LABORATORY REFERENCE DOCUMENT NO. 81-18

ESTIMATION OF DISCARDS IN MIXED TRAWL FISHERIES OFF THE NORTHEAST COAST OF THE UNITED STATES, BASED ON BOTTOM TRAWL SURVEY CATCHES.

by

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☑ Approved for Distribution

☑ Distribution to F/NWC, F/SWC, F/SEC; F/NWR1, & F/NEC (Technical Writer; Editor)

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Date September 15, 1981

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INTRODUCTION

An otter trawl is a relatively non-selective fishing gear. Thus, unmarketable fish are usually captured and discarded (presumably dead) at sea. The amount actually discarded is seldom quantified, but the potential for large amounts of discards on commercial trawlers exists.

Off the northeast coast of the US, several distinct mixed species trawl fisheries have been identified by Murawski et al. (MS 1981) based on the similarity of species composition of commercial landings from specific locations and seasons. The total effort expended in these fisheries has also been calculated by Lange et al. (MS 1981). In addition to differences in time and space, each of these mixed trawl fishery units are conducted with different codend mesh sizes ranging from 45 to 130 mm (1 3/4 to 5 1/8 in).

In an attempt to assess the amount and species composition of discards by otter trawls as they relate to codend mesh size, research vessel bottom trawl survey catch data were subjected to a series of computations intended to simulate commercial fishing practices. Survey catches initially obtained with a bottom trawl equipped with a 13 mm (0.5 in) mesh codend liner were reduced through a series of calculations which simulate the loss of smaller fish through codends of several mesh sizes. The resulting catch was then subjected to simulated culling of undesirable fish to approximate the species composition of commercial landings and discard.

METHODS

The Northeast Fisheries Center (NEFC) has conducted a stratified random bottom trawl survey each autumn since 1963 in offshore (>27 m) waters extending from Hudson Canyon to the Scotian Shelf; coverage in the Mid-Atlantic area from

Cape Hatteras to Hudson Canyon commenced in 1967 (Figure 1). A spring survey covering the same area was initiated in 1968, and a summer survey has also been conducted intermittently (1963-1968, 1969, and 1977-1980). Similar surveys have also been conducted in inshore (<27 m) waters since 1972. The research vessels ALBATROSS IV and DELAWARE II have been used in these surveys; a "36 Yankee" trawl equipped with 41 cm (16 inch) rollers has been used in the summer and autumn surveys and in the spring surveys between 1968 and 1972, while a "41 Yankee" trawl equipped with 30-46 cm (12-18 in) rollers has been used in subsequent spring survey work. Both trawls are equipped with 13 mm (0.5 in) codend liners. In all surveys, a thirty minute tow is performed at a vessel speed of 6.5 km/hour (3.5 knots) at each station. The total weight and number and the size composition of each species is recorded for each tow. Details of the NEFC survey methods are described by Grosslein (1969, 1971). Although there are known differences in fishing power between the two survey trawls (Sissenwine and Bowman 1978), no attempt was made at this time to adjust for trawl related differences. However, in the case of two species, yellowtail flounder and summer flounder, the observed survey catches were increased by a factor of 10 to account for their low catchability by trawls equipped with roller gear.

For the purposes of this study, all survey data collected throughout the years 1977, 1978, and 1979 were encoded with one of the 29 commercial sub-fishery designations derived from the cluster analysis performed by Murawski et al. (1981). That is, all catch and length frequency records from survey tows occurring in the same statistical areas, months, and depths which describe one of the 29 sub-fishery units were assigned the corresponding commercial sub-fishery code

regardless of sampling stratum or year. The survey catch records were then aggregated in an unweighted manner with respect to the 29 sub-fishery units and, further, by the 9 major fishery groupings. The survey species-composition was expressed by fishery in terms of total weights (kg) of the species taken and as a percentage of the weight of all species captured at these stations.

In two of the 29 cases, NEFC survey coverage was not comprehensive enough to provide the necessary species composition estimates. In one case (Sub-fishery 15-Gulf of Maine, Northern Shrimp), the NEFC survey occurs too late in the spring in the area attributed to this fishery. Therefore, the April-May spring survey records for the corresponding depths and areas were altered to reflect the months during which the fishery is conducted (February-March). In the second case (Sub-fishery 20 - Vineyard Sound, Loligo), NEFC surveys do not cover the statistical area (538) in which the fishery occurs. To determine the species composition in this area, Commonwealth of Massachusetts spring 1978 and 1979 inshore survey records from Vineyard Sound were utilized.

After the initial species composition of the survey catches corresponding to each fishery was calculated, the catch records were modified in two stages to:

1. simulate the effects of selection by various commercial mesh sizes currently in use and,
2. simulate the effect of culling and discarding of unmarketable species and undersized fish aboard commercial vessels.

To achieve these results, the catches from the survey stations were reduced or eliminated in two stages according to the observed length frequency distribution of each species captured using the NEFC computer program CHOP. After each stage of elimination, the resulting species composition of each sub-fishery unit was again summarized in the manner described above for the initial survey records.

This afforded fishery by fishery comparisons of species composition and the calculation of losses due to mesh selectivity and culling practices.

In the stage 1 computation, the mean retention length of each species captured by the small mesh survey gear was calculated for each of four common mesh sizes, judged to be applicable to one of the 29 sub-fishery units (Table 1), utilizing 50% selection factors taken from the published literature. For those species in which no selection factors were available, factors derived from species of similar body shape were employed.

Thus, a matrix of mean retention lengths for each species for each of the four mesh sizes (Table 2) was compared to the length frequency distributions of each species captured at each survey station. At those stations which corresponded with a particular fishery designation, all fish which were less than the applicable minimum length for the mesh size associated with that sub-fishery were enumerated and, through the application of species related length-weight equations, the weight of these small fish was calculated and subtracted from the initial catch. The species composition calculated from the weight that remained thus reflects the catch composition after mesh selection.

