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MAXIMUM YIELD IN THE SEA SCALLOP FISHERY

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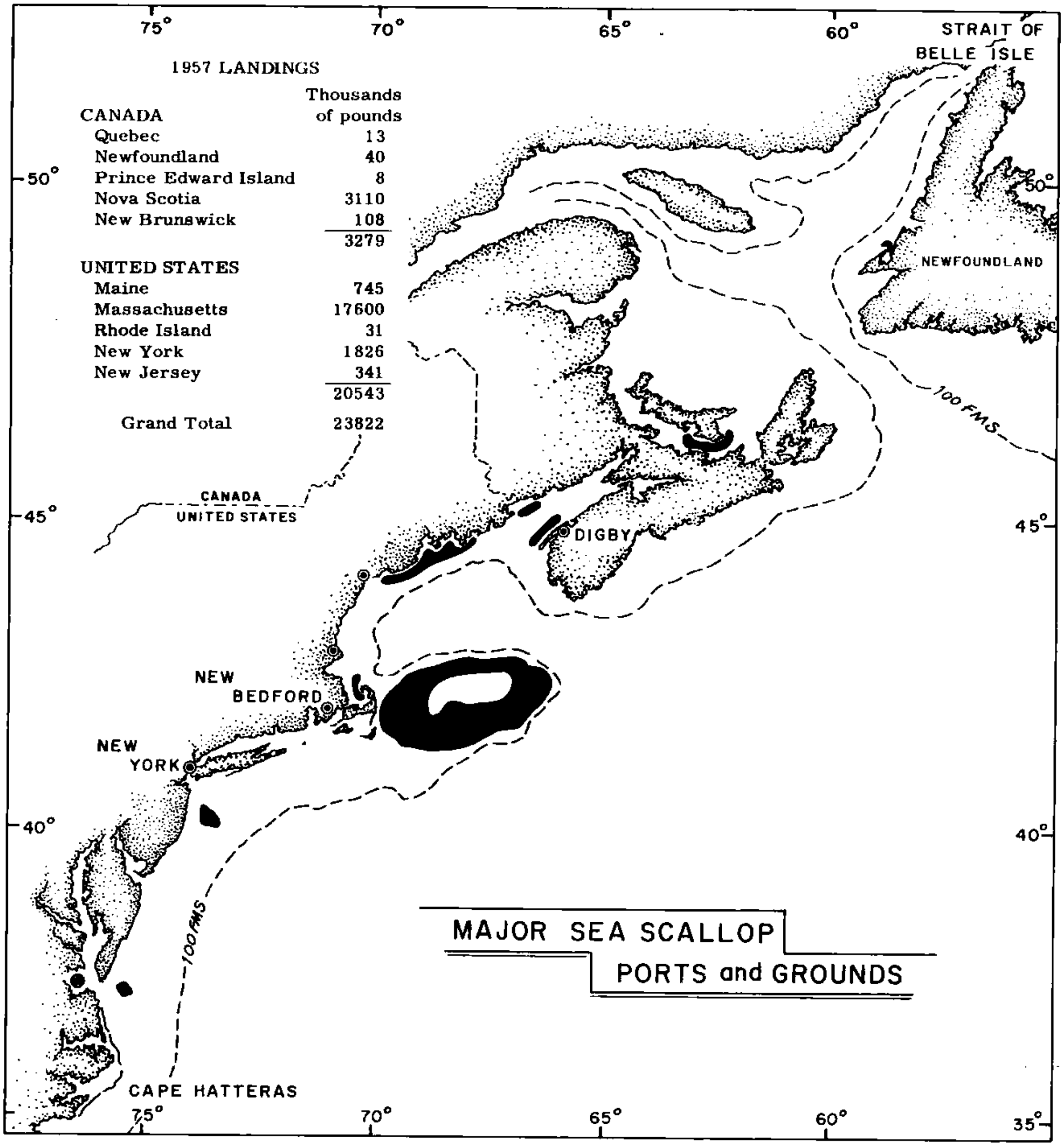
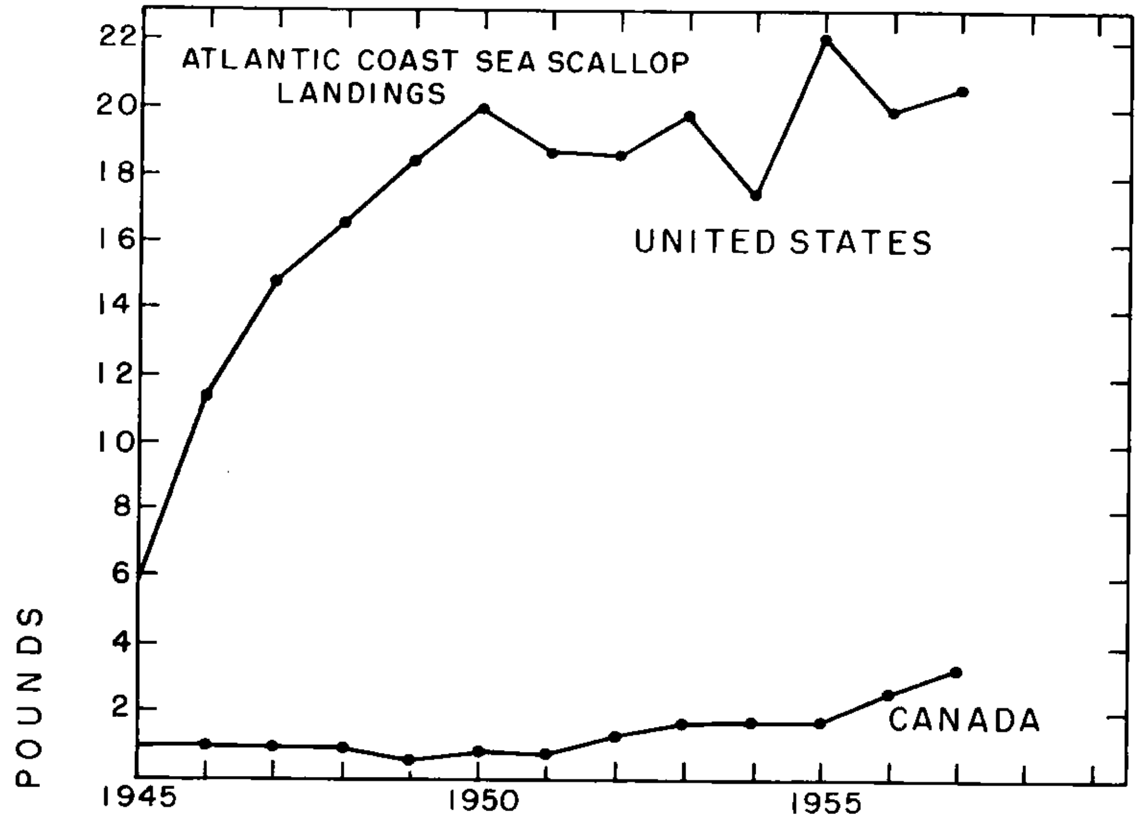
The sea scallop fishery of the Atlantic coast of North America has greatly expanded since the last war until it is now the most valuable of the New England offshore fisheries. Along with the expansion of effort and landings has come an increasing concentration of effort upon the Georges Bank beds, particularly those of the eastern half. During 1957, over 50 percent of the total sea scallop catch was taken from this relatively limited area.

This paper presents a brief summary of the statistical history of the fishery and a more detailed summary of effort and catch on Georges Bank. The catch, effort, and catch per unit of effort of the fleet landing at New Bedford, Massachusetts, the chief sea scallop port, are shown. The gear is described, and the results of gear selection experiments are given. The results are then analyzed by means of a simple population model to demonstrate that the total yield of a year-class would be increased if the fishermen were required to use a savings gear which would postpone the age of first capture.

