4/21	1334	063	26775.1	26778.5	42408.5	42381.0	S	5/4.5	03.5	02.3
4	4/21	1503	079	26779.9	26783.3	42379.5	42389.8	P	5/4.5	05.8	00.8
4	4/21	1503	079	26779.9	26783.3	42379.5	42389.8	S	5/4.5	05.5	02.5
5	4/21	1638	124	26793.2	26776.5	42382.1	42412.8	P	5/4.5	04.4	01.1
5	4/21	1638	124	26793.2	26776.5	42382.1	42412.7	S	5/4.5	04.1	03.0
6	4/22	0620	068	26488.8	26520.6	42963.2	42980.4	P	4/4.5	07.0	06.7
6	4/22	0620	068	26488.8	26520.6	42963.2	42980.4	S	5/4.5	02.1	06.0
7	4/22	0807	083	26502.8	26499.4	42984.6	43021.4	P	4/4.5	16.0	05.5
7	4/22	0807	083	26502.8	26499.4	42984.6	43021.4	S	5/4.5	05.5	06.0
8	4/22	1011	076	26495.8	26476.0	43023.9	43049.5	P	4/4.5	14.0	05.5
8	4/22	1011	076	26495.8	26476.0	43023.9	43049.5	S	5/4.5	05.2	05.0
9	4/22	1155	066	26473.9	26454.6	43053.0	43071.6	P	4/4.5	10.2	07.1
9	4/22	1155	066	26473.9	26454.6	43053.0	43071.6	S	5/4.5	03.5	05.0
10	4/22	1419	086	26445.4	26449.7	43079.6	43071.4	P	4/4.5	09.8	05.6
10	4/22	1419	086	26445.4	26449.7	43079.6	43071.4	S	5/4.5	03.5	04.0
11	4/22	1600	120	26449.7	26473.2	43077.2	43048.3	P	4/4.5	15.5	09.7
11	4/22	1600	120	26449.7	26473.2	43077.2	43048.3	S	5/4.5	07.7	07.5
12	4/22	2010	182	26484.0	26498.2	43043.0	42988.2	P	4/4.5	63.0	12.5
12	4/22	2010	182	26484.0	26498.2	43043.0	42988.2	S	5/4.5	30.0	
13	4/22	2349	141	26497.7	26499.9	42985.3	42998.2	P	4/4.5	41.0	07.0
13	4/22	2349	141	26497.7	26473.2	42985.3	42998.2	S	5/5	20.0	10.0
14	4/23	0238	154	26502.3	26500.2	42988.1	43001.4	P	4/4.5	21.0	
14	4/23	0238	154	26502.3	26500.2	42988.1	43001.4	S	5/5	26.0	
15	4/23	0545	160	26500.5	26498.2	42986.6	43052.6	P	4/4.5	23.0	13.0
15	4/23	0545	160	26500.5	26498.2	42986.6	43052.6	S	5/5	11.0	08.2
16	4/23	0939	073	26467.6	26448.8	43059.9	43084.8	P	4/4.5	10.0	09.0
16	4/23	0939	073	26467.6	26448.8	43059.9	43084.8	S	5/5	03.3	04.0

TOW #	DATE	TIME	TOW LENGTH (MIN.)	STARTING LORAN(X)	ENDING LORAN(X)	STARTING LORAN(Y)	ENDING LORAN(Y)	SHIP SIDE	MESH SIZE (")	BASKETS OF SCALLOPS	BASKETS OF TRASH
17	4/23	1110	060	26444.8	26464.0	43087.2	43866.0	P	4/4.5	05.5	04.0
17	4/23	1110	060	26444.8	26464.0	43087.2	43866.0	S	5/5	02.8	04.0
18	4/23	1355	060	26491.4	26500.0	43051.0	43030.4	P	4/4.5	12.0	07.5
18	4/23	1355	060	26491.4	26500.0	43051.0	43030.4	S	5/5	05.3	03.0
19	4/23	1519	091	26499.6	26504.2	43023.2	43036.8	P	4/4.5	16.2	07.5
19	4/23	1519	091	26499.6	26504.2	43023.2	43036.8	S	5/5	07.0	05.0
20	4/23	1815	135	26504.6	26505.0	43035.3	43031.6	P	4/4.5		
20	4/23	1815	135	26504.6	26505.0	43035.3	43031.6	S	5/5		
21	4/23	2100	150	26500.0	26498.7	43027.6	43998.6	P	4/4.5		
21	4/23	2100	150	26500.0	26498.7	43027.6	43998.6	S	5/5		
22	4/24	0050	220	26499.8	26499.1	43031.5	43191.9	P	4/4.5	21.0	
22	4/24	0050	220	26499.8	26499.1	43031.5	43191.9	S	5/5	40.0	
23	4/24	0405	155	26502.8	26497.8	43000.8	43011.6	P	4/4.5		
23	4/24	0405	155	26502.8	26497.8	43000.8	43011.6	S	5/5		
24	4/24	0712	146	26504.4	26502.4	43019.1	43028.5	P	5/5	09.5	04.0
24	4/24	0712	146	26504.4	26502.4	43019.1	43028.5	S	4/4.5	21.0	08.0
25	4/24	1204	030	26500.3	26499.7	43006.7	43013.1	P	CALICO		
25	4/24	1204	030	26500.3	26499.7	43006.7	43013.1	S	4/4.5	04.5	02.0
26	4/24	1357	010	26498.3	26498.9	43019.6	43009.3	P	CALICO		
26	4/24	1357	010	26498.3	26498.9	43019.6	43009.3	S	4/4.5	02.0	01.0
29	4/24	1650	032	26494.8	26499.0	42024.9	43035.8	P	CALICO	00.3	01.5
29	4/24	1650	032	26494.8	26499.0	42024.9	43035.8	S	4/4.5	06.0	04.0
30	4/24	1744	062	26498.7	26499.5	43036.4	43019.6	P	CALICO	02.0	02.5
30	4/24	1744	062	26498.7	26499.5	43036.4	43019.6	S	4/4.5	12.0	04.0
31	4/24	1910	060	26498.1	26500.7	43012.9	43016.9	P	CALICO	01.5	06.0
31	4/24	1910	060	26498.1	26500.7	43012.9	43016.9	S	4/4.5	10.0	03.0
32	4/25	1825	122	26501.4	26499.3	42990.9	42997.7	P	5/4/4.5	25.0	05.5
32	4/25	1825	122	26501.4	26499.3	42990.9	42997.7	S	4/4.5	24.0	
33	4/25	2055	125	26497.8	26500.3	42984.0	43000.5	P	5/4/4.5	23.0	08.0
33	4/25	2055	125	26497.8	26500.3	42984.0	43000.5	S	4/4.5	25.0	

TOW #	DATE	TIME	TOW LENGTH (MIN.)	STARTING LORAN(X)	ENDING LORAN(X)	STARTING LORAN(Y)	ENDING LORAN(Y)	SHIP SIDE	MESH SIZE (")	BASKETS OF SCALLOPS	BASKETS OF TRASH
34	4/26	1120	125	26503.9	26499.6	43009.6	43015.5	P	5/4/4.5		
34	4/26	1120	125	26503.9	26499.6	43009.6	43015.5	S	4/4.5		
35	4/26	1405	132	26500.2	26498.8	42990.9	43015.5	P	5/4/4.5	87.0*	
35	4/26	1405	132	26500.2	26498.8	42990.9	43015.5	S	4/4.5		
36	4/26	1655	120	26497.2	26500.5	43002.5	43020.1	P	5/4/4.5	48.0*	
36	4/26	1655	120	26497.2	26500.5	43002.5	43020.1	S	4/4.5		
37	4/26	1930	120	26496.7	26499.2	43006.4	43016.8	P	5/4/4.5	44.0*	
37	4/26	1930	120	26496.7	26499.2	43006.4	43016.8	S	4/4.5		
38	4/26	2205	120	26501.2	26498.8	43004.7	43022.1	P	5/4/4.5		
38	4/26	2205	120	26501.2	26498.8	43004.7	43022.1	S	4/4.5		
39	4/27	0255	097	26528.9	26519.0	42863.0	42867.3	P	5/4/4.5		
39	4/27	0255	097	26528.9	26519.0	42863.0	42867.3	S	4/4.5		
40	4/27	1240	065	26776.8	26783.2	42395.1	42364.5	P	5/4/4.5		
40	4/27	1240	065	26776.8	26783.2	42395.1	42364.5	S	4/4.5		
41	4/27	1820	065	26843.2	26844.9	42029.9	41998.3	P	5/4/4.5		
41	4/27	1820	065	26843.2	26844.9	42029.9	41998.3	S	4/4.5		
42	4/28	0105	060	26911.2	26911.9	41597.8	41567.4	P	5/4/4.5	1.0*	
42	4/28	0105	060	26911.2	26911.9	41597.8	41567.4	S	4/4.5		
43	4/28	0330	067	26892.3	26890.7	41504.2	41471.3	P	5/4/4.5	3.0*	
43	4/28	0330	067	26892.3	26890.7	41504.2	41471.3	S	4/4.5		

