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Foreword

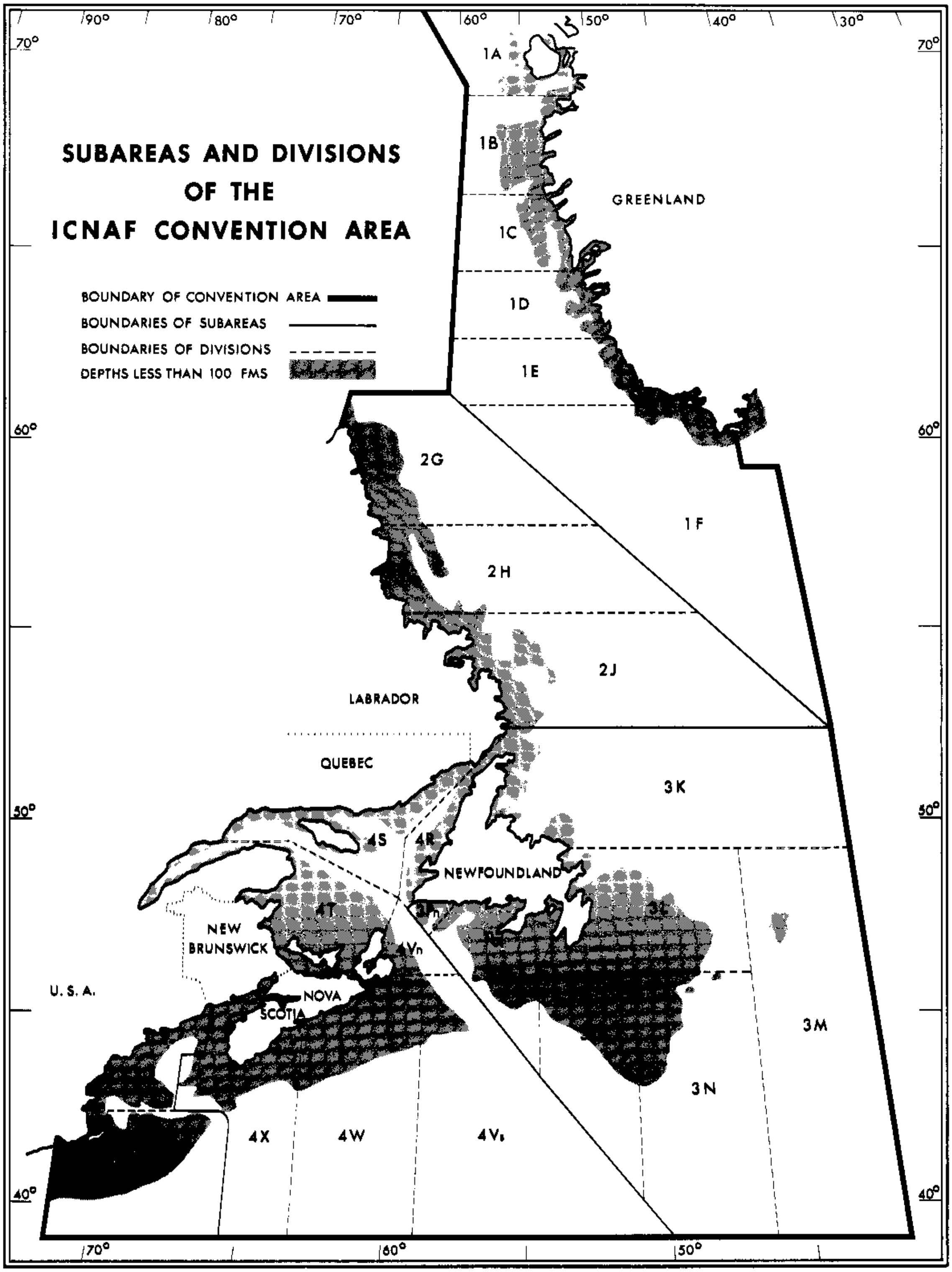
The present series of ICNAF publications provides for the dissemination of basic fisheries data, both statistical, in the Statistical Bulletin, and biological, in the Sampling Yearbook. Proceedings of scientific symposia held from time to time by the Commission are published in the ICNAF Special Publications Series, of which five have been issued since the Commission began in 1949.

Between these two kinds of information lie the results of much research by scientists of member countries which is of direct relevance to the work of the Commission research which, in many instances, has been promoted through, or at least inspired by, the activities of the Commission's Standing Committee on Research and Statistics. Hitherto, no Commission publication has existed in which this could appear. Some has been published, sooner or later, in national journals with varying degrees of accessibility. The greater part has never progressed beyond the stage of mimeographed meeting documents, often incomplete and provisional, though sometimes containing data and conclusions on which major Commission policy has been based.

It is to provide a means of publishing regularly the results of individual research relevant to the Commission that the ICNAF Research Bulletin, of which this is the first number, has been started. It will appear annually, and although it will normally take the majority of its material from topics which appear in the first instance as documents submitted to Annual Meetings of the Commission, any worth while piece of research of relevance to the work of the Commission will be considered for acceptance. All contributions will be subject to the scrutiny of the Editorial Board assisted by expert referees as required. In this way it is hoped to create a continuing scientific publication of a high standard which will both serve the direct needs of the Commission and stimulate the research among member countries on which effective advice to the Commission on the fisheries of the Northwest Atlantic ultimately depends.

R. J. H. Beverton, Chairman
Standing Committee on Research and Statistics of the International Commission for the Northwest Atlantic Fisheries

June 1964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Landings, Fishing Effort, and Apparent Abundance in the Yellowtail Flounder Fishery

BY FRED E. LUX[1]

Abstract

Otter-trawl exploitation of yellowtail flounder, *Limanda ferruginea* (Storer), on fishing grounds off New England began in the 1930's. Yellowtail are fished on three New England grounds: the southern New England ground (south of Massachusetts and Rhode Island), Georges Bank, and the Cape Cod ground (east and north of Cape Cod). The southern New England ground and Georges Bank have supplied most of the catch.

Landings have varied widely, rising to 68 million pounds (31,000 metric tons) in 1942, dropping to 13 million pounds (5,900 metric tons) in 1954, and rising again to 39 million pounds (17,700 metric tons) in 1961. An analysis of landings per day of fishing effort in 1943-61, calculated for New Bedford, Massachusetts vessels for each ground as a measure of relative apparent abundance, indicated that the pattern of apparent abundance generally was similar to that of landings. A comparison of total fishing effort with apparent abundance suggested that, following initial exploitation, apparent abundance varied independently of the effort level. The patterns of relative apparent abundance on the three grounds from 1949 to 1961 were similar.

A comparison between winter water temperature and landings per day suggested that there was an inverse relationship between temperature and apparent abundance.

Introduction

The yellowtail flounder, *Limanda ferruginea* (Storer), is the most important of New England commercial flatfishes. Landings of 39 million pounds (17,700 metric tons) by United States otter trawlers in 1961 were worth 3 million dollars to fishermen. The fishery is of comparatively recent development with active exploitation of the stocks beginning in the mid-1930's. The catch rose rapidly in the early years of the fishery, reaching a peak in 1942. Following this, it declined sharply, dropping to a low in 1954. Recent landings, 1957-61, have shown a marked increase.

The biology and population dynamics of yellowtail from the fishing ground off southern New England were studied in the early 1940's by Royce, Buller, and Premetz (1959). They assembled information on landings, fishing effort, and landings per day of fishing for the period 1942-49. They concluded from these data, and data on the size and age composition of the catch, that the major changes occurring in the fishery during the period of study resulted from natural fluctuations in abundance and availability rather than from overfishing. They cited evidence of faunal changes which they suggested may have been partly responsible for these fluctuations.

This present report results from a continuation and expansion of the abundance study of Royce and his co-workers. The development of the yellowtail fishery is traced, and an analysis of landings, fishing effort, and average landings per day of fishing for the three principal New England yellowtail fishing grounds for the period 1943-61 is given. Landings data were obtained from statistical digests issued by the Bureau of Commercial Fisheries and from the work cited above. Data for calculation of fishing effort and average landings per day of fishing effort, as a measure of apparent abundance, were obtained from fishing trip weighout schedules and vessel interviews for the port of New Bedford, Massachusetts.

Historical Information

While yellowtail flounder frequently were caught in otter trawls before 1935, they rarely were landed in quantity because of a market preference for thicker-bodied flatfish such as winter flounder, *Pseudopleuronectes americanus*, and summer flounder, *Paralichthys dentatus*, (Royce, *et al.*, 1959). A decline during the 1930's in the abundance of winter flounder (Perlmutter, 1947), which

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until then had made up most of the total flatfish catch, led fishermen to seek other species. More intensive exploitation of the abundant yellowtail began at this time and the fishery grew rapidly, with total landings rising to more than 68 million pounds (31,000 metric tons) in 1942.

1. Fishing Gear and Methods

All yellowtail are caught by otter trawlers, with vessels of 45 to 75 feet (14 to 23 m) in length landing most of the catch. Size of trawl nets used varies with vessel size and power, footropes being about 60 to 80 feet (18 to 24 m) in length. Vigneron-Dahl gear is used. During the early years of the fishery the nets were made of cotton twine, but since the end of World War II most fishermen have changed to nylon. Mesh size of codends has varied; in the early 1960's it commonly was 4½ inches (114 mm) stretched measure. Aside from small refinements, there have been no significant changes in gear since the late 1930's when Vigneron-Dahl gear came into widespread use.

A profitable catch for a yellowtail trip consists of about 10 to 20 thousand pounds (4.5 to 9.1 metric tons) for small draggers carrying 4 or 5 man crews. For larger vessels, carrying 6 or 8 men, it varies from 25 to 50 thousand pounds (11.3 to 22.7 metric tons). What constitutes a good trip is, of course, largely dependent upon price.

Trip length varies from 1 to 8 days depending on boat size, distance to ground, weather, fishing success, and fish price. The trawl is towed for about 2 hours for each set, and fishing operations are carried on day and night.

There is no yellowtail fleet in the same sense as there are haddock and redfish fleets which seek a particular species on a year-round basis. Fishermen fishing for yellowtail in the fall may change to summer flounder fishing in the winter months, when summer flounder are concentrated on offshore grounds, and to inshore winter flounder fishing in the spring. Sometimes fishermen fish for other species during a part of a yellowtail trip. Some vessels are converted to sea scallop dragging when yellowtail are scarce; they are reconverted to otter trawling when this again becomes more profitable. Some yellowtail fishermen join the industrial fishery in the spring and summer months when the abundance of industrial species, used for fish meal, is highest. All of these conditions prevent clear identification of a yellowtail fleet.

2. Fishing Grounds

Yellowtail inhabit Atlantic coastal waters from the Gulf of St. Lawrence and the Newfoundland banks southward to Chesapeake Bay (Bigelow and Schroeder, 1953). They are found in water as shoal as 5 fathoms (9 m) during winter months and in cold, deeper water in summer. They are usually caught in 20 to 35 fathoms (37 to 64 m) of water, however, and mostly over sandy bottoms. The species is fished commercially on grounds off New England, which supply most of the catch, and on fishing banks southeast of Nova Scotia.

Yellowtail fishing areas off New England are the ones principally considered here, and these have been divided into three major grounds based on results of marking experiments and other studies (Royce, *et al.*, 1959; Lux, 1963). The three grounds, defined in terms of the northwest Atlantic statistical units established for reporting catch by area (Fig. 1), are as follows[2]:

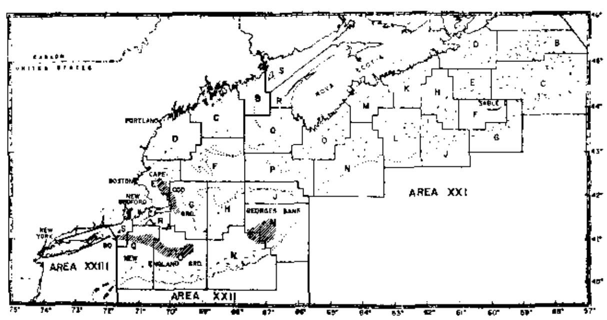

Fig. 1. Principal fishing grounds off New England and areas (shaded) where most yellowtail are caught. (The statistical areas are those defined by Rounsefell, 1948.)

Southern New England ground. This ground includes the area from south of Nantucket to south of Long Island. It is made up of subareas XXII O, Q, R, and S, and area XXIII. Yellowtail are caught between the 20 and 30 fathom (37 to 55 m) curves. Most of the catch is from subareas O and Q and is taken from fall to early spring.

[2])The subareas shown in Fig. 1 were used here for designating grounds because these are the statistical units by which United States landings are reported (Rounsefell, 1948). ICNAF subarea 4 is the equivalent of area XXI, and ICNAF subarea 5 is the equivalent of area XXII. Area XXIII, being outside of the convention area, has no ICNAF equivalent.

Georges Bank. This ground includes subareas XXII H, J, M, and N. Most of the yellowtail are caught between the 25 and 35 fathom (46 to 64 m) curves here. The catch is highest from subareas M and N, taken mainly in the summer and fall.

Cape Cod ground. This ground includes areas along the eastern shore of Cape Cod, Cape Cod Bay, Stellwagen Bank, and shoal waters around Cape Ann, off Gloucester, Massachusetts. The ground is included in subareas XXII E and G, and yellowtail landings reported for these subareas are considered to have come from this ground. Most yellowtail are caught here between the 5 and 35 fathom (9 to 64 m) curves and are taken principally from late fall to spring.

In addition to catches from these three major grounds, small quantities of yellowtail are taken off the Maine coast. These landings have been grouped under the heading "Northern Gulf of Maine," subareas XXII B, C, D, and F, in later discussion.

Results of tagging on each of the three major grounds showed that considerable movement, usually seasonal in nature, occurred within grounds, but that the amount of mixing between grounds was small. The movement patterns within each ground are given by Royce, *et al.* (1959) and Lux (1963). The extent of mixing is summarized below.

Of 2,945 yellowtail tagged on the southern New England ground in 1955, 1957, and 1959, there were 532 returns for which recovery ground was given. Of these, 513 were recaught on the southern New England ground, 14 on Georges Bank, and 4 on the Cape Cod ground.

Of 430 yellowtail tagged on Georges Bank in 1957, there were 119 returns for which recovery ground was given. Of these, 114 were recaught on Georges Bank and 5 on the southern New England ground.

Of 1,585 yellowtail tagged on the Cape Cod ground in 1957 and 1959, there were 268 returne for which recovery ground was given. Of thess 265 were recaught on the Cape Cod ground, 2 on the southern New England ground, and 1 on Georges Bank.

The above results indicated that yellowtail on each ground were relatively separate from those on other grounds. This geographic separation of yellowtail was supported by information on occurrence of parasitized fish (Lux, 1963). About 35 per cent of the yellowtail from samples taken on the Cape Cod ground were infested with metacercariae of the trematode, *Cryptocotyle lingua*, although samples from the other two grounds were uninfested. Fin ray counts of yellowtail from the three grounds showed no differences, suggesting that if there were distinguishing features in fish from each ground they were small.

On the basis of the preceding data, a separate group of yellowtail was tentatively recognized on each of the three grounds. Each group was treated individually for the analysis dealt with here.

The fishery for yellowtail on the Nova Scotian banks is primarily a Canadian one, but United States vessels have made occasional trips to these distant grounds at times when fish were abundant there and the price was high. Most of the United States catch was taken near Sable Island (Fig. 1). Nova Scotian yellowtail apparently are of a completely distinct group from those caught off New England, for they differ from them in fin ray numbers and body proportions (Scott, 1954).

3. Ports of Landing

Yellowtail are landed at ports from New Jersey to Maine but currently most of the catch is landed in Massachusetts and Rhode Island (Table 1). Ports in Connecticut, New York, and New Jersey received moderate amounts of fish during the late 1930's and through the 1940's, but their importance has declined in subsequent years.

By 1940 New Bedford, Massachusetts had become the principal yellowtail port because of its previously established facilities and its proximity to the fishing grounds In all years following 1940 one half or more of the total yellowtail catch has been landed there. Yellowtail landings there in 1961 of 30 million pounds (13,600 metric tons) made up about 75 per cent of total landings of this species. Other ports of importance are Provincetown and Woods Hole, Massachusetts and Point Judith and Newport, Rhode Island[3]. Their combined 1961 landings totaled about 5 million pounds (2,300 metric tons).

[3])Quantities landed at Woods Hole since 1961 have been insignificant.

TABLE 1. Annual United States landings of yellowtail flounder in New England States and in New York and New Jersey, 1938-61. (Landings 1938-45 are from data compiled by Royce *et al.* (1959). Landings for subsequent years are from Bureau of Commercial Fisheries annual statistical digests).
(In thousands of pounds; 1 metric ton = 2,205 pounds)

Year	Maine	Massachusetts	Rhode Island	Connecticut	New York & New Jersey	Total
1938	301	16,985	364	1,781	3,384	22,815
1939	222	20,662	397	3,129	4,316	28,726
1940	827	28,352	1,059	4,090	6,544	40,872
1941	276	37,912	334	4,246	8,921	51,689
1942	26	47,932	2,420	6,193	12,007	68,578
1943	46	32,897	2,052	3,605	7,187	45,787
1944	127	19,283	3,027	3,187	5,518	31,142
1945	73	24,358	2,852	2,801	3,085	33,169
1946	37	23,709	2,240	3,171	2,311	31,468
1947	91	27,630	2,259	3,006	3,333	36,319
1948	118	32,087	3,293	1,352	2,778	39,628
1949	120	25,409	1,138	550	1,519	28,736
1950	145	21,399	1,029	302	1,241	24,116
1951	82	16,735	723	100	774	18,414
1952	55	15,306	1,334	49	234	16,978
1953	58	12,627	1,014	24	50	13,773
1954	24	10,972	1,681	30	56	12,763
1955	30	12,661	1,448	60	174	14,373
1956	52	11,756	2,444	161	230	14,643
1957	41	19,910	2,230	91	179	22,451
1958	64	29,519	2,984	226	532	33,325
1959	113	25,932	3,012	139	615	29,811
1960	65	27,701	2,110	160	1,171	31,207
1961	34	34,667	2,338	107	2,082	39,228

TABLE 2. Yellowtail landings by fishing ground, 1942-61. Landings were calculated for each ground from vessel interviews, log book data, and published statistics of the Bureau of Commercial Fisheries.
Landings 1942-49 were taken from Royce *et al.*, (1959).
(In thousands of pounds; 1 metric ton = 2,205 pounds).

Year	Southern New England Ground	Georges Bank	Cape Cod Ground	Northern Gulf of Maine	Nova Scotian Banks	Total
1942	62,797	2,385	3,330	26	40	68,578
1943	39,777	2,784	2,831	74	321	45,787
1944	23,406	3,670	3,335	68	608	31,087
1945	22,862	2,990	2,554	30	4,733	33,169
1946	23,867	1,913	2,774	30	2,737	31,321
1947	26,706	4,976	2,387	49	1,636	35,754
1948	21,872	12,472	1,464	23	3,137	38,968
1949	10,305	16,097	2,711	46	651	29,810
1950	10,384	8,581	2,974	192	1,969	24,100
1951	6,144	9,505	1,858	137	770	18,414
1952	6,591	8,051	1,714	81	520	16,957
1953	4,358	6,389	1,705	89	1,225	13,766
1954	3,340	6,364	2,469	30	560	12,763
1955	4,807	6,495	2,874	45	152	14,373
1956	7,809	3,515	3,245	58	16	14,643
1957	11,996	5,074	5,196	57	123	22,446
1958	19,637	9,995	3,555	87	42	33,316
1959	17,060	9,106	3,365	140	122	29,793
1960	17,293	9,804	3,996	86	28	31,207
1961	25,645	9,365	4,145	49	24	39,228

Relative Importance of Grounds

Yellowtail landings, recorded separately since 1938, have varied widely during the short life of the fishery (Table 1). They rose rapidly to a peak of 68 million pounds (31,000 metric tons) in 1942, declined to a low of 13 million pounds (5,900 metric tons) in 1954, and increased substantially again in recent years.

Landings by fishing ground for 1942-61, based on vessel interview data, are given in Table 2. The southernNew England ground has generally provided most of the catch, with the importance of Georges Bank increasing sharply after 1947. Landings from the Cape Cod ground were smaller, and showed less year to year fluctuation, than those from the previous two grounds. Information from vessel interviews and trip weighout schedules indicates that yellowtail landings from the northern Gulf of Maine subareas were principally caught incidentally to other fish. These data are of importance primarily in that they show the scarcity of yellowtail there. Landings from Nova Scotian banks contributed little to the total catch except during the late 1940's. They cannot be considered indicative of yellowtail abundance on these grounds, because New England fishermen fished there sporadically.

1. Methods

Interviews of New Bedford vessel captains, upon return to port, for information on catch, grounds, and time fished have been obtained since October 1942. Average yellowtail landings per vessel per 24-hour day of fishing effort for vessels landing at New Bedford was calculated as a measure of relative apparent abundance on each of the three principal yellowtail grounds for the period October 1942 - December 1961.

The terms used here for describing yellowtail abundance and their definitions (Marr, 1951) are given below. *Abundance* is the absolute number of individuals in a population. *Availability* is the degree (a percentage) to which a population is accessible to the efforts of a fishery. *Apparent abundance* is the abundance as affected by availability, or the absolute number of fish accessible to the fishery. Landings per unit effort measures apparent abundance rather than absolute abundance. Because landings per unit effort for a particular period is only relative to similar measures for other periods, it is considered a measure of *relative apparent abundance.*

Vessels landing yellowtail at New Bedford range in size from about 12, to over 100 registered gross tons. The vessel size composition of this fleet varies from season to season and from year to year for reasons given earlier. Yellowtail catching power varied with vessel size, and it was therefore necessary to take into account changes in the vessel size composition of the fleet for the landings per day calculations. To do this the vessels were divided into four tonnage groups: under 26, 26-50, 51-75, and 76-100 gross tons. Each of these groups was treated as a separate fleet for the calculations; comparisons and combinations of data were made in final analyses.

A definition of yellowtail fishing effort was required for the landings per day calculations. Because yellowtail are actively fished on grounds where other species are fished, including cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), red hake (*Urophycis chuss*), silver hake (*Merluccius bilinearis*), winter and summer flounder, it was inaccurate to define all effort on these grounds as yellowtail effort. It was not feasible, using available fishing area data from interviews, to define yellowtail fishing areas within these grounds with sufficient precision so that all effort within certain areas could safely be treated as yellowtail effort. As an aid in deciding what effort might reasonably be considered yellowtail effort and what effort was expended for other species, frequency distributions of the proportions of yellowtail in New Bedford dragger catches were drawn up, as was suggested by ICNAF (1960) for dealing with mixed species grounds. These are given in Table 3 for 1954 and 1961, years of low and high yellowtail apparent abundance, respectively. It will be seen that these distributions were similar in form in both years. The proportion of yellowtail in trips was either high or low, with relatively few trips falling in the intermediate categories. It was inferred from the form of these distributions that effort intentionally directed toward yellowtail was the effort of trips landing mostly yellowtail. Based partly on this analysis yellowtail effort was therefore defined as that of trips whose landings consisted of 50 per cent or more yellowtail, and this effort alone was used in landings per day calculations[4].