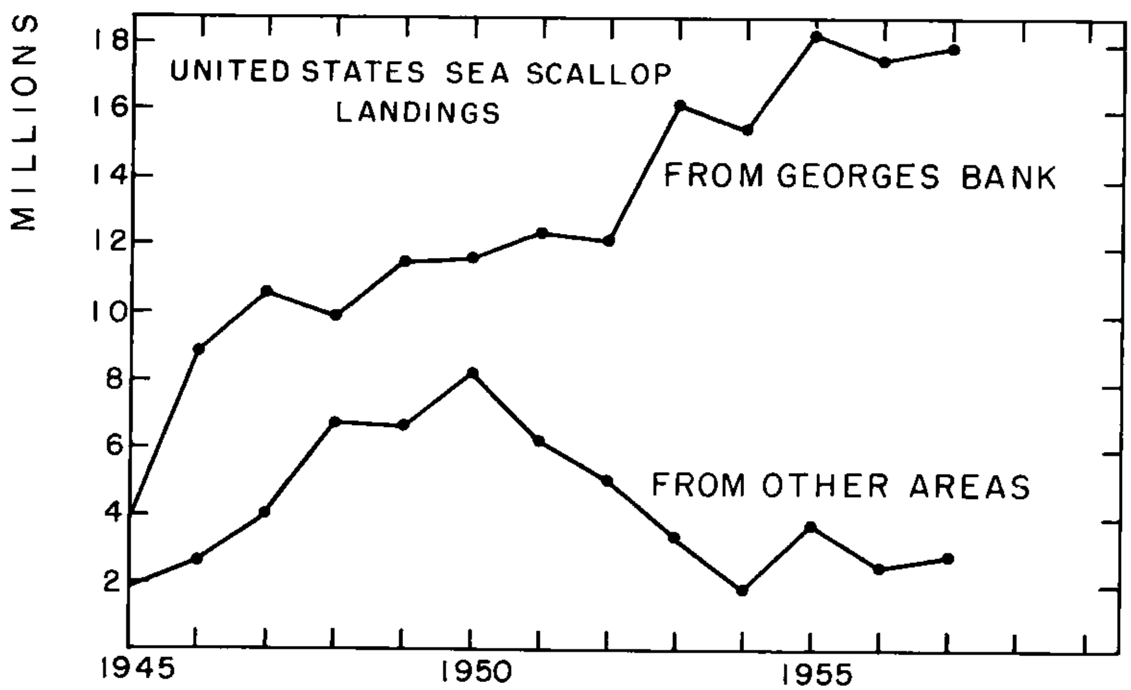


MAJOR SEA SCALLOP PORTS and GROUNDS

The sea scallop, Placopecten magellanicus, is found from the Strait of Belle Isle to Cape Hatteras. The beds are sufficiently dense to support a fishery from the southern shores of the Gulf of St. Lawrence to the Virginia Capes although the Newfoundland and Virginia beds often fail. The 1957 United States catch was valued at 10.1 million dollars ex-vessel.

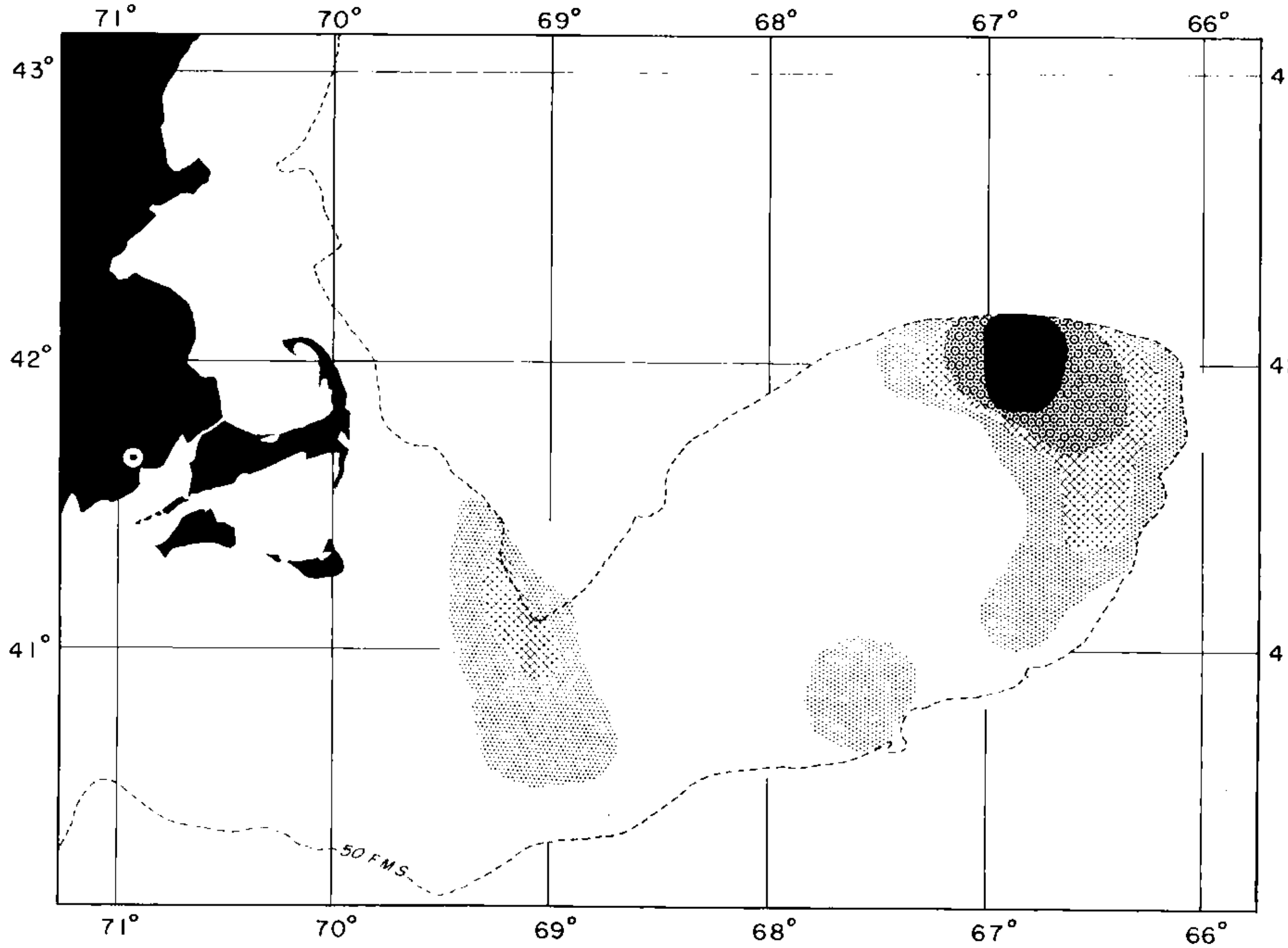


Landings have increased spectacularly since 1945. The total catch went from 6.6 to 23.8 million pounds per year.



The Georges Bank grounds have provided the greater proportion of this increased catch. In 1957, 84 percent of United States landings came from Georges Bank.