* catch figures are combined for both port and starboard sides

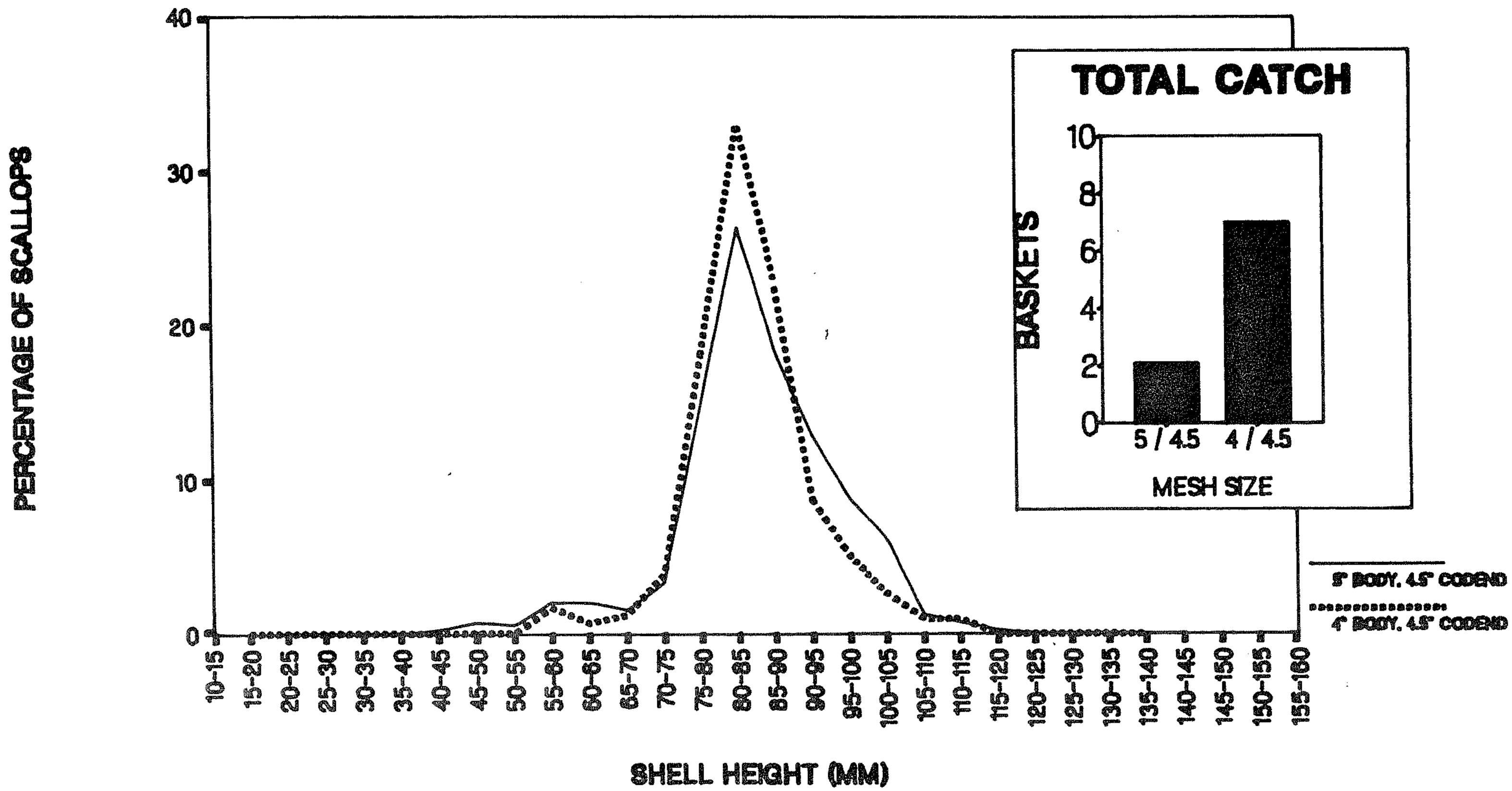
TOW #	DATE	TIME	TOW LENGTH (MIN.)	STARTING LORAN(X)	ENDING LORAN(X)	STARTING LORAN(Y)	ENDING LORAN(Y)	RING SIZE (")*	BASKETS OF SCALLOPS	BASKETS PER HOUR
61	4/22	0500	015	26455	26461	43069	43064	3-inch	2.00	8.00
61	4/22	0500	015	26455	26461	43069	43064	2-inch	1.50	6.00
62	4/22	0525	015	26463	26469	43063	43057	3-inch	1.50	6.00
62	4/22	0525	015	26463	26469	43063	43057	2-inch	0.33	1.32
63	4/22	0551	015	26472	26476	43054	43047	3-inch	2.75	11.00
63	4/22	0551	015	26472	26476	43054	43047	2-inch	0.75	3.00
64	4/22	0615	016	26474	26470	43048	43055	3-inch	2.50	9.38
64	4/22	0615	016	26474	26470	43048	43055	2-inch	0.75	2.81
65	4/22	0639	016	26467	26462	43058	43065	3-inch	1.50	5.63
65	4/22	0639	016	26467	26462	43058	43065	2-inch	0.50	1.88
84	4/23	1034	016	26454	26450	43084	43090	3-inch	3.50	13.13
84	4/23	1034	016	26454	26450	43084	43090	2-inch	0.75	2.81
85	4/23	1059	019	26450	26455	43091	43083	3-inch	3.00	9.47
85	4/23	1059	019	26450	26455	43091	43083	2-inch	1.00	3.16
86	4/23	1128	015	26453	26448	43085	43093	3-inch	1.25	14.00
86	4/23	1128	015	26453	26448	43085	43093	2-inch	1.50	2.00
87	4/23	1154	014	26448	26442	43094	43103	3-inch	1.75	5.36
87	4/23	1154	014	26448	26442	43094	43103	2-inch	0.75	2.14
88	4/23	1218	017	26444	26446	43101	43092	3-inch	3.50	6.18
88	4/23	1218	017	26444	26446	43101	43092	2-inch	1.00	2.65
106	4/24	1036	016	26498	26499	43017	43026	3-inch	3.50	13.13
106	4/24	1036	016	26498	26499	43017	43026	2-inch	1.00	3.75
107	4/24	1059	015	26499	26499	43030	43039	3-inch	3.75	15.00
107	4/24	1059	015	26499	26499	43030	43039	2-inch	1.25	5.00
108	4/24	1122	015	26499	26498	43038	43029	3-inch	3.50	14.00
108	4/24	1122	015	26499	26498	43038	43029	2-inch	1.00	4.00
109	4/24	1152	015	26498	26499	43021	43013	3-inch	3.00	12.00
109	4/24	1152	015	26498	26499	43021	43013	2-inch	1.00	4.00
110	4/24	1216	015	26498	26499	43012	43022	3-inch	3.00	12.00
110	4/24	1216	015	26498	26499	43012	43022	2-inch	0.75	3.00