In the stage 2 computations, minimum market lengths for selected species (Table 3) were compared to the truncated length frequency distribution which remained after the stage 1 computations. Again, by employing species related length-weight equations, the weight of those fish below the minimum market size was further subtracted from the catches remaining after the stage 1 computations. In addition, at the stage 2 level, the entire catch of those species for which minimum lengths were not specified were eliminated to simulate the total discard of unmarketable species. All survey catch records with the exception of stations

corresponding to the Southern New England industrial fishery (Sub-fishery 22) were treated in this manner. The Sub-fishery 22 survey catch records were allowed to pass through the stage 2 computations unchanged, i.e.: no discard of small fish or unmarketable species was assumed. The species composition calculated after stage 2 computations reflects the simulated survey catch composition of species landed after culling and discard of unwanted fish.

RESULTS & DISCUSSION

The effects of mesh selection and culling on total catch are presented in Tables 4, 5, and 6. The weights (kg) given in Table 4 represent the total cumulative catch of all species from all survey stations which coincide with each of the 29 sub-fishery units. The "After Mesh Selection" weights represent the weight remaining after the stage 1 computations of the selectivity of the indicated mesh have been performed. The "After Cull Selection" weights represent the weight remaining after the additional stage 2 computations for culling and discard have been performed. The percent lost after mesh selection represents the decline in weight from the initial survey catches due to stage 1 mesh selection, and the percent lost after cull selection represents the additional decline in weight from the "After Mesh Selection" weight due to stage 2 cull selection.

In general, the largest mesh selectivity losses occur in those fisheries utilizing the largest meshes (4 in and 5 1/8 in), while relatively low losses occur in the fisheries using the smaller (1 3/4 in and 2 1/2 in) meshes. The

average percentage losses calculated for each mesh size range from less than 1% for the 1 3/4 mesh to 26% for the 5 1/8 in mesh (Table 5). The average percent loss due to cull selection, however, is more constant, averaging between 40% and 50% for all mesh sizes. This suggests that, in general, small fish that are retained by the smaller mesh gear do not contribute substantially to the weight which is subsequently discarded. When the results are examined by fishery (Table 6) and species (Tables 7 and 8), the reasons for this conclusion become apparent.

The lower than expected average discard rates of the two smallest mesh sizes (i.e. similar to the averages for the two larger meshes) is due to the dominance of large, marketable species and the relatively low occurrence of dogfishes and skates. The lowest rates occur in sub-fisheries 5, 7, and 10, all of which are characterized by large proportions of cod, haddock, pollock, redfish, and white hake. Conversely, the average discard rates of fisheries using the two larger mesh sizes may be considered to be higher than expected. The highest discard rates occur in sub-fisheries 9, 11, and 12, all of which are dominated by large catches of spiny dogfish, and in sub-fisheries 25-28, which are dominated by spiny and smooth dogfish, and several species of skates. In particular, the presence or absence of spiny dogfish accounts for a large portion of the variation in discard rates among the 29 sub-fisheries.

Although the species composition of each of the 29 sub-fisheries is not presented here, the data for the 9 major fisheries (Tables 7 and 8) indicate the importance of spiny dogfish in the total demersal biomass available to

otter trawls. In 7 of the 9 major fisheries, spiny dogfish ranks first in the species composition of the initial survey trawl catches (Table 7), ranging from 12.2% to 55.9% of the total. When the species compositions after mesh selection are examined, spiny dogfish still ranks first in the 7 major fisheries and the percentages are slightly higher, particularly in those fisheries dominated by the larger mesh gear (major fisheries 1, 5, and 9 (Table 7)).

However, when the results after cull selection are examined, it can be seen that, except for fishery 7, all dogfish as well as several other species are removed entirely from the species composition lists. These results should reflect the final species composition of the commercial landings in each of the 9 major fisheries; a comparison of these data with the observed species composition given by Murawski et al (MS 1981; Table 7) indicate relatively good qualitative agreement. Differences in the two lists result from several factors. As stated previously, the final calculated species compositions are derived from the survey catches which remain after the stage 1 mesh selection computations are performed. These calculations were based on a minimum retention length for each species below which all fish were eliminated, rather than a mesh selection ogive, resulting in knife-edge selection. Also, only one of the four chosen mesh sizes was assumed to represent all catches in each of the 29 sub-fishery units upon which the selection calculations were performed. We realize that, in reality, meshes other than the dominant one are utilized in each fishery. Thus, the species composition data after mesh selection, and the results obtained after cull selection are dependent upon the choice of mesh size and the selection factors which we assumed to represent

each sub-fishery in the data set. Further, the calculated species composition resulting from cull selection depends on our choice of the minimum market sizes (Table 3). Any deviation between these lengths and those which are used by the industry will contribute to differences in the observed and calculated species compositions. Finally the stratified random nature of the bottom trawl survey design places stations in areas which may traditionally be avoided by the commercial vessels because of bottom type or the predominance of unmarketable or regulated species. Elimination of survey tows from these areas may further enhance the estimates of species composition.

Despite these problems of approximation, the two data sets produce relatively comparable results. With the exception of major fisheries 8 and 9, the ranking of the dominant species calculated from survey data is the same or similar to the actual ranking presented by Murawski et al (MS 1981). In the case of fisheries 8 and 9 (Middle Atlantic fisheries), the survey species composition may be more representative than the observed results since the commercial data were based only on vessels fishing out of New England ports. In the case of fishery 7, a large component reflects the Southern New England industrial fishery, and the catch is listed only as mixed industrial by Murawski et al (MS 1981), whereas the survey composition is listed by species. In this case, spiny dogfish remain dominant.

The data presented in Table 8 illustrate the rates of escapement through the meshes and the subsequent rate of discard of the top seven species from each of the 9 major fisheries. Although spiny dogfish account for large proportions of the initial survey catches (Table 7), in only a few instances (fisheries 4, 5, and 9) do they appear among the top seven species representing escape-

ment in Table 8. As in Table 6, the overall percent escapement is higher in those major fisheries which are dominated by the larger mesh gear.

The highest rates of discard, as indicated by the cull selection computations, are experienced by those species which were eliminated entirely, that is, those which were assumed to be unmarketable. At this stage, spiny dogfish ranks first in terms of percent of total discard in 8 of the 9 major fisheries representing between 34.1 and 79.1% of the total discard by major fishery. Other species which dominate the discard include little skate, winter skate and shortfin squid. Species of commercial importance which also rank in the top seven include yellowtail flounder, winter flounder, American plaice and cod.