From questioning New Bedford fishermen and examining trip interview data for that port it was learned that when yellowtail was the principal species being sought during a trip, the catch

[4])Royce *et al.* (1959) calculated average landings per day, 1942-49, for vessels of 26-50 tons landing 75 per cent or more yellowtail at New Bedford from the southern New England ground.

consisted of at least 50 per cent yellowtail. It was therefore believed that in restricting from consideration trips whose yellowtail catch was less than 50 per cent of the total catch, the fishing effort intentionally directed toward yellowtail was included in the calculations, and that effort for other species was, for the most part, excluded.

TABLE 3. Percentage of yellowtail flounder in landings of New Bedford otter trawler trips in 1954 and 1961.

Percentage Yellowtail	Number of trips 1954	1961
0	1071	668
Up to 9	805	438
10 - 19	107	147
20 - 29	45	97
30 - 39	31	82
40 - 49	33	88
50 - 59	36	90
60 - 69	51	128
70 - 79	43	172
80 - 89	83	271
90 - 100	265	842
Totals	2570	3023

TABLE 4. Percentages of total yellowtail landings included in landings per day calculations for the 3 principal grounds, 1943-61.

Year	Southern New England Ground	Georges Bank	Cape Cod Ground
1943	50.3	15.6	6.2
1944	36.4	43.9	9.9
1945	47.3	36.0	1.5
1946	54.8	26.2	2.9
1947	55.6	13.3	10.5
1948	58.2	40.9	3.0
1949	51.8	42.4	10.8
1950	37.0	52.0	10.2
1951	31.1	57.6	22.6
1952	30.9	48.3	26.4
1953	45.6	54.3	22.2
1954	26.8	74.7	17.4
1955	43.6	61.1	22.8
1956	44.0	78.2	8.3
1957	50.2	76.5	17.1
1958	61.6	85.3	4.3
1959	55.5	72.2	2.7
1960	61.8	67.6	5.8
1961	69.0	69.1	5.4

Percentages of annual yellowtail landings from the three grounds used in the landings per day calculations are given in Table 4. For the southern New England ground and Georges Bank these averaged about 48 and 53 per cent, respectively, including therefore a large part of total landings from these grounds. For the Cape Cod ground the proportion of landings included in the calculations was small, less than 10 per cent of total landings in many of the years. Because of this the landings per day figures for this ground may be considered less reliable for estimating apparent abundance than were data from the other grounds.

Vessels of the 26-50 ton group were chosen as the standard yellowtail fishing vessels, because boats of these sizes most consistently expended a large effort toward yellowtail. For analysis it was desirable to calculate, for a given ground, landings per standard day values (i.e., in terms of the 26-50 ton vessels) that included catch and effort data of all vessel size groups combined. This was done by first adjusting the recorded days fished for each vessel group by its fishing power relative to that of 26-50 ton vessels and by then calculating landings per day using the adjusted days fished[5].

An estimate of overall fishing intensity directed toward yellowtail on each ground in each year in 1943-61 was obtained by dividing total yellowtail catch, by landings per standard day fished. This gave values of total yellowtail fishing effort in standard days.

Yellowtail landings, fishing effort, and landings per day of fishing effort for the three New England grounds are discussed below. The southern New England ground is considered first.

2. Southern New England Ground

The southern New England ground supplied most of the yellowtail catch before 1948. Landings from there for the early part of the period 1942-61 were high, reaching a peak of about 63 million pounds (28,600 metric tons) in 1942 (Table 2, Fig. 2). A catch decline followed this, reducing annual landings to less than 10 million pounds (4,540 metric tons) for much of the 1950's. Following the 1954 low of 3.3 million pounds

[5])The procedure for this adjustment is given in an appendix; the adjusted values are given in Table A-1.

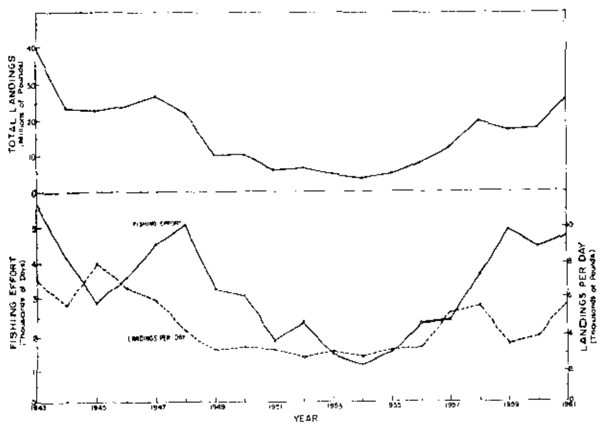

Fig. 2. Yellowtail landings per standard day, fishing effort in standard days, and total landings for the southern New England ground, 1943-61.

(1,500 metric tons) there has been a marked upward trend in catch, however, bringing landings to over 25 million pounds (11,300 metric tons) in 1961.

Average annual landings per standard day and total fishing effort in standard days on the southern New England ground for all vessels in 1943-61, adjusted to the fishing power of 26-50 ton vessels, are shown in Fig. 2 along with landings. The relative apparent abundance of yellowtail, as shown by landings per standard day, was high in the early part of the period, rising to 8,000 pounds (3.6 metric tons) in 1945 (Fig. 2). During the late 1940's and early 1950's it dropped to less than half of the 1945 peak, but in a number of years it has shown substantial increases. Overall patterns for landings and relative apparent abundance were similar.

Average landings per day and recorded days fished by season and year for October 1942 to December 1961 for interviewed boats of under 26, 26-50, 51-75, and 76-100 gross tons are given in Table A-2. These data show that apparent abundance generally was lowest in the second quarter, the spawning season, and highest in the third and fourth quarters. This seasonal pattern is similar to that shown by Royce *et al.* (1959) in their study of yellowtail from the southern New England ground, 1942-49, and it probably reflects seasonal changes in yellowtail availability.

The pattern of fishing effort was similar to that of relative apparent abundance in many of the years; however, there were notable exceptions (Fig. 2). One is seen in the middle 1940's when apparent abundance was high but fishing effort was low. This may have resulted in part from low ceiling prices paid for yellowtail during World War II and from dangers of fishing during the war. In any case, low landings in some years stemmed not from scarcity of fish, but from failure of the fleet to exploit stocks of relatively high apparent abundance.

Fishing effort for yellowtail, especially by smaller boats, dropped markedly in 1949 (Fig. 2, Table A-2). At this time many of the vessels began fishing for industrial species, which had recently come into demand, rather than for yellowtail, since the latter had become scarce. Effort for yellowtail, especially by larger boats, has again increased with the apparent abundance increases of the latter part of the period covered. Average total fishing effort for the 19-year period was 3,315 standard days per year.

3. Georges Bank

Georges Bank is second to the southern New England ground as a yellowtail producing area. Small catches of yellowtail were made there in the early 1940's by vessels whose principal effort was for other species. In addition, a small amount of yellowtail effort was expended on the Cultivator Shoal area of Georges Bank (subarea H) during the late winter and early spring, where concentrations of yellowtail were found in these seasons. Total landings of the early 1940's ranged from 2 to 3.5 million pounds (900 to 1,600 metric tons) per year (Table 2, Fig. 3). From 1947 on, subareas M and N were the most important yellowtail fishing areas on Georges Bank, the fish being caught there during the summer and fall. Increased catches from the Bank as a result of fishing in these subareas raised total landings to a peak of 16 million pounds (7,300 metric tons) by 1949. Following this, landings declined slowly to 3.5 million pounds (1,600 metric tons) in 1956. In 1957-61 they have again increased substantially.

Average annual landings per standard day and total fishing effort in standard days on Georges Bank for all vessels in 1943-61, adjusted to the fishing power of 26-50 ton vessels, are shown in Fig. 3 along with landings. Relative apparent abundance was high during the early part of the period covered, reaching nearly 17,000 pounds (7.7 metric tons) in 1944. This was followed by a decline, reducing apparent abundance to a comparatively stable level of about 5,000 pounds (2.3 metric tons) in 1950-56. A slight apparent

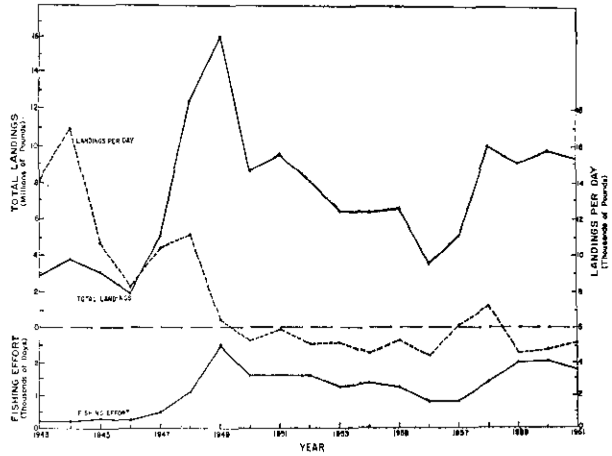

Fig. 3. Yellowtail landings per standard day, fishing effort in standard days, and total landings for Georges Bank, 1943-61.

abundance increase in 1957-58 was followed by a drop to approximately 5,000 pounds (2.3 metric tons) again in 1959-61.

Average landings per day and recorded days fished by season and year for October 1942 to December 1961 for interviewed vessels of 26-50, 51-75, and 76-100 gross tons, the vessel groups that fished this ground are given in Table A-3. Landings per day and fishing effort were highest in the winter months through 1946; following 1946 they were highest in the summer and fall.

Fishing effort on Georges Bank was low from 1943 to 1947, accounting for the low level of landings in these years when relative apparent abundance was high (Fig. 3, Table A-3). Effort increased in 1948 when intensive summer and fall exploitation of yellowtail in subareas M and N began. The high abundance of yellowtail in these subareas at this time, in contrast to the low abundance on the southern New England ground (Fig. 2), resulted in a rapid increase in Georges Bank fishing intensity, and by 1949, when effort and landings reached peaks there, apparent abundance had declined markedly. From 1950 to 1957 fishing effort gradually decreased despite the fairly stable level of apparent abundance in this period. An increase in effort in 1958-59 followed the apparent abundance increase of 1957-58. With the subsequent drop in apparent abundance in 1959-1961, effort increased, maintaining landings at nearly 10 million pounds per year in this period. Average Georges Bank fishing effort in the 19-year period of 1,186 standard days per year was about one third of the annual effort expended on the southern New England ground in the same period.

4. Cape Cod Ground

The Cape Cod ground is of least importance, in terms of landings, of the three principal grounds (Table 2, Fig. 4). During most of the period covered, the catch there was relatively stable at about 2 to 3 million pounds (900 to 1,400 metric tons) per year. Following 1953 it has increased, however, with peak landings of 5 million pounds (2,300 metric tons) being obtained in 1957.

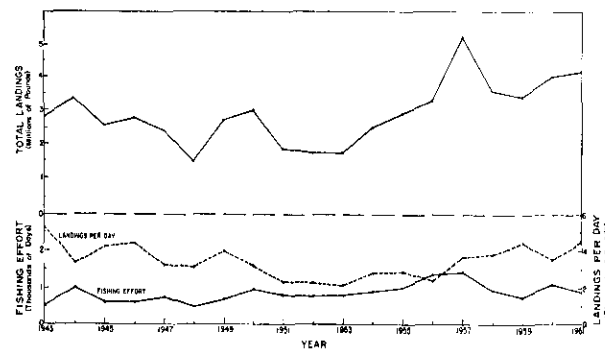

Fig. 4. Yellowtail landings per standard day, fishing effort in standard days, and total landings for the Cape Cod ground, 1943-61.

Annual landings per standard day and total fishing effort in standard days on the Cape Cod ground for all vessels in 1943-61, adjusted to the fishing power of 26-50 ton vessels, are shown in Fig. 4 with total landings. Average landings per day and recorded days fished in this period by interviewed New Bedford vessels of under 26, and 26-50 gross tons, data from which landings per standard day was calculated, are given in Table A-4. Annual landings per standard day was highest in 1943, dropped to its lowest point in the early 1950's, and increased again in the latter part of the period. Since, as mentioned earlier, only a small part of total landings from this ground were included in the landings per day calculations for some years (Tables 4, A-4), they cannot be considered as valid an estimation of relative apparent abundance here as on the other grounds. They are useful, however, in that they provide a broad picture of abundance fluctuations on this ground. The data show that apparent abundance of yellowtail on the Cape Cod ground was considerably lower than on the other principal grounds in most years and that it fluctuated less. It was highest in the early part of the period covered, declined in the early and middle 1950's, and increased again in recent years.

Yellowtail fishing effort also remained stable compared with that on the other grounds. Average annual effort was about 860 standard days.

Discussion

The patterns of relative apparent abundance of yellowtail on the southern New England ground and Georges Bank, after the period of initial exploitation, generally were similar to the patterns of landings. Landings per unit effort on Georges Bank was high on initial exploitation, and it declined when stocks that had been accumulated in years of little fishing were cropped down following increased fishing in 1948 and 1949 (Table A-3, Fig. 3). Relative apparent abundance data for the southern New England ground do not date back far enough to show what happened in the early years of the fishery on this ground. Landings per day there of 11,000 pounds (5 metric tons) and fishing effort of 6,264 days in 1942, calculated by Royce *et al.* (1959) from log book records, and the data of Table A-1 for subsequent years, indicate that apparent abundance was declining in the early 1940's. From what is known about the yellowtail fishery of these years, this coincided with a period of expanding exploitation on this ground.

While exploitation has reduced the size of the catchable population, there is no clear evidence from data presented here that overfishing has occurred. There is, in fact, some indication that, following initial exploitation, apparent abundance has varied independently of the fishery. This is indicated on the southern New England ground, for example, where apparent abundance has increased in recent years during a period of increasing fishing effort (Fig. 2, Table A-1).

The correlation coefficients between average landings per standard day and a three-year moving total of effort (the annual effort plus effort of the previous two years) for the three grounds in 1945-61 provided further information on the relation of stock abundance to effort (Table A-1, Fig. 5). For the southern New England ground $r = 0.46$ ($p = 0.07$), indicating that in the period covered the stock level has not been reduced by the amount of effort expended. The positive correlation suggests instead that the fishing level has followed, rather than preceded, the changes in apparent abundance, increasing when apparent abundance rose. A pattern of this kind might be expected in a mixed species fishery such as that of New England in which fishermen may change their effort to species other than yellowtail when it becomes profitable.

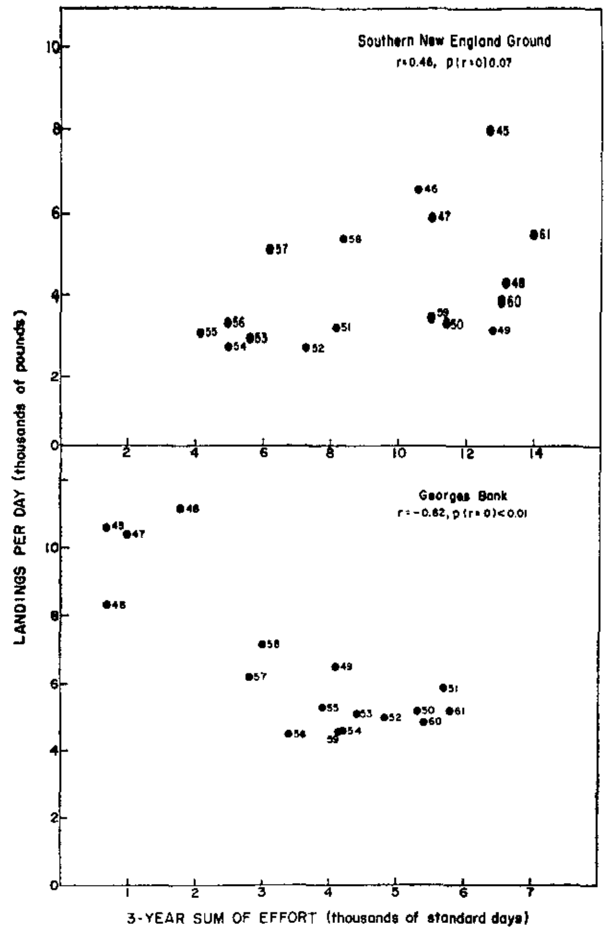

Fig. 5. The relationships between yellowtail apparent abundance and three-year sums of yellowtail effort for the southern New England ground and Georges Bank, 1945-61.

For Georges Bank the negative correlation coefficient between fishing effort and apparent abundance ($r = -0.82$, $p < 0.01$) shows that the stock level dropped during the period of increasing effort, indicating that fishing had a significant effect on the stock on this ground (Fig. 5). Apparent abundance level from 1949 on was about half that of the pre-1949 period when the stock was relatively unfished. As the data of Fig. 5 show, however, fluctuations in apparent abundance from 1949 on were not obviously related to variations in effort.

For the Cape Cod ground the correlation coefficient between effort and apparent abundance of 0.11 ($p > 0.50$) suggests that there was no relationship between stock abundance and effort on this ground in the period covered.

The effort and apparent abundance data for both the southern New England ground and

Georges Bank in the latter part of the period covered further suggested that fishing level has lagged behind, rather than preceded, apparent abundance changes (Fig. 2 and 3). When apparent abundance increased in 1957-58, there was no corresponding increase in fishing effort until 1958. Similarly, effort remained high in 1959-60 although apparent abundance had declined.

Total fishing effort on the New England grounds averaged about 5,400 standard days per year. Approximately 62 per cent of this was expended on the southern New England ground, 22 per cent on Georges Bank, and 16 per cent on the Cape Cod ground.

The patterns of relative apparent abundance on the three grounds show that there was some correspondence from ground to ground in broad trends in yellowtail apparent abundance (Fig. 6, Table A-1). This correspondence suggests that conditions influencing apparent abundance level operated on all grounds simultaneously.

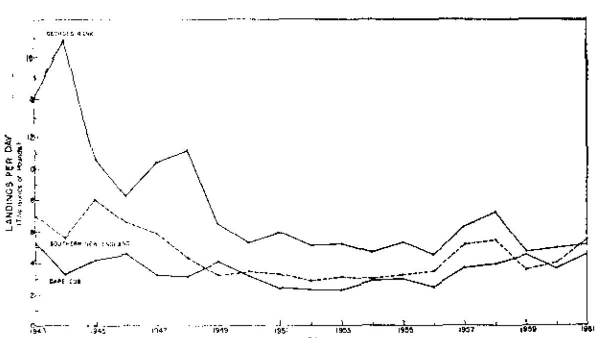

Fig. 6. Yellowtail flounder landings per standard day for the three principal New England grounds, 1943-61.

As noted in the introduction, Royce *et al.*, (1959) concluded that yellowtail catch variations in the 1940's resulted from natural fluctuations in availability and abundance. They suggested that a warming trend may have effected temporary northeastward shifts in population centers, increasing yellowtail availability on the southern New England ground in the early 1940's and on Georges Bank a few years later. Past work has shown that southern New England ground yellowtail normally move toward the east in the summer months and toward the west in winter, possibly in response to seasonal temperature changes (Royce *et al.*, 1959; Lux, 1963). An eastward movement there in summer is in the direction of cooler water (Bigelow, 1933).

There has indeed been a marked upward trend in temperature in New England, especially in the winter, in the period in which yellowtail have been exploited (Fig. 7). Surface water temperature at Boothbay Harbor, Maine, and at other temperature stations, reached a peak in the early 1950's and declined slightly in 1955-61 (Taylor, Bigelow, and Graham, 1957; Bumpus, 1957*a* and *b*; Day, 1959*a* and *b*, 1960, 1963)[6]. Taylor *et al.*, also found evidence of northward shifts in abundance and distribution of a number of marine animals in the period of rising temperature.

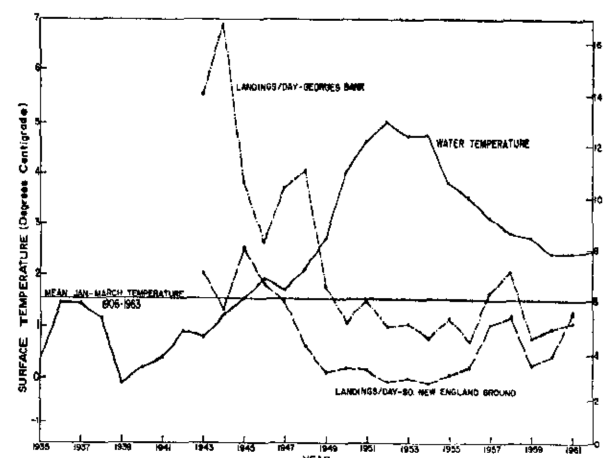

Fig. 7. Winter (January-March) surface water temperature at Boothbay Harbor, Maine in 1935-62, smoothed by 3's, and yellowtail landings per standard day for the southern New England ground and Georges Bank in 1943-61.

Yellowtail apparent abundance on the southern New England ground and Georges Bank dropped to its lowest level at about the time when temperature reached its peak in the early 1950's; it subsequently increased in 1957-58 during a period of decreasing temperature (Fig. 7). The pattern suggested that there was an inverse relationship between temperature and yellowtail apparent abundance, but, as the data show, this was not clear cut. The correlation coefficient between mean January - March temperature for each year (unsmoothed data) and average landings per standard day in the same year in 1943-61 for the southern New England ground was significant at the 5 per cent level ($r = -0.70$, $p < 0.01$), while that for Georges Bank in 1948-61 was not significant ($r = -0.48$, $p = 0.09$).

[6]Boothbay Harbor water temperatures for 1956-63 were obtained from unpublished data, U.S. Dept. of the Int., Bur. Comm. Fish. Biological Laboratory, Boothbay Harbor.

Boothbay Harbor temperature data comprise the only unbroken New England water temperature record covering the period 1943-61. While shoreline temperature undoubtedly reflects to some degree the trend in bottom temperature offshore on the fishing grounds, comparison between Boothbay Harbor January - March surface temperature and that recorded on lightships some distance from shore failed to show a high degree of association. The correlation coefficient between temperature at Boothbay Harbor and Portland lightship (43° 32′ N, 70° 06′ W; depth 27 m), using the 23 years comparable data given by Bumpus (1957a), although significant ($r = 0.61$, $p < 0.01$), was not high. The correlation between temperature at Boothbay Harbor and Nantucket lightship, moored on the southern New England ground (40° 37′ N, 69° 38′W; depth 55 m), using 21 years data, was similar in magnitude ($r = 0.63$, $p < 0.01$). However, the correlation coefficient between January - March temperature recorded at these 2 lightships was not significant ($r = 0.33$, $p = 0.25$), but here only 14 years data were available for comparison.

