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# UNITED STATES SEA SCALLOP RESEARCH IN SUBAREA 5 DURING 1958

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At the 1958 annual meeting of the Committee on Research and Statistics an *ad hoc* subcommittee was appointed to consider the available information on the sea scallop (*Placopecten magellanicus*) fishery of Subarea 5 in the light of a possible mesh regulation. The report of this subcommittee (Appendix III, 1958 Report of the Standing Committee on Research and Statistics) stated: "The rate of growth of sea scallops in relation to the likely mortality rate in the Georges Bank area seems to be so high in and above the present selection range of the gear that postponing the age of first capture is likely to increase the yield." The subcommittee therefore advised that particular emphasis in the research program should be placed on the collection of data on growth and mortality rates in various areas, tagging experiments designed to give mortality estimates, collection of catch and effort statistics from Canadian and United States vessels, measurement of the amount of area swept during a unit fishing time, attempts to measure the relative strengths of pre-recruit year-classes, fundamental research on the biology of the scallop and on its environment, and a direct measurement of natural mortality. This paper reports the progress made during the past year by United States investigators in implementing these recommendations.

## Catch and Effort Statistics

The catch and effort statistics are presently being collected in eight United States ports of landing. Both the United States and Canada are forwarding their statistics, tabulated by 10-minute unit area squares, at monthly intervals to the ICNAF. The 1958 yearly summary for both fleets is shown in Figure 1. The catch and effort of the 123 trips for which either effort or area of capture information is lacking has been distributed according to the fishing pattern of the respective fleet. In addition to the 17.1 million pounds from Georges Bank, the United States had landings of 3.0 million pounds and Canada 0.7 million pounds of sea scallop meats from other areas. The total landings of 20.8 million pounds makes 1958 the lowest year since 1954.

## Area Swept per Day

The amount of bottom area swept in a day of fishing effort has been estimated from data collected on three trips made on commercial scalloping vessels. The three trips had a total of 18.6 days of fishing effort during which the dredges were on the bottom fishing for 343.5 hours. They were towed at an average speed of 4.0 knots. Assuming that the effect of the tidal currents cancelled out, the two 11-foot dredges were towed 74 nautical miles per day, sweeping 0.27 square miles of bottom. At this rate, it would take 278 days to completely sweep the 75 square miles of a unit area. An attempt to get a direct measure of the area swept failed when the odometer attached to the dredge was badly damaged. A sturdier version of the odometer is being built and will be tested soon.

## Relative Strength of Pre-recruits

Samples of the pre-recruit year-class have been collected but we do not yet have anything with which to compare them. A cruise is planned for this May which should give added information.