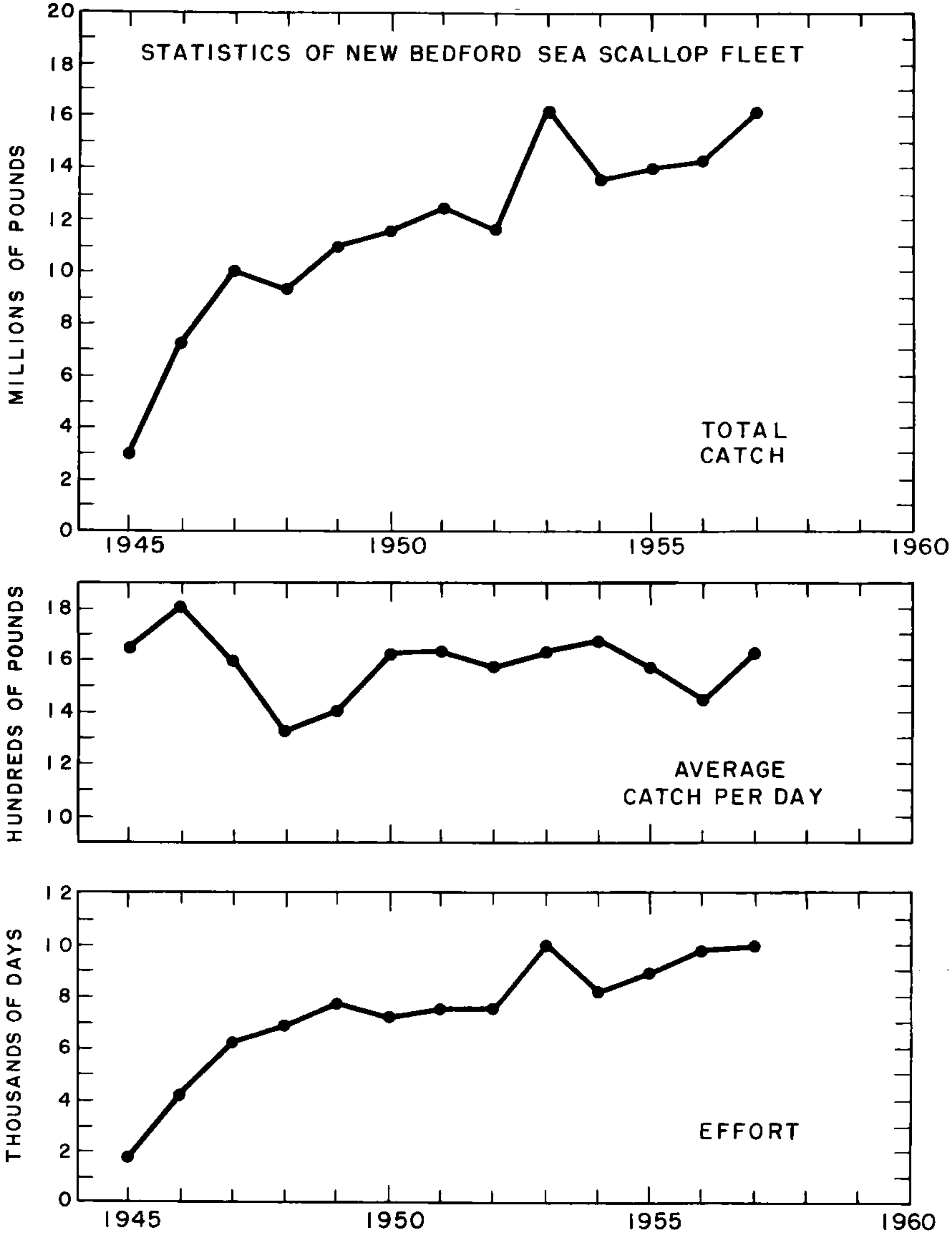
SEA SCALLOP EFFORT ON GEORGES BANK 1944-1957



95,357 DAYS OF FISHING

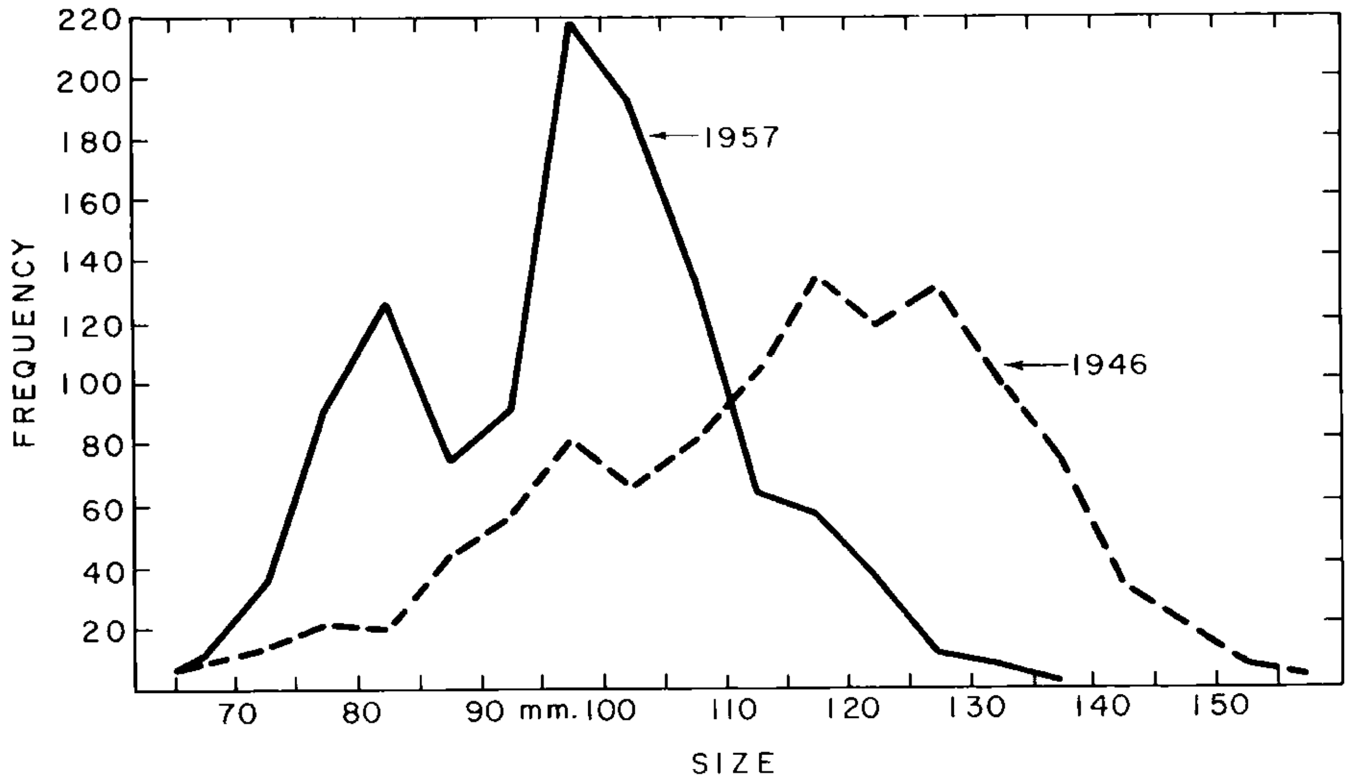
10% 15% 25% 25% 20%

The fleet of sea scallopers which fishes on Georges Bank explores all parts of the bank between the twenty and the sixty fathom curve but, like all fishermen, they tend to congregate where the fishing is best. This chart of effort by area shows that a relatively small part of the available grounds supports a large proportion of the fishing pressure. Ten percent of the total fishing effort of the last fourteen years was expended on less than 3 percent of the area fished and 50 percent on less than 15 percent. The total yield from the fishing effort shown above amounted to 149.8 million pounds of scallop meats. The effort of vessels landing at Canadian ports is not shown.



Almost all of the Georges Bank catch is landed at New Bedford, Massachusetts, and very few of the New Bedford trips come from other areas. Since 1943, the United States Fish and Wildlife Service has collected catch, effort, and area of capture information at New Bedford. These data show that the great rise in landings has been almost entirely a reflection of the greatly increased effort. The average catch per boat per day has not varied much from the average of 1580 pounds.