In view of the inconclusiveness of the above comparisons and of lack of continuous records of bottom temperature on fishing grounds, further analysis of the relationship of climatic change to yellowtail apparent abundance appears to be of little use at present.

Conclusions

1. Fluctuations in yellowtail flounder landings on the principal New England fishing grounds have resulted from variations in apparent abundance and fishing effort.

2. Relative apparent abundance of yellowtail, as shown by landings per day of fishing effort, was high in the early part of the period 1943-61, declined in the late 1940's and early 1950's, and increased again in the late 1950's.

3. Apparent abundance usually was higher on Georges Bank, an offshore ground, than on the southern New England and Cape Cod grounds, which are inshore.

4. Trends in relative apparent abundance were similar on all grounds.

5. The available data provide no evidence that overfishing has occurred on the three New England grounds in the period covered. This is the conclusion reached by Royce *et al.* (1959) for the southern New England ground alone in 1942-49.

Summary

The New England fishery for yellowtail flounder developed in the 1930's when a demand for the species arose.

Otter trawlers of 45-75 feet (14-23 m) in length are the vessel sizes used. There is no true yellowtail fleet because the activities of the boats vary with season and with price and abundance of a number of species.

New Bedford, Massachussetts, where 75 per cent of the catch currently is landed, is the principal yellowtail port.

Yellowtail are fished on three New England grounds: the southern New England ground (south of Cape Cod), Georges Bank, and the Cape Cod ground (east and north of Cape Cod). Marking experiments indicate that each ground supports a relatively separate yellowtail group, with little movement occurring between grounds.

Total landings have fluctuated widely. They rose to a peak of 68 million pounds (31,000 metric tons) in 1942, declined to a low of 13 million pounds (5,900 metric tons) in 1954, and have risen again to 39 million pounds (17,700 metric tons) in 1961. The southern New England ground usually has supplied most of the landings.

Yellowtail landings per day of fishing effort, as a relative apparent abundance measure, was calculated for each ground for vessels landing 50 per cent or more yellowtail at New Bedford in 1943-61. Results indicated that the patterns of landings and relative apparent abundance were similar. In some years, however, low landings apparently stemmed from low effort on abundant stocks. Apparent abundance usually was highest on Georges Bank and lowest on the Cape Cod ground. Overall patterns of relative apparent abundance were similar on all three of the New England grounds.

Changes in the level of fishing effort often followed changes in apparent abundance level, effort in some cases increasing markedly after a relatively small apparent abundance increase. Total fishing effort for all grounds averaged about 5,400 standard days per year.

There was no evidence that overfishing has occurred. A comparison of New England winter

water temperature with landings per day suggested, however, that there may have been an inverse relationship between temperature and apparent abundance, but this was not clear.

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Appendix

As noted in the text, yellowtail landings per day was calculated for each of the defined vessel size groups that fished yellowtail. The 26-50 ton group was chosen as the standard yellowtail fishing gear, and it was desired to express landings per day for each year, of all vessel groups combined, in landings per standard day fished, that is, in terms of the 26-50 ton group. This was accomplished by dividing total yellowtail landings obtained through the recorded yellowtail effort on a given ground, by total standard days fished in obtaining this catch, as shown in the equation

$$A' = \frac{(DA)_1 + (DA)_2 + (DA)_3 + (DA)_4}{D'_1 + D'_2 + D'_3 + D'_4}$$

in which, for a given year:

the subscripts 1, 2, 3, and 4 refer to the under 26, 26-50, 51-75, and 76-100 ton vessel groups, respectively;

D = days fished for yellowtail by a given vessel group (Tables A-2, A-3, and A-4);

A = landings per day for a given vessel group (Tables A-2, A-3, and A-4);

D' = standard days fished for yellowtail by a given vessel group;

A' = landings per standard day for all vessel groups combined.

To obtain the values for D' for the different vessel groups, the fishing power of each group in relation to fishing power of the 26-50 ton group was calculated. For the southern New England ground, as an example, data in Table A-2 were used. To find the relative fishing power of the under 26 ton vessels, the average landings per day for the entire period for this group, unweighted for fishing effort, was calculated, using annual landings per day data from all years in which 50 or more days of yellowtail fishing effort was recorded[7]. The resulting average of 4,232 pounds per day was based on annual landings per day for 13 years (1943-50 and 1957-61). Average landings per day for these years for the 26-50 ton vessels, calculated in the same way, was 5,184 pounds. Evidently the fishing power of the smaller vessels was 4,232 /5,184 or 0.816 times that of the 26-50 ton vessels. This fishing power factor was used to convert days fished of the smaller vessels (Table A-2) to standard days fished. This same method was used in converting the days fished of 51-75 and 76-100 ton vessels into standard days.

The above procedure, except as noted below for the Cape Cod ground, was followed for the three principal grounds, using data from Tables A-2, A-3, and A-4. Resulting mean landings per standard day for all grounds are given in Table A-1.

For the Cape Cod ground the data of Table A-4 were considered inadequate for determining relative fishing power of the two vessel groups that fished this ground, since recorded effort was less than 50 days in many of the years. The fishing power factor calculated for the same vessel groups on the southern New England ground was therefore used to convert days fished by the under 26-ton vessels on the Cape Cod ground to standard days.

Total fishing effort in standard days fished, by year for each ground, was obtained by dividing the total yellowtail landings (Table 2) by landings per standard day (Table A-1). The resulting fishing effort figures are given in Table A-1.

TABLE A-1. Total estimated yellowtail fishing effort in standard days fished and average yellowtail landings per standard day in pounds for the principal New England grounds, 1943-61.
(1 metric ton = 2,205 pounds)

	Southern New England Ground		Georges Bank		Cape Cod Ground	
Year	Days fished	Landings per day	Days fished	Landings per day	Days fished	Landings per day
1943	5,681	7,002	198	14,047	529	5,350
1944	4,164	5,621	217	16,881	1,008	3,308
1945	2,852	8,015	282	10,605	606	4,218
1946	3,596	6,636	232	8,264	622	4,457
1947	4,550	5,869	480	10,360	746	3,202
1948	5,047	4,334	1,122	11,116	472	3,101
1949	3,248	3,173	2,493	6,458	677	4,004
1950	3,062	3,391	1,636	5,246	952	3,123
1951	1,889	3,253	1,611	5,900	792	2,345
1952	2,364	2,788	1,596	5,043	760	2,255
1953	1,442	3,023	1,241	5,149	778	2,193
1954	1,200	2,784	1,385	4,595	890	2,773
1955	1,529	3,143	1,234	5,262	996	2,887
1956	2,297	3,399	790	4,452	1,340	2,421
1957	2,396	5,063	821	6,181	1,439	3,610
1958	3,666	5,356	1,400	7,139	925	3,842
1959	4,904	3,479	1,969	4,625	762	4,415
1960	4,439	3,896	2,018	4,858	1,121	3,564
1961	4,686	5,473	1,816	5,158	914	4,535

[7])A comparison of landings per day of the different vessel size groups for the 19-year period covered suggested that a useful estimate of landings per day could be obtained where 50 or more days fishing effort had been recorded.

TABLE A-2. Days fished and average yellowtail landings per day in pounds for otter trawler trips landing 50 per cent or more yellowtail at New Bedford from the southern New England ground, by vessel size and by calendar quarter and year, 1942-61. (1 metric ton = 2,205 pounds).

	Vessel Size (Gross Tons)							
	Under 26		26 - 50		51 - 75		76 - 100	
Year and Quarter	Days fished	Landings per day	Days fished	Landings per day	Days fished	Landings per day	Days fished	Landings per day
1942								
Oct. - Dec.	161.5	11,102	297.1	8,583	54.5	10,712	—	—
1943								
Jan. - Mar.	277.8	4,993	632.4	5,594	155.6	8,454	—	—
Apr. - Jun.	356.3	4,185	299.0	4,821	9.9	6,749	—	—
Jul. - Sept.	490.3	7,683	392.4	10,280	34.0	18,304	20.7	12,202
Oct. - Dec.	76.5	5,298	209.4	5,493	44.2	8,024	24.8	7,625
Annual Total	1,200.9	5,871	1,533.4	6,628	243.7	9,681	45.5	9,707
1944								
Jan. - Mar.	273.7	4,304	547.6	5,509	63.3	5,925	8.5	5,106
Apr. - Jun.	76.0	4,029	48.2	5,108	—	—	—	—
Jul. - Sept.	153.4	4,558	317.6	6,690	37.6	7,111	6.3	7,798
Oct. - Dec.	3.5	1,707	47.1	4,173	3.1	3,010	—	—
Annual Total	506.6	4,322	960.5	5,814	104.0	6,267	14.8	6,252
1945								
Jan. - Mar.	136.0	4,554	239.7	5,764	35.3	6,274	—	—
April. - Jun.	4.0	5,616	12.3	4,358	—	—	—	—
Jul. - Sept.	167.5	7,396	253.7	9,157	44.8	8,876	—	—
Oct. - Dec.	153.2	7,005	297.3	9,551	64.2	10,080	—	—
Annual Total	460.7	6,412	803.0	8,216	144.3	8,775	—	—
1946								
Jan. - Mar.	122.2	5,726	212.6	6,113	56.3	7,249	—	—
Apr. - Jun.	19.0	4,544	58.2	6,463	1.0	7,750	—	—
Jul. - Sept.	185.5	5,228	367.6	6,883	81.5	6,230	11.1	6,844
Oct. - Dec.	213.1	5,777	545.3	7,066	129.2	7,386	12.1	6,073
Annual Total	539.8	5,533	1,183.7	6,808	268.0	7,007	23.2	6,442
1947								
Jan. - Mar.	82.8	5,064	285.5	5,634	88.3	6,196	12.7	5,298
Apr. - Jun.	136.5	3,817	176.9	4,522	7.4	2,164	—	—
Jul. - Sept.	145.9	6,719	364.6	7,871	82.3	8,648	—	—
Oct. - Dec.	326.5	4,824	756.0	5,295	104.9	5,254	24.9	6,871
Annual Total	691.7	5,054	1,583.0	5,863	282.9	6,455	37.6	6,340
1948								
Jan. - Mar.	193.2	2,927	540.8	3,144	69.5	4,185	13.5	3,076
Apr. - June	152.9	3,524	328.8	3,850	16.0	5,535	—	—
Jul. - Sept.	186.3	4,399	588.1	4,793	60.4	4,703	11.4	7,513
Oct. - Dec.	114.1	4,131	593.4	4,896	104.7	6,478	26.5	6,831
Annual Total	646.5	3,705	2,051.1	4,237	250.6	5,354	51.4	5,996
1949								
Jan. - Mar.	101.6	2,295	725.5	2,534	65.0	2,854	7.0	6,964
Apr. - Jun.	16.5	2,084	91.7	2,429	6.5	2,154	—	—
Jul. - Sept.	4.2	2,547	103.2	4,738	10.0	5,146	12.0	7,135
Oct. - Dec.	45.8	2,966	361.8	3,788	94.7	4,969	24.2	5,954
Annual Total	168.1	2,464	1,282.2	3,058	176.2	4,095	43.2	6,446
1950								
Jan. - Mar.	52.0	2,548	266.2	2,973	62.6	3,225	32.1	3,584
Apr. - Jun.	—	—	12.5	2,233	—	—	—	—
Jul. - Sept.	9.8	4,254	48.9	2,556	3.0	1,027	—	—
Oct. - Dec.	34.2	3,327	437.8	3,852	135.6	4,118	10.5	4,706
Annual Total	96.0	3,000	765.4	3,437	201.2	3,794	42.6	3,860
1951								
Jan. - Mar.	—	—	95.6	2,318	13.5	3,195	4.0	3,750
Apr. - Jun.	—	—	6.4	2,238	4.0	1,781	—	—
Jul. - Sept.	—	—	122.6	3,592	33.6	7,136	4.0	1,406
Oct. - Dec.	7.2	3,538	195.5	3,069	77.4	3,871	—	—
Annual Total	7.2	3,538	420.1	3,038	128.5	4,589	8.0	2,578
1952								
Jan. - Mar.	1.3	2,273	37.4	3,820	8.2	4,417	—	—
Apr. - Jun.	2.0	2,660	3.0	1,472	—	—	—	—
Jul. - Sept.	4.0	969	65.0	2,179	10.0	4,375	—	—
Oct. - Dec.	9.3	2,126	342.2	2,704	185.9	3,346	22.5	3,930
Annual Total	16.6	1,923	447.6	2,713	204.1	3,439	22.5	3,930
1953								
Jan. - Mar.	7.3	2,171	156.0	2,440	44.0	2,728	2.6	2,571
Apr. - Jun.	1.0	2,125	27.7	2,758	6.5	5,212	—	—
Jul. - Sept.	3.0	1,833	92.2	3,626	47.0	5,484	—	—
Oct. - Dec.	—	—	134.1	3,145	95.5	3,144	5.2	5,920
Annual Total	11.3	2,077	410.0	2,959	193.0	3,689	7.8	4,804
1954								
Jan. - Mar.	10.0	2,611	34.5	2,319	56.2	3,231	14.0	4,107
Apr. - Jun.	—	—	9.8	2,386	—	—	—	—
Jul. - Sept.	4.0	348	7.5	2,639	—	—	—	—
Oct. - Dec.	21.3	1,596	103.8	3,201	40.0	3,142	5.0	2,800
Annual Total	35.3	1,742	155.6	2,927	96.2	3,194	19.0	3,763

TABLE A-2 (continued)

	Vessel Size (Gross Tons)							
	Under 26		26 - 50		51 - 75		76 - 100	
Year and Quarter	Days fished	Landings per day	Days fished	Landings per day	Days fished	Landings per day	Days fished	Landings per day
1955								
Jan. - Mar.	8.6	1,875	127.2	2,840	34.1	3,330	17.5	3,018
Apr. - Jun.	2.0	1,237	7.0	2,969	—	—	—	—
Jul. - Sept.	4.0	719	24.2	4,661	1.5	9,817	—	—
Oct. - Dec.	14.0	1,328	264.9	3,267	114.7	3,882	18.0	3,772
Annual Total	28.6	1,401	423.3	3,213	150.3	3,816	35.5	3,400
1956								
Jan. - Mar.	30.1	2,354	117.3	2,503	58.5	2,633	1.0	3,750
Apr. - Jun.	—	—	16.7	3,331	10.5	4,401	—	—
Jul. - Sept.	11.1	2,667	121.1	4,236	45.5	4,563	—	—
Oct. - Dec.	6.8	3,299	380.5	3,718	160.0	3,614	9.5	5,408
Annual Total	48.0	2,560	635.6	3,582	274.5	3,593	10.5	5,250
1957								
Jan. - Mar.	7.0	3,356	230.2	3,388	76.0	4,116	8.5	4,634
Apr. - Jun.	1.0	2,500	24.5	3,392	4.5	4,667	—	—
Jul. - Sept.	21.4	1,965	74.5	3,579	20.5	5,530	18.7	2,333
Oct. - Dec.	24.5	5,269	307.3	6,495	266.1	7,257	40.5	7,014
Annual Total	53.9	3,658	636.5	4,911	367.1	6,478	67.7	5,422
1958								
Jan. - Mar.	39.5	5,366	304.0	4,908	166.2	5,215	40.5	5,028
Apr. - Jun.	8.0	3,929	97.2	4,072	72.2	3,196	4.3	3,284
Jul. - Sept.	6.4	5,816	166.1	6,111	59.6	6,390	12.8	6,948
Oct. - Dec.	10.8	3,928	562.9	5,954	440.4	6,643	106.1	7,626
Annual Total	64.7	4,993	1,130.2	5,534	738.4	5,964	163.7	6,816
1959								
Jan. - Mar.	37.8	2,696	462.8	3,425	157.0	3,942	30.0	4,672
Apr. - Jun.	5.2	3,540	186.1	3,453	81.0	2,880	17.0	3,094
Jul. - Sept.	6.5	4,590	201.3	5,524	188.8	6,277	15.8	5,979
Oct. - Dec.	39.3	2,098	546.4	3,030	468.3	3,400	93.2	3,468
Annual Total	88.8	2,619	1,396.6	3,576	895.1	4,055	156.0	3,913
1960								
Jan. - Mar.	48.1	1,780	451.8	2,575	188.4	3,869	19.2	3,785
Apr. - Jun.	36.5	2,281	117.8	2,205	40.3	2,234	21.2	4,682
Jul. - Sept.	20.7	3,852	395.6	4,374	191.6	4,278	39.9	4,460
Oct. - Dec.	52.8	4,369	515.9	5,017	373.4	5,802	78.6	5,219
Annual Total	158.1	3,031	1,481.1	3,877	793.7	4,794	158.9	4,221
1961								
Jan. - Mar.	83.4	3,790	508.4	4,246	348.5	4,607	50.0	6,415
Apr. - Jun.	44.5	2,986	239.7	3,463	99.7	3,769	5.0	4,835
Jul. - Sept.	20.5	5,808	392.3	5,352	177.4	5,930	40.9	7,138
Oct. - Dec.	32.9	6,741	452.5	7,866	482.2	8,443	51.2	10,041
Annual Total	181.3	4,356	1,592.9	5,429	1,107.8	6,413	147.1	7,824

TABLE A-3. Days fished and average yellowtail landings per day in pounds for otter trawler trips landing 50 per cent or more yellowtail at New Bedford from Georges Bank, by vessel size and by calendar quarter and year, 1942-61. (1 metric ton = 2,205 pounds).

	Vessel Size (Gross Tons)					
	26 - 50		51 - 75		76 - 100	
Year & Quarter	Days fished	Landings per day	Days fished	Landings per day	Days fished	Landings per day
1942						
Oct. - Dec.	3.1	28,703	9.4	16,037	2.9	32,025
1943						
Jan. - Mar.	5.6	14,786	16.7	14,932	5.2	19,455
Apr. - Jun.	—	—	—	—	—	—
Jul. - Sept.	—	—	—	—	—	—
Oct. - Dec.	—	—	—	—	—	—
Annual Total	5.6	14,786	16.7	14,932	5.2	19,455
1944						
Jan. - Mar.	17.7	13,103	40.8	21,769	19.8	18,482
Apr. - Jun.	—	—	—	—	—	—
Jul. - Sept.	—	—	—	—	—	—
Oct. - Dec.	—	—	6.4	19,756	—	—
Annual Total	17.7	13,103	47.2	21,496	19.8	18,482
1945						
Jan. - Mar.	12.1	6,748	27.9	7,184	37.8	17,527
Apr. - Jun.	—	—	—	—	—	—
Jul. - Sept.	—	—	9.0	14,076	—	—
Oct. - Dec.	0.3	12,867	—	—	—	—
Annual Total	12.4	6,896	36.9	8,865	37.8	17,527
1946						
Jan. - Mar.	2.5	13,259	24.7	9,925	13.7	8,507
Apr. - Jun.	—	—	—	—	—	—
Jul. - Sept.	—	—	10.9	8,962	—	—
Oct. - Dec.	—	—	—	—	—	—
Annual Total	2.5	13,259	36.5	9,630	13.7	8,507

TABLE A-3 (continued)

	Vessel Size (Gross Tons)					
	26 - 50		51 - 75		76 - 100	
Year & Quarter	Days fished	Landings per day	Days fished	Landings per day	Days fished	Landings per day
1947						
Jan. - Mar.	—	—	—	—	—	—
Apr. - Jun.	—	—	—	—	—	—
Jul. - Sept.	1.8	5,586	5.8	8,966	—	—
Oct. - Dec.	1.9	7,871	13.5	13,016	30.6	13,377
Annual Total	3.7	6,759	19.3	11,799	30.6	13,377
1948						
Jan. - Mar.	—	—	15.0	8,228	7.2	9,021
Apr. - Jun.	—	—	—	—	—	—
Jul. - Sept.	117.0	11,008	55.1	13,485	112.9	15,629
Oct. - Dec.	39.4	8,548	21.8	10,806	37.9	14,287
Annual Total	156.4	10,388	91.9	11,991	158.0	15,006
1949						
Jan. - Mar.	20.1	3,986	19.5	6,482	2.9	17,210
Apr. - Jun.	51.6	3,909	7.9	5,839	4.8	5,313
Jul. - Sept.	261.3	6,580	154.9	8,365	119.8	8,831
Oct. - Dec.	125.2	6,088	103.6	7,075	93.2	7,798
Annual Total	458.2	6,031	285.9	7,699	220.7	8,428
1950						
Jan. - Mar.	—	—	—	—	—	—
Apr. - Jun.	76.0	3,937	42.3	4,170	5.0	3,710
Jul. - Sept.	346.9	5,146	267.8	6,884	87.0	6,052
Oct. - Dec.	34.3	5,908	18.8	4,620	—	—
Annual Total	457.2	5,002	328.9	6,406	92.0	5,925
1951						
Jan. - Mar.	—	—	—	—	—	—
Apr. - Jun.	20.5	5,705	18.3	6,223	3.5	4,064
Jul. - Sept.	282.2	5,178	143.4	7,953	46.5	7,113
Oct. - Dec.	76.8	6,178	121.1	6,597	15.5	9,278
Annual Total	379.5	5,409	282.8	7,260	65.5	7,463
1952						
Jan. - Mar.	—	—	—	—	—	—
Apr. - Jun.	58.5	4,484	30.0	5,049	4.0	7,156
Jul. - Sept.	331.8	5,147	203.5	5,721	48.0	6,399
Oct. - Dec.	66.6	5,182	48.5	5,127	23.0	6,832
Annual Total	456.9	5,068	282.0	5,547	75.0	6,572
1953						
Jan. - Mar.	—	—	—	—	—	—
Apr. - Jun.	35.4	3,960	29.3	4,461	—	—
Jul. - Sept.	307.0	4,663	231.1	5,543	63.2	5,852
Oct. - Dec.	121.0	6,848	73.1	6,996	8.5	9,505
Annual Total	463.4	5,180	333.5	5,766	71.7	6,285
1954						
Jan. - Mar.	—	—	—	—	—	—
Apr. - Jun.	52.5	4,435	46.0	4,529	20.7	5,543
Jul. - Sept.	282.7	4,540	182.9	4,530	37.5	6,131
Oct. - Dec.	67.3	5,103	65.9	6,187	31.7	7,513
Annual Total	402.5	4,620	294.8	4,900	89.8	6,483
1955						
Jan. - Mar.	—	—	—	—	—	—
Apr. - Jun.	59.0	4,250	41.0	4,241	—	—
Jul. - Sept.	270.5	4,717	214.3	5,896	60.5	6,288
Oct. - Dec.	98.8	7,013	84.3	6,765	64.0	7,383
Annual Total	428.3	5,182	339.6	5,912	124.5	6,851
1956						
Jan. - Mar.	—	—	—	—	—	—
Apr. - Jun.	3.7	3,203	10.0	3,300	3.5	2,678
Jul. - Sept.	194.3	4,505	179.4	4,728	67.0	5,778
Oct. - Dec.	27.2	4,972	63.5	5,429	5.5	8,182
Annual Total	225.2	4,540	252.9	4,847	76.0	5,809
1957						
Jan. - Mar.	—	—	—	—	—	—
Apr. - Jun.	10.0	4,473	3.5	7,250	4.5	4,944
Jul. - Sept.	216.0	6,626	203.8	6,568	72.0	6,746
Oct. - Dec.	28.5	7,956	20.8	7,963	15.0	8,317
Annual Total	254.5	6,690	228.1	6,705	91.5	6,915
1958						
Jan. - Mar.	—	—	—	—	—	—
Apr. - Jun.	35.2	5,601	101.0	4,896	13.5	8,852
Jul. - Sept.	253.0	8,174	445.5	8,040	103.5	9,342
Oct. - Dec.	25.3	8,206	69.0	8,608	34.5	8,488
Annual Total	313.5	7,884	615.5	7,588	151.5	9,104
1959						
Jan. - Mar.	—	—	3.0	9,208	—	—
Apr. - Jun.	53.6	4,065	197.4	4,092	34.0	5,833
Jul. - Sept.	242.4	4,796	525.5	5,548	130.5	5,849
Oct. - Dec.	28.6	4,606	50.0	5,232	16.5	5,280
Annual Total	324.6	4,658	775.9	5,172	181.0	5,794
1960						
Jan. - Mar.	2.5	2,550	—	—	—	—
Apr. - Jun.	66.5	3,855	120.7	4,009	35.0	3,668
Jul. - Sept.	295.4	5,234	392.9	5,594	149.7	5,861
Oct. - Dec.	47.9	7,128	89.7	5,963	34.4	7,363
Annual Total	412.3	5,216	603.3	5,331	219.1	5,746
1961						
Jan. - Mar.	5.0	3,045	2.5	3,900	—	—
Apr. - Jun.	61.9	4,878	158.1	4,716	39.5	5,835
Jul. - Sept.	249.6	5,365	440.2	5,901	83.3	5,745
Oct. - Dec.	32.8	6,324	50.0	8,084	17.5	8,078
Annual Total	349.3	5,336	650.8	5,773	140.3	6,062