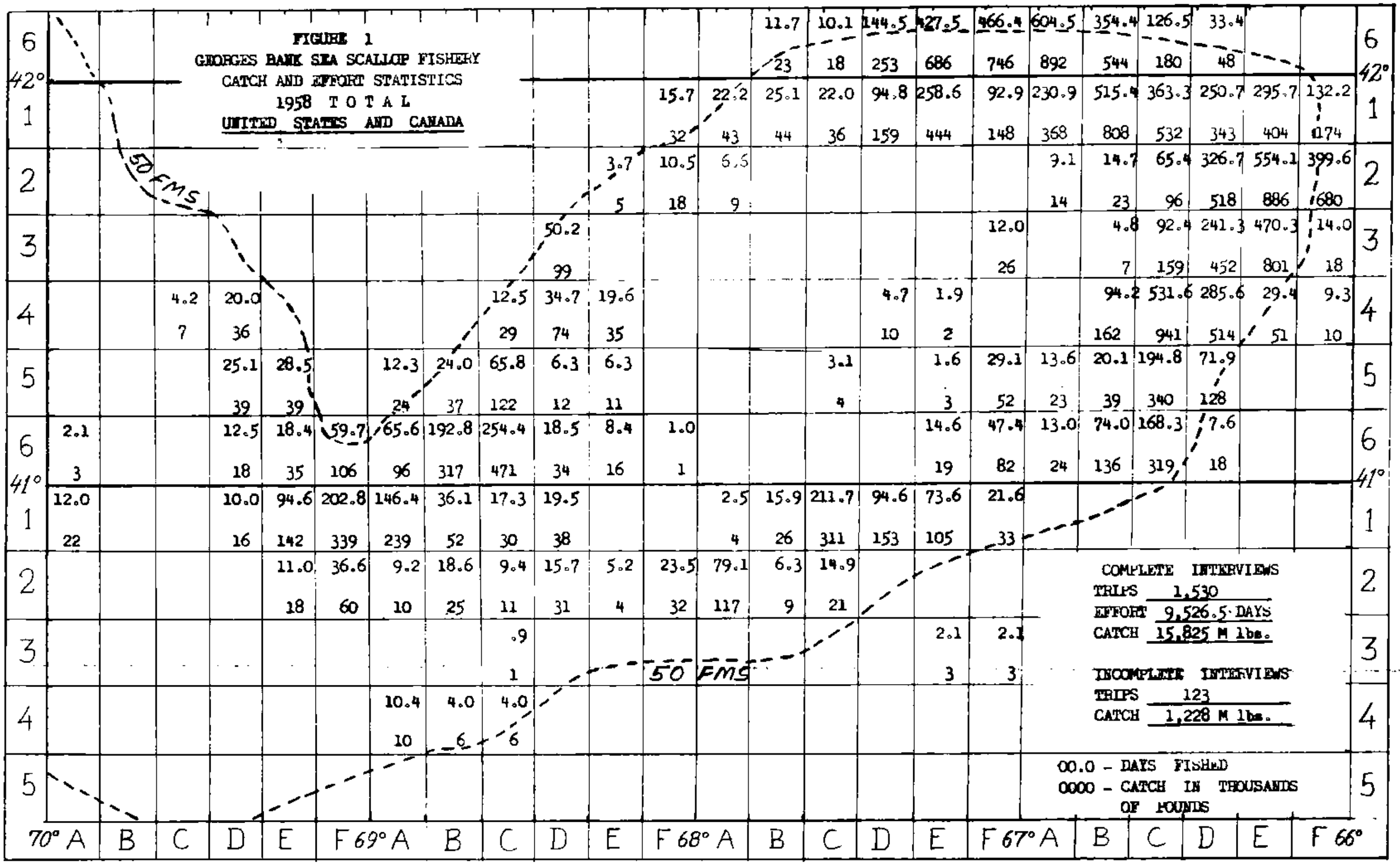
FIGURE 1
GEORGES BANK SEA SCALLOP FISHERY
CATCH AND EFFORT STATISTICS
1958 T O T A L
UNITED STATES AND CANADA
6
42°
1
2
3
4
5
6
41°
1
2
3
4
5
70° A
B
C
D
E
F 69° A
B
C
D
E
F 68° A
B
C
D
E
F 67° A
B
C
D
E
F 66°
50 FMS
50 FMS
11.7 23
10.1 18
144.5 253
427.5 686
466.4 746
604.5 892
354.4 544
126.5 180
33.4 48
15.7 32
22.2 43
25.1 44
22.0 36
94.8 159
258.6 444
92.9 148
230.9 368
515.4 808
363.3 532
250.7 343
295.7 404
132.2 174
3.7 5
10.5 18
6.5 9
9.1 14
14.7 23
65.4 96
326.7 518
554.1 886
399.6 680
50.2 99
12.0 26
4.8 7
92.4 159
241.3 452
470.3 801
14.0 18
4.2 7
20.0 36
12.5 29
34.7 74
19.6 35
4.7 10
1.9 2
94.2 162
531.6 941
285.6 514
29.4 51
9.3 10
25.1 39
28.5 39
12.3 24
24.0 37
65.8 122
6.3 12
6.3 11
3.1 4
1.6 3
29.1 52
13.6 23
20.1 39
194.8 340
71.9 128
2.1 3
12.5 18
18.4 35
59.7 106
65.6 96
192.8 317
254.4 471
18.5 34
8.4 16
1.0 1
14.6 19
47.4 82
13.0 24
74.0 136
168.3 319
7.6 18
12.0 22
10.0 16
94.6 142
202.8 339
146.4 239
36.1 52
17.3 30
19.5 38
2.5 4
15.9 26
211.7 311
94.6 153
73.6 105
21.6 33
11.0 18
36.6 60
9.2 10
18.6 25
9.4 11
15.7 31
5.2 4
23.5 32
79.1 117
6.3 9
14.9 21
.9 1
2.1 3
2.1 3
10.4 10
4.0 6
4.0 6
COMPLETE INTERVIEWS
TRIPS 1,530
EFFORT 9,526.5 DAYS
CATCH 15,825 M lbs.
INCOMPLETE INTERVIEWS
TRIPS 123
CATCH 1,228 M lbs.
00.0 - DAYS FISHED
0000 - CATCH IN THOUSANDS OF POUNDS

Biology

We have been successful for the first time in collecting specimens of the early postlarval stages. Baird (1953) has reported the collection of two small samples of sea scallops ranging from 1150 to 2250 microns but, with this exception, no one has ever reported the collection of any smaller than about 5 mm. We found several thousand specimens, ranging in size from 250 microns to 14 mm, attached by their byssal threads to the inner wall of the stabilizer tube of a navigation buoy. This observation confirms our previous assumption that the egg and larval stages of the sea scallop are pelagic.

Tagging Experiments

Four tagging experiments have been conducted on Georges Bank since 1955. The first two were rather small scale preliminary attempts to test techniques and gather information on growth rates. In the first, 825 sea scallops were tagged and released at three locations (Figure 2) in December 1955. By March 1, 1959, 2.2 percent had been recovered in the 38 months that had passed. In the second, 2100 scallops were tagged and released at eleven locations (Figure 2) in July 1956. In 32 months, 3.3 percent were recovered.