CHANGE IN SIZE COMPOSITION OF GEORGES BANK SEA SCALLOP CATCHES



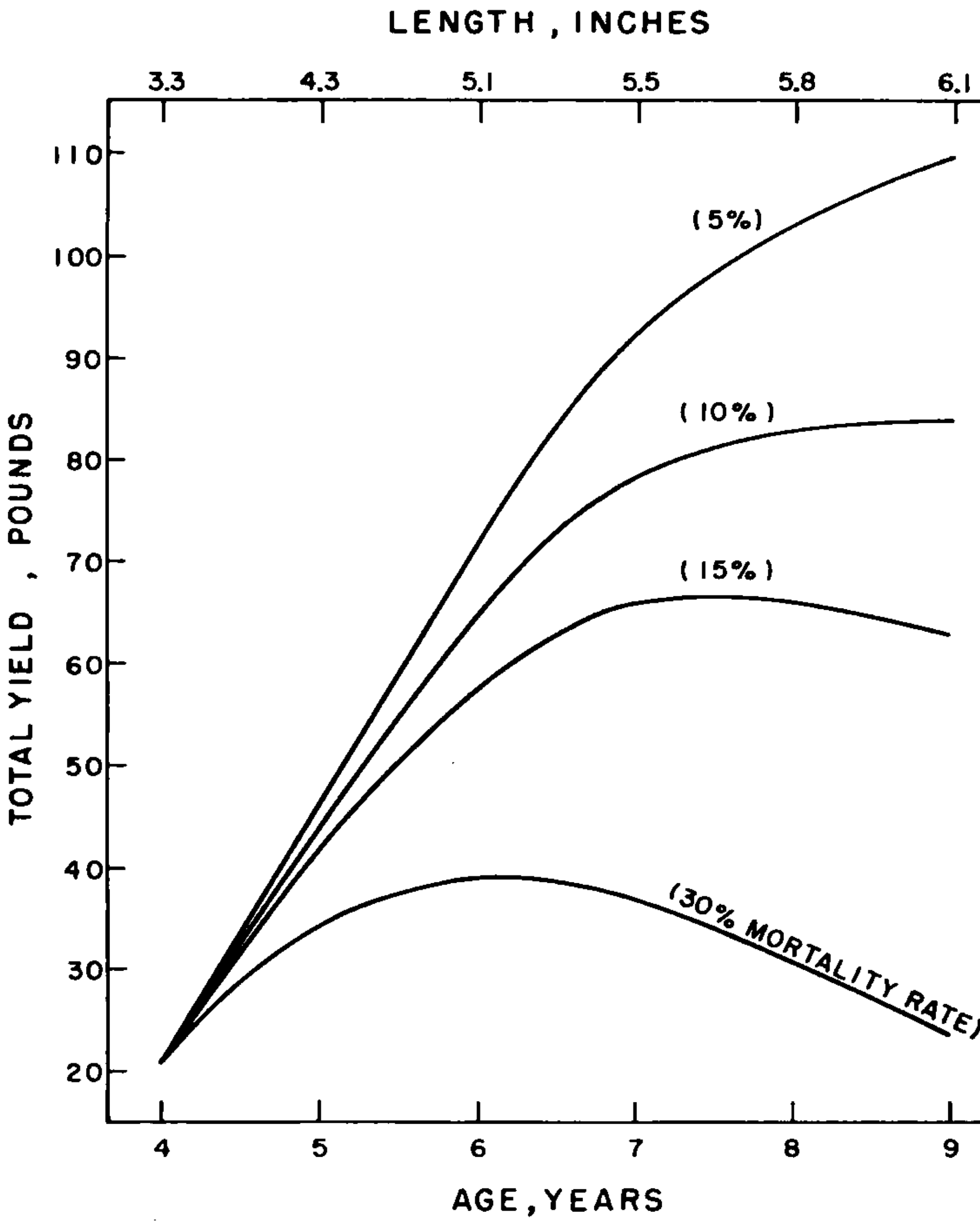
The fishermen claim that the stability of the catch per unit of effort is more apparent than real. They argue that today's boats, larger, more powerful, equipped with ship to shore radios, echo-sounders, Loran and Radar, have a greater fishing power than the boats in use ten years ago. If these factors could be used to weight the effort figures, they say, the catch per unit of effort would show a steady decline.

The fishermen also claim that there has been a drastic decline in the average size of scallop being caught on Georges Bank. This claim cannot be confirmed or denied since there was no regular collection of size distribution samples before 1955. Dr. L. M. Dickie of the Fisheries Research Board of Canada collected one sample in 1946. Another sample collected from the same area in 1957 shows that there were very few of the older, larger scallops which had been present in 1946. Most of the samples which have been collected from the commercial landings since 1955 show that a large fraction of the catch is made up of scallops which have been available to the gear for less than two years.

If we accept the fishermen's claims, since all of the available data supports them and none refutes them, we have the classic pattern of an "old" fishery: expanded landings leveling off, declining catch per unit of effort, declining average size which has about reached the minimum catchable size.

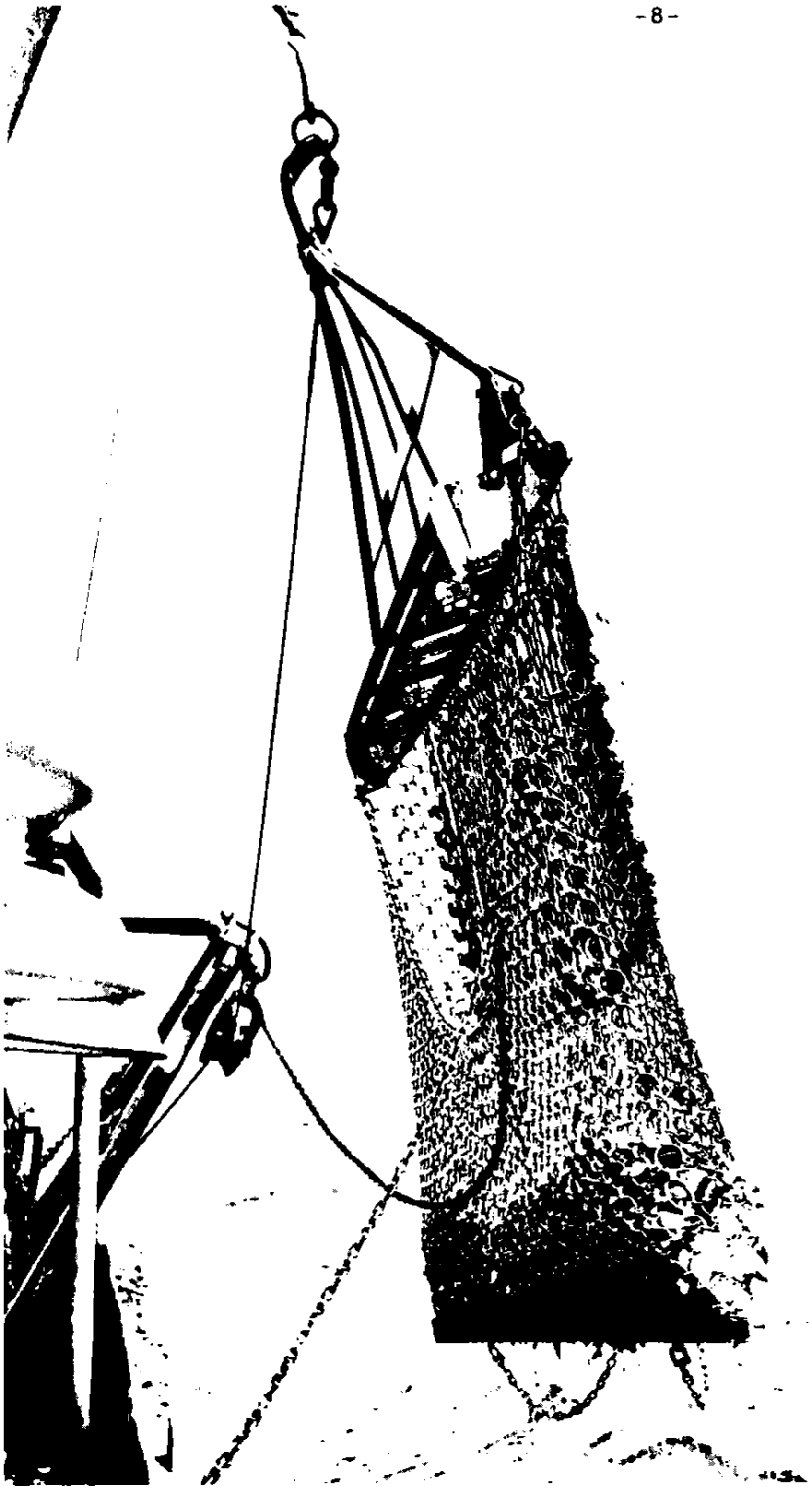
The evident success of the haddock mesh regulation has led many scallop fishermen, particularly those from New Bedford, to ask if something of the same sort would benefit them and their fishery.