TABLE A-4. Days fished and average yellowtail landings per day in pounds for otter trawler trips landing 50 per cent or more yellowtail at New Bedford from the Cape Cod ground, by vessel size and year, 1943-61. (1 metric ton = 2,205 pounds)

Year	Under 26 ton vessels		26 to 50 ton vessels	
	Days fished	Landings per day	Days fished	Landings per day
1943	34.6	4,305	4.7	5,814
1944	65.1	3,363	46.4	2,374
1945	5.1	4,668	5.0	2,959
1946	10.9	2,795	8.9	5,492
1947	63.0	2,295	27.1	3,944
1948	9.2	2,668	6.9	2,920
1949	17.4	2,414	58.7	4,258
1950	15.1	2,396	85.2	3,150
1951	33.4	1,809	151.6	2,368
1952	40.2	1,839	168.2	2,255
1953	53.3	1,744	129.2	2,212
1954	24.6	2,435	134.8	2,742
1955	44.0	1,730	191.2	3,031
1956	24.2	1,604	91.0	2,520
1957	33.0	3,167	219.0	3,577
1958	11.5	2,919	30.1	3,926
1959	7.9	4,332	14.3	4,016
1960	17.7	2,828	50.1	3,593
1961	26.3	4,107	27.6	4,149

1963 ICNAF Cod Otolith Exchange

BY A. C. KOHLER[1]

Abstract

Results of cod otolith age readings of three samples, by six different laboratories situated in ICNAF[2] countries are presented. They indicate that there are discrepancies in criteria used to define annuli and point to the need for continuing validation studies in age determination of cod.

Material

In November 1962, samples of cod otoliths from ICNAF Subareas 2, 3, and 4, read by Miss G. Quartin of Portugal, were sent to the Bergen Workshop on Ageing Techniques. Preliminary readings of parts of the otolith samples by participants at the Workshop, indicated varying amounts of agreement on age estimations for individual fish. It was therefore decided to do a complete analysis, and the samples were circulated to those laboratories expressing interest. The otoliths were read, the readings were sent to ICNAF headquarters, and the data were summarized for the 1963 Annual Meeting of ICNAF in Document No. 69. Since then, readings by the St. John's laboratory of the Fisheries Research Board of Canada and the Instituto de Investigaciones Pesqueras, Spain, have been added to the summary.

Results

Figures 1A to 3D show comparisons of age estimations by the various laboratories, plotted by ages in the manner used by Kohler and Clark (1958). For each comparison the agreements (i.e., the cases where ages read by the two laboratories were identical) are shown by the numbers inside the squares. The disagreements are outside. The plots indicate that most of the disagreements do not differ by more than one year. The comparison also shows the biased nature of the disagreements for some of the samples. These are examined further in Table 1.

Table 1 shows agreements and disagreements in age readings by the various laboratories involved in the exchange. For convenience, these

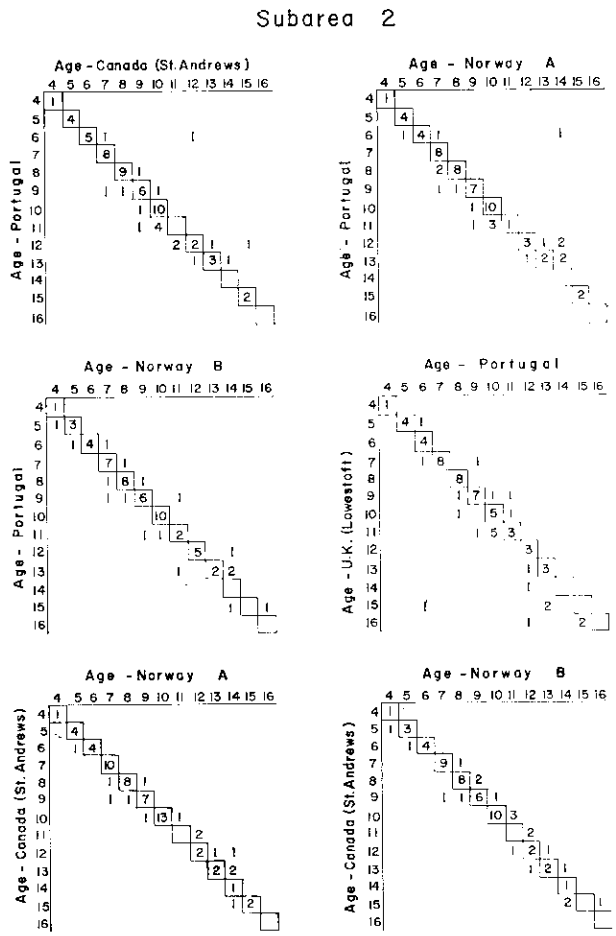

Fig. 1A. Comparisons of age readings for Subarea 2 cod samples by the various laboratories participating in the exchange.

are expressed as percentages of the total number of otoliths read in each comparison. The percentage agreement varies from 66 to 80 in Subarea 2, 55 to 80 in Subarea 3, and 48 to 84 in Subarea 4. Agreement is consistently better for the Subarea 2 samples because cod otoliths from this region usually have better defined hyaline and opaque zones. Cod otoliths from Subareas 3 and 4 are generally more troublesome because of atypical centres, indistinct outer zones,

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[1])Fisheries Research Board of Canada Biological Station, St. Andrews, N. B.

[2])International Commission for the Northwest Atlantic Fisheries.

TABLE 1. Summary of agreements and disagreements in age estimates from cod otolith samples submitted by Portugal to the Bergen Workshop on Ageing Techniques.

Laboratories whose readings are compared		No. otoliths	% agreements	Distribution of disagreements by laboratories (% that were higher)			
Subarea 2 - 1960							
Canada (St. Andrews)	— Portugal	69	74	Portugal	16%	— Canada	10%
Norway A	— Portugal	69	74	Portugal	16%	— Norway A	10%
Norway B	— Portugal	67	72	Portugal	15%	— Norway B	13%
U.K. (Lowestoft)	— Portugal	69	68	U.K.	25%	— Portugal	7%
Norway A	— Canada (SA)	69	80	Norway A	12%	— Canada	9%
Norway B	— Canada (SA)	67	69	Norway B	18%	— Canada	13%
U.K. (Lowestoft)	— Canada (SA)	69	67	U.K.	32%	— Canada	1%
U.K. (Lowestoft)	— Norway A	69	72	U.K.	28%	— Norway A	0%
U.K. (Lowestoft)	— Norway B	67	72	U.K.	25%	— Norway B	3%
U.K. (Lowestoft)	— Canada (St. John's)	69	71	U.K.	20%	— Canada	9%
Portugal	— Canada (SJ)	69	76	Canada	17%	— Portugal	7%
Norway A	— Canada (SJ)	69	75	Canada	22%	— Norway A	3%
Norway B	— Canada (SJ)	67	67	Canada	27%	— Norway B	6%
Canada (SA)	— Canada (SJ)	69	78	Canada (SJ)	22%	— Canada (SA)	0%
U.K. (Lowestoft)	— Spain	68	66	U.K.	28%	— Spain	6%
Portugal	— Spain	68	75	Portugal	10%	— Spain	15%
Norway A	— Spain	68	77	Norway A	7%	— Spain	16%
Norway B	— Spain	66	73	Norway B	11%	— Spain	16%
Canada (SA)	— Spain	68	74	Canada (SA)	6%	— Spain	20%
Canada (SJ)	— Spain	68	75	Canada (SJ)	18%	— Spain	7%
Subarea 3 - 1957							
Canada (SA)	— Portugal	40	62	Canada	25%	— Portugal	12%
Norway A	— Portugal	40	68	Portugal	22%	— Norway A	10%
Norway B	— Portugal	40	65	Portugal	22%	— Norway B	12%
U.K. (Lowestoft)	— Portugal	40	60	U.K.	25%	— Portugal	15%
Norway A	— Canada (SA)	40	60	Canada	32%	— Norway A	7%
Norway B	— Canada (SA)	40	60	Canada	30%	— Norway B	10%
U.K. (Lowestoft)	— Canada (SA)	40	65	U.K.	18%	— Canada	18%
U.K. (Lowestoft)	— Norway A	40	70	U.K.	25%	— Norway A	5%
U.K. (Lowestoft)	— Norway B	40	68	U.K.	25%	— Norway B	8%
U.K. (Lowestoft)	— Canada (SJ)	40	68	Canada	17%	— U.K.	15%
Portugal	— Canada (SJ)	40	70	Canada	23%	— Portugal	7%
Norway A	— Canada (SJ)	40	55	Canada	37%	— Norway A	8%
Norway B	— Canada (SJ)	40	62	Canada	33%	— Norway B	5%
Canada (SA)	— Canada (SJ)	40	68	Canada (SA)	15%	— Canada (SJ)	17%
U.K. (Lowestoft)	— Spain	40	78	U.K.	10%	— Spain	12%
Portugal	— Spain	40	75	Portugal	5%	— Spain	20%
Norway A	— Spain	40	67	Norway A	3%	— Spain	30%
Norway B	— Spain	40	70	Norway B	3%	— Spain	27%
Canada (SA)	— Spain	40	80	Canada	10%	— Spain	10%
Canada (SJ)	— Spain	40	80	Canada	10%	— Spain	10%
Subarea 4 - 1958							
Canada (SA)	— Portugal	101	61	Canada	28%	— Portugal	11%
Norway A	— Portugal	101	59	Norway A	26%	— Portugal	15%
Norway B	— Portugal	100	64	Norway B	23%	— Portugal	12%
U.K. (Lowestoft)	— Portugal	101	56	U.K.	40%	— Portugal	4%
Norway A	— Canada (SA)	101	84	Canada	12%	— Norway A	4%
Norway B	— Canada (SA)	100	77	Canada	15%	— Norway B	7%
U.K. (Lowestoft)	— Canada (SA)	101	73	U.K.	18%	— Canada	9%
U.K. (Lowestoft)	— Norway A	101	70	U.K.	25%	— Norway A	5%
U.K. (Lowestoft)	— Norway B	100	66	U.K.	26%	— Norway B	7%
Portugal	— Canada (SJ)	101	48	Canada	42%	— Portugal	10%
Norway A	— Canada (SJ)	101	66	Canada	32%	— Norway A	2%
Norway B	— Canada (SJ)	100	64	Canada	33%	— Norway B	3%
U.K. (Lowestoft)	— Canada (SJ)	101	57	Canada	23%	— U.K.	20%
Canada (SA)	— Canada (SJ)	101	73	Canada (SJ)	23%	— Canada (SA)	4%
Portugal	— Spain	101	62	Portugal	6%	— Spain	32%
Norway A	— Spain	101	80	Norway A	0%	— Spain	20%
Norway B	— Spain	100	69	Norway B	5%	— Spain	26%
U.K. (Lowestoft)	— Spain	101	71	U.K.	17%	— Spain	12%
Canada (SA)	— Spain	101	83	Canada	2%	— Spain	15%
Canada (SJ)	— Spain	101	76	Canada	17%	— Spain	7%

Subarea 2

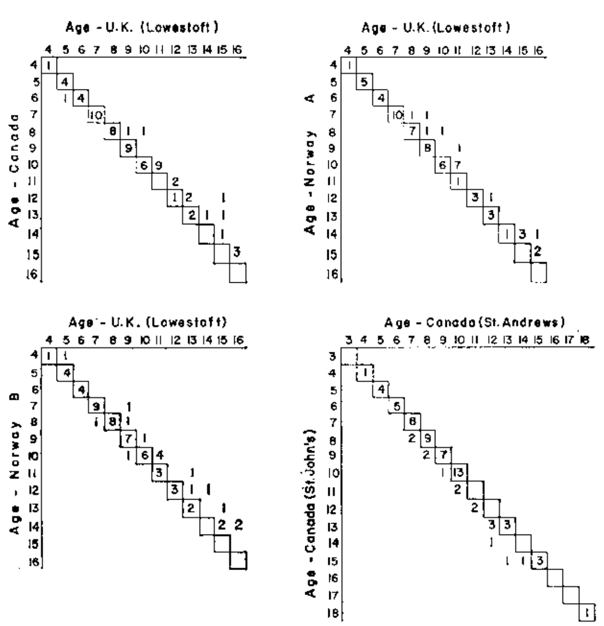

Fig. 1B. Comparisons of age readings for Subarea 2 cod samples by the various laboratories participating in the exchange.

Subarea 2

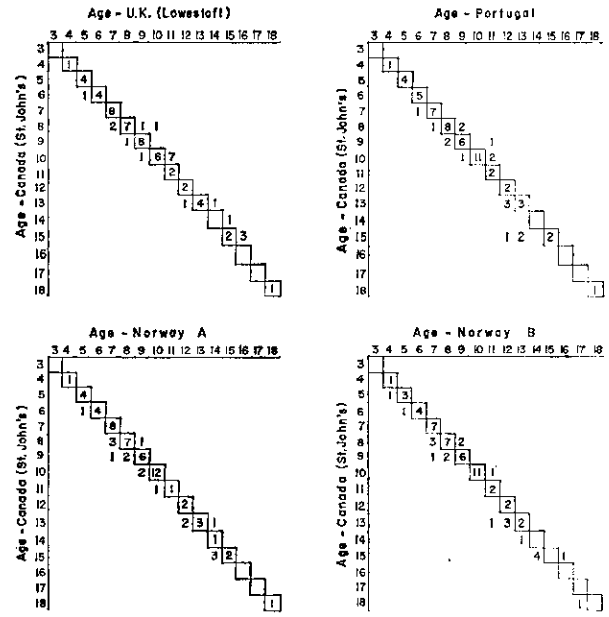

Fig. 1C. Comparisons of age readings for Subarea 2 cod samples by the various laboratories participating in the exchange.

Subarea 2

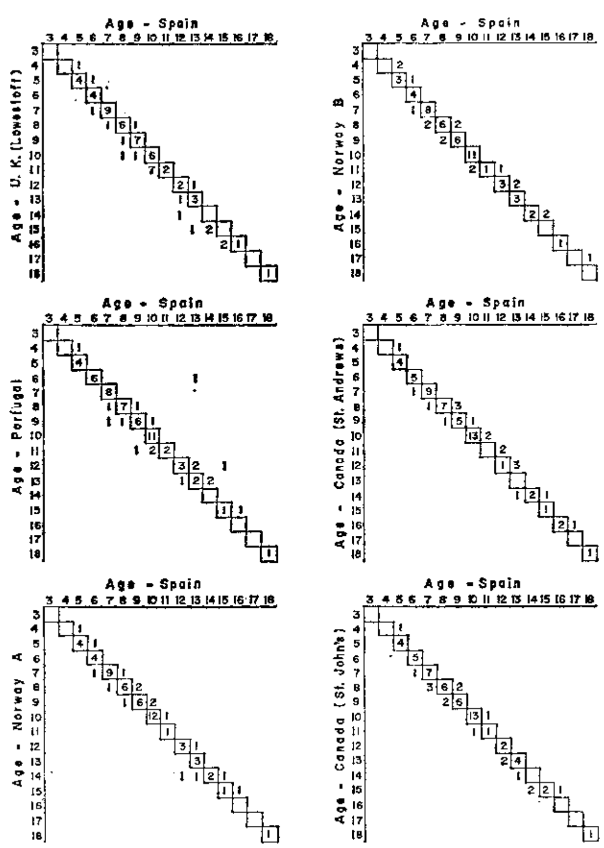

Fig. 1D. Comparisons of age readings for Subarea 2 cod samples by the various laboratories participating in the exchange.

Subarea 3

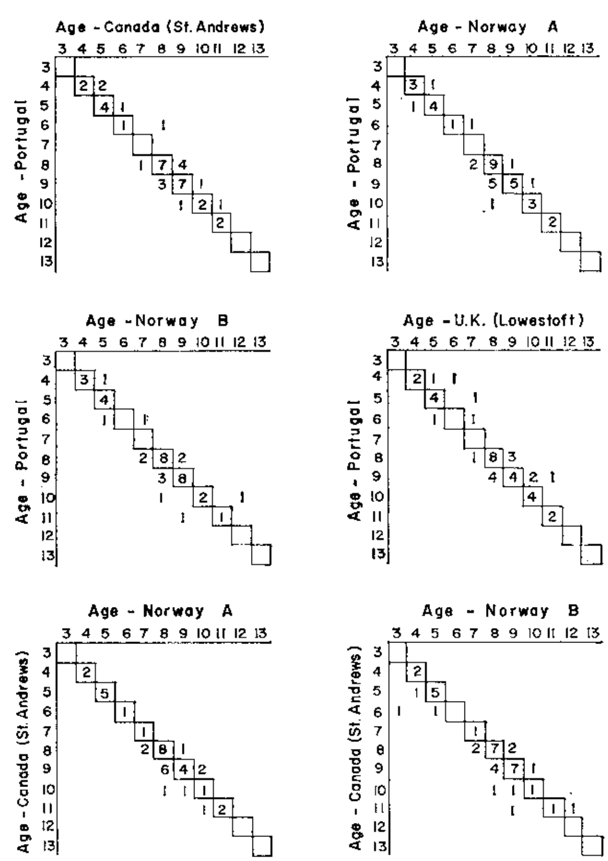

Fig. 2A. Comparisons of age readings for Subarea 3 cod samples by the various laboratories participating in the exchange.

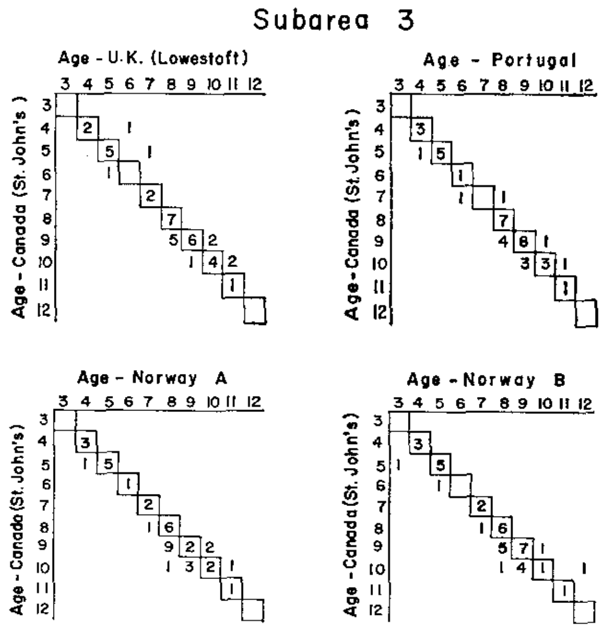

Fig. 2B. Comparisons of age readings for Subarea 3 cod samples by the various laboratories participating in the exchange.

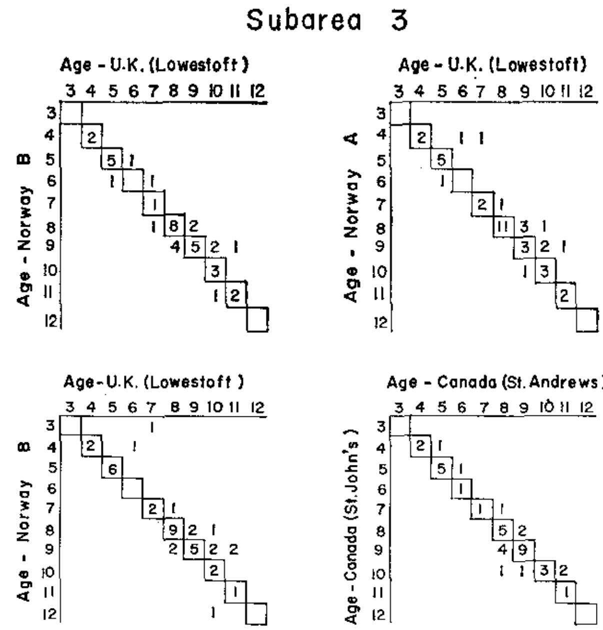

Fig. 2C. Comparisons of age readings for Subarea 3 cod samples by the various laboratories participating in the exchange.