The scallops in these two experiments were tagged with a single, numbered Petersen disc pinned through the anterior ear of the left valve. This is the only place on a sea scallop where a tag can be fastened without wounding the animal. However, the tags are not very conspicuous and this valve is held down in the fisherman's left palm when the scallop is being shucked. We therefore believe that the low rate of return is caused by tags not being seen. To make the tags more conspicuous, we added a 6-inch length of yellow plastic tape to the disc in the next two experiments.

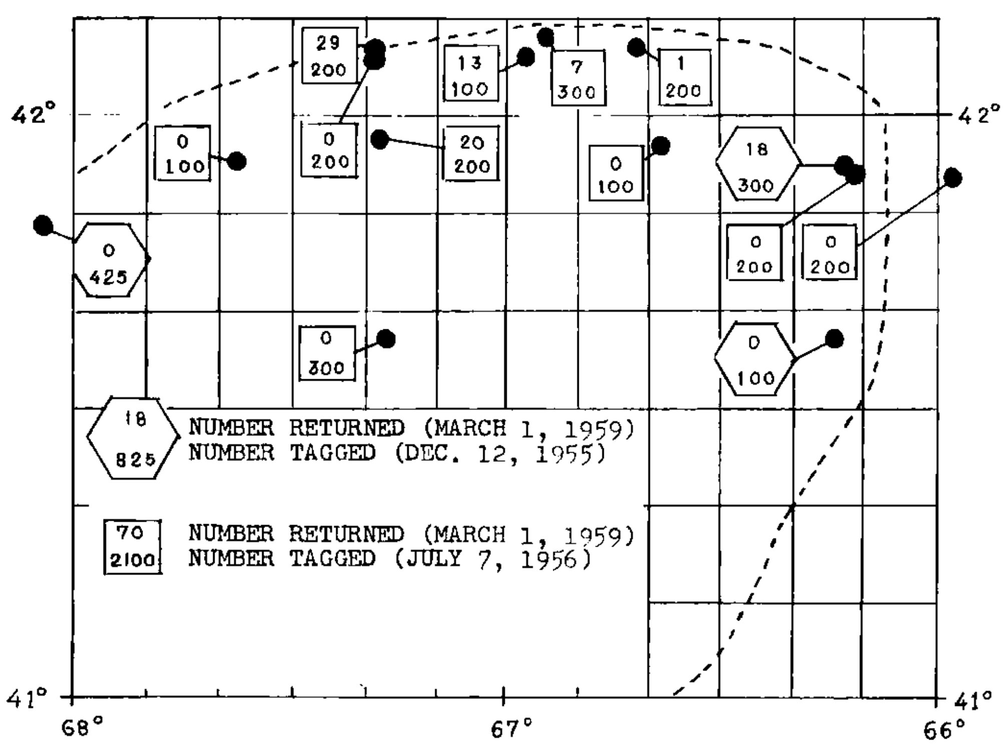


Figure 2. --1955 and 1956 tagging experiments.