* 3-inch = 15-foot dredge, 2-inch = 8-foot dredge

APPENDIX II

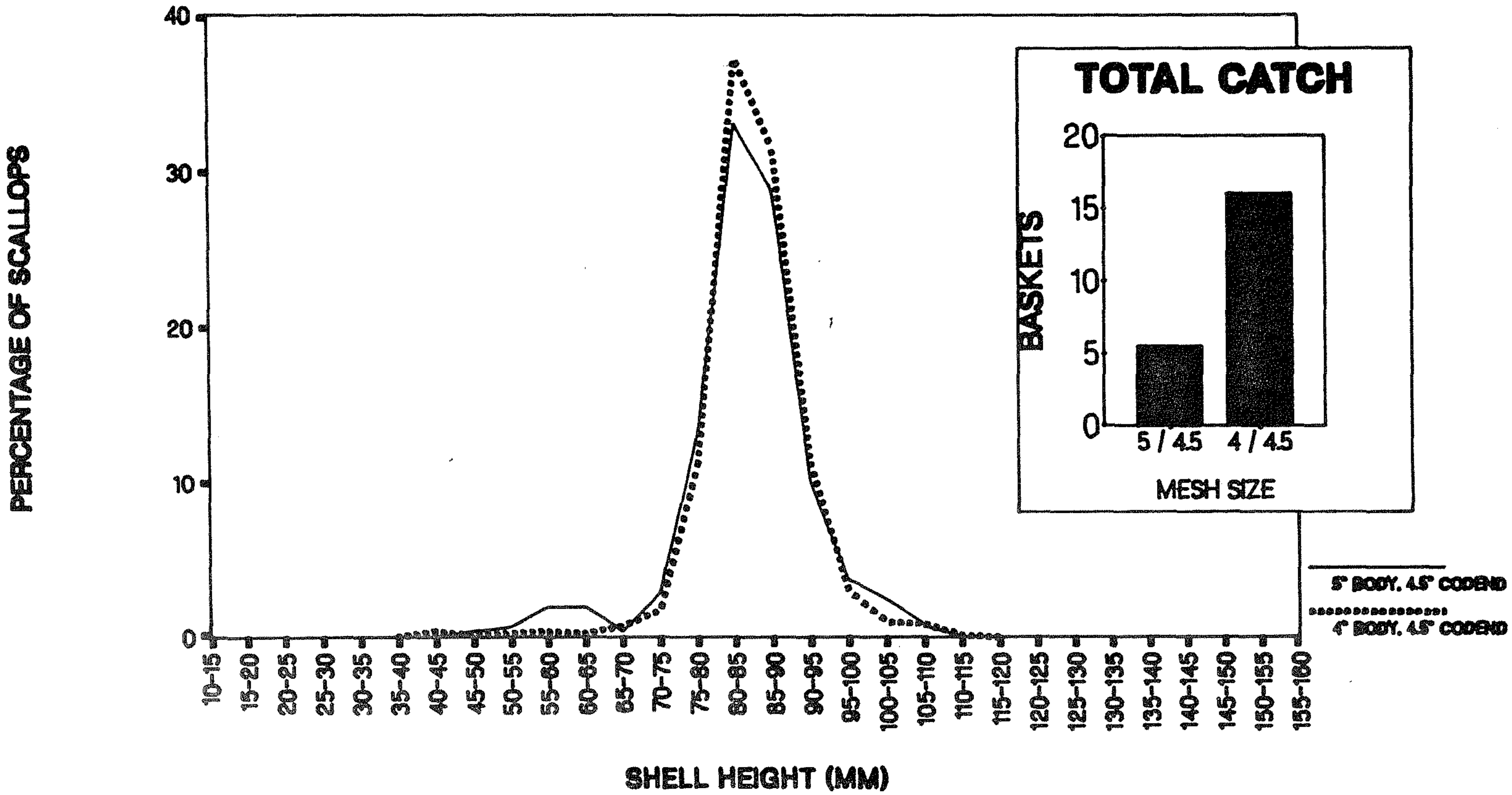
SIZE DISTRIBUTION OF SEA SCALLOPS CAPTURED BY VARIOUS MESH SIZES

TOW #6



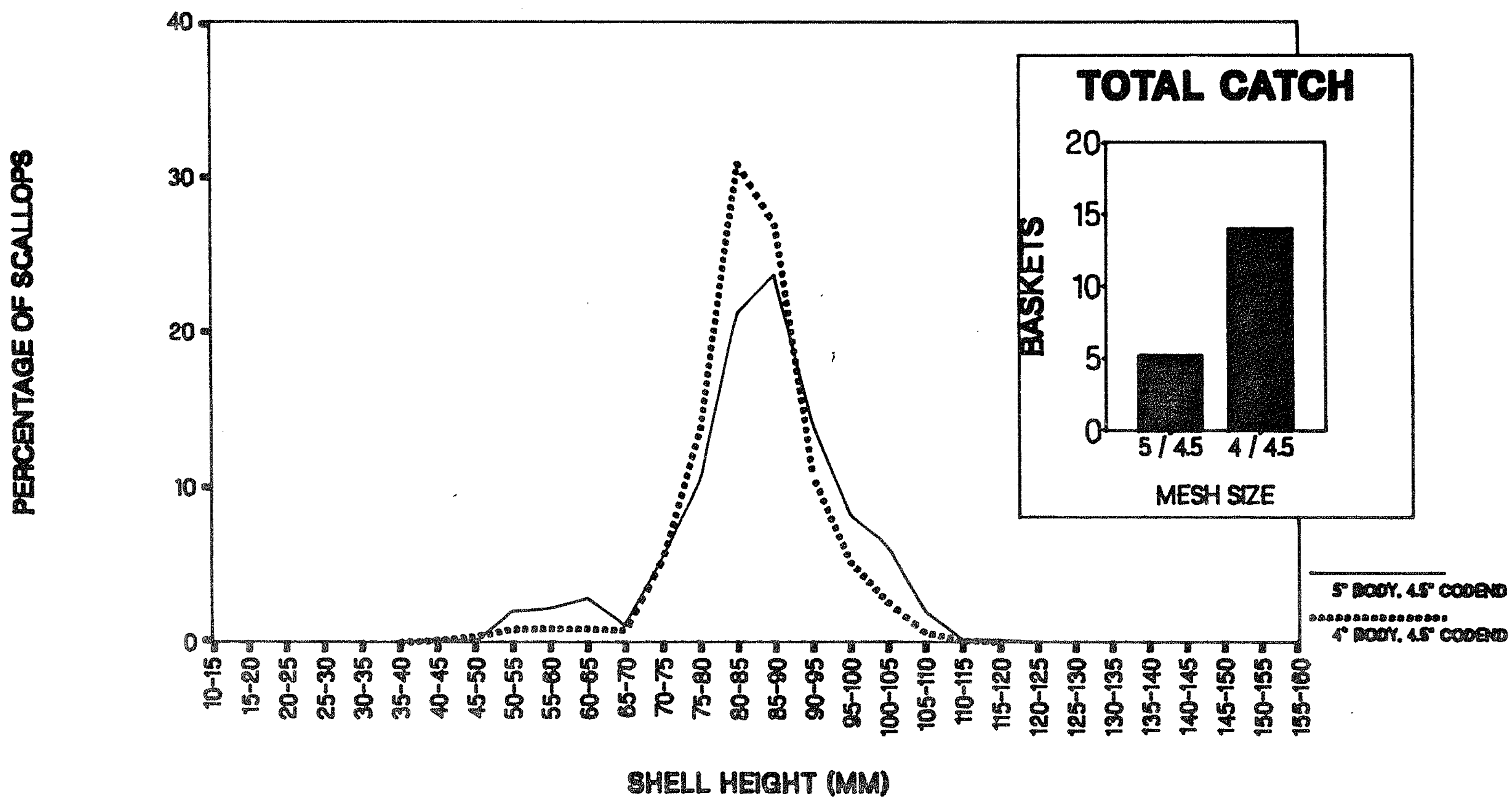
SIZE DISTRIBUTION OF SEA SCALLOPS CAPTURED BY VARIOUS MESH SIZES

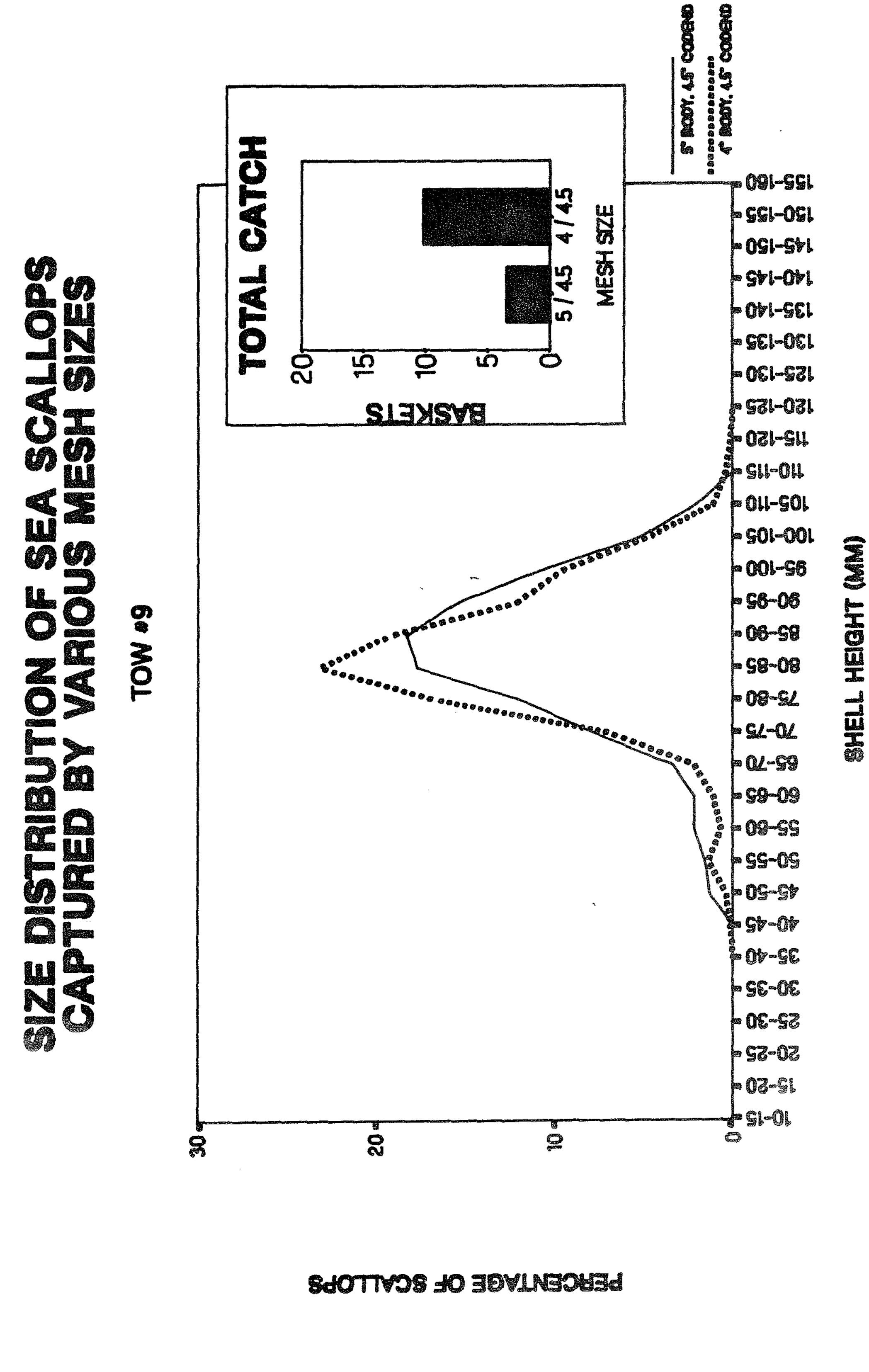
TOW #7



SIZE DISTRIBUTION OF SEA SCALLOPS CAPTURED BY VARIOUS MESH SIZES

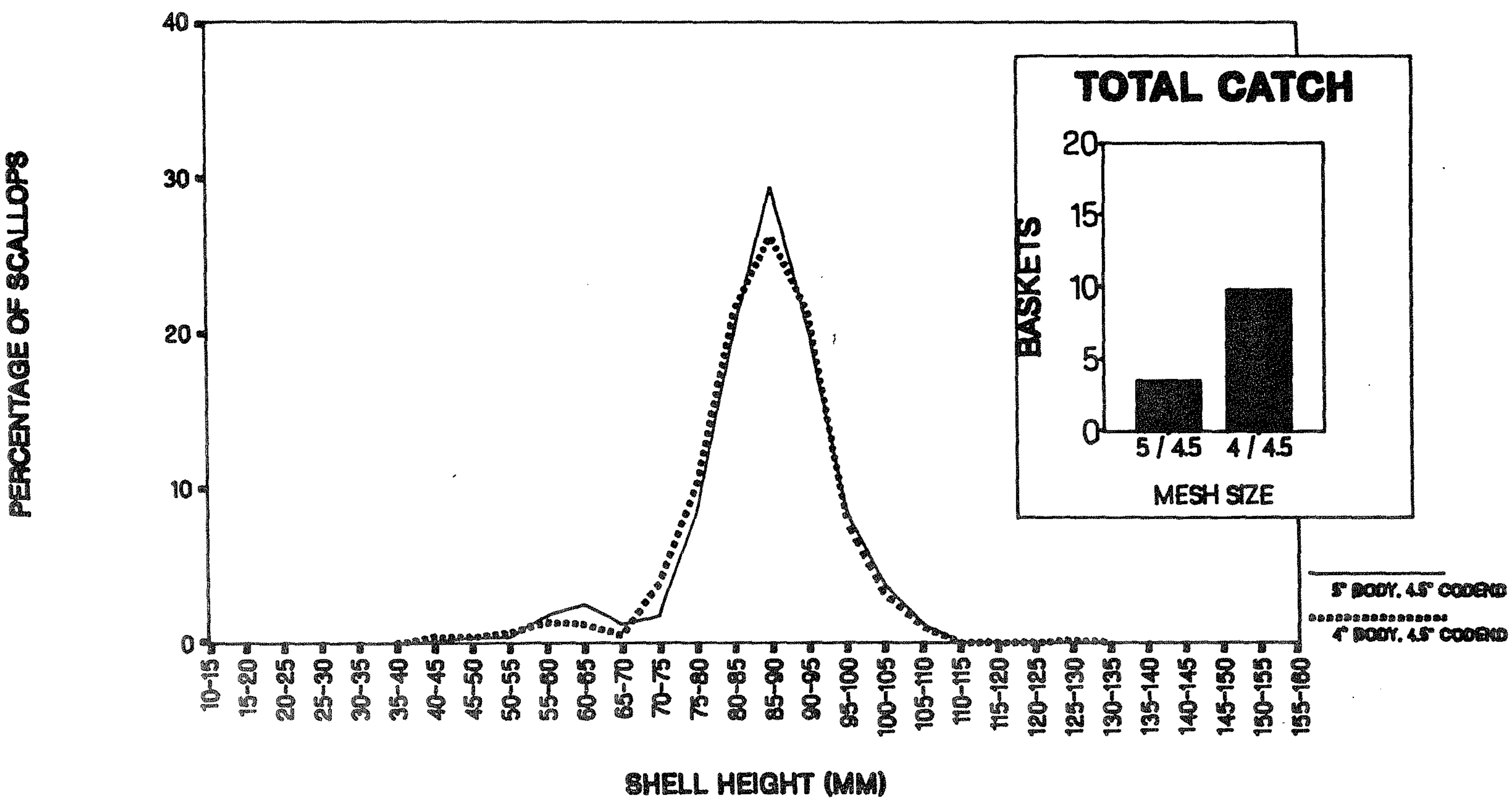
TOW #8




SIZE DISTRIBUTION OF SEA SCALLOPS
CAPTURED BY VARIOUS MESH SIZES
TOW #9
TOTAL CATCH
BASKETS
20
15
10
5
0
5 / 4.5
4 / 4.5
MESH SIZE
5" BODY, 4.5" CODEND
4" BODY, 4.5" CODEND
PERCENTAGE OF SCALLOPS
30
20
10
0
10-15
15-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-95
95-100
100-105
105-110
110-115
115-120
120-125
125-130
130-135
135-140
140-145
145-150
150-155
155-160
SHELL HEIGHT (MM)