CHANGE IN TOTAL YIELD WITH TIME
OF 1000 FOUR YEAR OLD SEA SCALLOPS
AT DIFFERENT MORTALITY RATES



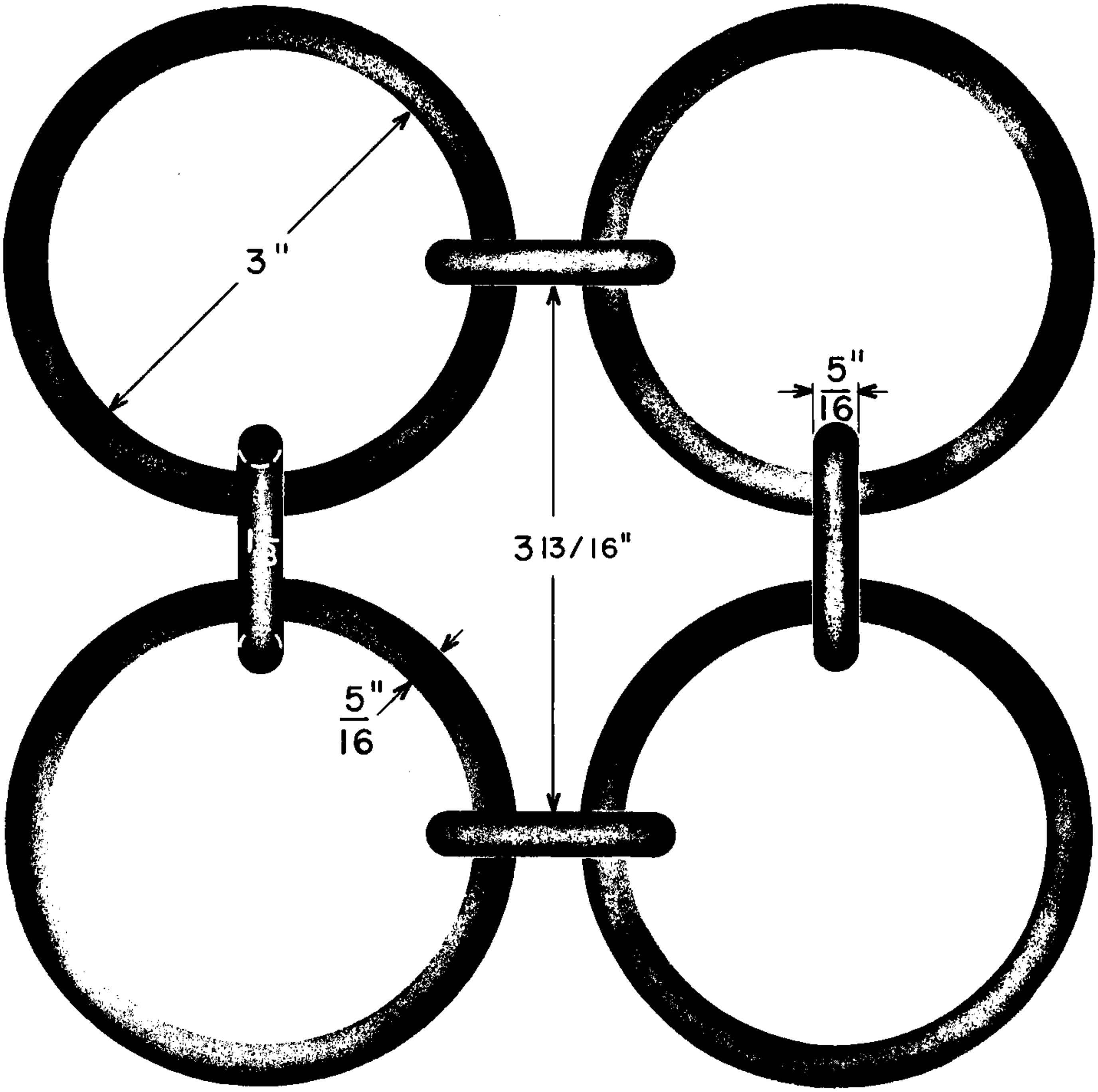
This crude, preliminary analysis of sea scallop population dynamics was made by Posgay (1953). It assumed the rate of growth in weight which had been determined for the Cape Cod Bay beds, a constant rate of natural mortality in the catchable sizes, and 100 percent fishing mortality at any selected age. It predicted an 85 percent increase in yield if all the scallops were fished out at age 6 rather than at age 4 even if the rate of natural mortality were as high as 30 percent per year.

Investigations carried out on Georges Bank since that time, particularly on the growth rate, and a more sophisticated analysis have shown that the predicted increase in yield was too high but that the basic conclusion was valid. Postponement of capture should lead to increased yields.



The type of dredge used by the offshore scallop fleet has been described by Posgay (1957). The heavy, steel frame is usually ten or eleven feet across the mouth. The bag is made up of steel rings and links with a section of rope netting in the back. Other types and sizes of sea scallop dredges are in use on the inshore grounds of Maine, Massachusetts, and Canada but these fisheries usually account for less than 10 percent of total landings.

SCALLOP DREDGE RINGS and LINKS



The only practical way to be sure that small scallops are not shucked and landed is to make it unlikely that they will be caught. This can be done by requiring that the fishermen use a properly designed "savings gear", a dredge made up with a bag whose meshes are too large to retain the smaller sizes.

The present standard for dredges built in New Bedford is to use 5/16 inch by 3 inch rings and 5/16 inch by 1 1/8 inch links. The sketch shows that this results in an inter-ring space of 3 13/16 inches. The rings which come in contact with the bottom are sometimes double and occasionally triple-linked. The twine back is usually 3 inch bar mesh.

MESH SELECTION

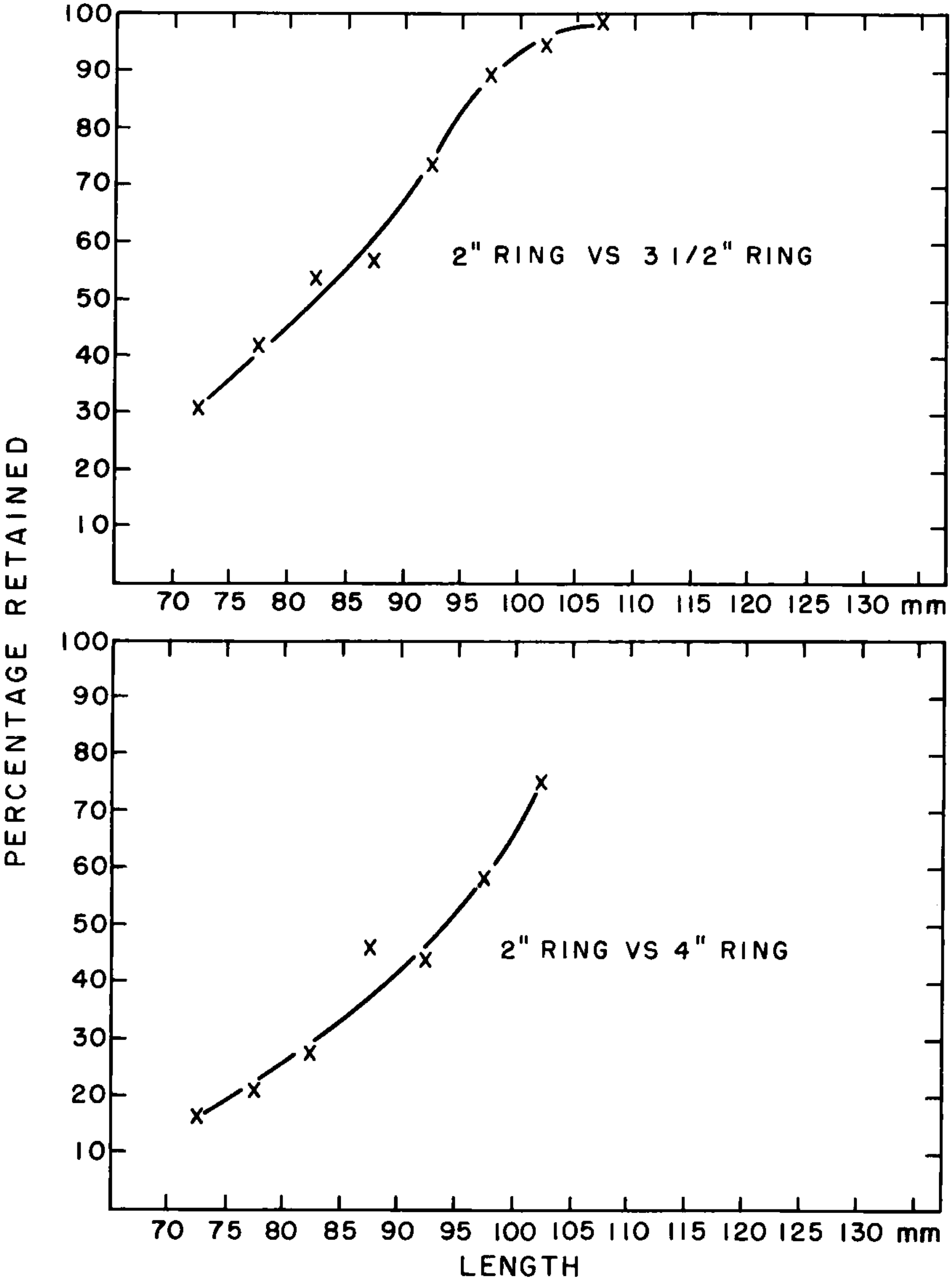
SIZE CLASS (mm)	2" RING	3" RING	PERCENT RETAINED	IRS - MP
70 - 75	292	149	51.1	24.3
75 - 80	678	290	42.7	19.3
80 - 85	645	302	46.8	14.3
85 - 90	252	239	94.8	9.3
90 - 95	129	85	65.9	4.3
95 - 100	274	195	71.2	
100 - 105	373	293	78.6	
105 - 110	289	242	83.7	
110 - 115	188	133	70.7	
115 - 120	146	142	97.3	
120 - 125	167	128	76.6	