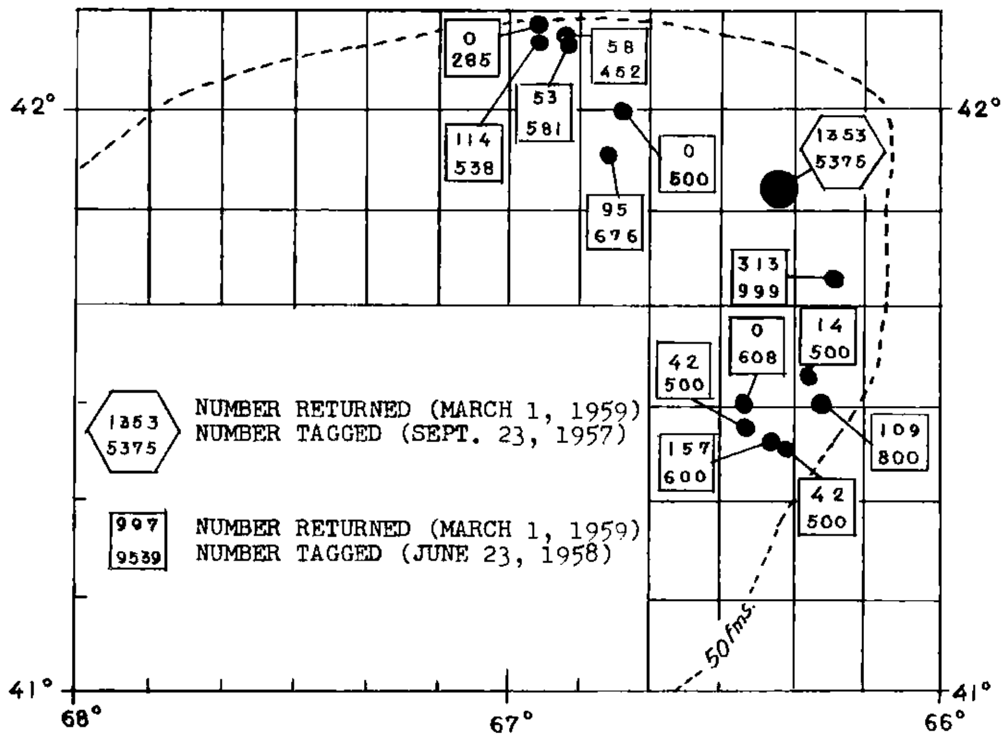


Figure 3. -- 1957 and 1958 tagging experiments.

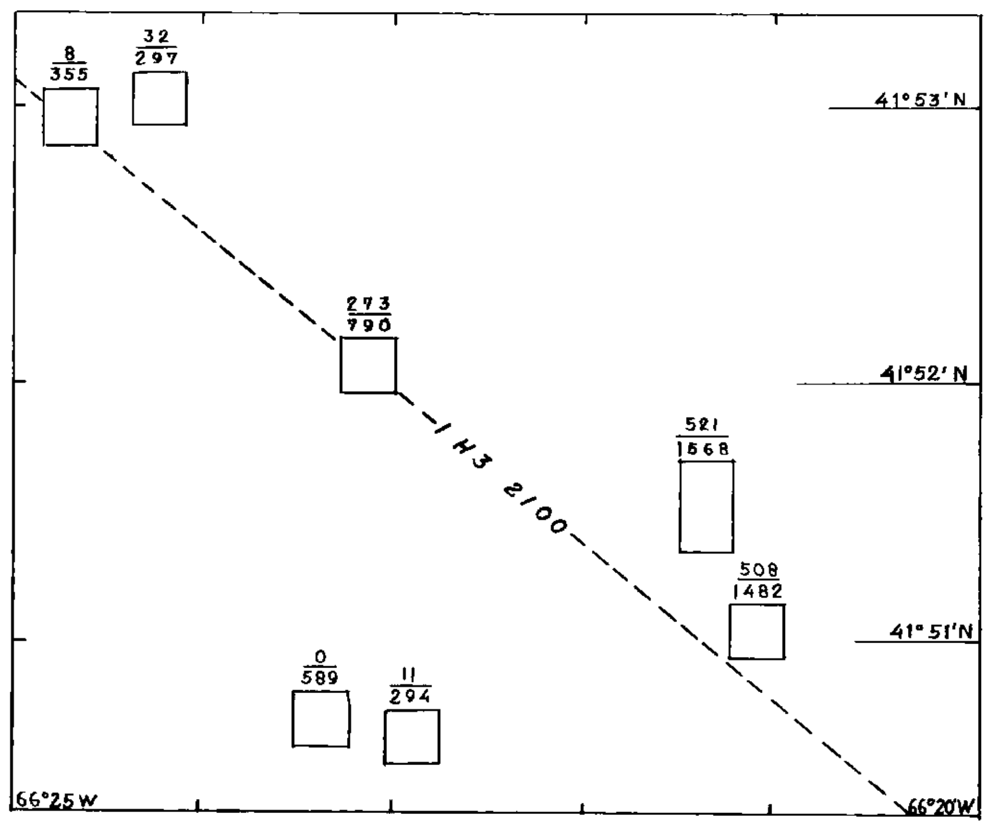


Figure 4. Sea Scallop Tagging, Sept. 1957. The numbers show the number of tag returns as of March 1, 1959, over the number released.

The third tagging experiment was set up primarily to measure the rate of return of tags from a limited area as a function of the fishing effort within the area. 5375 tagged scallops were released in September 1957 (Figures 3 and 4). There were 198 returned during the remainder of 1957 and 1106 during 1958. We had hoped to measure the amount of effort expended within the area of liberation rather precisely, but this was not possible so it was necessary to fall back on the assumption that the effort within the unit area (10-minute square) in which the scallops were released was distributed at random over the unit area. This assumption is probably not strictly valid for a short time interval but should be resonably true for heavily fished areas over several years. Realizing that it is only a first approximation, we have used the 1958 data to calculate $\bar{F}$ = (.000957) (days fished per unit area per year).

The fourth tagging experiment is another attempt to measure the mortality rate. This time, instead of concentrating the tags in a small area, they were released in groups of 500 or so in a pattern roughly comparable to the distribution of the fishing effort on the eastern half of Georges Bank (Figure 3). 997 tagged shells, 13.2 percent, were returned in the first eight months after release.