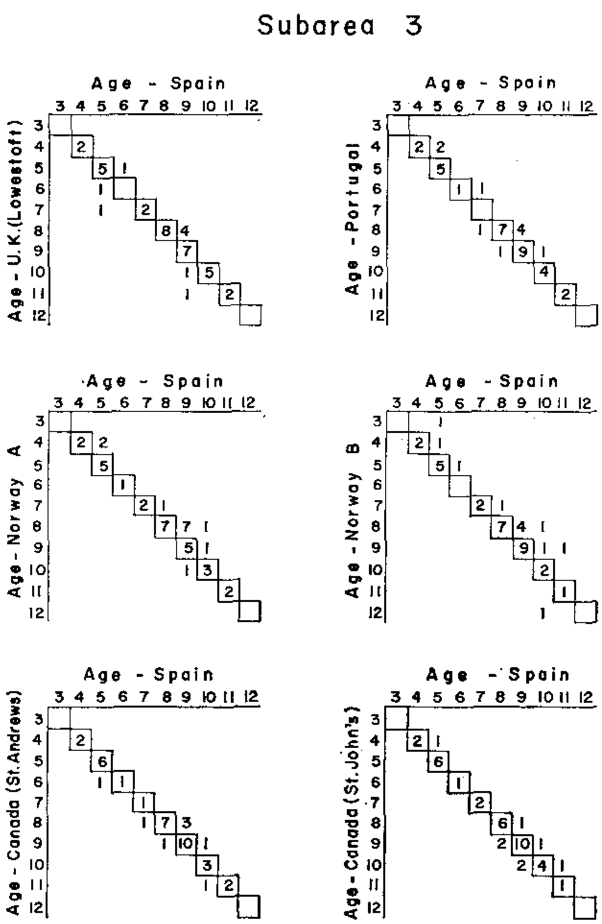

Fig. 2D. Comparisons of age readings for Subarea 3 cod samples by the various laboratories participating in the exchange.

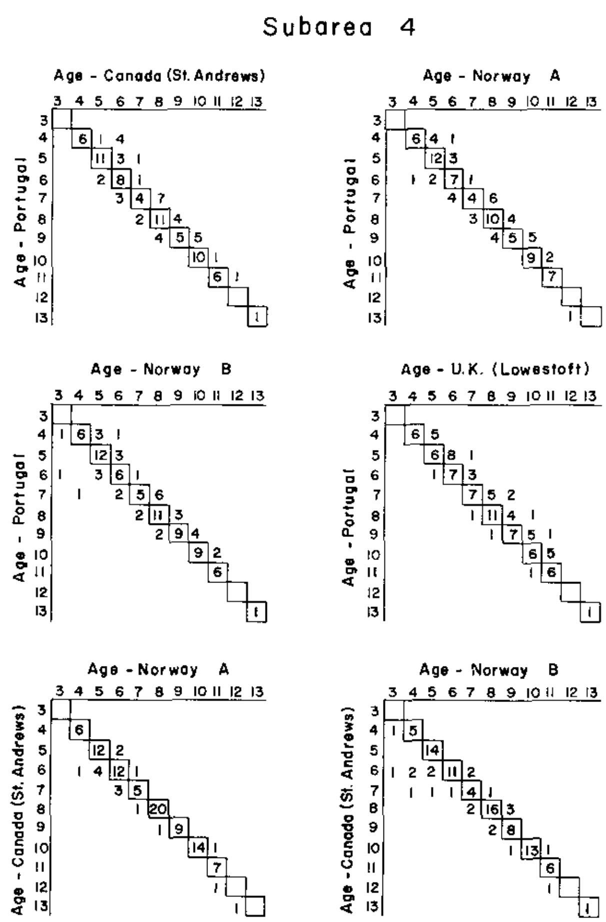

Fig. 3A. Comparisons of age readings for Subarea 4 cod samples by the various laboratories participating in the exchange.

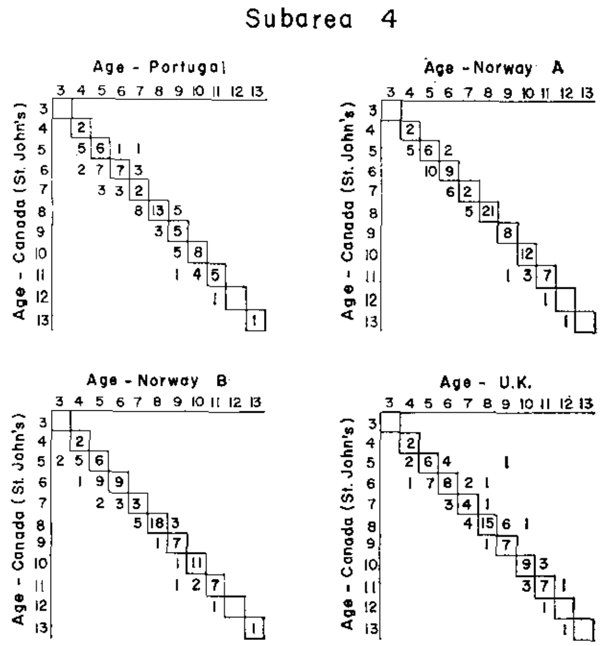

Fig. 3B. Comparisons of age readings for Subarea 4 cod samples by the various laboratories participating in the exchange.

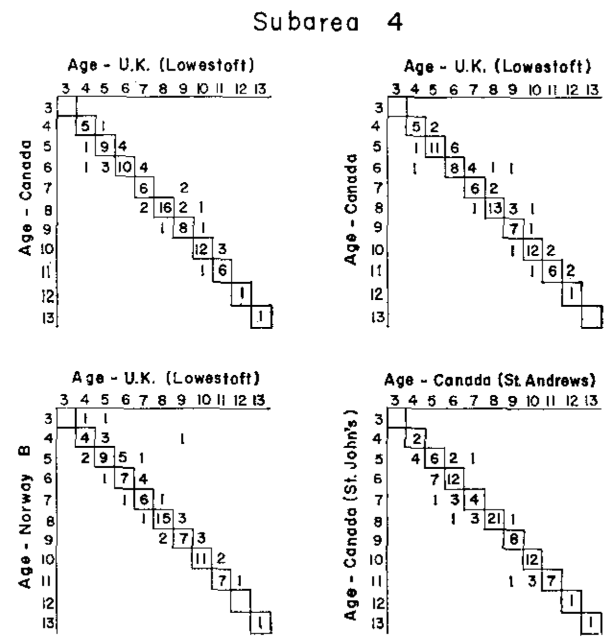

Fig. 3C. Comparisons of age readings for Subarea 4 cod samples by the various laboratories participating in the exchange.

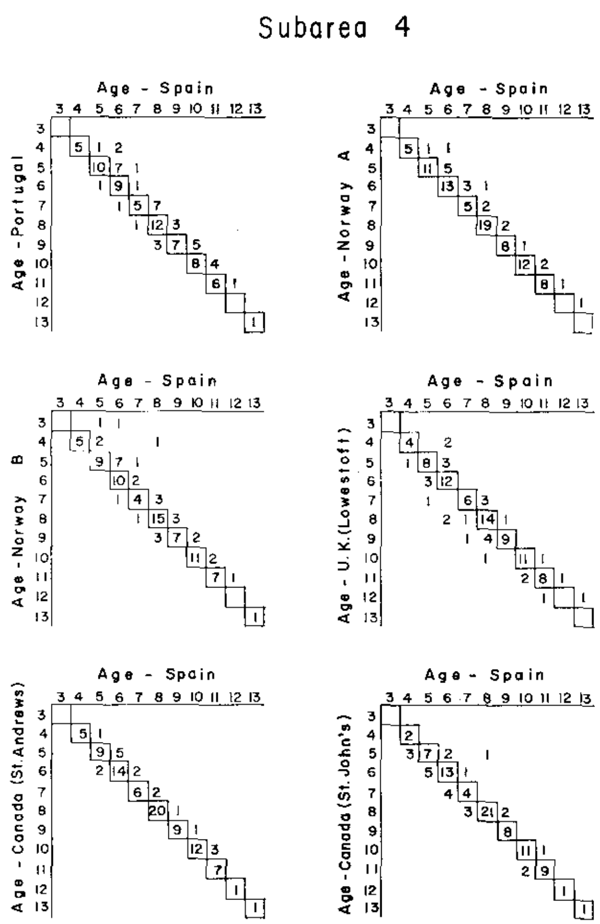

Fig. 3D. Comparisons of age readings for Subarea 4 cod samples by the various laboratories participating in the exchange.

checks, and ill-defined annuli in some of the specimens.

The figures and the table both show an uneven distribution of the disagreements in age estimation. The last column of Table 1 summarizes this. Here, the distribution of disagreements is shown by countries. In the first entry, for instance, there are disagreements in 39% of the 101 age estimates. In 28% the Canadian estimates are higher than the Portuguese, and in 11% the Portuguese are higher than the Canadian - a ratio of nearly 3:1. In two thirds of the comparisons the ratio of percentages is 2:1 or greater. If disagreement were random, the ratio would have been close to 1:1. Obviously there is considerable bias in the distribution of the disagreeing readings. Some laboratories tend to estimate high and others low.

Discussion

This summary of 1963 cod otolith exchange data shows that serious discrepancies still exist among laboratories in criteria used for age determination. Reasons for these discrepancies are usually specific to certain areas and cod populations and to factors affecting otolith formation there. These differences, especially the ones that give biased results, can affect growth and mortality estimates made for cod in the ICNAF area. The existence of such discrepancies points to the need for further studies of age-determination validity to perfect the method for the various cod populations of the ICNAF area. When such studies have been made, the information on correct methods of interpreting otolith rings can be disseminated by means of marked photographs, slides, and other visual aids.

Acknowledgements

The work on cod otolith age determination is a co-operative effort by laboratories in several countries. Among the scientists involved are: B. Rasmussen (Bergen, Norway); G. Trout and B. Bedford (Lowestoft, U.K.); G. Quartin (Portugal); J. Messtorff (Hamburg, Germany); A. Fleming (St. John's, Canada), A. Figueras (Spain).

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The Effect of Catch Size on the Selectivity of Otter Trawls

BY V. M. HODDER AND A. W. MAY[1]

Abstract

Available data pertaining to the effect of catch size on otter-trawl selectivity of cod, haddock, and redfish have been reviewed. Selectivity experiments on cod in Subarea 2 and haddock in Subarea 3, carried out by the research trawler *A. T. Cameron* between 1959 and 1962, have been analysed on a catch size basis. In all cases, a slight negative correlation is shown to exist between selection factor and size of catch. There is no indication, at least for cod and haddock, that the reduction of selection factors for large catches is of such an extent as to seriously affect assessments based on overall selectivity data. For redfish the evidence is conflicting and more research on selectivity in relation to size of catch is required.

Introduction

A common characteristic of the results of mesh selection experiments is the considerable haul-to-haul variation in the values of the selection parameters for a particular mesh size. Although much of this variation may be attributed to factors of a random nature which cause variability in all experimental work, many workers have shown that some of the variation in mesh selection, other than that related to mesh size, is associated with the gear itself (size and type of material, type of trawl, etc.), with the method of fishing (length, speed, and direction of tow, method of handling gear, etc.), with the fishing locality and species composition of the catches, and with the size of the catch. It is the last factor which concerns us in this paper.

At a symposium on problems for biological fishery research and techniques for their solution, held at Biarritz, France in 1956 (ICNAF, 1958), Working Party VI discussed the various factors, other than mesh size, which influence selectivity of trawls. It recommended that several possible sources of variation in mesh selection should be particularly studied, among them the effect of catch size. A symposium on fishing effort, the effect of fishing on resources and the selectivity of fishing gear was held at Lisbon, Portugal in 1957. Some data showing the effect of catch size on mesh selectivity were presented by Clark (1963a, 1963b) for haddock and redfish and by McCracken (1963) for cod and haddock of the Northwest Atlantic, both demonstrating a slight decrease in selection factor with increase in catch size. Similar results were reported by Beverton (MS, 1959) for cod of the Spitzbergen area. Consequently the assessments of the Northwest Atlantic fisheries in relation to regulation problems (ICNAF, 1962) were made using selectivity data as summarized by Clark, McCracken and Templeman (1958) and based largely on the data reported at the Lisbon Symposium.

From covered codend experiments carried out on East Greenland fishing grounds, Bohl (1962) found that there was a clear negative relationship when the selection factors calculated for the catches individually were plotted against the quantity of redfish in the codend. Bohl states that from a biological point of view a sensible minimum mesh size for redfish can never be derived from selection data which are based mainly on small or medium catches, since redfish are often caught in large quantities by commercial trawlers. Similar results were shown by von Brandt (MS, 1961) for redfish of Subarea 1 (West Greenland).

Considerable interest in these recent investigations on selectivity of redfish was shown by the Subcommittees for Assessments and for Gear and Selectivity at the 1962 Annual Meeting of ICNAF. Member countries were urged to examine their selectivity data for all species of groundfish from this point of view. The main interest to the Assessment Subcommittee lies in the effects that reduced selection factors, which result from large catches, might have on the fishery assessments which have already been made (ICNAF, 1962).

Materials and Methods

In 1959 and 1960 investigations on the selection of haddock were carried out by the research trawler *A. T. Cameron* on haddock concentrations on the Grand Bank (ICNAF Divisions 3N and 3O).

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The gear consisted basically of the No. 41-5 Yankee trawl, but nets of different series of mesh sizes were tested against a standard small-meshed trawl. The method of alternate hauls was used and the procedure was to alternate most of the trawl (codend, lengthening piece and belly) rather than just the codend as usually occurs in covered codend experiments. The mesh measurements were made with the ICNAF wedge-type gauge using a pressure of approximately 12 pounds (5.5 kg). The measurements were taken after the first, second, fifth, tenth, fifteenth, and twentieth drags, with each net in a longitudinal row along the upper surface of the trawl. Further details on the gear used are included with the results of the individual experiments.

Due to the large quantities caught it was not possible, in many cases, to take length measurements of all haddock in the catches, but usually a random sample of about 1000 fish were measured from each catch. Before analysis, however, the frequencies were converted to catch frequencies. The catches recorded for each net were arranged in ascending order of magnitude, and the catch frequencies for haddock were then combined on the basis of 2, 3 or 4 equal catch size categories, depending on the number of hauls with each trawl on a particular cruise. Because of the variability in size composition of the haddock concentrations from one cruise to the next, it was not feasible to combine the data of one cruise with those of another. The selection curve for each size category with a particular trawl was found by taking the ratios of the numbers at length for a large-meshed trawl to the corresponding numbers at length for a small-meshed trawl. The ratios, smoothed by moving averages of three, were then plotted on ordinary graph paper and the 50% retention lengths estimated from the freehand curves. A set of typical selection curves is shown in Fig. 1.

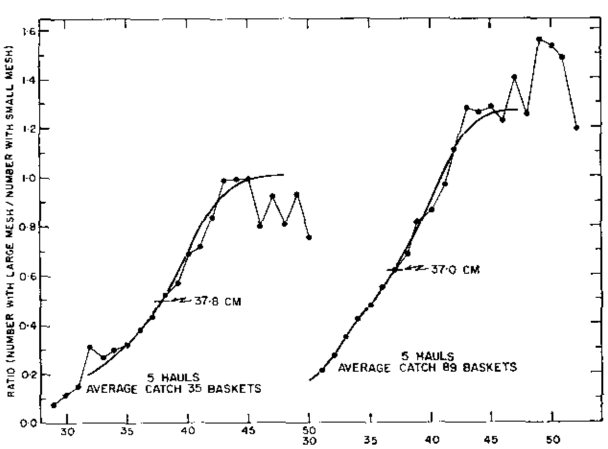

Fig. 1. Typical selection curves by the alternate haul method for two different catch sizes with a 110 mm-mesh codend (the 50% retention length is taken as one-half the vertical height of the selection curve).

In 1962 covered codend experiments on cod were carried out on one cruise of the *A. T. Cameron* in the vicinity of Hamilton Inlet Bank (ICNAF Division 2J). The gear consisted basically of the standard small-meshed No. 41-5 trawl but codends of 4 different mesh sizes were used. The bottom half of the codend was lined with small-meshed (30 mm) nylon netting and the top covered with 50 mm courlene material, the width of which was more than twice the width of the codend. The mesh measurements of the codends were made using the Westhoff gauge (1959 model).

The covered codend catch frequencies were analysed in the usual way and 50% retention lengths obtained from the lines fitted by eye to the data on probability paper. In drawing the lines only those percentages falling between about 20 and 80% retention were considered.

All of the covered codend hauls for cod were of 1-hour duration with trawl on bottom. Most of the alternate hauls for haddock were 1-hour tows on bottom, but on one cruise when the haddock concentrations were very heavy 40-minute drags were made. All nets used were of manila material throughout, except for the courlene cover and nylon bottom liner in the covered codend experiments.

The lengths of both cod and haddock were recorded as fork lengths to the nearest centimetre.

Results

Haddock

During the course of the investigations on haddock selection by the alternate haul method, two large-meshed trawls were usually tested against a small-meshed standard trawl. Except for the differences in mesh size the trawls were of the same general dimensions and for convenience are labelled B, C, and D. Trawl B, the small-meshed standard, generally ranged in mesh size from about 70 mm in the codend and 85 mm in the lengthening piece and after section of the belly to about 125 mm in the wings and square;

the meshes of Trawl C ranged from about 100 mm or a little less in the codend to 125 mm in the forward parts, and in Trawl D the meshes ranged from about 110 mm in the codend to 125 mm in the wings and square. For one series of drags with Trawl D a codend of 125 mm was also tested. The only chafing gear used was a piece of small-meshed manila netting, covering the bottom part of the codend from the splitting strap to the codline.

The catches, consisting mostly of haddock with small quantities of cod, ranged from 3 to more than 400 baskets (1 basket = 95 pounds = 43 kg). Nine catches over 200 baskets were recorded, 7 with Trawl B, and 1 each with Trawls C and D. A summary of the ranges in catch size for the 4 series of experiments is given in Table 1.

TABLE 1. Range of catch sizes in baskets for haddock selectivity experiments on the Grand Bank (Subarea 3). Figures in brackets are for catches of haddock plus cod. Letters refer to the trawls used. (1 basket = 43 kg).

Series	Dates	B	C	D	D[1]
I	May 28 - June 10, 1959	3-133 (5-137)	3-100 (4-107)	5-77 (13-78)	
II	July 31 - Aug. 4, 1959	125-270 (132-277)	18-213 (19-227)	33-189 (37-191)	
III	May 13 - 23, 1960	18-165 (28-190)	27-108 (40-119)	13-201 (34-218)	
IV	July 8 - 21, 1960	50-396 (51-415)	12-180 (12-198)	9-104 (11-114)	13-187 (13-194)

There was great variation in the size of the individual catches of the trawls used, but the number of hauls with each trawl during a cruise were so few as not to make it feasible, in this analysis, to consider the data from the viewpoint of having more than 4 major catch size categories in two instances, 3 in one case and 2 in another. The results of the analysis are given in Tables 2 to 5.

TABLE 2. Gear, catches and selectivity data for Series I haddock experiments (alternate hauls) on the Grand Bank (Subarea 3) in 1959.

Trawl	B	C				D			
Runnage									
– codend	75/4 double manila	50/4 double manila				50/4 double manila			
– lengthening piece	75/4 single manila	50/4 single manila				50/4 single manila			
Avg mesh size									
– codend	2.80 in. (71 mm)	3.70 in. (94 mm)				4.10 in. (104 mm)			
– lengthening piece	3.10 in. (79 mm)	3.70 in. (94 mm)				4.20 in. (107 mm)			
Catch category	—	I	II	III	IV	I	II	III	IV
No. of hauls	19	5	5	5	4	5	5	5	4
Avg no. haddock (calc.)	4,680	1,176	2,298	3,943	7,828	1,171	1,561	2,767	5,330
Avg catch haddock (bask.)	39.1	10.7	20.0	34.8	68.8	11.7	15.7	25.8	52.0
Avg catch haddock and cod (bask.)	49.0	14.0	28.9	39.3	75.5	16.1	27.5	33.5	62.3
Est. 50% retention length (cm)	—	30.6	28.6	29.8	25.6	34.7	33.8	31.4	31.4
Selection factor (based on codend mesh size)	—	3.26	3.04	3.17	2.72	3.34	3.25	3.02	3.02

TABLE 3. Gear, catches and selectivity data for Series II haddock experiments (alternate hauls) on the Grand Bank (Subarea 3) in 1959.

Trawl	B	C		D	
Runnage					
– codend	75/4 double manila	50/4 double manila		50/4 double manila	
– lengthening piece	75/4 single manila	50/4 single manila		50/4 single manila	
Avg mesh size					
– codend	2.77 in. (70 mm)	3.75 in. (95 mm)		4.10 in. (104 mm)	
– lengthening piece	2.96 in. (76 mm)	3.60 in. (91 mm)		4.18 in. (106 mm)	
Catch category	—	I	II	I	II
No. of hauls	6	3	3	3	2
Avg no. haddock (calc.)	25,870	5,070	19,690	4,895	15,500
Avg catch haddock (bask.)	207.5	49.7	177.7	49.3	140.0
Avg catch haddock and cod (bask.)	212.9	51.4	195.2	52.2	143.0
Est. 50% retention length (cm)	—	34.0	32.0	36.8	33.7
Selection factor (based on codend mesh size)	—	3.58	3.37	3.54	3.24

TABLE 4. Gear, catches and selectivity data for Series III haddock experiments (alternate hauls) on the Grand Banks (Subarea 3) in 1960.

Trawl	B	C			D		
Runnage							
– codend	60/3 double manila	50/4 double manila			50/4 double manila		
– lengthening piece	60/4 single manila	60/4 single manila			60/4 single manila		
Avg mesh size							
– codend	2.65 in. (67 mm)	3.70 in. (94 mm)			4.30 in. (109 mm)		
– lengthening piece	3.33 in. (84 mm)	3.92 in. (100 mm)			4.20 in. (107 mm)		
Catch category	—	I	II	III	I	II	III
No. of hauls	15	5	5	5	5	5	5
Avg no. haddock (calc.)	8,330	4,095	7,020	9,390	2,215	4,175	8,880
Avg catch haddock (bask.)	95.1	48.5	81.9	113.4	27.5	50.5	115.3
Avg catch haddock and cod (bask.)	113.5	58.5	96.9	136.5	41.5	65.8	139.5
Est. 50% retention length (cm)	—	32.4	32.0	31.2	34.5	33.8	33.7
Selection factor (based on codend mesh size)	—	3.42	3.37	3.28	3.17	3.10	3.09

TABLE 5. Gear, catches and selectivity data for Series IV haddock experiments (alternate hauls) on the Grand Bank (Subarea 3) in 1960.