The discard data are also expressed as percent by species of the total amount of all species retained in each major fishery. In this case, some of the spiny dogfish discard rates exceed 100 percent when the total weight discarded exceeds the total weight retained (Fisheries 4, 5, and 8). The application of these discard rates to total annual commercial catches by fishery provides estimates of actual amounts of these species discarded in commercial fishing operations.

Estimates of total commercial discard by fishery were obtained for each of the seven dominant species discarded by first calculating the ratio of weight discarded to the total weight of all species in the survey catches retained after cull selection simulation in each major fishery. These ratios, expressed as a percent (x100), are given in Table 8 under the heading "Percent of total retained". Each ratio was then mulyiplied by the total commercial landings of all species in that fishery (Lange et al. MS 1981) to obtain the discard estimate in

terms of metric tons (MT) (Table 8, last column). In general, the discard calculated in this manner is dominated by species which were entirely eliminated; i.e., assumed to be unmarketable. To derive estimates for selected species of commercial importance (Table 9) a second set of discard ratios was calculated for each fishery. In this procedure the ratio of weight lost to weight retained was calculated for each species listed in Table 9. These ratios were then multiplied by the estimated average 3-year annual commercial landings of the species in each fishery (Lange et al. MS 1981) to obtain the discarded weight. This permitted, in some cases, comparisons of discard estimated by the two methods.

The first procedure, which utilizes the ratio of discard weight to total weight retained, is affected by the relative contribution of each species to the total survey catch. In cases where a species accounts for a greater proportion of the survey catch than the commercial catch (e.g. yellowtail flounder in fishery 6), this procedure provides a lower estimate of discard than the second procedure. In cases where the survey percent is higher than the commercial percent (e.g. winter flounder in fishery 8) the first procedure provides a higher estimate of the weight discarded. The proportionate difference between the two estimates is equivalent to the ratio of the percentage contributions of the species to the total survey and commercial catches. The discard estimates presented in Table 8, therefore, should be interpreted to represent only the general magnitude of discard, given the above assumptions concerning mesh size and culling practices.

SUMMARY

Bottom trawl survey data can be used to simulate the escapement of small fish through various codend mesh sizes, and the subsequent discard of undersized fish or unmarketable species. Obviously, the rate of escapement through the meshes increases with increasing mesh size. However, the subsequent rate of discard remained relatively constant, regardless of the mesh size initially used to capture the fish, suggesting that species composition of the population and catch are instrumental in determining the eventual rate of discard. In particular, it was noted that the presence or absence of spiny dogfish accounted for a large portion of the variation in discard rates among the 29 sub-fishery units, regardless of the mesh size utilized. The rate of escapement of spiny dogfish was extremely low at all mesh sizes considered in this study.

Discards, from each of the 9 major fisheries calculated from survey ratios, were dominated by species which were considered to be unmarketable. This included smooth and spiny dogfish and several species of skates. Species of commercial importance which also ranked among the dominant species discarded included yellowtail flounder, winter flounder, American plaice, and cod. Estimated discards of yellowtail flounder and winter flounder represented 32.0 and 46.6% respectively of the 1977-1979 average annual landed weight of those species.

LITERATURE CITED

Grosslein, M.D. 1969. Groundfish survey program of BCF Woods Hole. Commer. Fish. Rev. 31(8-9): 22-35.

_____. 1971. Some observations on accuracy of abundance indices derived from research vessel surveys. Int. Comm. Northw. Atl. Fish. Redbook 1971(III): 249-266.

Lange, A.M., S.A. Murawski, M.P. Sissenwine, R.K. Mayo, and B.E. Brown. MS 1981. Fishery trends off the Northeastern Coast of the United States, 1964-1980. NMFS, NEFC, Woods Hole Laboratory Ref. No. 81-17.

Murawski, S.A., A.M. Lange, R.K. Mayo, M.P. Sissenwine, and B.E. Brown. MS 1981. Species similarity of otter trawl catches off the Northeast Coast of the United States. NMFS, NEFC, Woods Hole Laboratory Ref. No. 81-16.

Sissenwine, M.P., and E.W. Bowman. 1978. An analysis of some factors affecting the catchability of fish by bottom trawls. Int. Comm. Northw. Atl. Fish. Res. Bull. 13:81-87.

Table 1. Codend mesh size associated with each of the fisheries used in the mesh selection simulations.

Fishery	Mesh Size	
	mm	in
1	130	5 1/8
2	64	2 1/2
3	130	5 1/8
4	102	4
5	64	2 1/2
6	102	4
7	64	2 1/2
8	64	2 1/2
9	130	5 1/8
10	64	2 1/2
11	130	5 1/8
12	130	5 1/8
13	130	5 1/8
14	130	5 1/8
15	45	1 3/4
16	130	5 1/8
17	102	4
18	102	4
19	130	5 1/8
20	64	2 1/2
21	64	2 1/2
22	64	2 1/2
23	64	2 1/2
24	64	2 1/2
25	102	4
26	102	4
27	102	4
28	130	5 1/8
29	130	5 1/8

Table 2. Mean retention lengths (cm) used in the simulation of mesh selection by four codend mesh sizes.