The 2438 tagged sea scallop shells that have so far been returned out of the 15,839 that have been released have provided an extremely valuable body of data on growth rates by area and by season. They have also established the fact that sea scallop beds move very little if at all. Over 95 percent of the returned tags were reported as being recaptured at the same place where they had been released. Most of the remaining 5 percent are either obvious navigation errors or errors in recording. There remain only about ten shells which may possibly have moved from the point of release.

Natural Mortality Rate

Dickie (1955) has described an ingenious method of directly estimating the natural mortality rate of sea scallops. It depends on the fact that the two valves of a scallop which has died from natural causes remain attached at the hinge for some period of time while the fishermen always break the hinge and separate the valves when they shuck out the meats. Part of every dredge haul is made up of these "clappers" along with live scallops, single shells, and other trash. The clapper/live scallop ratio divided by the fraction of a year that the clappers persist before the hinge ligament decomposes and the valves separate gives an estimate of the instantaneous natural mortality rate. Table 1 gives the results of applying this formula

$$M = \frac{C}{L} \times \frac{365}{t}$$

to clapper shell/live scallop ratios collected at various places on Georges Bank. The number of days that the clappers persist, t, was taken as 100 days, the value given by Dickie (1955) as the result of some tank experiments. His calculations for the Digby area gave an average value of 0.10.

Making the reasonable assumption that live scallops and clappers are equally liable to capture by scallop gear, the sensitive parameter is t. It seems likely that clappers would separate more rapidly on the fishing grounds than in a tank because of currents and dredging action but even if we halve the value of t and thus double our estimate of M, it would still only bring the average estimate of M for Georges Bank up to 0.18, about 16 percent per year. Posgay (1958) has presented yield isopleth diagrams (Figure 5) which were calculated for natural mortality rates of 0.15 and 0.20. It now seems that these diagrams are, if anything, conservative.