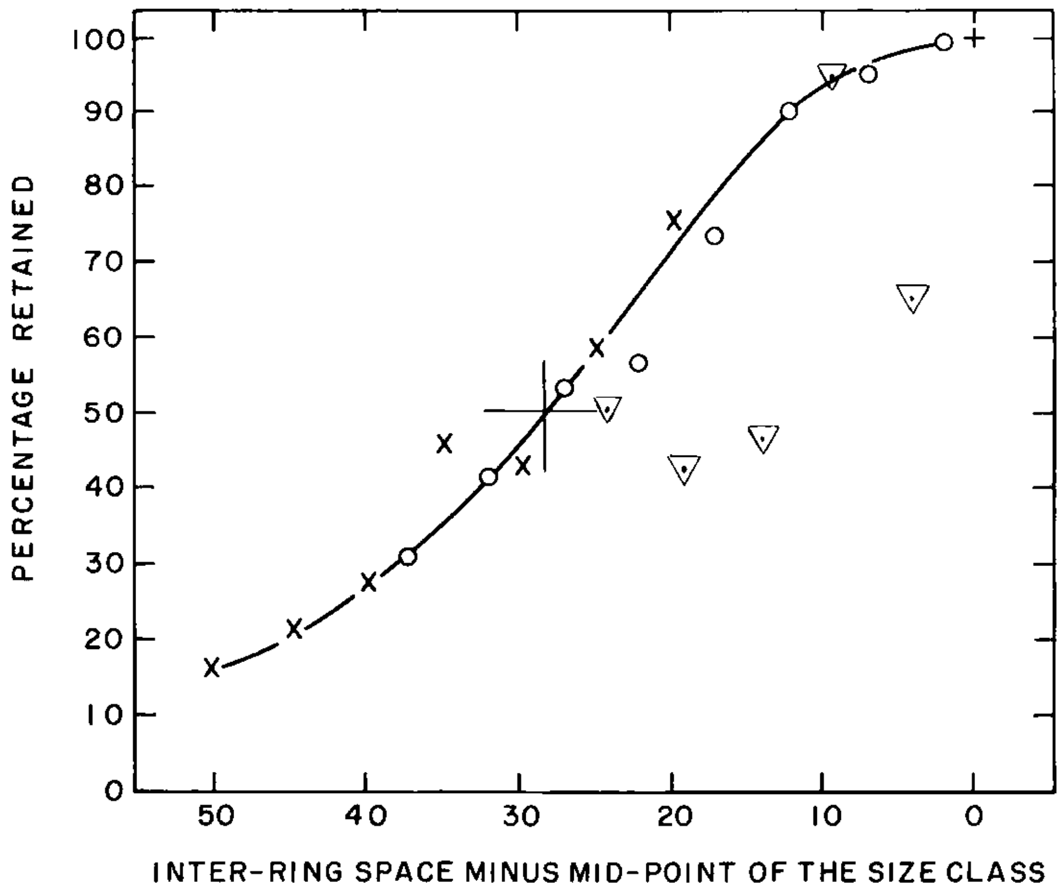
SIZE CLASS	2" RING	3-1/2" RING	PERCENT RETAINED	IRS - MP
70 - 75	2429	754	31.0	37.0
75 - 80	3503	1479	42.2	32.0
80 - 85	3338	1803	54.0	27.0
85 - 90	2103	1206	57.3	22.0
90 - 95	1066	787	73.8	17.0
95 - 100	1527	1380	90.3	12.0
100 - 105	1825	1738	95.2	7.0
105 - 110	1288	1275	99.7	2.0
110 - 115	563	616	109.4	
115 - 120	329	343	104.2	
120 - 125	236	179	75.8	

SIZE CLASS	2" RING	4" RING	PERCENT RETAINED	IRS - MP
70 - 75	1574	263	16.7	49.7
75 - 80	2535	538	21.2	44.7
80 - 85	2757	765	27.7	39.7
85 - 90	1406	649	46.2	34.7
90 - 95	766	337	43.9	29.7
95 - 100	1040	610	58.7	24.7
100 - 105	1332	1011	75.9	19.7
105 - 110	756	814	107.6	14.7
110 - 115	329	369	112.1	9.7
115 - 120	182	247	135.7	4.7
120 - 125	115	136	118.2	

This table shows the mesh selection data collected by towing two dredges simultaneously. One dredge was made up of two inch rings to collect a sample of the population present, and the other was made up with the ring being tested. All dredges were single-linked. As shown on the previous page, the inter-ring space is the largest mesh in the bag. Since a 2 inch ring bag has an inter-ring space of 71.4 mm, it was assumed that all scallops larger than that would be retained. The percent retention points are plotted on page 11. The curves were fitted by eye.