Species	50 Percent Selection Factor	Mesh Size (mm)			
		45	64	102	130
Smooth dogfish	4.0	18	25	41	52
Spiny dogfish	4.0	18	25	41	52
Barndoor skate	2.0	9	13	20	26
Winter skate	2.0	9	13	20	26
Clearnose skate	2.0	9	13	20	26
Little skate	2.0	9	13	20	26
Thorny skate	2.0	9	13	20	26
Round herring	4.0	18	25	41	52
Atlantic herring	3.4	15	22	35	44
Alewife	2.6	12	17	26	34
Blueback herring	2.6	12	17	26	34
American shad	2.6	12	17	26	34
Menhaden	2.7	12	17	27	35
Bay anchovy	4.0	18	25	41	52
Striped anchovy	4.0	18	25	41	52
Silver hake	4.0	18	25	41	52
Atlantic cod	3.6	16	22	36	46
Haddock	3.4	16	22	35	44
Pollock	3.3	15	21	34	43
White hake	4.0	18	25	41	52
Red hake	4.0	18	25	41	52
Spotted hake	4.0	18	25	41	52
Cusk	4.0	18	25	41	52
Atlantic halibut	2.2	10	14	22	29
American plaice	2.2	10	14	22	29
Summer flounder	2.2	10	14	22	29
Four spot flounder	2.2	10	14	22	29
Yellowtail flounder	2.2	10	14	22	29
Winter flounder	2.0	9	13	21	27
Witch flounder	2.2	10	14	22	29
Windowpane flounder	2.0	9	13	21	27
Atlantic mackerel	4.0	18	25	41	52
Butterfish	1.8	8	11	18	23
Bluefish	4.0	18	25	41	52
Croaker	2.9	13	19	30	39
Black sea bass	2.9	13	19	30	39
Scup	2.9	13	19	30	39
Weakfish	4.0	18	25	41	52
Spot	2.9	13	19	30	39
Tilefish	3.4	16	22	35	44
Redfish	2.5	11	16	25	33
Long horned sculpin	2.9	13	19	30	39
Sea raven	2.9	13	19	30	39
Northern sea robin	2.9	13	19	30	39
Striped sea robin	2.9	13	19	30	39
Armored sea robin	2.9	13	19	30	39
Sand launce	4.0	18	25	41	52
Wolffish	4.0	18	25	41	52
Ocean pout	4.0	18	25	41	52
Cusk eel	4.0	18	25	41	52
Goosefish	2.2	10	14	22	29
American lobster	N/A	1	1	1	1
Sea scallop	1.3	6	8	13	17
Squid (NS)	1.8	8	12	19	25
Short finned squid	1.8	8	12	19	25
Long finned squid	1.8	8	12	19	25

Table 3. Minimum market lengths (cm) used in the simulation of cull selection and discard estimation for selected species.

Species	Length (cm)
Atlantic herring	11
Silver hake	24
Atlantic cod	50
Haddock	44
Pollock	43
White hake	41
Cusk	60
Atlantic halibut	30
American plaice	32
Summer flounder	30
Yellowtail flounder	32
Winter flounder	32
Witch flounder	32
Windowpane flounder	30
Atlantic mackerel	25
Butterfish	16
Bluefish	25
Croaker	25
Black sea bass	18
Scup	18
Weakfish	30
Spot	18
Tilefish	45
Redfish	18
Wolffish	65
Goosefish	30
American lobster	08
Sea scallop	07
Squid (NS)	10
Long finned squid	10

Table 4. Total catch of all species in bottom trawl surveys before and after mesh selection and cull selection computations, and the percentage of the catch lost at each stage in the analysis.

	Initial Survey Catch		Survey Catch After Mesh Selection		Survey Catch After Cull Selection	
Fishery	Mesh (mm)	Weight (kg)	Weight (kg)	%Escape-ment	Weight (kg)	%Discard
1	130	30094.3	21096.2	29.90	17233.6	18.31
2	64	26195.0	25971.0	0.86	8852.2	65.92
3	130	488.9	441.9	9.61	379.0	14.23
4	102	2794.1	2490.5	10.87	1820.1	26.92
5	64	5528.5	5495.4	0.60	4590.9	16.46
6	102	1719.2	1346.0	21.71	994.8	26.09
7	64	3366.1	3316.6	1.47	2621.4	20.96
8	64	3426.6	3300.8	3.67	1836.4	44.37
9	130	3040.2	1791.4	41.08	507.7	71.66
10	64	14099.1	13893.3	1.46	10583.9	23.82
11	130	14520.8	9861.5	32.09	3338.8	66.14
12	130	5194.8	3448.2	33.62	1705.9	50.53
13	130	4701.2	3651.1	22.34	3143.0	13.92
14	130	38.9	27.1	30.33	18.9	30.26
15	45	2424.9	2149.1	0.24	1249.7	48.34
16	130	7064.0	4722.6	33.51	2503.5	46.99
17	102	3801.8	3316.4	12.77	2375.0	28.39
18	102	3230.2	3007.7	6.89	2007.8	33.24
19	130	15707.3	11074.3	29.50	8729.7	21.17
20	64	18857.7	18598.7	1.37	6619.8	64.41
21	64	30313.8	29265.6	3.46	6681.2	77.17
22	64	38062.8	34811.2	8.54	34811.2	0.00
23	64	3473.6	3246.7	6.53	1632.3	49.72
24	64	3582.8	3568.3	0.40	1311.4	63.25
25	102	7343.0	6131.9	16.49	1948.0	68.23
26	102	54295.5	45655.5	15.91	10933.7	76.05
27	102	12122.7	11410.1	5.88	2402.8	78.94
28	130	68451.6	61312.3	10.43	22962.6	62.55
29	130	8222.7	6964.7	15.30	3752.0	46.13

Table 5. Average percentage loss in weight of all species combined due to mesh selection and cull selection for each of the four mesh sizes used in the analysis.

Fishery	Mesh (mm)	Mesh Selection %Escapement	Cull Selection %Discard
15	45	0.24	48.34
2	64	0.86	65.92
5	64	0.60	16.46
7	64	1.47	20.96
8	64	3.67	44.37
10	64	1.46	23.82
20	64	1.37	64.41
21	64	3.46	77.17
22	64	8.54	0.00
23	64	6.53	49.72
24	64	0.40	63.25
		AVE = 2.84	42.61
4	102	10.87	26.92
6	102	21.71	26.09
17	102	12.77	28.39
18	102	6.89	33.24
25	102	16.49	68.23
26	102	15.91	76.05
27	102	5.88	78.94
		AVE =12.93	48.27
1	130	29.90	18.31
3	130	9.61	14.23
9	130	41.08	71.66
11	130	32.09	66.14
12	130	33.62	50.53
13	130	22.34	13.92
14	130	30.33	30.26
16	130	33.51	46.99
19	130	29.50	21.17
28	130	10.43	62.55
29	130	15.30	46.13
		AVE =26.16	40.17

Table 6. Average percentage loss in weight of all species combined due to mesh selection for each of the 9 major fisheries.[1]