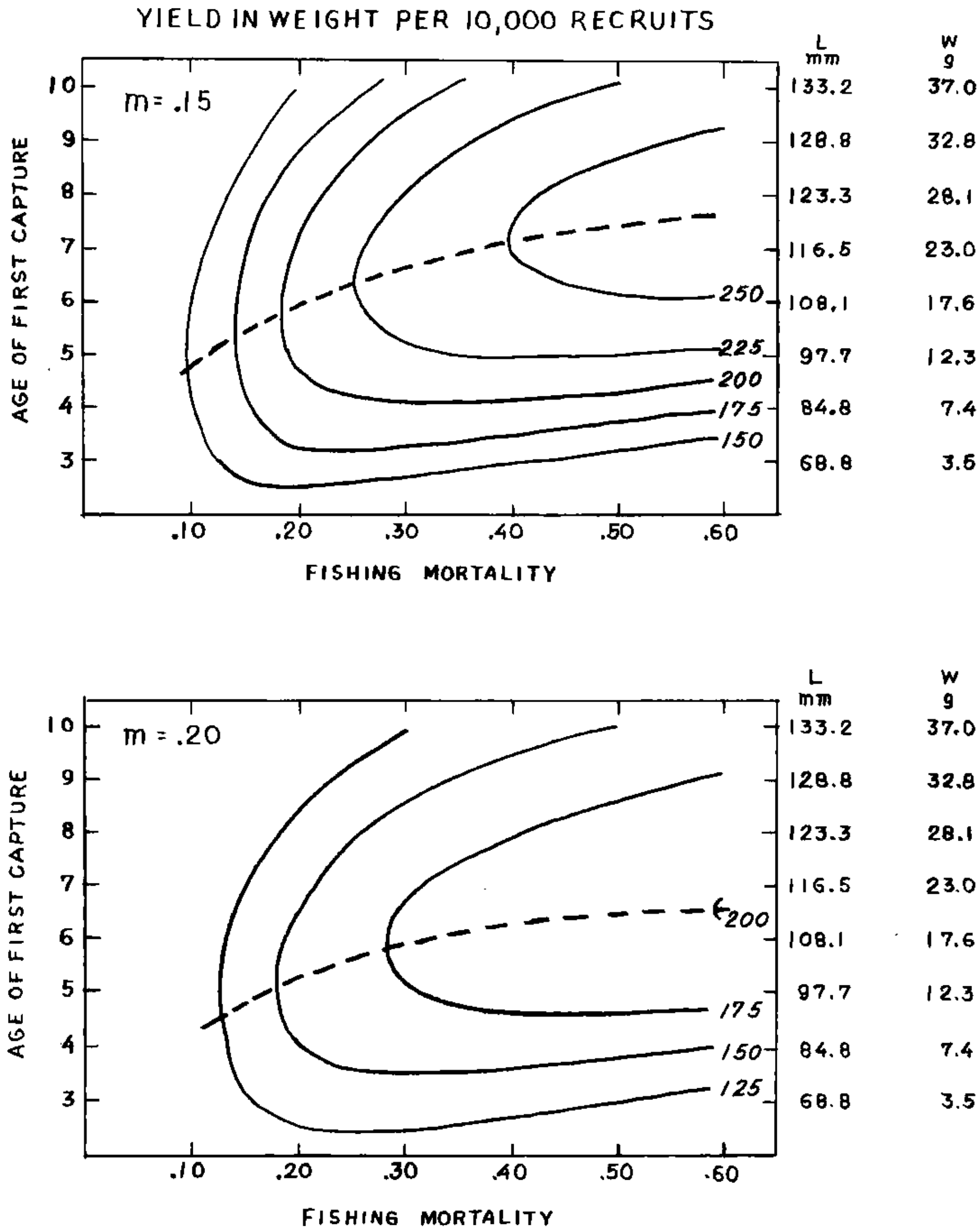


Figure 5. Yield isopleth diagrams calculated for the Georges Bank sea scallop fishery using the growth rate shown in the two right-hand columns. The contour values are in pounds.

TABLE 1. Natural mortality rate from the ratio of clapper shells (C) to live scallops (L) $M = \frac{(C)}{(L)} \times \frac{(365)}{(100)}$

| Length (mm) | Channel L | Channel C | Channel M | N.E. Peak N. Edge L | N.E. Peak N. Edge C | N.E. Peak N. Edge M | Bird's Bill L | Bird's Bill C | Bird's Bill M | Total M |
|---|---|---|---|---|---|---|---|---|---|---|
| 85- 95 | 118 | 15 | .464 | 4408 | 30 | .025 | 2286 | 80 | .128 | .067 |
| 95-105 | 439 | 11 | .091 | 2540 | 21 | .030 | 1522 | 79 | .189 | .090 |
| 105-115 | 302 | 16 | .193 | 1171 | 25 | .078 | 926 | 53 | .209 | .143 |
| 115-125 | 134 | 2 | .054 | 933 | 26 | .102 | 328 | 12 | .133 | .104 |
| 125-135 | 49 | 1 | .074 | 888 | 15 | .062 | 83 | 5 | .220 | .075 |
| 135-145 | -- | -- | | 350 | 9 | .094 | 15 | -- | | |
| 85-145 | 1042 | 45 | .158 | 10290 | 126 | .045 | 5160 | 229 | .162 | .088 |

## Fishing Mortality

We have two kinds of data from which to calculate the rate of fishing mortality; year-class frequency distributions and the rate of return of tagged animals. We have analyzed many length frequency distributions to determine the relative numbers of the successive year-classes and then calculated the total mortality rate. Subtracting the natural mortality estimate derived from the clapper/live scallop ratio we have obtained values of F ranging from about .2 to about .7. The necessary assumption of equal recruitment each year is probably too gross to regard these values as anything more than maximum-minimum estimates, and we have not made any attempt to relate them to fishing intensity. As pointed out above, estimates of fishing mortality rates derived from rate of tag returns should probably be regarded with some degree of caution until more data have accumulated but these data are the most reliable that are presently available.

The rate of return of tagged scallops from the September 1957 tagging experiment gives $\hat{F}$ = (.000957) X (days fished/unit area/year) if the fishing effort was distributed either uniformly or at random over the entire 75 square miles of the unit area. If the effort was not distributed over the entire unit area but was concentrated on some smaller section, the apparent value of the second term, (days fished/unit area/year), will be smaller than the true value and the estimate of F will be too low.

Since it has been shown above that it requires at least 278 days of fishing effort to completely sweep a unit area, it must follow that any unit area which had much less than 278 days of fishing effort per year was not completely swept. It may have been fished at random but the more likely presumption, fishermen being what they are, is that the boats found a small pocket which they fished until it was cleaned out.

We have therefore calculated an average value of F = .31 for Georges Bank in 1958 from the amount of effort expended on the 25 most heavily fished unit areas (Figure 1). These accounted for a total of 8092.3 days of fishing and landings of 13,148 thousand pounds, 77 percent of the total landings from Georges Bank. The least heavily fished area of this group had 144.5 days of fishing and the most heavily fished had 694.5 days with an average of 323.7 days/unit area/year.