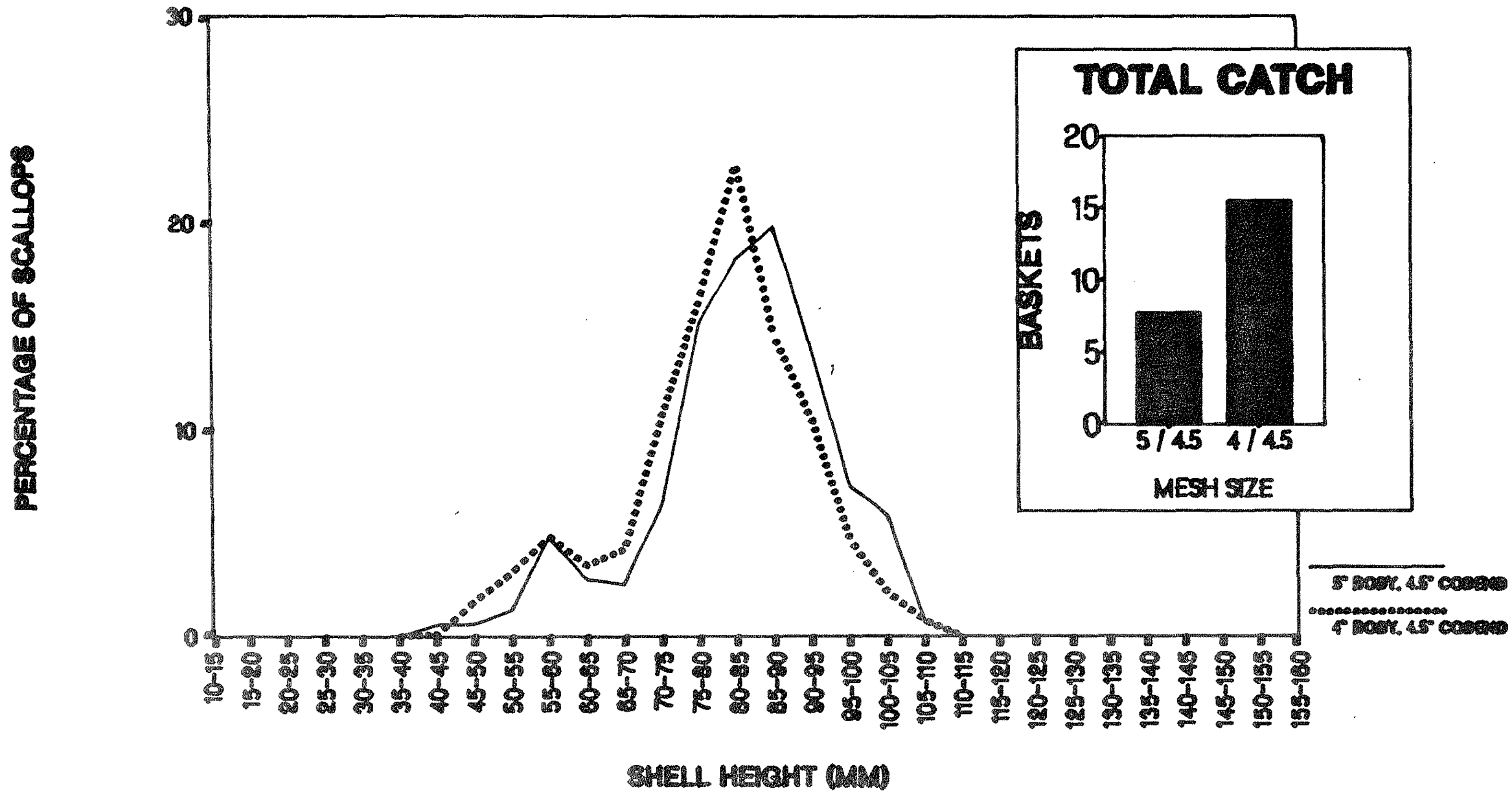
SIZE DISTRIBUTION OF SEA SCALLOPS CAPTURED BY VARIOUS MESH SIZES

TOW #10



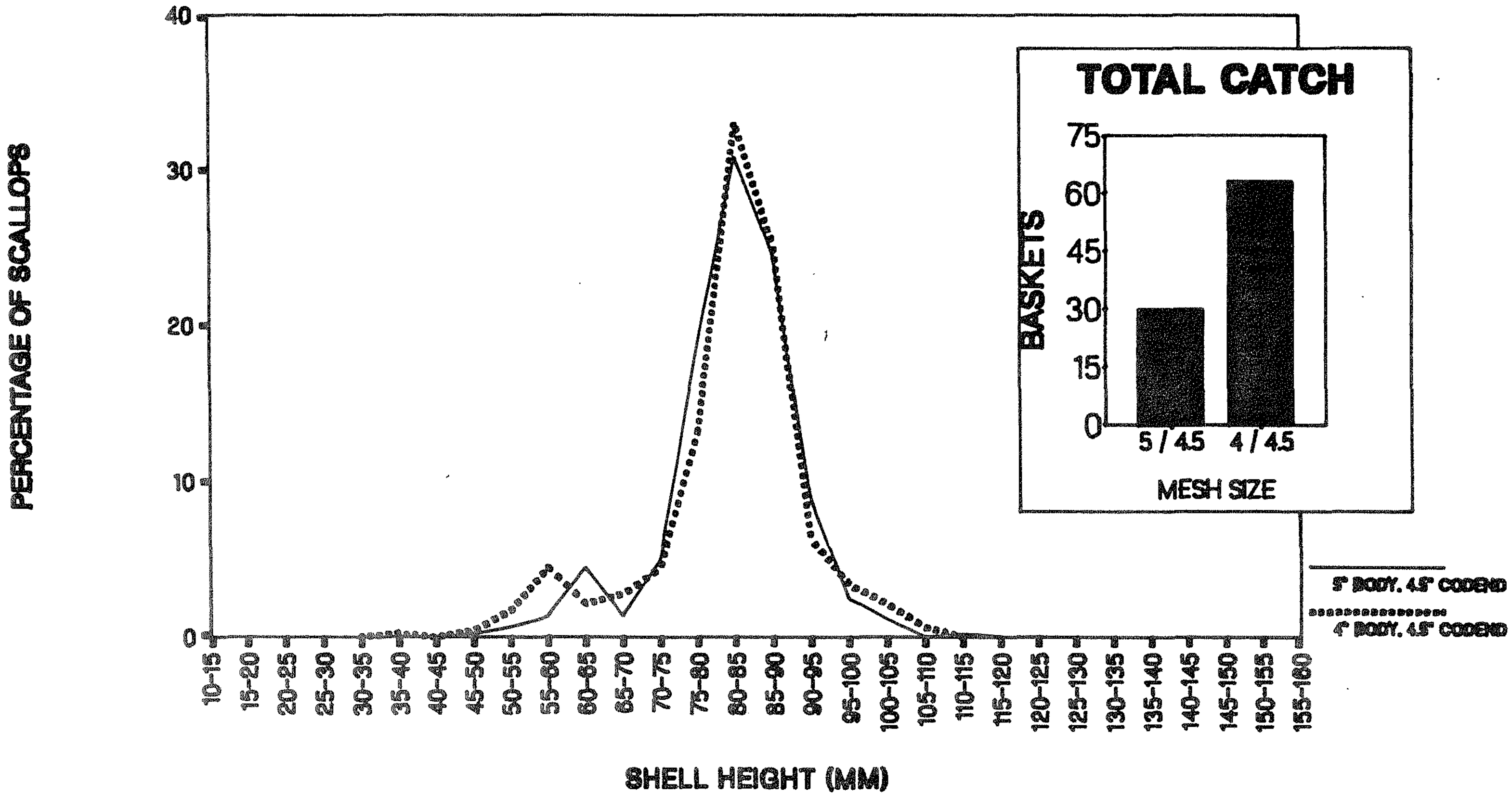
SIZE DISTRIBUTION OF SEA SCALLOPS CAPTURED BY VARIOUS MESH SIZES

TOW #11



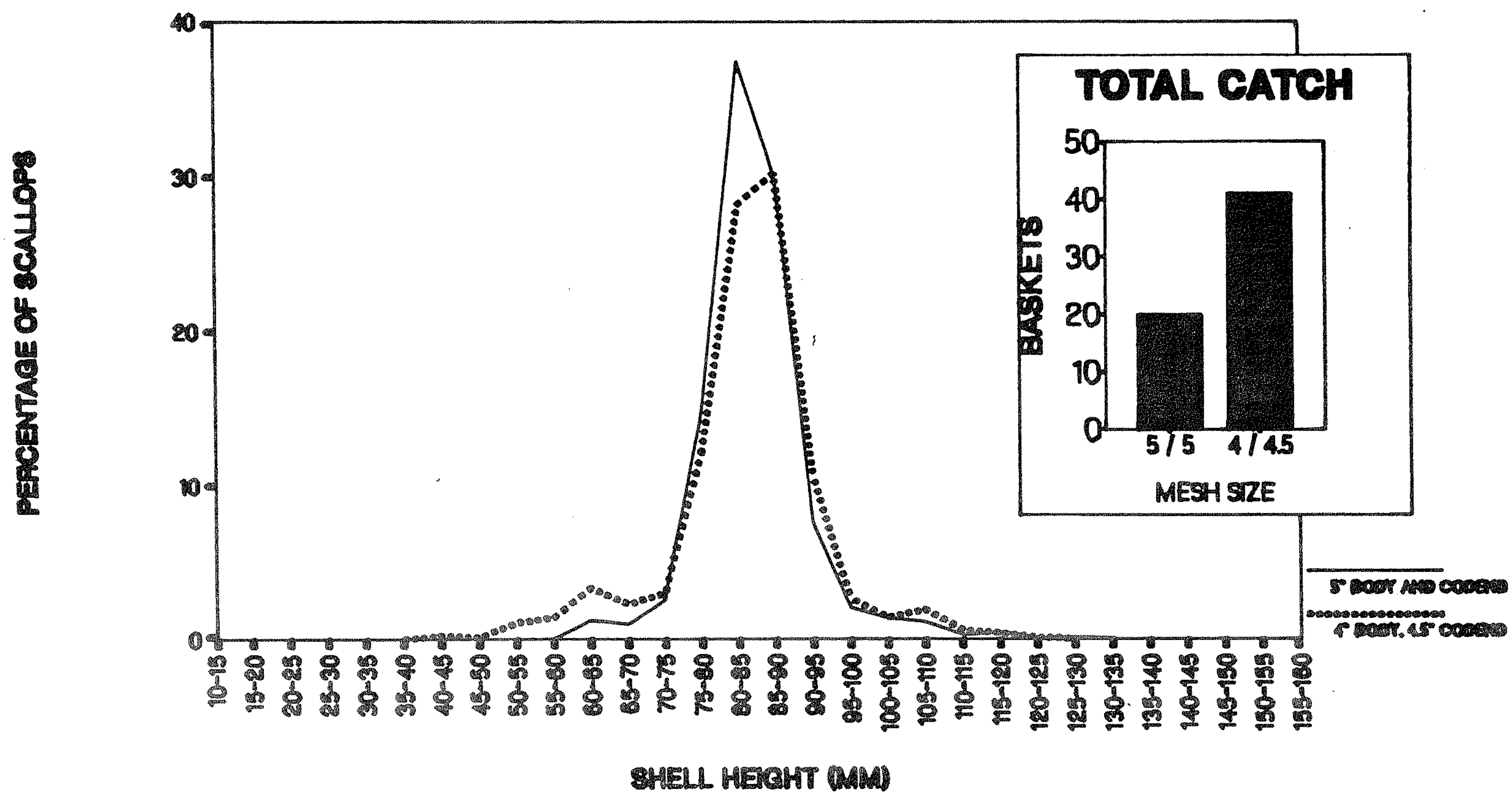