Trawl	B	C				D		D[1]	
Runnage									
– codend	60/3 double manila	60/4 double manila				50/4 double manila		60/4 double manila	
– lengthening piece	60/4 single manila	60/4 single manila				60/4 single manila		60/4 single manila	
Avg mesh size									
– codend	2.92 in. (74 mm)	4.25 in. (108 mm)				4.32 in. (110 mm)		4.93 in. (125 mm)	
– lengthening piece	3.28 in. (83 mm)	4.12 in. (105 mm)				4.45 in. (113 mm)		4.66 in. (118 mm)	
Catch category	—	I	II	III	IV	I	II	I	II
No. of hauls	20	5	5	5	5	5	5	5	5
Avg no. haddock (calc.)	11,780	2,220	5,175	7,490	10,610	2,490	6,020	1,505	6,835
Avg catch haddock (bask.)	139.0	30.0	67.2	94.0	141.2	33.5	82.4	23.2	103.2
Avg catch haddock and cod (bask.)	145.0	34.2	72.0	97.8	157.0	35.0	88.6	26.0	112.2
Est. 50% retention length (cm)	—	36.0	35.4	34.0	34.8	37.8	37.0	40.8	40.0
Selection factor (based on codend mesh size)	—	3.33	3.28	3.15	3.22	3.44	3.36	3.26	3.20

In Fig. 2 the estimated selection factors for haddock are plotted against the various catch size categories for each of the 4 series of experiments. In all cases a decrease in selection factor with increasing catch size is indicated by the fitted regression lines. The rates of decrease for the last 3 series are similar, about 0.1 change in selection factor per 50-basket increase in catch. For the first series the rate of decrease in selection factor with increasing catch is considerably greater, about 0.1 per 20-basket increase in catch. Also it must be noted that for Series II the selection factors are higher than those for Series III and IV and particularly higher than those for Series I, despite the fact that the very same nets were used for Series I and II, about 2 months apart, and the average mesh sizes were almost identical (Fig. 2, Tables 2 and 3).

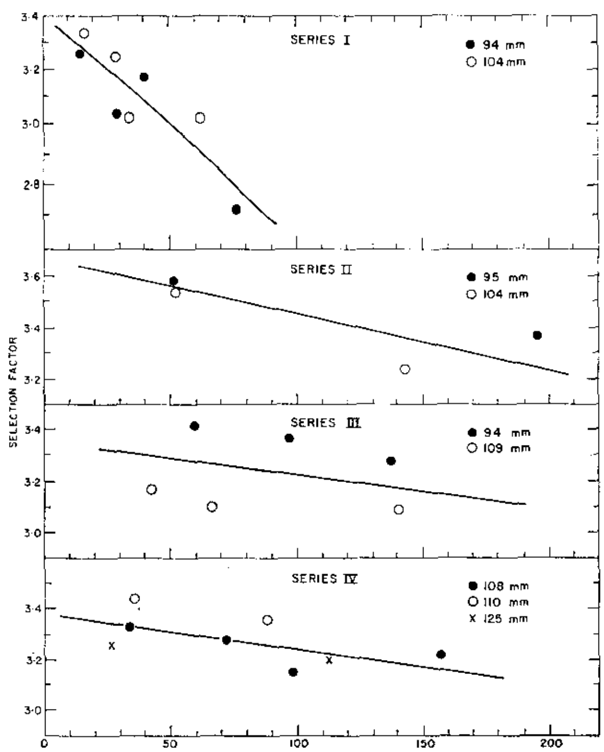

Fig. 2. Catch sizes and selection factors for Grand Bank (Subarea 3) haddock by alternate hauls with trawls of various mesh sizes.

Cod

The extent of our recent investigations on mesh selectivity of cod is limited to the results of one cruise in 1962. Although a small amount of alternate haul data was obtained on this cruise, the range in catch size was not great enough to analyse the material in the same way as the alternate haul data for haddock were treated. We are, therefore, limited to a number of covered codend hauls, mainly with codends of 3 different mesh sizes. In most cases selection factors were estimated for each haul individually, but some of the catches were so small that they were combined and the resulting selection factor plotted against the average catch for the group. The details on mesh size, codend and total catches, and estimated selection factors are given in Table 6.

In Fig. 3 the selection factors are plotted against the total weight of cod in cover and codend and also against the weight in codend only. Although the best catches were not large from a commercial point of view, there is some indication of a decrease in selection factor with increasing catch size, but this is not very pronounced for catches up to about 500 kg. Furthermore, the selection factors for the 125 mm mesh lie considerably above those for the 100 and 115 mm meshes. The only explanation we have for this is that, although the codend meshes averaged 125 mm in a longitudinal row, the meshes in the after part of the codend averaged about 130 mm. These extra large meshes were the result of much greater than average stretching by several large hauls of Laminaria, when the codend was used on

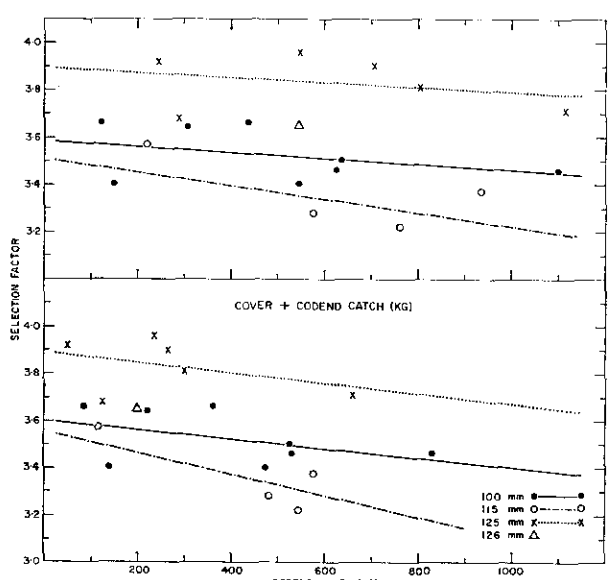

Fig. 3. Catch sizes and selection factors for cod of Subarea 2 with covered codends of different mesh sizes (the codends were of 50/4 double manila twine).

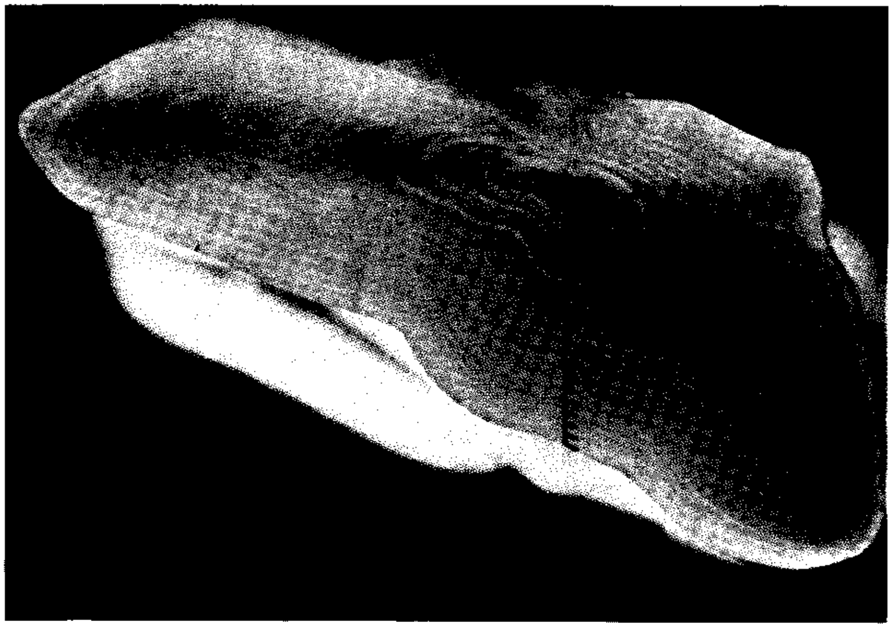

Fig. 4. Two examples of prints from Kodachrome II transparencies taken with the apparatus.

Above. Eastern Barents Sea Cod otolith (Area I), fifteen years old, showing seven "spawning" zones (taken at *f*8 with 7.5 cm extension of the bellows).

Below. Cod (Area 4). The interpretation agreed at Lowestoft is nine years old (B), but other observers have discounted one or more of the three innermost hyaline zones as being splits. For example (A) indicates an interpretation as a seven year-old, discounting the second and third hyaline zones. (Taken at *f*5.6, maximum bellows extension).

TABLE 6. Codend mesh sizes, codend and total catches and selectivity data for cod (covered codend experiments) on Hamilton Inlet Bank (Subarea 2) in August 1962.

Codend mesh size	Expt. No.	No. of Cod Codend	No. of Cod Total	Wt of Cod Codend	Wt of Cod total	50% retention length	Selection factor
mm				*kg*	*kg*	*cm*	
100	1[a]	136	176	138	148	34.0	3.40
	2[b]	98	226	83	117	36.6	3.66
	3	273	611	220	304	36.4	3.64
	4	423	629	358	433	36.6	3.66
	5	494	630	472	543	34.0	3.40
	6	657	971	522	633	35.0	3.50
	7	661	963	531	625	34.6	3.46
	8	1,103	1,998	831	1,103	34.6	3.46
115	9	135	441	120	219	41 0	3.57
	10	460	673	479	572	37.7	3.28
	11	684	1,208	544	762	37.0	3.22
	12	640	1,947	574	932	38.8	3.37
125	13[b]	64	382	48	245	49.0	3.92
	14	118	469	123	291	46.0	3.68
	15	232	1,084	263	704	48.8	3.90
	16	560	1,320	661	1,114	46.4	3.71
	17	172	770	234	545	49.5	3.96
	18	268	1,412	300	804	47.6	3.81
126	19	201	1,033	195	544	46.0	3.65

[a]Selection factor based on average of 4 hauls.
[b]Selection factor based on average of 2 hauls.

an earlier cruise. Thus, if the selective action of the gear is more pronounced in the after part of the codend, as shown by Clark (1963a), this might account for the higher selection factors with this codend.

Redfish

Although we have some data on redfish selectivity by the alternate haul method from 3 cruises of the *A. T. Cameron* in 1961, the catches were not large and the range in catch size not great enough for the results to be of any benefit in an analysis of this type. Also estimation of 50% retention lengths was rendered difficult by the scarcity of fish in the lower half of the selection range. Other factors, which caused a great deal of variation in the selection parameters, were the great haul-to-haul variation in the size composition of the catches at different times of the day and, of course, the multimodal frequencies resulting from the different growth characteristics of males and females. Consequently the only consideration that we can give to the effect of catch size on redfish selectivity must be based on the data of other workers.

Discussion and Conclusions

For haddock, the results of the 4 series of alternate haul experiments indicate that the selection factors for large catches are slightly lower than those estimated for the smaller catches for equal amounts of fishing effort in the same area on the same concentrations. Even for the very large catches, the selection factors of 3.1 - 3.2 are very similar to those obtained by Clark (1963a) from covered codend hauls on haddock in Subarea 5 (Georges Bank).

Data concerning the effect of catch size on mesh selectivity are given by Clark (1963a) for 3 series of covered codend experiments, using double manila codends whose mesh sizes were 73, 105 and 112 mm. The twine sizes are given as 75/4[2] for the small-meshed codend and 50/4

[2]) The twine size 75/4 means 4-ply twisted manila twine running at 75 yards to the pound.

for the others. Catches of haddock in codend and cover ranged between about 200 and 3200 fish (the weights of the catches were not reported). It is apparent from his data that for catches up to about 1000 haddock the selection factor averaged about 3.3, but it decreased to about 3.1 for catches up to 3000 haddock.

Clark (1963a) also gives some results for codends made of synthetics (tightly braided dacron and loosely braided nylon twines running about 43 yards to the pound). Although his largest catches in these experiments did not exceed 1500 fish, with considerable haul-to-haul variation, there is some indication from his data that the rate of decrease in selection factor with increasing catch size is somewhat greater than that indicated for manila codends.

McCracken (1963) reported on the effects of catch size on selectivity of haddock, for both manila and nylon codends in covered codend experiments. His codends were made of 45/4 double manila twine with mesh sizes between 112 and 132 mm and 80-yard braided nylon with mesh sizes of 112 and 122 mm. His data for Subarea 4 (Nova Scotian Banks) and Subarea 3 (St. Pierre Bank) are similar to Clark's (1963a) in that for catches greater than about 1000 fish the selection factors tend to be slightly lower than those for small catches. The decrease in selection factor for manila codends is about 0.2 between the catch size range of about 1000 to 3000 haddock. For nylon codends the decrease in selection factor appears to be about 0.4 between a similar range of catch sizes, but there were only 4 hauls with catches greater than 1000 fish. However, there is one obvious difference between McCracken's data and Clark's and our data. His selection factors for St. Pierre Bank (2.8 - 2.5) are substantially lower than those of Clark's for Georges Bank and ours for the Grand Bank.

Previous information on the relationship between catch size and mesh selectivity for cod is scanty. McCracken (1963) found no consistent variation in selection factor which could be related to size of catch, but none of his catches exceeded 1000 fish. Beverton (MS, 1959), in the course of investigating the selectivity of topside chafers by the covered codend method, obtained information on the relationship between catch size and selection factor for cod in the Spitzbergen area of the Northeast Atlantic. His data, for catches ranging between 10 and 110 baskets of cod with a codend mesh size of 119 mm, show that the rate of decrease in selection factor is about 0.1 per 30-basket increase in catch size. Although his selection factors (averaging 3.5 to 3.1 over the catch range) are on an average not as high as ours (Fig. 3), because his fish were feeding heavily at the time, the general order of magnitude of the decrease in selection factor with increasing catch size is about the same.

For redfish the only reported data known to the authors on the relationship between catch size and selectivity are those of Clark (1963b), von Brandt (MS, 1961), and Bohl (1962). From covered codend experiments in the Gulf of Maine and on the western Nova Scotian Banks, Clark found no correlation between selection factor and catch size; catches yielding about 2000 fish gave selection factors about the same as those for much smaller catches and one catch of 9800 fish gave a selection factor about the same as those for the 200-400-fish catches. On the other hand, Bohl (1962) and von Brandt (MS, 1961) both found clear negative relationships between catch size and selection factor for redfish of East and West Greenland. They stated that the decline in selection factor with increasing catch size was so pronounced, that a sensible minimum mesh size for redfish can never be derived from selection data, which are based on small or medium catches, since redfish are often caught commercially in large quantities.

For haddock and cod the available information indicates that for large catches the selection factors are slightly lower than for small catches, but there is no indication that, as Bohl (1962) has shown for redfish, the selection factors are reduced to the extent that escapement through the meshes of the net is drastically decreased. In fact, in our data the selection factors even for the largest catches of cod and haddock are not very different from those summarized by Clark, McCracken, and Templeman (1958) and used to obtain the selection ogives used in the mesh assessments for haddock in Subareas 3 to 5 and for cod in all subareas of the Northwest Atlantic (ICNAF, 1962). Although the information is scanty, there is some indication (Clark, 1963a; McCracken, 1963) that the decrease in selection factor with increasing catch size may be greater for codends made of synthetic twines, than for manila codends.

For redfish, on the other hand, the available information is conflicting and there is urgent need for more research on selectivity in relation to catch size. If the recent information on selectivity of redfish in Greenland waters is general for all redfish stocks in the Northwest Atlantic, assessment of the effect of mesh size would need to take account of the average catch size in the commercial fishery.

The apparent difference in escapement of cod and haddock on the one hand, and redfish on the other, would seem to be due to the obvious differences in shape and other external characteristics such as the presence or absence of hard spines.

Summary

1. Previous data relating selectivity to catch size for cod, haddock, and redfish indicate that a negative correlation exists between the two, it being much more pronounced for redfish than for cod and haddock.

2. Four series of haddock selectivity experiments by the alternate haul method, carried out in Subarea 3, have been analysed on the basis of catch size. The results indicate a slight decrease in selection factor with increasing catch size.

3. Cod selectivity data, from covered codend experiments in Subarea 2, also indicate a decrease in selection factor with increasing catch size.

4. The material from recent redfish selectivity experiments in Subarea 3 did not readily lend itself to this type of analysis. The available information by other workers is conflicting, and more research on this aspect of selectivity is required for this species.

5. For cod and haddock it is concluded that the reduction in selection factors for large catches is not great enough to seriously affect the recent assessments of the cod and haddock fisheries in the Northwest Atlantic, which were made using selectivity data based largely on small catches.

6. If the recent information on selection of redfish in Greenland waters (very pronounced decrease in selection factor with increasing catch size) is general for all redfish stocks, then assessment of the effect of mesh size would need to take account of the average catch size in the commercial fishery.

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Electronic Flash Photography of Gadoid Otoliths

BY R. W. BLACKER[1]

Abstract

A simple apparatus and method for photographing otoliths is described, using a 35 mm single-lens reflex camera with a specially designed otolith mount and ring flash illumination.

Introduction

A simple technique of photographing cod and other gadoid otholiths has long been needed. The usual method of photographing them using the same side-lighting system that is used for their examination through the microscope, tends to give very variable and disappointing results on black and white film. However, in November 1962 some promising results were obtained on colour film using this method of illumination. The writer was then asked to find a method and apparatus whereby consistently good results could be obtained easily.

The problems to overcome were partly photographic and optical (adequate even illumination and ease of focussing) and partly mechanical (always getting the otolith in the same position relative to the light source). Electronic flash was the obvious source of illumination. Parrish and Sharman (1959) have used a ring flash unit successfully for photographing herring otoliths by reflected light. Experiments showed that with the ring mounted in a suitable reflector this system could be used for side-lighting an otolith. A 35 mm single-lens reflex camera overcomes focussing difficulties. The otolith mount and staging described below are designed to ensure that the otoliths are always photographed in the same position relative to the light source.

The Apparatus

The complete apparatus is shown in Fig. 1.

The Camera is an Edixamat Reflex D-L with a standard Edixa bellows extension. The waist-level viewfinder allows focussing on a ground-glass screen. Alternatively a pentaprism viewfinder is available. The lens used is a 38 mm focal length *f*3.5 Schneider-Kreuznach Radionar with an adapter ring to fit the Edixa lens thread. With this lens a linear magnification of 4.3 times is obtained at the 13.5 cm maximum extension of the bellows. This is sufficient magnification for all but the smallest gadoid otoliths, and the bellows allows the use of smaller magnifications for photographing the largest cod and haddock otoliths. A wide variety of standard lenses is available for this camera. The camera is mounted on a bracket which can be racked up and down a vertical support pillar.

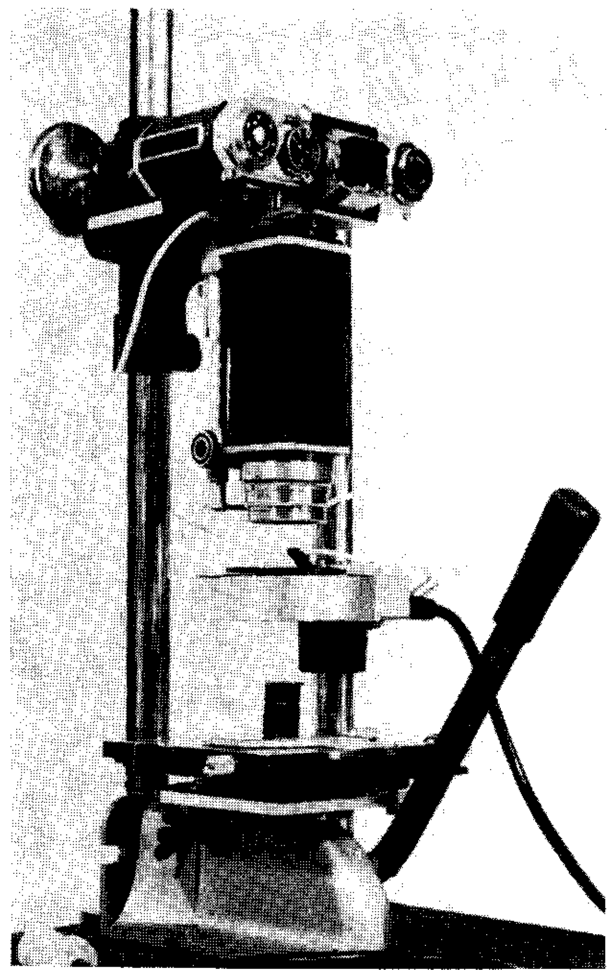

Fig. 1. A general view of the apparatus with the stage lowered to show the otolith mount in position. The electronic flash power unit is not shown.

The Electronic Flash Unit. The flash tube is a Mazda F.A.16 operating at 350 volts and giving an output of 120 joules. The 2½″ (about

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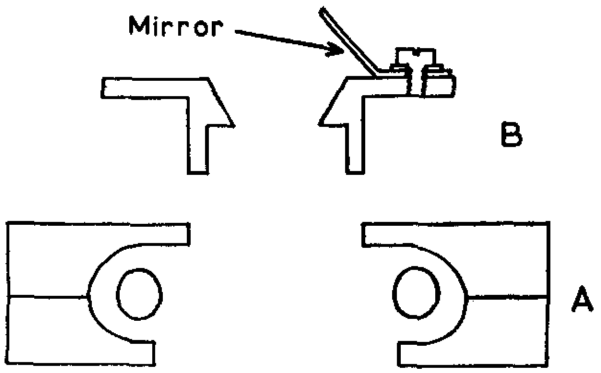

Fig. 2. A section through the flash reflector (A) and the shield (B) with its mirror.

63.5 mm) diameter ring is mounted in an aluminium reflector (Fig. 2A) which directs the light towards the centre of the ring. This is fixed to a pillar so that the flash ring itself is just over an inch above the mechanical stage when this is raised to its maximum height. A circular shield (Fig. 2B) fits into the centre of the upper side of the flash reflector, to prevent extraneous light reaching the camera lens. A small aluminium mirror is fixed at 45° to the top of this shield to reflect light into the otolith surface for focussing.

The Stage consists of a Watson's Bactil-60 Mechanical Rotating and Centring Stage fixed onto a Wolf Electric Drill stand. This gives a vertical movement of about two inches which allows easy access to the otolith mount, without the need to move the flash ring. When raised to its maximum height the stage is locked in position by a wing nut. The vertical movement of the stage is not used for focussing.