Fishery		Mesh (mm)	Mesh Selection %Escapement	Cull Selection %Discard
1.	12	130	33.62	50.32
	13	130	22.34	13.92
	14	130	30.33	30.26
	15	45	0.24	48.34
	16	130	33.51	46.99
	17	102	12.77	28.39
	18	102	6.89	33.24
			AVE. = 19.96	35.92
2.	1	130	29.90	18.31
	2	64	0.86	65.92
	3	130	9.61	14.23
	4	102	10.87	26.92
	5	64	0.60	16.46
	6	102	21.71	26.09
	7	64	1.47	20.96
	8	64	3.67	44.37
	10	64	1.46	23.82
			AVE. = 8.91	28.56
3.	19	130	29.50	21.17
			AVE. = 29.50	21.17
4.	25	102	16.49	68.23
	26	102	15.91	76.05
	27	102	5.88	78.94
	28	130	10.43	62.55
	29	130	15.30	46.13
			AVE. = 12.80	66.38
5.	9	130	41.08	71.66
			AVE. = 41.08	71.66
6.	20	64	1.37	64.41
			AVE. = 1.37	64.41
7.	22	64	8.54	0.00
	23	64	6.53	49.72
	24	64	0.40	63.25
			AVE. = 3.16	37.66
8.	21	64	3.46	77.17
			AVE. = 3.46	77.17
9.	11	130	32.09	66.14
			AVE. = 32.09	66.14

[1] Description of the fisheries may be obtained from Murawski *et al.* (1981).

Table 7. Estimated species composition of the seven dominant species in bottom trawl survey catches before and after mesh size and cull selection computations have been performed.

	Initial Survey Catch			After Mesh Selection			After Cull Selection		
Fishery	Species	Weight (kg)	%	Species	Weight (kg)	%	Species	Weight (kg)	%
1	Total	26455.9	100.00	Total	20592.2	100.00	Total	13003.8	100.00
	Spiny Dogfish	3227.6	12.20	Spiny Dogfish	3226.6	15.67	Cod	2464.3	18.95
	Haddock	3068.2	11.60	Cod	2690.6	13.07	Haddock	1998.3	15.37
	Cod	3973.6	11.24	Haddock	2157.0	10.47	American Plaice	1579.1	12.14
	American Plaice	2173.4	8.22	American Plaice	1891.8	9.19	Pollock	1229.2	9.45
	Short Fin Squid	1739.6	6.58	Yellowtail Fl.	1306.0	6.34	Yellowtail Flounder	1176.0	9.04
	Yellowtail Fl.	1446.0	5.47	Pollock	1237.4	6.01	Goosefish	879.3	6.76
	Pollock	1333.8	5.04	Winter Flounder	1004.9	4.88	White Hake	852.3	6.55
2	Total	87710.3	100.00	Total	77350.3	100.00	Total	48912.3	100.00
	Spiny Dogfish	16169.6	18.44	Spiny Dogfish	16159.0	20.89	Redfish	8675.0	17.74
	Haddock	11280.9	12.86	Redfish	8679.4	11.22	Cod	7622.0	15.58
	Redfish	10702.9	12.20	Cod	7993.3	10.33	Haddock	6728.4	13.76
	Cod	8059.1	9.19	Haddock	7022.8	9.08	Pollock	5727.5	11.71
	White Hake	6121.9	6.98	Pollock	5745.6	2.43	White Hake	5217.2	10.67
	Pollock	5752.5	6.56	White Hake	5525.5	7.14	American Plaice	4577.3	9.36
	American Plaice	5513.7	6.29	American Plaice	5319.2	6.88	Goosefish	2743.4	5.61
3	Total	15707.3	100.00	Total	11074.3	100.00	Total	8729.7	100.00
	Haddock	6314.7	40.20	Haddock	4013.4	36.24	Haddock	4013.4	45.97
	Cod	2216.1	14.11	Cod	2109.0	19.04	Cod	1980.6	22.69
	Pollock	1223.9	7.79	Pollock	1118.3	10.10	Pollock	1118.3	12.81
	Spiny Dogfish	894.4	5.69	Yellowtail Fl.	809.0	7.31	Yellowtail Flounder	768.0	8.80
	Yellowtail Fl.	836.0	5.32	Spiny Dogfish	799.4	7.22	Lobster	186.4	2.14
	Short Fin Squid	824.5	5.25	Winter Skate	475.3	4.29	Wolf Fish	142.2	1.63
	Silver Hake	633.3	4.03	Thorny Skate	287.1	2.59	Goosefish	120.5	1.38
4	Total	150434.8	100.00	Total	131473.0	100.00	Total	41999.1	100.00
	Spiny Dogfish	59174.8	39.34	Spiny Dogfish	53838.1	40.95	Yellowtail Flounder	14910.0	35.50
	Yellowtail Fl.	19575.0	13.01	Yellowtail Fl.	18494.0	14.07	Cod	9561.7	22.77
	Winter Skate	15365.9	10.21	Winter Skate	15364.2	11.69	Haddock	6990.5	16.64
	Cod	10492.5	6.97	Cod	9990.5	7.60	Winter Flounder	2406.9	5.73
	Haddock	10463.3	6.96	Haddock	8059.2	6.13	Goosefish	1416.0	3.37
	Little Skate	6296.5	4.19	Little Skate	6258.5	4.76	Summer Flounder	1371.0	3.26
	Short Fin Squid	5212.8	3.47	Short Fin Squid	3992.3	3.04	Lobster	922.1	2.20

Table 7. (cont.)