SIZE DISTRIBUTION OF SEA SCALLOPS CAPTURED BY VARIOUS MESH SIZES

TOW #12



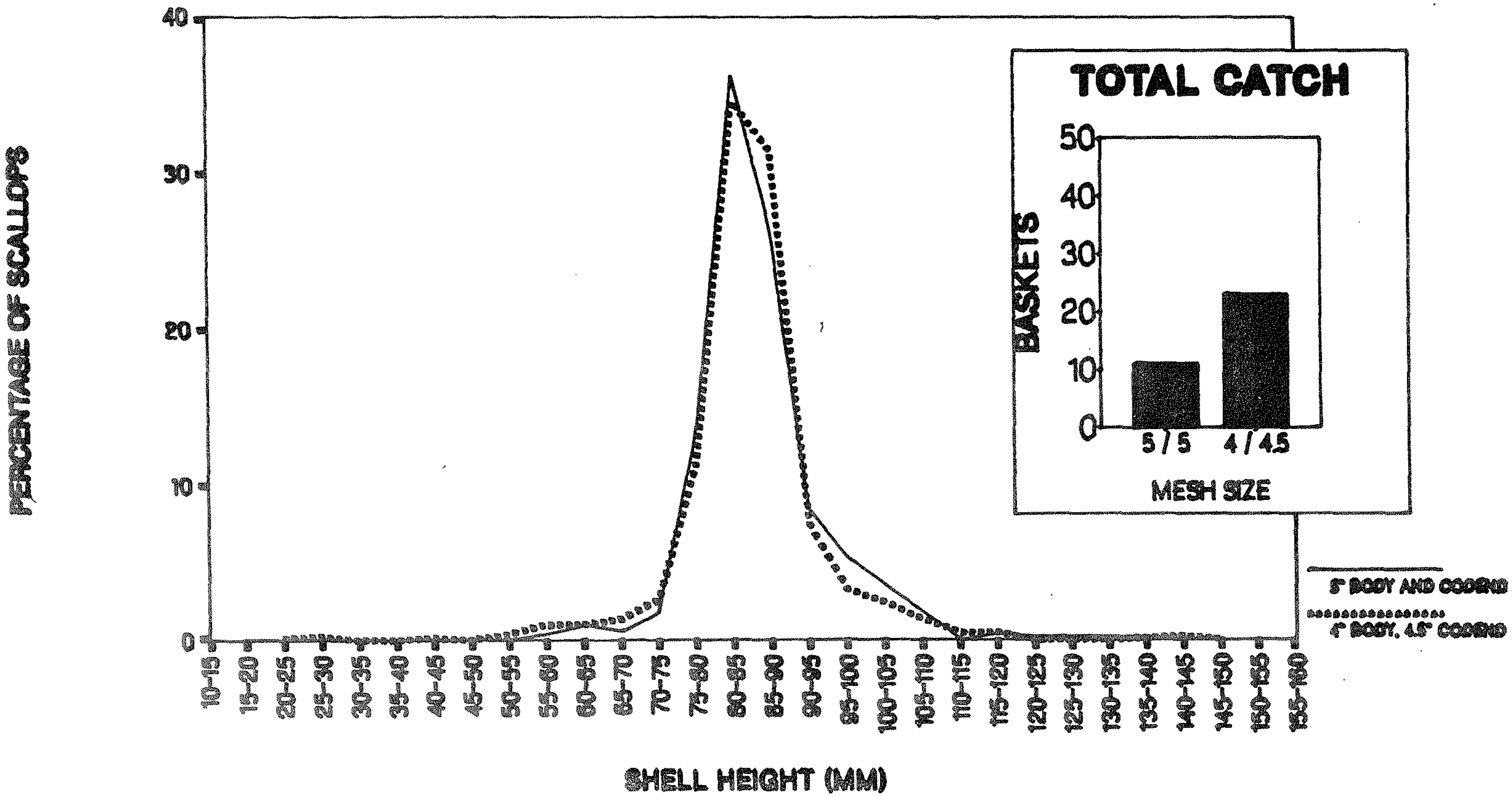
SIZE DISTRIBUTION OF SEA SCALLOPS CAPTURED BY VARIOUS MESH SIZES

TOW #13



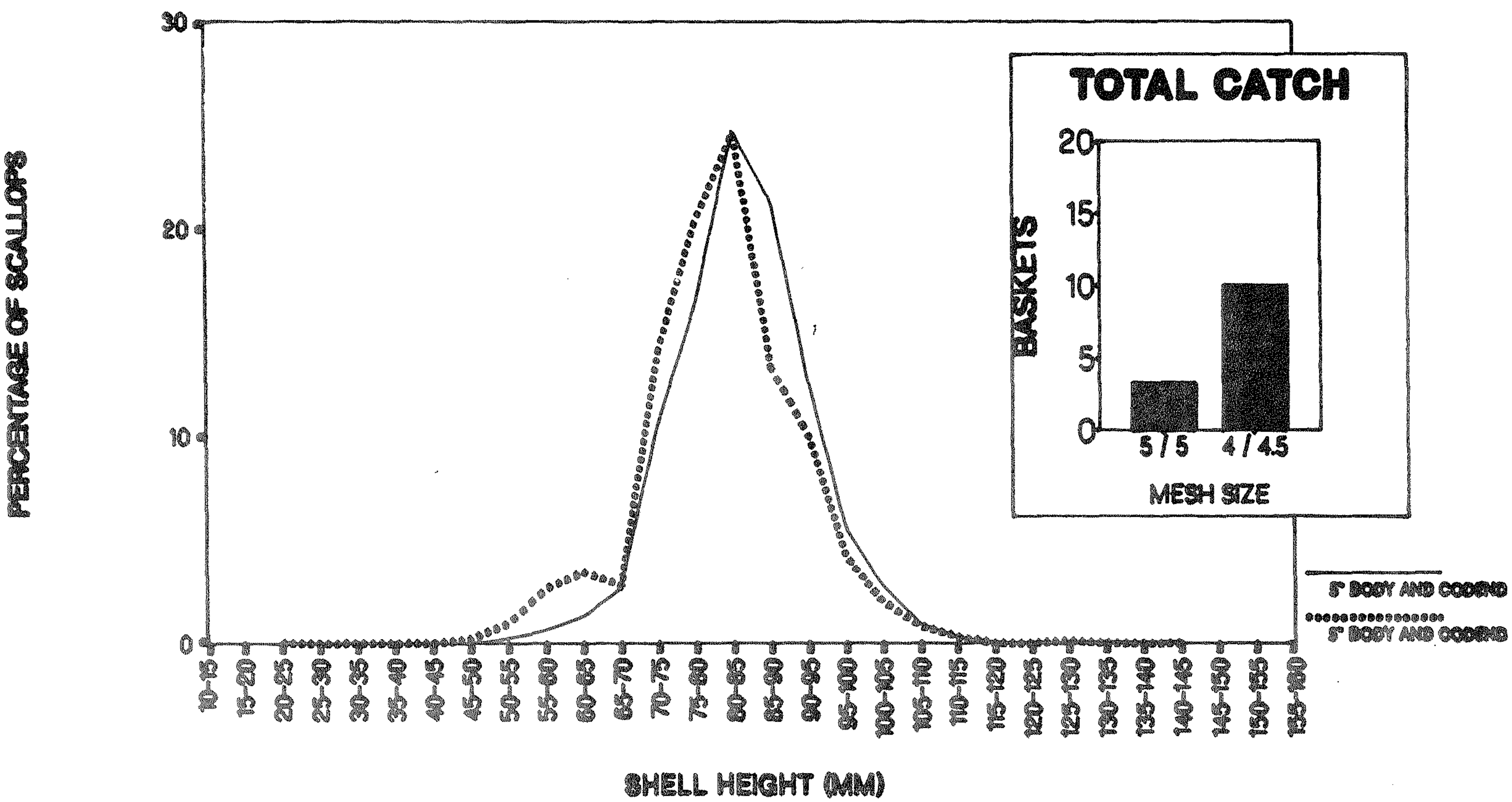
SIZE DISTRIBUTION OF SEA SCALLOPS CAPTURED BY VARIOUS MESH SIZES