The Otolith Mount consists of two parts, a 3″ (about 76.2 mm) x 1″ (about 25.4 mm) x $\frac{1}{8}$″ (about 3.2 mm) brass plate with a small plinth $\frac{1}{8}$″ (about 3.2 mm) high fixed at its centre (Fig. 3A) and a box tube $\frac{1}{2}$″ (about 12.7 mm) x $\frac{3}{8}$″ (about 9.7 mm) internal dimensions which fits neatly over the plinth (Fig. 3B). There are $\frac{1}{16}$″ (about 1.6 mm) slots in the two long sides of the tube $\frac{5}{8}$″ (about 15.9 mm) from the bottom. A circular shield fixed to the top of the tube fits loosely into the shield on the flash reflector. The inside of the box tube, the edges of the slots, and the shield on top are painted matt black. The otolith is mounted in plasticine stuck to the plinth. It is adjusted until it is nearly level and is then pressed down with a plunger, (Fig. 3C) which just fits into the tube, until only $\frac{3}{64}$″ (about 1 mm) is above the level of the slots. By this means the otolith surface is always put into the same position relative to the slots and flash tube.

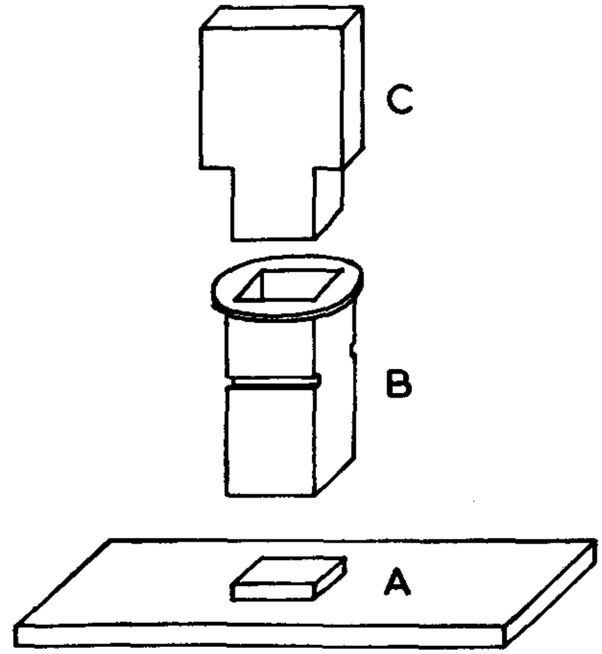

Fig. 3. The otolith mount: (A) the slide with its plinth onto which the box tube (B) just fits; (C) the plunger for pressing the otolith into its correct position.

Operation

The otolith is mounted in the way described above and the surface is brushed with cedarwood oil. (Creosote or xylene may be used, but the latter evaporates rather quickly.) Best results are obtained from otoliths with a ground surface (Bedford, 1964) although broken otoliths can be used as long as the surface is not too uneven. The cedarwood oil effectively clears cracks in the otolith so that they are undetectable in the photograph. The otolith mount is put on the stage which is then raised to its maximum height. A narrow beam of light from a microscope lamp is reflected onto the surface of the otolith by the aluminium mirror. The camera is racked up or down to give the optimum magnification. Minor adjustments to centre the otolith are made by means of the mechanical stage. Critical focussing adjustments are usually made with the lens focussing mount, although the bellows movement may be used.

When the final focussing has been done the microscope lamp is switched off and the electronic flash unit switched on. To obtain uniform results exposures must be made at the same charge level. With the present apparatus this is achieved by making the exposure within ten seconds of the lighting-up of the charge level neon on the power-pack. If a voltage limiter is fitted into the power-pack circuit the maximum charge level will be maintained, provided sufficient charging time is allowed between exposures.

Results

Two photographs taken on Kodachrome II reversal film are shown in Fig. 4. These results are very close to what is seen through the microscope and viewers are agreed that their interpretation is easier than that of black and white prints. The general practice has been to take two photographs of each otolith, one using a stop of *f* 5.6 and the other taken at *f* 8, regardless of the size of otolith and the bellows extension. These two exposures give good results with all except the smallest otoliths, for which *f* 4.5 may be needed. The largest cod otoliths which, perhaps, need only one third of the full extension may require an exposure at *f* 11 to avoid burning out the image of the outer zones. These exposures are for Kodachrome II with a speed rating of 25 ASA. Satisfactory results have also been obtained on fine grain panchromatic films.

Summary

1. The problem of photographing cod otoliths is discussed.
2. An apparatus for routine photographing of otoliths is described and illustrated.
3. The operation of the apparatus is described.
4. Samples of the results are given.

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Redfish Above the Ocean Depths

BY G. P. ZAKHAROV [1]

Abstract

Evidence is presented from cruises by the USSR R/T *Pobeda* and *Zapad* during June, 1962 and February, 1963 in the area from the Southwest of Greenland to the Southwest of Iceland, that *Sebastes mentella* Tr. inhabits the bathypelagic part of the North Atlantic while *Sebastes marinus* L. probably does not migrate far from the continental slope.

In 1962 and 1963, the Polar Research Institute of Marine Fisheries and Oceanography (PINRO) set up two research cruises to study the bathypelagic concentrations of redfish in the North Atlantic.

Results of Cruise of Research Trawler Pobeda

The cruise of the Trawler *Pobeda* was carried out in the West and East Greenland areas in April-June 1962.

TABLE 1. Data on redfish obtained by the Research Trawler *Pobeda* 4-24 June, 1962.

Station No.	Position	Date	Fishing depth	Temperature at fishing depth	Redfish species	Length	Sex and maturity stage	
			m	°C		cm		
288	62°05′N — 50°48′W	1	330		*marinus*	45	♂	III
					,,	65	♂	III
					,,	41	♀	II
					,,	50	♀	II
293	62°02′N — 50°43′W	2	360		,,	39	♂	III
					,,	46	♂	III
					,,	48	♂	III
					,,	60	♂	III
					,,	63	♂	III
					,,	40	♀	II
					,,	41	♀	II
					,,	42	♀	II
					,,	48	♀	II
294	62°02′N — 50°44′W	3	330		,,	43	♂	III
					,,	47	♀	II
					,,	61	♀	II
297	61°45′N — 50°45′W		350	3.87	,,	(1)		
301	60°31′N — 49°00′W	4	350	4.30	,,	(1)		
305	59°52′N — 47°26′W		290	4.10	,,	(1)		
308	59°32′N — 45°48′W	5	310	4.90	,,	(2)		
312	58°35′N — 44°00′W	6	330	4.40	*mentella*	(2)		
313	57°53′N — 44°00′W	7	290	4.10	,,	37	♂	IV
					,,	38	♂	IV
314	57°25′N — 44°00′W		250	3.36	,,	34	♂	IV
					,,	37	♀	IX
317	57°05′N — 42°00′W		310	3.90	,,	38	♀	IX
318	57°35′N — 42°09′W	8	350	3.60	,,	35	♂	IV
					,,	36	♂	IV

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TABLE 1. (continued)

Station No.	Position	Date	Fishing depth	Temperature at fishing depth	Redfish species	Length	Sex and maturity stage	
			m	°*C*		*cm*		
319	58°05'N — 42°00'W		250	4.40	*mentella*	39.5	♀	IX
					,,	38	♀	
					,,	37	♂	
					,,	32	♀	
322	58°48'N — 41°08'W	10	350	4.07	,,	37	♀	IX
					,,	35	♂	IV
					,,	36	♀	IX
					,,	35	♀	IX
					,,	41	♀	IX
323	58°31'N — 40°00'W	10	400	4.19	,,	36	♂	IV
					,,	38	♂	IV
324	58°11'N — 38°42'W		250		,,	41.5	♀	IX
326	58°12'N — 36°45'W	11	300	5.81	,,	36	♀	IX
327	58°25'N — 35°55'W		350	4.80	,,	44	♂	IV
330	59°35'N — 37°50'W	12	310	4.00	,,	39	♀	IX
333	60°44'N — 39°30'W	13	300	4.80	,,	36	♂	IX
345	61°02'N — 37°20'W	16	300	4.33	interm. type	38	♀	IX
347	60°12'N — 36°04'W		250	4.40	*mentella*	40.5	♀	IX
349	59°27'N — 34°55'W	17	300	6.15	interm.type	35	♂	IV
351	59°10'N — 33°15'W		300	5.20	,,	43	♀	IX
352	59°20'N — 32°20'W		200	5.40		(6)		
357	61°05'N — 33°55'W	18	260	5.50	*mentella*	40	♀	IX
					,,	35	♂	IV
					,,	34	♂	IV
					,,	38	♀	IX
358	61°28'N — 34°31'W	19	200	5.51	interm. type	33	♂	III
362	62°37'N — 32°36'W	20	250	5.20	*mentella*	39	♀	IX
					,,	38	♀	IX
					interm. type	41	♂	IV
374	61°38'N — 26°45'W	22	570	6.30	*mentella*	47.5	♀	II
375	62°15'N — 25°50'W		570		,,	43	♀	II
					,,	42	♂	III
376	62°37'N — 25°26'W	23	570	6.26	,,	44	♂	III
					,,	46	♂	III
					,,	46	♀	IX
					,,	43	♂	
378	63°45'N — 26°17'W		550	6.20	,,	44	♀	
380	64°34'N — 27°36'W		550	5.08	,,	48	♂	
382	65°25'N — 29°13'W	24	550	6.06	,,	47	♂	III
					,,	45	♂	II

One of the tasks of this cruise was to investigate the area south-west and south-east of Greenland for the purpose of discovering redfish over the oceanic depths. A total of 73 control hauls were made with 20 m mid-water trawl of the PINRO design from 4 to 24 of June. The route covered the area from West Greenland to Iceland. One-hour tows were made at depths of 200-570 m, at 25 nautical mile intervals. Taking into account the possible diurnal vertical migrations of redfish, hauls were made at great depths (300-570 m) in the day time, and mainly at 200-250 m in the evening and night hours. Some redfish, chiefly *Sebastes mentella* Travin, were found in almost every haul. Some individuals were at first attributed to the intermediate type. *Sebastes* *marinus* L. was not encountered above the great depths south and east of Greenland. Only 22 specimens of this redfish were caught above depths of 600-1000 m near the continental slope in South-West Greenland. A total of 76 redfish were taken. Each fish was studied as to its length, weight, sex, stage of maturity, fatness grade (according to fat content on the internal organs). The degree to which redfish are parasitized by *Sphyrion lumpi* Kröyer and *Chondrocanthopsis nodusus* (O. F. Müller) was studied. Scales and otoliths of each fish were taken for age determination. Morphometric studies of 41 specimens were carried out.

Depth	Hauls	Redfish caught
m	*no*	*no*
200	9	7
201-250	12	11
251-300	18	12
301-350	22	23
351-400	5	12
> 500	7	11

The stomachs of most redfish were turned out. Of 20 stomachs which were not turned out, 6 contained squids, ctenophores, shrimps, euphausiids and lantern anchovies.

The length of *Sebates mentella* Tr. was 32 to 48 cm. of *Sebastes marinus* L. 39 to 65 cm. The number of each sex was almost the same (32 females and 31 males).

The males of *Sebastes mentella* Tr. were mature (the III and IV stages of maturity). Most females were at the IX stage (after extrusion of the larvae). Some fishes contained single not yet extruded larvae. Some females taken over the Reykjanes Ridge were immature.

Almost all specimens of *Sebastes mentella* Tr. had no fat on the internal organs except some redfish with low fat content. Of 54 specimens of *Sebastes mentella* Tr. 13 contained from one to several parasites of *Sphyrion lumpi*. *Chondrocanthopsis nodosus* was not found in a single specimen of *Sebastes mentella* Tr.

Results of Cruise of Research Trawler *Zapad*

The cruise of the Trawler *Zapad* was carried out in February 1963.

The object of the cruise was to discover places and times of formation of pre-spawning concentrations of redfish above the oceanic depths southwest of Iceland. Choice of the area of investigation was based on the data on redfish larvae distribution in May 1961 obtained by Magnusson (Positions: 62°N to 65°N and 22°W to 34° W).

TABLE 2. Data on redfish obtained by the Research Trawler *Zapad* 9-23 February, 1963.

Station No.	Position	Date	Fishing depth	Temperature at fishing depth	Redfish species	Length	Sex and maturity stage	
			m	°C		*cm*		
	62°14′N — 30°00′W	11	150		*mentella*	44	♂	II
					,,	44	♀	IV
	62°40′N — 26°59′W	12	150		,,	42	♀	
	64°02′N — 31°11′W	13	150		,,	39	♀	VI
	64°36′N — 31°04′W	17	170		,,	43	♂	II

From 9 to 22 February, 1300 miles were covered and 6 traverses along the latitude were made. The continuous fish detection with the "Kalmar" echo-sounder was conducted in the 0-600 m range. Records were often obtained from the 150-250 m layer.

In the experts opinion, these records were not those of commercial fishes. Control tows were made with a 20 m mid-water trawl at depths of 150-200 m in the areas where records were obtained.

An 8-mm cotton net was inserted into the trawl codend. Sometimes a plankton net was fixed to the trawl. During the entire period of investigations, 24 hauls were made, only 5 specimens of *Sebastes mentella* Tr. were taken at 150-170 m. Sizes of males were 43 and 44 cm, females 39, 42, and 44 cm. Males were at the II maturity stage and females at the IV and VI maturity stages. Euphausiids and medusa were found in the stomachs.

Of other fishes, *Maurolicus mülleri* and lantern anchovies (*Myctophidae*) were often taken with a trawl on the southern traverses. Of invertebrate animals, medusa were encountered in great quantity (up to 100 kg), shrimps and euphausiids were found in smaller quantity. Small amounts of euphausiids, *Calanus*, amphipods and lantern anchovies were taken with a plankton net. Fish were seldom observed in the trawl on the northern traverses, the plankton nets were empty, and only medusa occurred in the trawl catches.

Summary

The materials collected during the two cruises give rise to the assumption that only *Sebastes mentella* Tr. inhabits the waters in the bathypelagic part of the North Atlantic. *Sebastes marinus* L. probably does not migrate far from the slope. The discovery of the *Sebastes mentella* Tr. females above the great depths during the period of eggs ripening and after the extrusion of larvae testifies to the fact that they extrude larvae in these areas.

Both males and females occur above great depths. They may be mature and immature. The presence of redfish of only large sizes in the bathypelagic zone suggests they are a population of old fish.

Catches of single specimens of *Sebastes mentella* Tr. show that redfish are dispersed over the entire area investigated. This consideration does not exclude the possibility of formation of redfish concentrations in other seasons.

Abundance, Age Composition of Landings, and Total Mortality of Haddock Caught Off Southern Nova Scotia, 1956-1961

BY R. C. HENNEMUTH,[1] M. D. GROSSLEIN,[1] AND F. D. McCRACKEN[2]

Abstract

Haddock stocks in Division 4X of the Convention Area for the International Commission for the Northwest Atlantic Fisheries (ICNAF) have been exploited for many years by Canada and the United States. The present study covers the period 1956-1961 and represents the first comprehensive analysis of this fishery. General characteristics of the fishery are described, and estimates of abundance, growth, year class strength, and total mortality are presented.

About 70 percent of the 1956-61 landings (91,161 metric tons) were accounted for by otter trawls and the remainder by hook and line gear. Nearly three-fourths of the landings came from waters off southern Nova Scotia (chiefly Browns Bank) and the remainder from the Bay of Fundy.

Average annual survival rate of Division 4X stocks was approximately 0.50 corresponding to an instantaneous total mortality rate of 0.7. However, Bay of Fundy haddock exhibit faster growth and a younger age composition than those from waters off southern Nova Scotia. Age composition of Bay of Fundy stocks is similar to that of Division 5Z (Georges Bank), but growth is faster in the latter area. Both growth and age composition of haddock off southern Nova Scotia is similar to that for stocks off central Nova Scotia, (Divisions 4V-W).

Certain year classes appeared strong in all Divisions (5Z to 4W) suggesting that factors common to the entire area may control brood success, or that stocks mix at some pre-recruit stage.

CONTENTS PAGE

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Introduction

The fishing area under study is delineated by the boundaries of Division 4X of the Convention Area for the International Commission for the Northwest Atlantic Fisheries (ICNAF) (Fig. 1). The relationship of the stocks within these boundaries to those to the north and south is not yet clearly defined, although there is some evidence of autonomy (Clark and Vladykov, 1960). Regardless of racial structure, neither the stocks of haddock nor the fishery is continuously distributed throughout its western Atlantic range. Division 4X encompasses one geographical segment where the fishery and the fish tend to be concentrated, forming a convenient unit area for study.

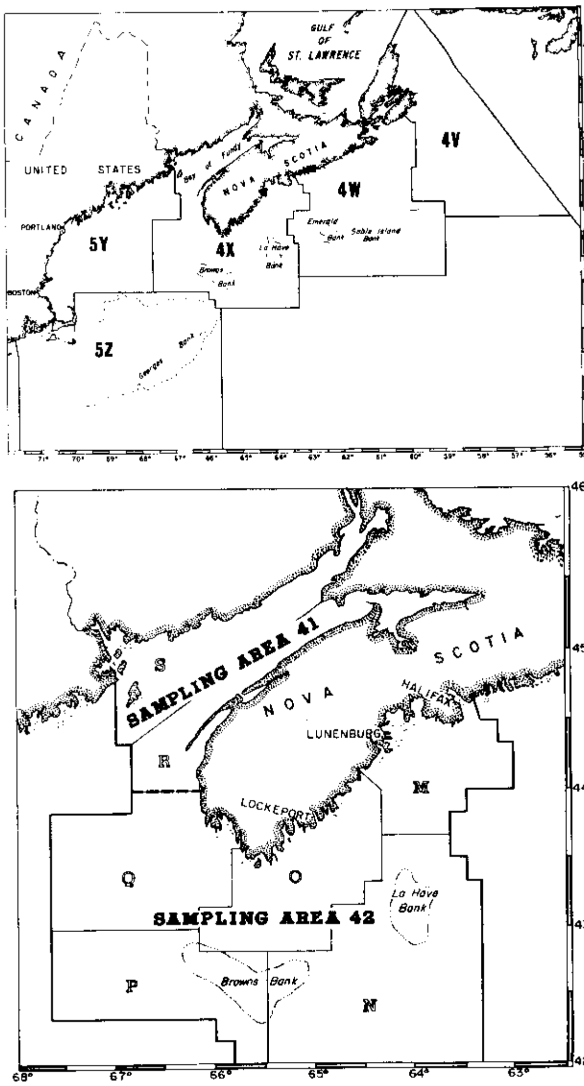

Fig. 1. Geographical divisions of the International Commission for the Northwest Atlantic Fisheries (upper panel), and sampling areas and subareas (lettered) of Division 4X employed in this study (lower panel).

The stocks within this area have been exploited for many decades by Canadian and American fishermen. During the years under study, 1956 to 1961, the total landings have fluctuated between 28 and 40 million pounds (13 and 18 thousand metric tons)[3] annually. Landings are summarized in Table 1 and Fig. 2 by quarter[4], type of gear, and sampling areas.

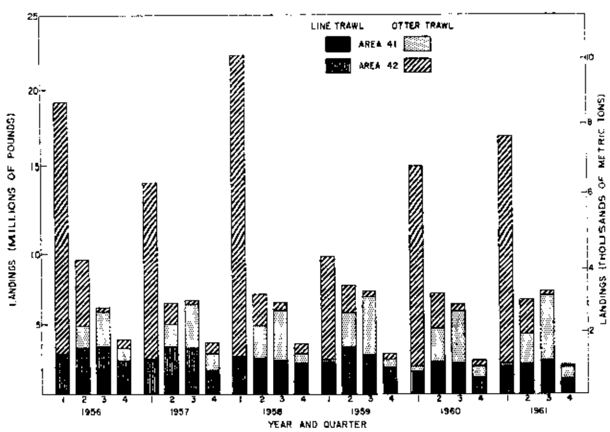

Fig 2. Landings of haddock caught in Division 4X by type of gear, sampling area and quarter.

Landings by hook and line gear, exclusively Canadian, accounted for 29 per cent of the total during the period, and gradually declined from 10.7 million pounds (4.8 thousand metric tons) in 1956 to 7.7 million pounds (3.5 thousand metric tons) in 1961. Vessels using line gear fished mostly in Sampling Area 42, and their landings were fairly uniform throughout the year. Otter trawlers, predominantly U.S., have landed between 17 and 30 million pounds (8 and 14 thousand metric tons) annually. The catch by otter trawlers in Sampling Area 42 averaged 17 million

[3])All weights in this paper refer to dressed weights; haddock are gutted and stored in ice for periods up to two weeks before landing. Approximate estimates of round, fresh weights may be obtained by multiplying the as-landed weights by 1.17.

[4])These are not calendar quarters. The first quarterly period commences with February, and the fourth quarter of a given year terminates with January of the following year. These periods were chosen by earlier investigators to center the peak of spawning within a time stratum, the first quarter. This choice is somewhat arbitary, and we have used the system for sake of conformity.

TABLE 1. Landings in thousands of pounds of haddock caught in Division 4X by quarter, sampling area, and type of gear, 1956-61. Totals shown in parentheses are in metric tons.

		Hook and Line - Canada			Otter Trawl - U.S. and Canada			
		Sampling Area			Sampling Area			
Year	Qtr.	41	42	Totals	41	42	Totals	Grand Totals
1956	1	303	2494	2797	81	16348	16429	19226
	2	1522	1746	3268	1590	4770	6360	9628
	3	1775	1641	3416	2464	287	2751	6167
	4	901	1473	2374	900	636	1536	3910
Totals		4501	7354	11855	5035	22041	27076	38931
		(2042)	(3336)	(5377)	(2284)	(9998)	(12282)	(17659)
1957	1	17	2441	2458	78	11506	11584	14042
	2	1244	2113	3357	1624	1485	3109	6466
	3	357	2940	3297	3056	329	3385	6682
	4	360	1337	1697	1178	832	2010	3707
Totals		1978	8831	10809	5936	14152	20088	30897
		(897)	(4006)	(4903)	(2693)	(6419)	(9112)	(14015)
1958	1	99	2466	2565	144	19629	19773	22338
	2	804	1789	2593	2343	2206	4549	7142
	3	633	1746	2379	3595	528	4123	6502
	4	545	1705	2250	662	676	1338	3588
Totals		2081	7706	9787	6744	23039	29783	39570
		(944)	(3495)	(4439)	(3059)	(10450)	(13509)	(17949)
1959	1	55	2266	2321	222	7243	7465	9786
	2	453	2972	3425	2350	1905	4255	7680
	3	479	2354	2833	4088	412	4500	7333
	4	337	1545	1882	661	364	1025	2907
Totals		1324	9137	10461	7321	9924	17245	27706
		(600)	(4145)	(4745)	(3321)	(4501)	(7822)	(12567)
1960	1	30	1591	1621	339	12915	13254	14875
	2	352	1992	2344	2316	2590	4906	7250
	3	352	1845	2197	3672	516	4188	6385
	4	211	1048	1259	771	371	1142	2401
Totals		945	6476	7421	7098	16392	23490	30911
		(429)	(2937)	(3366)	(3220)	(7435)	(10655)	(14021)
1961	1	1	2064	2065	181	14509	14690	16755
	2	277	1875	2152	2142	2451	4593	6745
	3	259	2160	2419	4572	317	4889	7308
	4	310	795	1105	851	193	1044	2149
Totals		847	6894	7741	7746	17470	25216	32957
		(384)	(3127)	(3511)	(3513)	(7924)	(11437)	(14949)
Grand Totals		11676	46398	58074	39880	103018	142898	200972
		(5296)	(21046)	(26342)	(18089)	(46729)	(64819)	(91161)

pounds per year (8 thousand metric tons), which was over twice that in Sampling Area 41. About 80 percent of the otter-trawl landings from Sampling Area 42 was taken in the first quarter, whereas about 80 percent of the otter-trawl landings in Sampling Area 41 was taken in the second and third quarters.