**TABLE 2. Length and weight of sea scallops at time of formation of the annual ring**

| AREA | N.E. PEAK | | N. EDGE | | BIRD'S BILL | | CHANNEL | | DIGBY | |
|---|---|---|---|---|---|---|---|---|---|---|
| NUMBER IN SAMPLE | 426 | | 254 | | 178 | | 1035 | | 172 | |
| RING NO. | L(mm) | W(gm) | L(mm) | W(gm) | L(mm) | W(gm) | L(mm) | W(gm) | L(mm) | W(gm) |
| 1 | 11.2 | | 13.0 | | 16.8 | | 19.5 | | 13.1 | |
| 2 | 30.2 | | 34.1 | | 41.1 | | 53.9 | 2.4 | 25.4 | |
| 3 | 51.8 | 1.3 | 56.4 | 3.1 | 67.5 | 3.7 | 79.7 | 7.1 | 58.3 | 2.3 |
| 4 | 79.9 | 6.0 | 80.8 | 7.7 | 87.0 | 8.0 | 97.3 | 12.4 | 82.8 | 6.7 |
| 5 | 98.5 | 12.6 | 96.7 | 12.2 | 97.1 | 11.2 | 108.5 | 16.5 | 97.5 | 10.9 |
| 6 | 110.4 | 19.0 | 107.5 | 16.1 | 104.4 | 14.1 | 117.2 | 20.7 | 107.8 | 14.8 |
| 7 | 119.7 | 25.3 | 114.9 | 18.9 | 111.0 | 16.8 | 123.6 | 24.3 | 117.0 | 18.9 |
| 8 | 126.4 | 30.7 | 121.4 | 21.5 | 114.7 | 18.8 | | | 121.8 | 21.4 |
| 9 | 131.8 | 35.6 | 127.6 | 24.8 | | | | | 126.0 | 23.7 |
| 10 | | | | | | | | | 130.7 | 26.4 |

**Parameters of fitted growth curve**

$$L_t = L_\infty \left[ 1 - e^{-k(t-t_0)} \right]$$

| | N.E. PEAK | N. EDGE | BIRD'S BILL | CHANNEL | DIGBY |
|---|---|---|---|---|---|
| $L_\infty$ | 146.5 | 141.8 | 121.5 | 137.6 | 146.3 |
| K | .30 | .28 | .41 | .35 | .23 |
| $t_0$ | 1.32 | 1.00 | 1.00 | .54 | .22 |

**TABLE 3. Growth of tagged sea scallops**

| Age 9/22/57 (yrs) | 3.98 | 4.98 | 5.98 | 6.98 | 7.98 |
|---|---|---|---|---|---|
| Number | 22 | 33 | 46 | 25 | 15 |
| $\bar{L}$ 9/22/57 (mm) | 94.2 | 107.2 | 117.1 | 125.2 | 131.4 |
| $\bar{L}$ 8/5/58 (mm) | 111.1 | 117.9 | 125.3 | 130.1 | 135.1 |

Since 12 of the 25 unit areas had less than 278 days of fishing we are certainly overestimating the area swept and thus obtaining a minimum value of F. If the estimate is confined to the 13 unit areas which had over 278 days of fishing in 1958, $\hat{F}$ = .41.

Growth Rate

Almost all the published sea scallop growth rate estimates made by United States investigators have been calculated from the growth increments measured on relatively small samples of tagged and recaptured specimens (Posgay, 1953, 1958). Canadian investigators have, however, successfully interpreted prominent annuli on the shell as annual rings and derived growth rates from these data much as is commonly done from fish scales (Stevenson & Dickie, 1954; Dickie, 1955). We have recently made a vigorous attempt to master the technique of reading annual rings from Georges Bank specimens and believe that we can now use this method to derive growth rates for different areas and for different year-classes.

Our confidence is based on the close coincidence of results obtained from using both methods on the same sample. The sample consisted of 426 shells which had been tagged and released on the Northeast Peak of Georges Bank on September 22, 1957, and later recaptured and returned. The entire sample was aged and the average size at the time of ring formation determined (Table 2). Part of the sample, 141 shells, had been recaptured in a group after being at large for 49.6 weeks. This group (Table 3) was used to calculate the growth rate from the average increment added by each year-class between tagging and recapture.

In order to compare the two kinds of data, it was nescessary to allow for the difference in time between the unknown date of formation of the annual rings and the known birthday of the year-classes. This was done by fitting the linear form of the growth equation (Beverton and Holt, 1957) to each set of data using the actual values of t for the tag data and arbitrary values of t for the ring data. The calculations gave values identical to two significant figures for the parameter K but the parameter $t_0$ differed by 0.17 years. The $t_0$ value of the ring data was therefore adjusted by this amount and a single equation, $L_t = 146.5\ (1 - e^{-.30(t-1.32)})$, fitted to the combined data. The correlation coefficients are: tag data, 0.9898, annual ring data 0.9996. There can be little doubt that the two methods give equally precise estimates of the growth rate.

Growth rates have been calculated by reading annual rings for three other areas on Georges Bank (Table 2) and the Digby grounds in Subarea 4. The exact locations where the samples were collected are: the Northeast Peak, 41°51'N-66°23'W; the Northern Edge, 42°09'N-67°14'W; the Bird's Bill, 41°26'N-66°23'W; the Channel, 41°03'N-68°45'W; Digby, 44°45'N-65°47'W.

The weights given in Table 2 were not, except for the Bird's Bill sample, derived from the same sample as the lengths. They are calculated average weights derived from samples collected at various times from locations close to the locations of the growth rate samples. Some of these length-weight data suggest that the length-weight ratio may vary seasonally. Samples are being collected to test this hypothesis.