Fishery	Initial Survey Catch Species	Weight (kg)	%	After Mesh Selection Species	Weight (kg)	%	After Cull Selection Species	Weight (kg)	%
5	Total	3040.2	100.00	Total	1791.4	100.00	Total	507.7	100.00
	Spiny Dogfish	1063.7	34.99	Spiny Dogfish	1015.9	56.71	Lobster	159.6	31.44
	Silver Hake	854.7	28.11	Lobster	161.1	8.99	Cod	96.8	19.07
	Lobster	161.1	5.30	Cod	97.8	5.46	Goosefish	54.3	10.70
	Short Fin Squid	129.2	4.25	Goosefish	54.3	3.03	Pollock	34.2	6.74
	Red Hake	126.3	4.15	Windowpane Fl.	45.1	2.52	Long Fin Squid	32.1	6.32
	Cod	99.3	3.27	Short Fin Squid	44.8	2.50	Silver Hake	24.0	4.73
	Windowpane Fl.	83.3	2.74	Blackbellied Rose-fish	43.5	2.43	Cusk	22.7	4.47
6	Total	18857.7	100.00	Total	18598.7	100.00	Total	6619.8	100.00
	Scup	2611.6	13.85	Scup	2466.6	13.26	Scup	2466.6	37.26
	N. Sea Robin	2457.3	13.03	N. Sea Robin	2454.3	13.20	Summer Flounder	1301.0	19.65
	Little Skate	2368.9	12.56	Little Skate	2368.3	12.73	Winter Flounder	1148.5	17.35
	Winter Flounder	1807.9	9.59	Winter Flounder	1799.8	9.68	Windowpane Flounder	816.7	12.34
	Winter Skate	1577.7	8.37	Winter Skate	1577.6	8.48	Yellowtail Flounder	270.0	4.08
	Spiny Dogfish	1527.6	8.10	Spiny Dogfish	1527.6	8.21	Long Fin Squid	217.0	3.28
	Windowpane Fl.	1355.0	7.19	Windowpane Fl.	1353.3	7.28	Silver Hake	216.3	3.27
7	Total	45119.2	100.00	Total	41626.1	100.00	Total	37754.8	100.00
	Spiny Dogfish	10551.5	23.39	Spiny Dogfish	10549.2	25.34	Spiny Dogfish	9181.1	24.32
	Yellowtail Fl.	5638.0	12.50	Yellowtail Fl.	5613.0	13.48	Yellowtail Flounder	5484.0	14.53
	Little Skate	3923.6	8.70	Little Skate	3917.8	9.41	Little Skate	3833.9	10.15
	Summer Flounder	2956.0	6.55	Summer Flounder	2956.0	7.10	Summer Flounder	2956.0	7.83
	Butterfish	2527.7	5.60	Butterfish	2102.8	5.05	Butterfish	1606.0	4.25
	Long Fin Squid	1772.7	3.93	Red Hake	1504.7	3.61	Silver Hake	1482.1	3.93
	Silver Hake	1610.9	3.57	Cod	1482.1	3.56	Windowpane Flounder	1180.0	3.13
8	Total	30313.8	100.00	Total	29265.6	100.00	Total	6681.2	100.00
	Spiny Dogfish	16958.9	55.94	Spiny Dogfish	16957.9	57.94	Summer Fl.	2160.0	32.33
	Summer Flounder	2181.0	7.19	Summer Flounder	2181.0	7.45	Scup	1076.3	16.11
	Yellowtail Fl.	1412.0	4.66	Yellowtail Fl.	1412.0	4.82	Silver Hake	615.9	9.22
	Scup	1409.2	4.65	Smooth Dogfish	1164.7	3.98	Yellowtail Flounder	548.0	8.20
	Smooth Dogfish	1164.7	3.84	Scup	1076.3	3.68	Short Fin Squid	415.8	6.22
	Little Skate	939.1	3.13	Little Skate	948.7	3.24	Goosefish	363.4	5.44
	Long Fin Squid	870.3	2.87	Butterfish	669.2	2.29	Butterfish	328.2	4.91
9	Total	14520.8	100.00	Total	9681.5	100.00	Total	3338.8	100.00
	Spiny Dogfish	3317.2	22.84	Spiny Dogfish	2798.3	28.38	Summer Flounder	2141.0	64.12
	Summer Flounder	2163.0	14.90	Summer Flounder	2147.0	21.77	Yellowtail Flounder	341.0	10.21
	Smooth Dogfish	1859.4	12.81	Smooth Dogfish	1835.0	18.61	Goosefish	147.7	4.42
	Croaker	632.3	4.35	Anchovy	628.5	6.37	Croaker	142.1	4.26
	Yellowtail Fl.	632.0	4.35	Yellowtail Fl.	447.0	4.53	Weakfish	86.1	2.58
	Anchovy	628.5	4.33	Horseshoe Crab	170.3	1.73	Sea Scallop	77.9	2.33
	Weakfish	573.4	3.95	N. Stingray	169.5	1.72	Bluefish	76.2	2.28

Table 8. Estimated weight lost due to mesh selection and estimated weight discarded due to cull selection of unmarketable and undersized fish, and an estimate of the average annual commercial discard (1977 -1979) based on calculated survey discard rates.

		After Mesh Selection			After Cull Selection				
Fishery	Species	Weight (kg) Escaped	Percent Escaped	Percent of Total Escapement	Species	Weight (kg) Discarded	Percent Discarded	Percent of Total Discard	Retained	Estimated Average Annual Discard in the Commercial Fishery (metric tons)
1	Total	5863.7	22.16		Total	7588.4	36.85			
	Haddock	911.2	29.70	15.54	Spiny Dogfish	3226.6	100.0	45.52	26.46	5850
	Short Fin Squid	816.8	46.95	13.93	Short Fin Squid	922.8	100.0	14.15	8.22	1817
	Silver Hake	812.2	85.98	13.85	Thorny Skate	757.2	100.0	9.98	5.80	1282
	Red Hake	434.5	74.32	7.41	Ocean Pout	335.0	100.0	4.41	2.56	566
	Sand Launce	428.4	94.40	7.31	American Plaice	312.7	16.53	4.12	2.39	528
	Redfish	351.1	47.05	5.99	Winter Flounder	287.9	28.65	3.79	2.20	486
	Cod	283.0	9.51	4.83	Cod	226.3	8.41	2.98	1.73	382
2	Total	10360.0	11.81		Total	28438.0	36.77			
	Haddock	4258.1	37.75	41.10	Spiny Dogfish	16159.0	100.0	56.82	33.04	15823
	Redfish	2023.5	18.91	19.53	Thorny Skate	3570.2	100.0	12.55	7.30	3496
	Silver Hake	1814.5	52.33	17.51	Red Hake	1613.4	100.0	5.67	3.30	1580
	Red Hake	632.6	28.17	6.11	Short Fin Squid	1512.0	100.0	5.32	3.09	1480
	White Hake	596.4	9.74	5.76	Yellowtail Flounder	1184.0	39.2	4.16	2.42	1159
	Lobster	415.5	21.56	4.01	American Plaice	741.9	13.9	2.61	1.52	728
	American Plaice	194.5	3.53	1.88	Shrimp (Uncl)	467.7	100.0	1.64	0.95	455
3	Total	4633.0	29.50		Total	2344.6	21.17			
	Haddock	2301.3	36.44	49.67	Spiny Dogfish	799.4	100.0	34.10	9.16	558
	Silver Hake	622.1	98.23	13.43	Winter Skate	475.3	100.0	20.27	5.44	332
	Short Fin Squid	620.3	75.23	13.39	Thorny Skate	287.1	100.0	12.25	3.29	201
	Red Hake	302.6	96.09	6.53	Short Fin Squid	204.2	100.0	8.71	2.34	143
	Lg Horned Sculpin	260.1	96.16	5.61	Little Skate	138.9	100.0	5.92	1.59	97
	Haddock	107.1	4.83	2.31	Cod	128.4	6.9	5.48	1.47	90
	Pollock	105.6	8.63	2.28	Sea Raven	125.3	100.0	5.34	1.43	87
4.	Total	18961.8	12.60		Total	89473.0	68.05			
	Spiny Dogfish	5336.7	9.02	28.14	Spiny Dogfish	53838.1	100.0	60.17	128.18	56270
	Haddock	2404.1	22.98	12.68	Winter Skate	15364.2	100.0	17.17	36.58	16058
	Lg. Horned Sculpin	2096.2	88.57	11.05	Little Skate	6258.5	100.0	6.99	14.89	6537
	Red Hake	1587.4	87.30	8.37	Short Fin Squid	3992.3	100.0	4.46	9.50	4170
	Silver Hake	1574.3	84.85	8.30	Yellowtail Flounder	3584.0	19.38	4.01	8.54	3749
	Short Fin Squid	1220.5	23.41	6.44	Winter Flounder	1068.7	12.54	1.19	2.54	1115
	Yellowtail Flounder	1081.0	5.52	5.70	Thorny Skate	1004.3	100.0	1.12	2.39	1049