MESH SELECTION

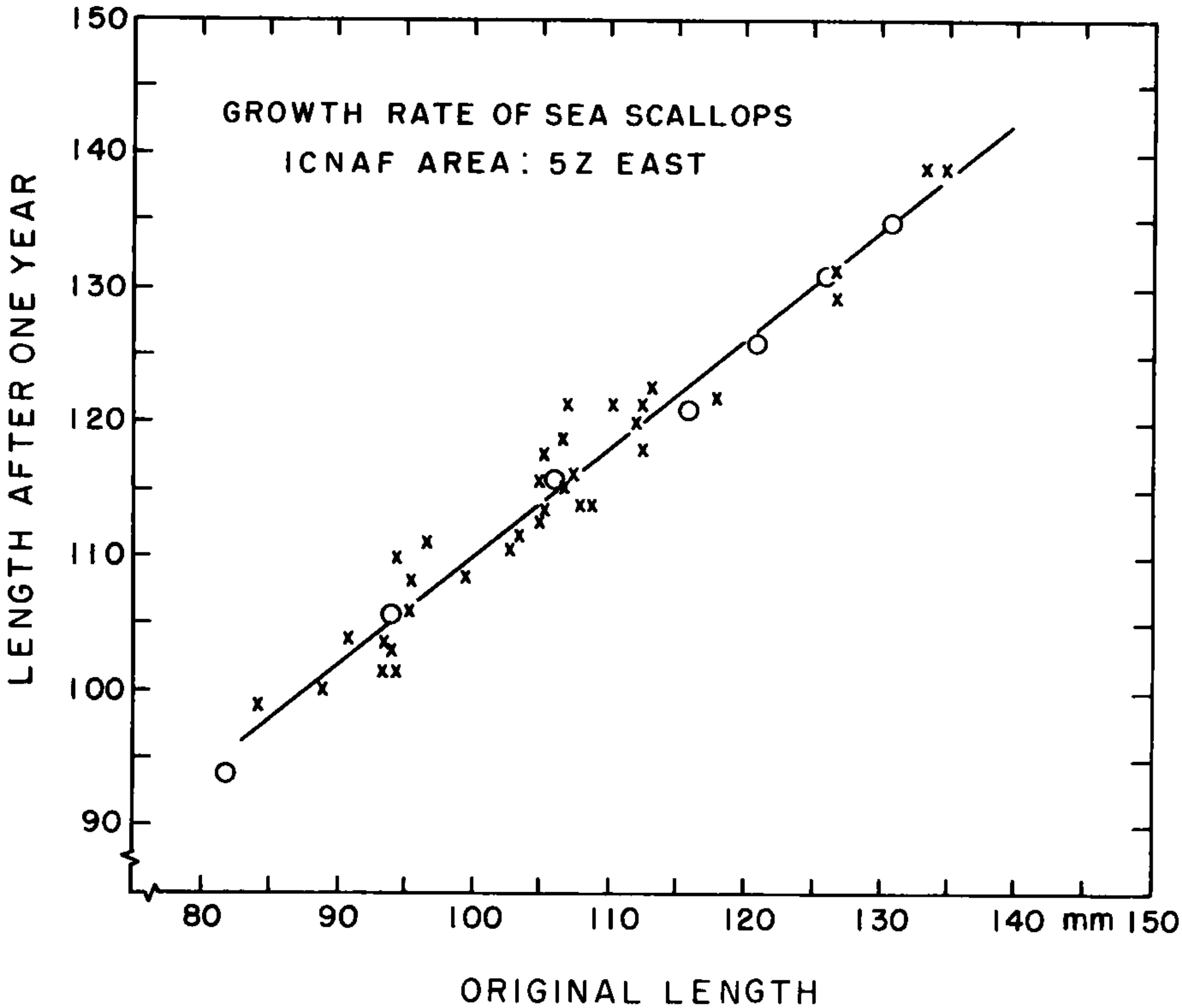




This graph generalizes the results of the mesh selection experiments. Since the inter-ring space is the largest mesh in the dredge bag, it must control the escapement. Scallops which are larger than the inter-ring space are fully retained. Those which are very much smaller than the inter-ring space have a very good chance of escaping and few of them are retained. Those which are only slightly smaller than the inter-ring space have a very poor chance of escaping and most of them will be retained. The percent retention of any size class must, therefore, be related to the difference between the mid-point of the size class and the size of the inter-ring space.

The last column of the table on page 10, headed IRS-MP, gives the difference between the mid-point of the size class and the inter-ring space of the dredge being tested. As shown above, plotting percent retained against IRS-MP gives a very good fit for the data for the 3-1/2 inch ring (circles) and the 4 inch ring (crosses). The 3 inch ring data (triangles) was not considered when the curve was drawn since they seem to be completely anomalous. No good explanation of this anomaly can be offered at this time except the relatively small size of the sample or the small difference between the 2 inch ring and the 3 inch ring. Further work will be done on this problem in the near future.

The cross in the center of the graph shows the location of the 50 percent selection point. A scallop which is 28 mm. smaller than the size of the inter-ring space will have a 50-50 chance of escaping.



The growth rate of sea scallop in the area which sustains most of the fishing pressure on Georges Bank has been established from data on the growth increments of tag returns (crosses) and measurement of shell annuli (circles). The tag returns, all of which had been out over ten months, were extrapolated linearly to a full year. The shell annuli were read by Dr. Dickie from his 1946 sample. The equation of the fitted line is $L_1 = .807\ L_0 + 29.3$.

Large numbers of scallops from the same area have been measured and the meats weighed to arrive at the length-weight equation, $\text{Log } W = 3.56 \text{ Log } L - 5.98820$. These data combined give the growth in weight. Starting at the calculated 50 percent point of the 3 inch ring:

AGE	LENGTH	WEIGHT	INCREASE/YEAR
2	68.8 mm.	3.5 gm.	
3	84.8	7.4	106%
4	97.7	12.3	66
5	108.1	17.6	43

YIELD

The yield to be expected from a year-class during its lifetime in the fishery was calculated using the formula:

$$C_t = \frac{RF}{F + M}\left(1 - e^{-(F + M)t}\right)$$

C_t is the total catch in numbers for the number of years, t, that the stock has been exploited. R is the size of the stock when fishing mortality, F, first affects it; it is calculated from the original stock, R_o, by $R = R_o e^{-Ma}$ when a is the number of years during which no fishing mortality occurred. M is the natural mortality. F and M are instantaneous rates derived from the annual rates by using the formulae:

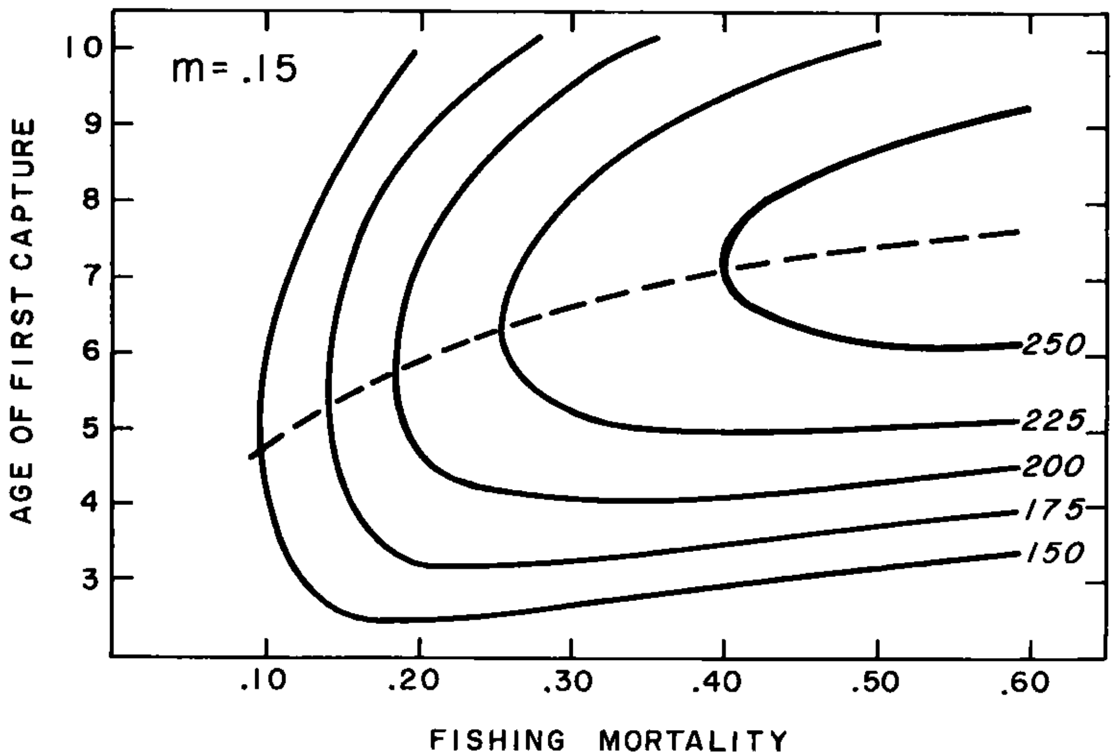
$$\text{Annual total mortality} = 1 - e^{-(F + M)}$$