TOW #15



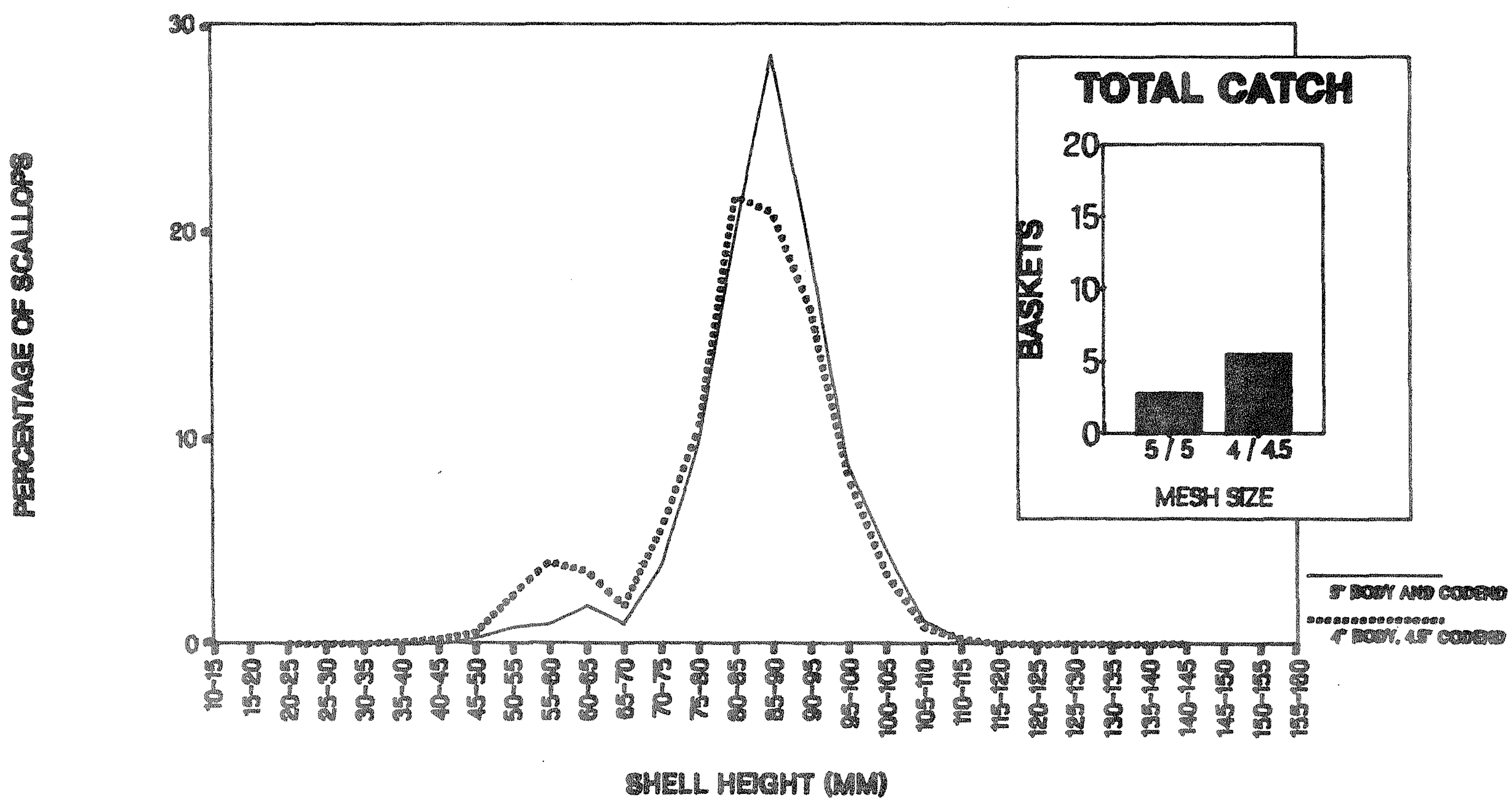
SIZE DISTRIBUTION OF SEA SCALLOPS CAPTURED BY VARIOUS MESH SIZES

TOW #16



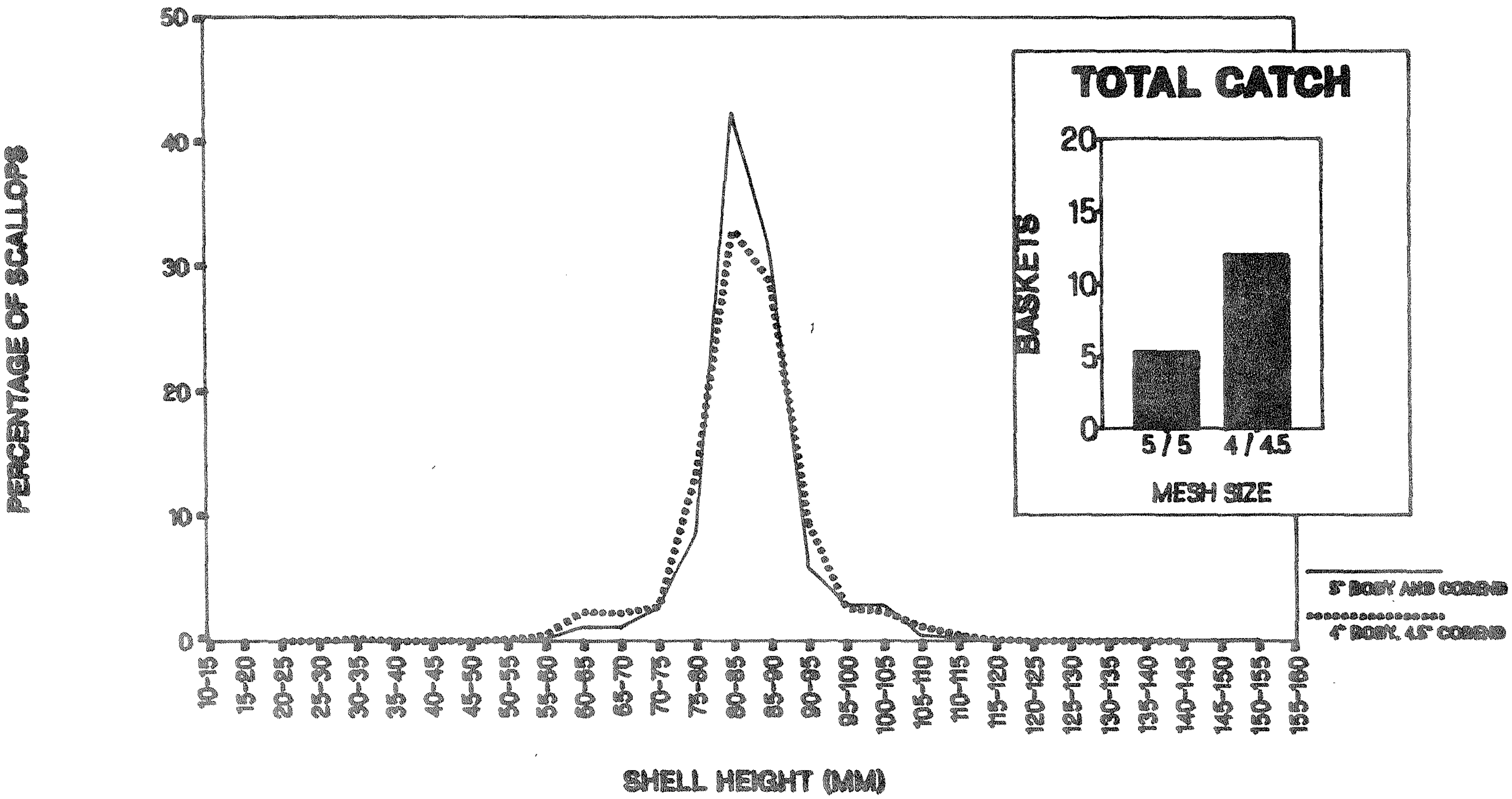
SIZE DISTRIBUTION OF SEA SCALLOPS CAPTURED BY VARIOUS MESH SIZES