Table 8 (continued)

Fishery	Species	After Mesh Selection: Weight (kg) Escaped	Percent Escaped	Percent of Total Escapement	Species	After Cull Selection: Weight (kg) Discarded	Discarded	Percent of Total: Discard	Retained	Estimated Average Annual Discard in the Commercial Fishery (metric tons)
5	Total	1248.8	41.08		Total	1283.7	71.66			
	Silver Hake	830.7	97.19	66.52	Spiny Dogfish	1015.9	100.0	79.14	200.10	215
	Red Hake	121.9	96.52	9.76	Short Fin Squid	44.8	100.0	3.49	8.82	9
	Short Fin Squid	84.4	65.33	6.76	Blk. Bellied Rosefish	43.5	100.0	3.39	8.57	9
	Spiny Dogfish	47.8	4.49	3.83	Windowpane Flounder	38.3	85.59	2.98	7.53	8
	Windowpane Fl.	38.2	45.86	3.06	Long Fin Squid	32.1	100.0	2.50	6.32	7
	Long Fin Squid	32.8	50.54	2.63	Little Skate	26.5	100.0	2.06	5.21	6
	4-Spotted Flounder	16.2	45.52	1.30	Thorny Skate	24.0	100.0	1.87	4.73	5
6	Total	259.0	1.37		Total	11978.9	64.41			
	Scup	145.0	5.55	55.98	N. Sea Robin	2454.3	100.0	20.49	37.08	701
	Sand Launce	27.7	58.94	10.69	Little Skate	2368.3	100.0	19.77	35.77	676
	Long Fin Squid	24.9	10.29	9.61	Winter Skate	1577.6	100.0	13.17	23.83	450
	Alewife	18.4	20.89	7.10	Spiny Dogfish	1527.6	100.0	12.75	23.07	436
	Winter Flounder	8.1	0.45	3.13	Tautog	834.6	100.0	6.97	12.61	238
	Silver Hake	4.0	1.82	1.54	Winter Flounder	651.3	36.19	5.44	9.84	186
	Red Hake	3.7	0.65	1.43	Red Hake	563.6	100.0	4.70	8.50	161
7	Total	3493.1	7.74		Total	3871.3	9.30			
	Long Fin Squid	1184.3	66.81	33.90	Spiny Dogfish	1368.1	12.97	35.34	3.62	431
	Butterfish	424.9	16.81	12.16	Butterfish	496.8	23.63	12.83	1.32	157
	Scup	393.5	81.98	11.27	Short Fin Squid	480.8	43.79	12.42	1.27	151
	Sand Launce	302.3	89.68	8.65	Red Hake	436.3	29.00	11.27	1.16	138
	Anchovy	292.8	81.86	8.38	Haddock	189.0	37.71	4.88	0.50	60
	Round Herring	280.3	99.96	8.02	Yellowtail Flounder	129.0	2.30	3.33	0.34	41
	Silver Hake	128.8	8.00	3.69	4-Spotted Flounder	101.2	11.05	2.61	0.27	32
8	Total	1048.2	3.46		Total	22584.4	77.17			
	Long Fin Squid	454.5	52.22	43.36	Spiny Dogfish	16957.9	100.0	75.09	253.83	33532
	Scup	332.9	23.62	31.76	Smooth Dogfish	1164.7	100.0	5.16	17.44	2304
	Butterfish	99.4	12.93	9.48	Little Skate	948.7	100.0	4.20	14.20	1876
	N. Sea Robin	48.2	12.31	4.60	Yellowtail Flounder	864.0	61.19	3.83	12.95	1711
	Silver Hake	42.0	6.38	4.01	Red Hake	420.2	100.0	1.86	6.29	831
	Red Hake	13.0	3.00	1.24	N. Sea Robin	343.5	100.0	1.52	5.14	679
	Short Fin Squid	6.9	2.37	0.66	Winter Flounder	204.4	69.22	0.91	3.08	407
9	Total	4659.3	32.09		Total	6522.7	66.14			
	Spiny Dogfish	518.9	15.64	11.14	Spiny Dogfish	2798.3	100.0	42.90	83.81	17214
	Butterfish	492.3	94.78	10.57	Smooth Dogfish	1835.0	100.0	28.13	54.95	11286
	Croaker	490.2	77.53	10.52	Anchovy	628.5	100.0	9.64	18.83	3867
	Weakfish	487.3	84.98	10.46	Horseshoe Crab	170.3	100.0	2.61	5.10	1047
	Silver Hake	406.1	95.37	8.72	N. Sting Ray	169.5	100.0	2.60	5.08	1043
	N. Sea Robin	382.1	98.96	8.20	4-Spotted Flounder	126.3	100.0	1.94	3.79	778
	Long Fin Squid	307.9	82.13	6.61	Little Skate	114.3	100.0	1.75	3.42	702

Table 9. Simulated discards of selected commercially utilized species based on stage 2 cull selection computations and 3-year average commercial landings for the years 1977-1979.