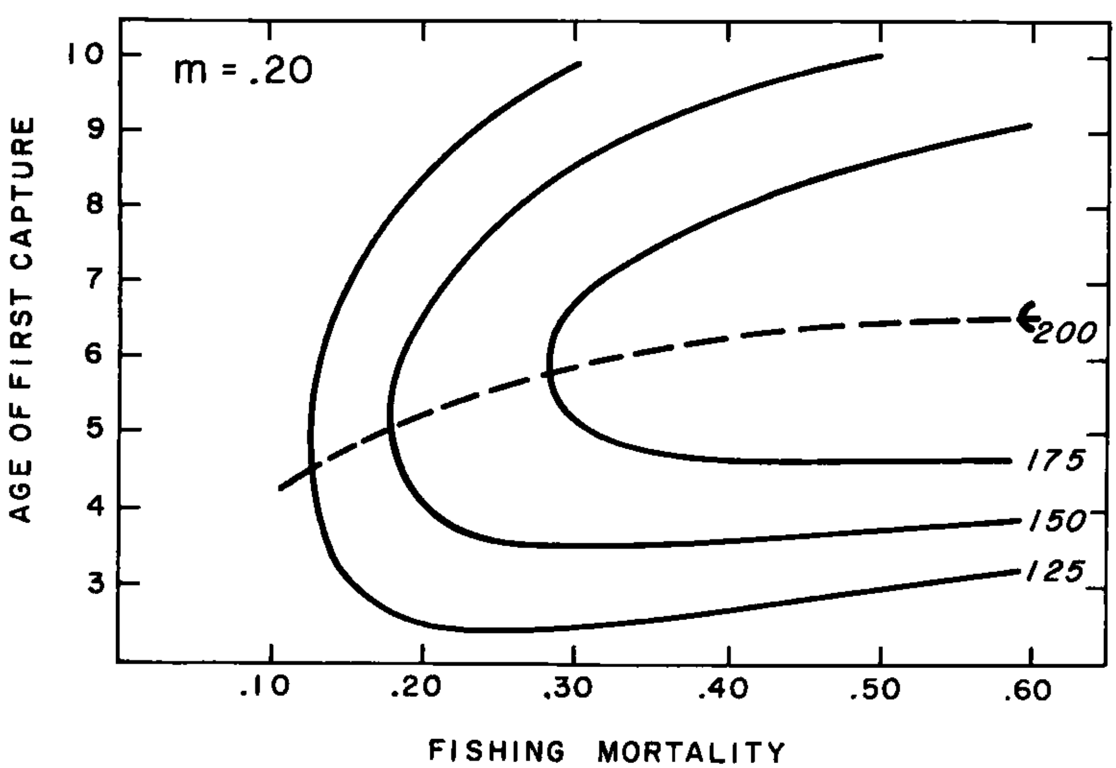
$$\text{Annual fishing mortality} = 1 - e^{-F}$$

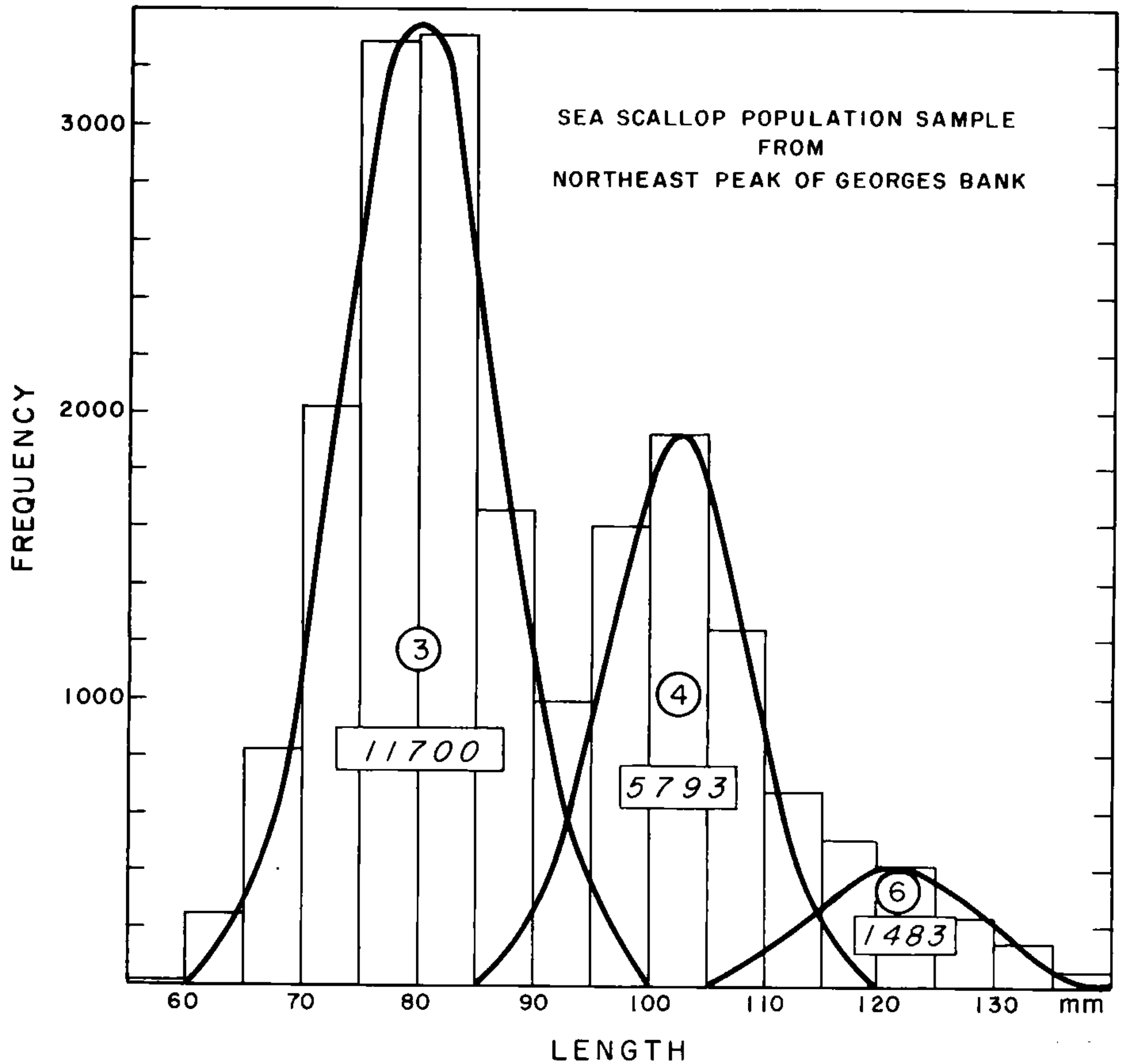
$$\text{Annual natural mortality} = 1 - e^{-M}$$

The original stock, R_o, was taken as ten thousand animals one year before they become available to the gear. Ages of first capture from 3 to 10 were considered for fishing mortality rates of .10, .20, .30, .40, .50, and .60. Very little is known about the natural mortality rate. Dickie (1955) found rates between 4 and 16 percent per year for the Digby beds. To be on the safe side, calculations were made for rather high rates, .15 (14% annual) and .20 (18% annual). A table of annual catch in numbers was compiled, and the average weight of scallops of the various ages was then multiplied by the catch at that age. Yields in weight per year were then summed to give total lifetime yield in weight. These figures were then used to plot the yield isopleth diagrams on page 15.

YIELD IN WEIGHT PER 10,000 RECRUITS







This population sample was collected with a small mesh dredge in an area that has been heavily fished for some years. The histogram shows the raw data to which the normal curves were fitted. The circled numbers give the age of the year-class as determined by counting shell annuli. The numbers in boxes give the total number of individuals present in each year-class.

The three year olds have been available to the commercial gear for about six months. Assuming that each year-class was about the same size when it entered the fishery, the six year olds show an average annual total mortality of .69, the fours, of .70. This is not, of course, a very precise estimate but it does indicate that it is the right half of the yield isopleth diagrams that most closely represents the present condition of the Georges Bank fishery.

Evidence has been presented to demonstrate that a postponement of first capture would increase the total yield of a year-class during its lifetime in the fishery. The available data show that the growth in weight is rapid, the natural mortality is low, fishing pressure on the most productive grounds is high, and that a savings gear is possible.

REFERENCES

Dickie, L. M., 1955. Fluctuations in abundance of the giant scallop, *Placopecten magellanicus* (Gmelin) in the Digby area of the Bay of Fundy. *J. Fish. Res. Bd. Canada*, XII, pp. 797-857.

Posgay, J. A., 1953. Sea scallop investigations. Sixth Report on Investigations of the Shellfisheries of Massachusetts. Comm. of Mass., Dept. Nat. Res., Div. of Mar. Fish.

Posgay, J. A., 1957. Sea scallop boats and gear. Fishery Leaflet 442, U. S. Dept. Int., Fish & Wildlife Service.