TOW #17



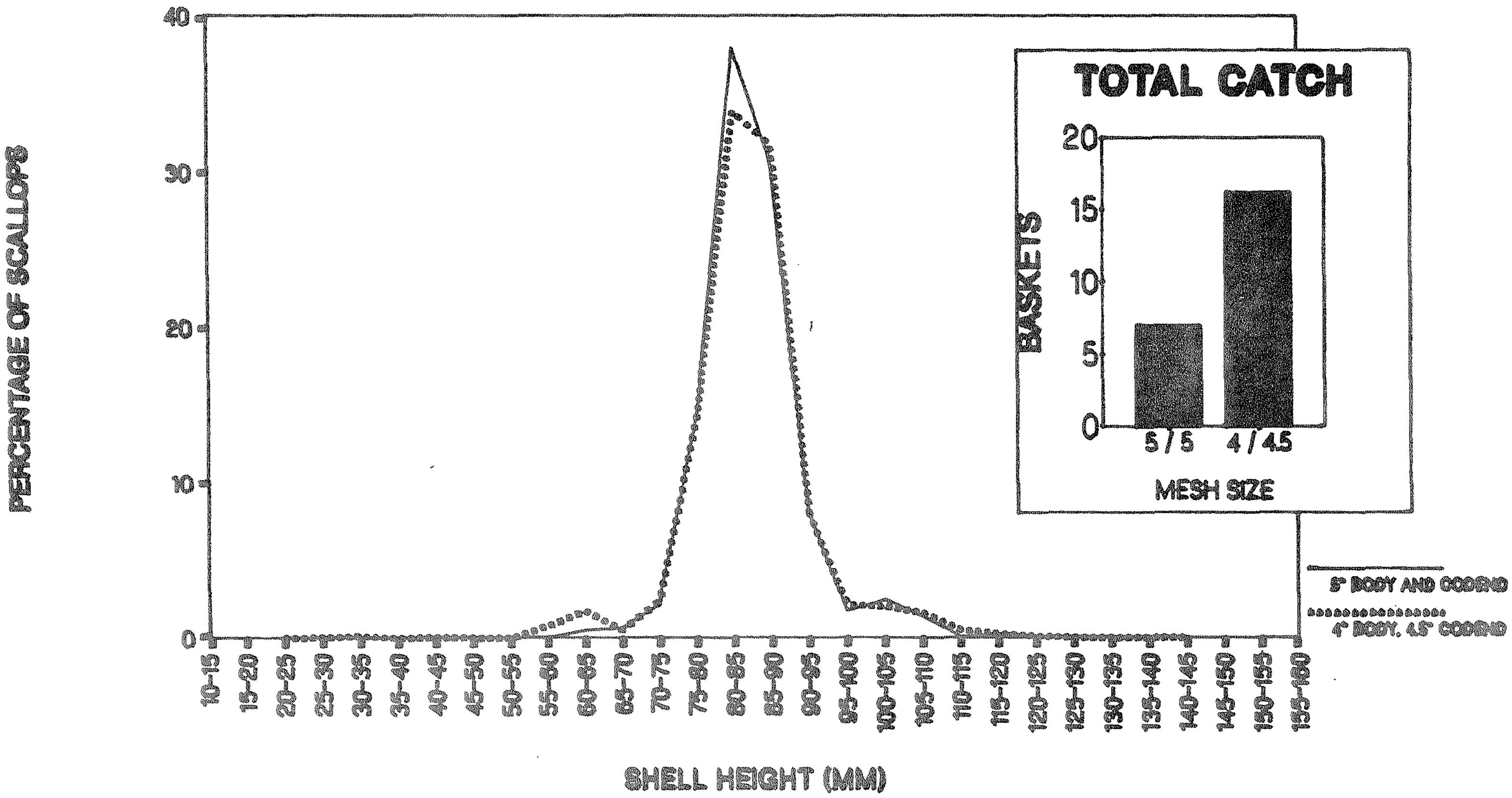
SIZE DISTRIBUTION OF SEA SCALLOPS CAPTURED BY VARIOUS MESH SIZES

TOW #18



SIZE DISTRIBUTION OF SEA SCALLOPS CAPTURED BY VARIOUS MESH SIZES

TOW #19



SIZE DISTRIBUTION OF SEA SCALLOPS CAPTURED BY VARIOUS MESH SIZES

TOW #24