Fishery	Cod	Haddock	Silver Hake	Yellowtail Flounder	Winter Flounder	Summer Flounder	Scup
1							
Discard/Landings Ratio	.0918	.0794	.0091	.1105	.4015	0.0	0.0
Landings (MT)	7627	2326	1158	968	599	4	0
Est. Discard (MT)	700	185	11	107	240	0	0
2							
Discard/Landings Ratio	.0487	.0438	0.0	.6459	.5750	0.0	0.0
Landings (MT)	6508	6537	6551	603	374	5	0
Est. Discard (MT)	317	286	0	390	215	0	0
3							
Discard/Landings Ratio	.0648	0.0	0.0	.0534	.0590	0.0	0.0
Landings (MT)	2734	1835	38	330	382	1	0
Est. Discard (MT)	177	0	0	18	23	0	0
4							
Discard/Landings Ratio	.0448	.1529	0.0	.2404	.1434	0.0	0.0
Landings (MT)	16405	5474	364	9285	6089	439	35
Est. Discard (MT)	801	837	0	2232	873	0	0
5							
Discard/Landings Ratio	.0103	0.0	0.0	.2941	0.0	0.0	0.0
Landings (MT)	0	0	21	0	0	0	0
Est. Discard (MT)	0	0	0	0	0	0	0
6							
Discard/Landings Ratio	.0698	0.0	0.0	.1333	.5671	0.0	0.0
Landings (MT)	6	0	10	2	224	75	481
Est. Discard (MT)	<1	0	0	<1	127	0	0
7							
Discard/Landings Ratio	.0808	.6054	0.0	.0235	.0049	0.0	0.0
Landings (MT)	475	17	2134	833	757	480	180
Est. Discard (MT)	38	10	0	20	4	0	0
8							
Discard/Landings Ratio	.0855	.0638	0.0	1.5766	2.2486	.0097	0.0
Landings (MT)	223	1	585	867	1329	1382	4514
Est. Discard (MT)	19	<1	0	1381	2988	13	0
9							
Discard/Landings Ratio	0.0	0.0	0.0	.3109	1.667	.0028	0.0
Landings (MT)	113	18	645	175	66	13650	175
Est. Discard (MT)	0	0	0	54	110	38	0
TOTAL							
Landings (MT)	34091	16208	11506	13[illegible]3	9820	16036	5385
Est. Discard (MT)	2033	1336	11	4202	4580	51	35
% Discarded	6.0	8.2	0.1	32.2	46.6	0.3	0.6

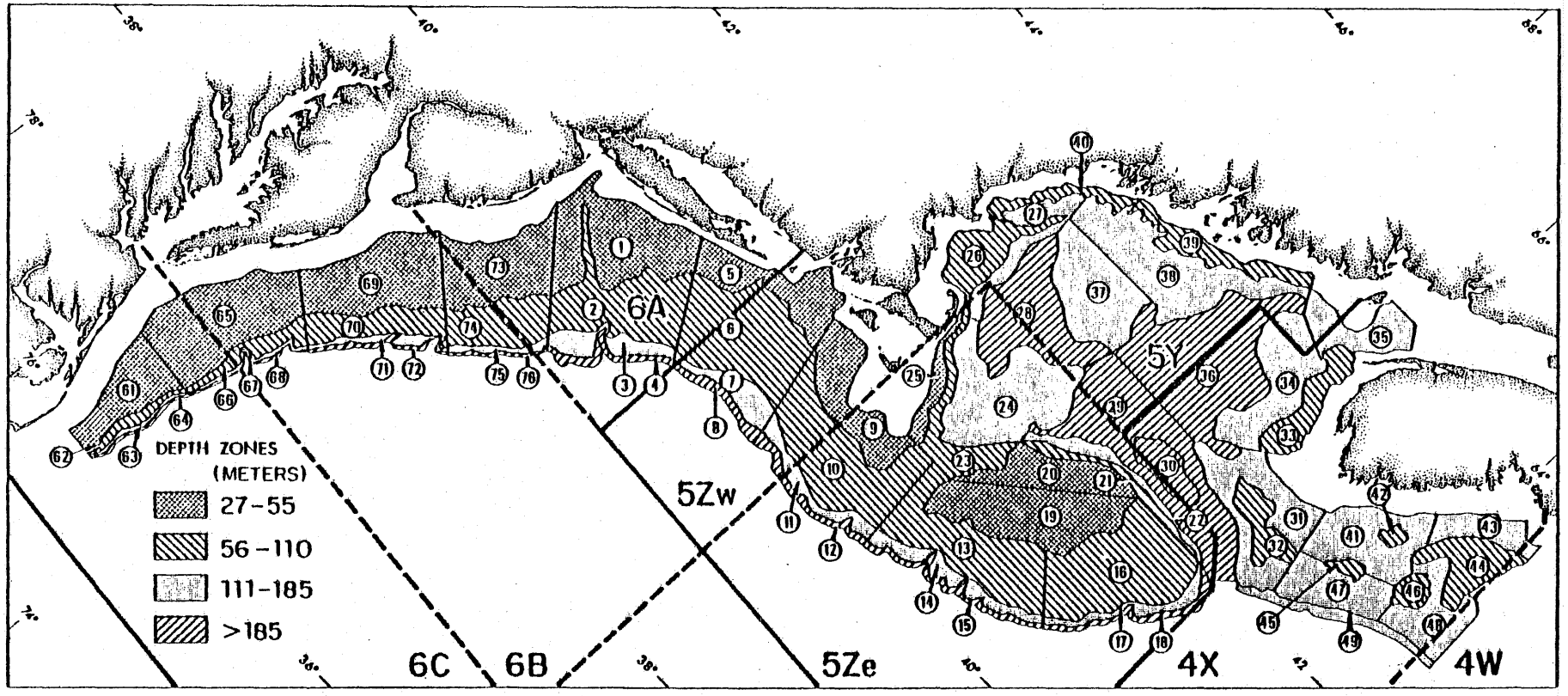

Figure 1. Sampling strata used in NEFC offshore (>27 m) spring, summer, and autumn bottom trawl surveys.