The most important factor in deciding if there will be any increase in the yield of a year-class if a savings gear is introduced is the relative balance between the average annual rate of natural mortality and the average annual increase in weight in the sizes which fall between the 50 percent retention points of the old and the new gear. Although the 3-inch ring presently in use has a 50 percent retention point at about 69 mm, the fishermen rarely shuck anything

TABLE 4. Growth of sea scallops for three years after they are recruited to the fishery

| | N.E. PEAK | | | N. EDGE | | | BIRD'S BILL | | | CHANNEL | | | DIGBY | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YEARS DELAY | L | W | % Inc. | L | W | % Inc. | L | W | % Inc. | L | W | % Inc. | L | W | % Inc. |
| 0 | 85.0 | 7.4 | | 85.0 | 8.7 | | 85.0 | 7.4 | | 85.0 | 8.5 | | 85.0 | 7.2 | |
| 1 | 100.9 | 13.7 | 85 | 98.8 | 12.8 | 47 | 97.2 | 11.3 | 53 | 100.5 | 13.6 | 60 | 97.6 | 11.0 | 53 |
| 2 | 112.7 | 20.4 | 49 | 109.3 | 16.6 | 30 | 105.4 | 14.5 | 28 | 111.5 | 18.1 | 33 | 107.6 | 14.7 | 34 |
| 3 | 121.5 | 26.6 | 30 | 117.2 | 19.8 | 19 | 114.4 | 18.6 | 28 | 119.2 | 21.8 | 20 | 115.6 | 18.3 | 24 |

TABLE 5. Increase in Yield to be Expected from a Savings Gear

| | $1^y$ | $2^y$ | $(2^{t_c}-1^{t_c})$ | x | $e^x-1$ | Benefit % | 1958 Landings M lbs. | Benefit M lbs. |
|---|---|---|---|---|---|---|---|---|
| | | | 4" ring (50% Point = 94.2 mm) | | | | | |
| N.E. PEAK | .0153 | .9847 | .54 | .167 | .1818 | 16.4 | 4846 | 795 |
| N. EDGE | .0468 | .9532 | .63 | .195 | .2153 | 15.8 | 4296 | 679 |
| BIRD'S BILL | .0754 | .9246 | .71 | .220 | .2461 | 15.2 | 4095 | 622 |
| CHANNEL | .0152 | .9848 | .55 | .170 | .1853 | 16.7 | 3816 | 637 |
| | | | | | | Total Benefit | | 2733 |
| | | | 4-1/2" ring (50% Point = 106.9 mm) | | | | | |
| N.E. PEAK | .1204 | .8796 | 1.47 | .456 | .5778 | 38.8 | 4846 | 1880 |
| N. EDGE | .2830 | .7170 | 1.74 | .539 | .7143 | 22.9 | 4296 | 983 |
| BIRD'S BILL | .4915 | .5085 | 2.73 | .846 | 1.3303 | 18.5 | 4095 | 758 |
| CHANNEL | .1202 | .8798 | 1.53 | .474 | .6064 | 41.3 | 3816 | 1576 |
| | | | | | | Total Benefit | | 5197 |

smaller than 85 mm. The meats are too small to make it worthwhile. Starting at the 85 mm commercial cull therefore, Table 4 gives the average increase in length and weight for one, two, and three years postponement of first capture for the five areas. So long as the annual rate of natural mortality is less than the annual percent increase in weight, there would be a net increase in the biomass available for exploitation.

EFFECT OF A SAVINGS GEAR ON YIELD

Holt (1958) has described a short method of calculating the benefit to be expected from the introduction of a mesh regulation.

$$\text{Percent Benefit} = 100 \left[ {}_2y(e^{F({}_2t_c - {}_1t_c)} - 1) - {}_1y \right]$$

It requires that the proportion of the mean annual catch in weight of animals larger (${}_2y$) and smaller (${}_1y$) than the proposed new length at first capture be known, as well as the fishing mortality (F), and the difference in age (${}_2t_c - {}_1t_c$) between those animals whose lengths fall at the 50 percent retention points of the old and new gear.

This method has been applied to the Georges Bank data. Table 5 gives the results to be expected from the introduction of a 4-inch ring and a 4½-inch ring. The size distribution of the catch was calculated from samples collected from the commercial fleet, F = .31 from the tag return data, and the growth rates from the data of Table 2. The length at ${}_1t_c$ was taken as 85 mm, the commercial cull, not the 50 percent point of the 3-inch ring now in use. The 50 percent points were taken from the mesh selection data reported by Posgay (1958).

The first column of Table 5, headed ${}_1y$, gives the proportion of the catch which would have been lost during 1958 if the savings gear had been in use. The sixth column gives the percent benefit that would have resulted and the total of the last column, the eventual benefit in pounds. These calculations indicate that the introduction of a savings gear into the Georges Bank sea scallop fishery would result in a very substantial increase in the yield.

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