Biologists of the U.S. Bureau of Commercial Fisheries Biological Laboratory, Woods Hole, and the Fisheries Research Board of Canada, Biological Station at St. Andrews, initiated a co-operative study of this fishery in 1956. Although investigations had been conducted previously by each country, the studies had not been comprehensive, and had not adequately considered the joint nature of the fishery. The landings of vessels of the two countries were nearly equal from 1956-61, but there was a differential distribution of fishing effort among gear, seasons, and areas. Emphasis was placed on the collection of statistics of landings and effort, and of samples of length and age frequencies of the landings.

This paper presents the results of analysis of these data. Estimates of average length and weight at age, abundance of year classes, and total mortality have been obtained. Comparisons of these statistics have been made among areas and quarters to elucidate interrelationships of the stocks.

Most of the otter trawls are fitted with a cod end of 4½ inch, manila mesh or its equivalent in synthetic material, as stipulated by ICNAF regulations. The sizes of fish retained by this mesh size are generally acceptable on the market, and there is little discard. Discarding of fish caught by line gear is also negligible. The landings are nearly equivalent, therefore, to the catch with respect to length of fish and amount. Neither the catch nor landings truly represent the population, of course, but we do assume the changes observed in landings and samples therefrom reflect changes in the population beyond the age of full recruitment.

Methods of Sampling, Ageing and Analysis

1. Sampling methods

For purposes of sampling and recording fishery statistics, Division 4X was originally divided into seven small subareas, lettered M through S (Fig. 1). Off Southern Nova Scotia, the offshore fishing grounds are contained within N and P, and the inshore grounds within M, O, and Q. R and S represent the Bay of Fundy fishing grounds. Samples were taken from landings of fish caught entirely within one of the subareas, and the day of landing determined the month to which a sample or landing was assigned. For purposes of analysis, the data were subsequently grouped into two larger sampling areas: Sampling Area 42, which includes Subareas M through Q, the Southern Nova Scotia grounds; and Sampling Area 41, which includes Subareas R and S, the Bay of Fundy grounds.

United States and Canadian haddock catches are landed in three market categories: scrod (1.5 to 2.5 pounds; 0.7 to 1.1 kg), large (over 2.5 pounds), and ungraded (over 1.5 pounds). A 2.5 pound haddock is about 50 cm in length. Fish are unloaded from vessels typically into boxes or carts, and length measurements and otoliths are taken from haddock selected from containers of each market category. The sample is best described as a "grab" sample, i.e., fish are taken from the container in a blind fashion, topmost layer first, until the requisite number has been obtained.

Virtually all haddock caught by U.S. otter trawlers are culled at sea and landed as large or scrod. A minimum of 100 large haddock and 50 scrod haddock are measured for each sample, and usually both large and scrod are obtained from each trip sampled. Otoliths are taken from 20 large and 15 scrod selected, insofar as possible, so that the entire range of lengths encountered is uniformly represented.

Canadian fishermen employ otter trawls, and hook and line (longlines and handlines) gear. Haddock are landed in all three market categories. The large and scrod categories are similar in size of fish to the corresponding U.S. categories. The ungraded category is from catches which have not been culled at sea. During the period of study usually 200 or more lengths were obtained from a single landing[5]. If both large and scrod were sampled from a single landing, the scrod sample was limited to about 15 percent of the total sample. Usually not less than 40 otoliths and often more than 100 were collected from a single landing, but for the samples of more than 50 otoliths, a stratified (by length) subsample of 50 was drawn for reading. Haddock were sampled representatively for both length frequency measurements and otoliths.

2. Age assessment

All ages are based on otolith readings by Norman McFarlane, St. Andrews, and John P. McDermott, Woods Hole. Criteria for identifying year marks on haddock otoliths in Nova Scotian waters were established by Kohler (1958), who guided the training of the two readers.

Otoliths from 736 fish were read independently by each of the two readers, and they disagreed on 143 (20 percent). Among the 143 discrepancies, 114 (80 percent) involved a difference of only one year and 22 a difference of two years. McFarlane's readings, however, were lower than McDermott's in 70 percent of the 143 discrepancies. The tendency for McFarlane to get

[5]) In Canada, catches of small vessels are frequently combined at time of unloading, in which case a single sample would represent the catch of several vessels.

TABLE 2. Comparison of 736 haddock otoliths read independently by each of two readers. Readings in agreement are in **bold** figures.

Aged by McDermott	Aged by McFarlane 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Total
1	**14**															14
2		**68**	2													70
3		6	**129**	6												141
4		3	10	**116**	13											142
5			1	6	**102**	7										116
6				3	14	**58**	3									78
7					1	7	**50**	4								62
8					1	4	10	**19**	5		1					40
9							2	9	**20**		1					32
10								4	4	**7**	1					16
11								1	2	6	**4**	1				14
12										1		**4**				5
13										1			**1**			2
14										1	1					2
15+													1		**1**	2
Total	14	77	142	131	131	76	65	37	31	16	8	5	2		1	736

lower ages appears to begin about age 6 and is present thereafter (Table 2). Simultaneous examination of otoliths by these two readers showed that discrepancies were due primarily to differences in interpreting weak marks, which occurred on some otoliths, either as annuli or as checks.

An approximate measure of the effect of discrepancies of this magnitude on estimates of mortality was obtained by converting Table 2 into a hypothetical set of percentage errors in age readings. This was done by assuming that the readings of one reader were correct and then converting discrepancies with the other reader into percentages. The "percentage errors" were then applied to a percentage age frequency corresponding to the average percentage age distribution of the first quarter of otter-trawl landings in Sampling Area 42. Survival estimates were computed from both the original and the adjusted age frequencies using a simple estimator described by Robson and Chapman (1961). Differences in survival estimates between ages 6 and 11 were less than 5 percent, and the difference in average age landed was less than 0.2 of one year. Consequently the results based on age data in this report are essentially the same as if only one reader had been used.

Winter growth zones of haddock are noticeable on otoliths beginning in the third quarter of the year and are consistently distinguishable by 1 February. The birthday was taken as 1 February, that is, otoliths showing n winter growth zones in the third and fourth quarter were assigned an age n-1, but commencing in the first quarter an age n was assigned.

3. Methods of analysis

Let n_{ijk} be the pooled sample length frequencies for the ith 2-cm length interval, jth month and kth market category within each type of gear, sampling area, and quarter. The estimated quarterly number of fish landed per 2-cm length interval is,

$$N_i = \sum_{jk} (n_{ijk} W_{jk} / \sum_i n_{ijk} w_{ij}),$$

where W_{jk} is the weight landed, and w_{ij} is the mean weight at length taken from data of Clark and Dietsch (1959).

Whenever a particular set of n_{ijk} was missing from the data, the average length frequency of the other months or market categories within the quarter was used to supply estimates of the N_{ijk}, which were added to the quarterly totals. The N_i were not estimated if there was not at least one length frequency sample for each of the market categories within the quarter, or if the numbers of fish measured were too small to provide a reliable frequency (here, the minimum number was set arbitrarily at about 100). Some exceptions to this rule were made for strata where length samples from ungraded landings were used to prorate all landings including large and scrod, or vice versa. These instances are mentioned under the appropriate section, and suitable comparisons made where necessary to validate the procedure.

Having thus obtained the quarterly N_i, the sample age-frequencies were pooled within each quarter by 2-cm intervals, to obtain an age-length key. The N_i were multiplied by the percentage age-at-length frequencies and summed within each age group to obtain the numbers of fish landed at each age. Mean length and weight per fish of each age group then were computed, again using data on mean weight at length given by Clark and Dietsch (1959).

In most quarters, the sum of the estimated numbers landed in each age group was 1 or 2 percent less than the total numbers landed as estimated from the length-frequency data. This difference occurs because otoliths from fish in the larger and smaller length intervals were not always obtained in the samples. Age groups 2, 3, 11, and 12 are affected, primarily. Therefore, the numbers of fish landed are underestimated for all these age groups, and the mean length and weight are overestimated for the younger age groups, and underestimated for the older. We shall point out in subsequent sections the results which are affected by this bias.

In addition, the lesser numbers of otoliths sampled from larger and smaller fish increases the variability of the corresponding estimates, but the above points up an inaccuracy rather than imprecision.

TABLE 3. Landings (gutted weights, lb. x 10^{-3}) of haddock and numbers of fish measured and aged for otter-trawl landings, Division 4X, Sampling Area 42.

		Landings				
Year	Qtr.	U.S.	Can.	Total	Measured	Aged
1956	1	15754	594	16348	3782	218
	2	4549	221	4770	906	–
	3	84	203	287	668	–
	4	453	183	636	345	–
1957	1	10687	818	11505	2984	381
	2	1320	165	1485	160	34
	3	162	166	329	222	–
	4	740	92	832	56	15
1958	1	18116	1513	19629	2903	305
	2	2067	138	2205	204	–
	3	279	249	528	159	–
	4	566	110	676	121	15
1959	1	6856	388	7243	1830	383
	2	1736	169	1905	1396	243
	3	346	66	412	82	61
	4	344	20	364	110	–
1960	1	12559	356	12915	2561	610
	2	2197	393	2590	855	143
	3	233	282	516	125	75
	4	248	123	371	—	—
1961	1	14452	56	14509	3502	704
	2	2264	187	2451	471	75
	3	284	34	317	319	34
	4	151	42	193	—	–

Sampling Area 42 (Southern Nova Scotia)

1. Otter-trawl fishery

Quarterly otter-trawl landings by country, and numbers of fish measured and aged in samples of the landings are presented in Table 3. The bulk of the landings (76 percent for the 1956-1961 period) were accounted for by the United States fleet in the first quarter. The United States vessels fished principally on Browns Bank.

Adequate estimates of length and age composition of landings were obtained only for U.S. landings in the first quarter of each year, and in the second quarter of 1959 and 1960. Canadian landings, therefore, had to be prorated by the length and age composition of the United States landings to provide the total biostatistics for these quarters.

Comparison of length samples collected from otter trawl landings of both countries in March of 1956 and 1958, and in April 1957 indicate that Canadian landings have a somewhat higher proportion of smaller-sized fish within both market categories (Fig. 3).

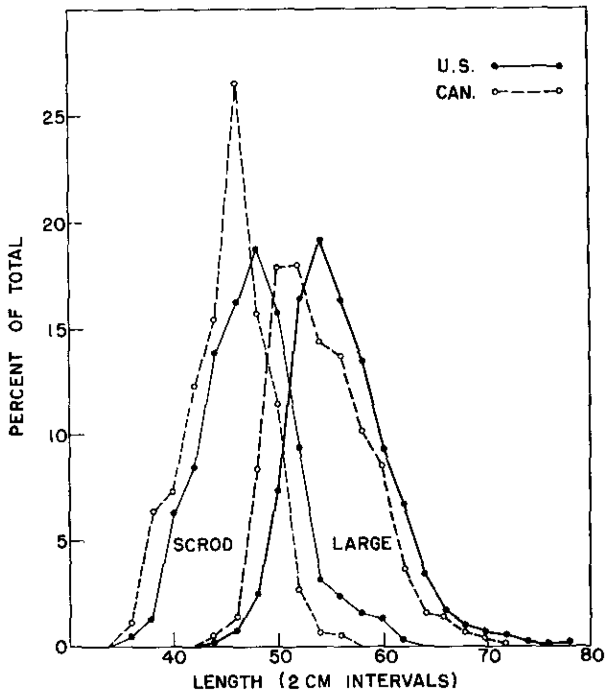

Fig. 3. Comparison of length-frequencies of samples from U.S. and Canadian landings of otter trawlers fishing in Sampling Area 42.

However, the bias introduced in the estimates is negligible because of the relatively small amounts landed by Canadian otter trawlers in the first quarter.

1.1 Average length and weight at age

The average length and weight at age in the landings are presented in Table 4 and Fig. 4. The vertical bars at each point in Fig. 4 represent the range of quarterly averages.

There is no major trend in mean lengths or weights among the years, although the mean lengths for 1961 are, on the average, about 1 cm below the other years in the first quarter (Table 4). The means of the second quarter are somewhat less than those of the first, particularly in weight, for almost all ages. This difference may be related to post spawning condition. The age composition of the two quarters is the same (see below) so that a size differential migration does not seem probable. It is not possible at this time to provide a full explanation.

The means for age groups 3-5 are undoubtedly over-estimates of the underlying population because fish of these ages are only partially recruited to the fishery, and we would expect a higher proportion of the faster growing fish to be retained by the trawl nets. Also, the means of the two youngest and two oldest age groups are over-and under-estimates, respectively, because of the lack of age assessments for the smaller fish of the youngest age groups, and the larger fish of the oldest age groups.

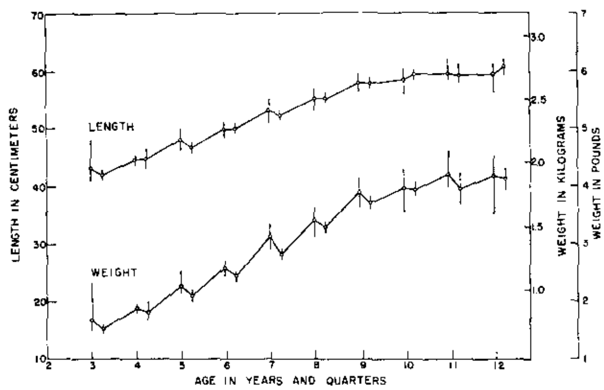

Fig. 4. Quarterly means of length and weight (gutted condition) at age in otter-trawl landings from Sampling Area 42.

TABLE 4. Average length (cm) and weight (lb., gutted) of haddock age groups in otter-trawl landings, Sampling Area 42, Division 4X. Average weights in parentheses are in kilograms.

		Age Group										Grand Mean
		3	4	5	6	7	8	9	10	11	12	
Year	Qtr.	Length										
1956	1	42.4	45.0	50.4	50.4	53.2	57.3	57.2	57.6	59.2	61.3	53.4
1957	1	43.5	45.4	48.6	51.2	55.6	55.9	60.1	60.0	60.2	61.6	54.2
1958	1	42.5	44.1	48.1	51.0	54.3	56.7	59.7	60.8	62.3	56.5	53.6
1959	1	41.5	44.9	47.7	50.2	54.9	55.3	58.4	59.0	60.9	58.0	53.1
1960	1	48.5	45.3	47.8	49.4	53.1	55.6	57.1	60.1	58.9	61.4	53.8
1961	1	41.7	45.0	47.0	49.1	51.7	53.9	57.7	56.3	59.1	60.6	52.1
Average		43.4	45.0	48.3	50.2	53.8	55.8	58.4	59.0	60.1	59.9	
1959	2	42.5	43.6	46.5	50.2	52.6	56.5	57.9	59.3	58.3	60.5	52.8
1960	2	42.5	46.8	48.0	50.9	53.2	55.2	59.0	60.6	61.5	62.1	54.0
Average		42.5	45.2	47.2	50.6	52.9	55.8	58.4	60.0	59.4	61.3	
		Weight										
1956	1	1.57	1.88	2.58	2.59	2.98	3.67	3.62	3.71	4.01	4.35	2.63 (1.19)
1957	1	1.72	1.91	2.32	2.68	3.36	3.42	4.18	4.14	4.24	4.53	2.79 (1.27)
1958	1	1.58	1.82	2.31	2.69	3.23	3.64	4.19	4.36	4.64	3.54	2.73 (1.24)
1959	1	1.48	1.89	2.25	2.57	3.29	3.36	3.90	4.02	4.32	3.79	2.78 (1.26)
1960	1	2.35	1.96	2.30	2.52	3.07	3.49	3.85	4.28	4.07	4.58	2.81 (1.27)
1961	1	1.51	1.91	2.16	2.46	2.85	3.17	3.74	3.59	4.08	4.40	2.53 (1.15)
Average		1.70	1.90	2.32	2.59	3.14	3.46	3.92	4.02	4.24	4.21	
		(0.77)	(0.86)	(1.05)	(1.17)	(1.42)	(1.57)	(1.78)	(1.82)	(1.92)	(1.91)	
1959	2	1.55	1.69	2.01	2.48	2.81	3.42	3.64	3.89	3.69	4.01	2.48 (1.12)
1960	2	1.55	2.01	2.21	2.46	2.92	3.21	3.83	4.11	4.25	4.36	2.84 (1.29)
Average		1.55	1.85	2.11	2.47	2.86	3.32	3.74	4.00	3.97	4.18	
		(0.70)	(0.84)	(0.96)	(1.12)	(1.30)	(1.50)	(1.70)	(1.81)	(1.80)	(1.90)	

1.2 Index of relative abundance

An index of relative abundance in terms of landings-per-days-fished was derived from interview records of trips of large otter trawlers (150 to 300 Gross Tons) landing in Boston and fishing wholely within Sampling Area 42, primarily on Browns Bank. This fleet accounts for most of the otter-trawl catch of haddock within the area, although not all trips were interviewed.

The landings, days fished, and landings-per-days-fished of the interviewed fleet are presented in Table 5. The activity of this fleet is concentrated in the first quarter, when apparent abundance is high. There are very few trips upon which to base estimates in the other quarters, and no data are available for the third quarter in any year. However, even the limited data indicate a sharply reduced apparent abundance in the last three quarters of the year. Haddock spawn on Browns Bank during the first quarter (J. B. Colton, 1962, Report No. 62-11, Woods Hole Bureau of Commercial Fisheries Biological Laboratory, unpublished), and the fish thus may be more densely concentrated at that time. Haddock tagged on inshore grounds off Lockeport, Nova Scotia during summer, were recaptured in fair numbers on Browns and Lahave banks the following winter, suggesting offshore winter movement (McCracken, 1956). Movement inshore in the summer has not been demonstrated, because haddock tagged on Browns Bank have yielded few returns from inshore areas (unpublished U.S. and Canadian records). However, the relative magnitude, and seasonal pattern of haddock movements in the area is difficult to ascertain from these data because of seasonal and geographical variations in fishing effort, and lack of sufficient tag returns.

Total effort for each quarter was estimated by dividing the total landings by the landings-per-days-fished (Table 5). Effort for the third quarter of each year was estimated using the average of the landings-per-day for the second and fourth quarters.

TABLE 5. Estimates of apparent abundance and total effort of otter trawls, Division 4X, Sampling Area 42. (Weight in lb. x10^{-3}).

		Interviewed Fleet				
Year	Qtr.	Days fished	Landings	Landings per day	Total Landings	Total Effort (days fished)
1956	1	298	7896	26.5	16348	617
	2	6	92	15.9	4770	300
	3	—	—	—	287	24
	4	4	25	6.3	636	100
	T			21.2	22042	1041
1957	1	201	3633	18.1	11506	636
	2	8	104	13.9	1485	107
	3	—	—	—	329	32
	4	15	133	8.7	832	96
	T			16.2	14151	871
1958	1	311	6065	19.5	19629	1007
	2	31	387	12.5	2206	176
	3	—	—	—	528	57
	4	26	146	5.5	676	123
	T			16.9	23039	1363
1959	1	80	1149	14.4	7243	503
	2	30	248	8.2	1905	232
	3	—	—	—	412	64
	4	18	56	3.2	364	114
	T			10.9	9924	913
1960	1	295	4232	14.4	12915	897
	2	34	371	10.9	2590	238
	3	—	—	—	516	49
	4	7	56	8.5	371	44
	T			13.3	16392	1228
1961	1	326	4530	13.9	14509	1045
	2	30	301	10.0	2451	245
	3	—	—	—	317	30
	4	—	—	—	193	19
	T			13.0	17470	1339

TABLE 6. Estimated numbers of fish landed per day fished by otter trawls in Sampling Area 42, Division 4X.

		Age Group										Totals of	
Year	Qtr.	3	4	5	6	7	8	9	10	11	12	Age groups	Length groups
1956	1	201	2512	1206	3014	1507	703	241	332	201	100	9884	10070
1957	1	324	584	2658	454	972	778	324	214	130	65	6483	6483
1958	1	30	998	1070	3423	570	499	285	143	21	26	7130	7140
1959	1	41	462	1386	1181	1181	257	308	194	82	30	5133	5211
1960	1	10	511	1074	1534	614	869	205	169	102	12	5114	5124
1961	1	66	602	1753	1260	1013	334	329	71	60	22	5477	5488
1959	2	19	619	912	424	619	189	209	195	65	9	3258	3311
1960	2	16	344	727	995	459	612	192	230	153	39	3827	3831

1.3 Relative abundance of age groups

The estimated numbers landed in each age group were divided by the appropriate days fished to provide estimates of abundance at age (Table 6 and Fig. 5). The magnitude of the inaccuracy in estimating numbers landed by not obtaining age assessments for every 2-cm length interval is indicated by the difference in the two total columns in Table 6.

The year classes of 1950, 1952, and 1954 are all relatively large, with that of 1952 being the largest of any of those included in the data. The 1949 year class may also have been relatively large since its abundance in 1956 at age 7 exceeded that of the 1952 year class at the same age. The abundance of the 1956 year class in 1961 at age 5 indicates it is moderately large.

Although the span of years is short, the data clearly show an alternation of year class abundance, the even numbered years yielding the greater abundance. The ratios of the sum of the numbers-per-day-fished for the two series of year classes at each age, given below, indicate that the difference persists throughout the range of age groups, although the ratio decreases with increasing age. At the present time we cannot specify the population processes which might generate such a system.

The average percentage age composition of landings in the first quarter, 1956-61, is given below and shows the highest frequency at age 6, with less than 1 percent of the landings in age groups 13 and above.

Although the apparent abundance in the second quarter is much lower than in the first, the percentage age distribution is similar for the two quarters in 1959 and 1960 combined, as shown below.

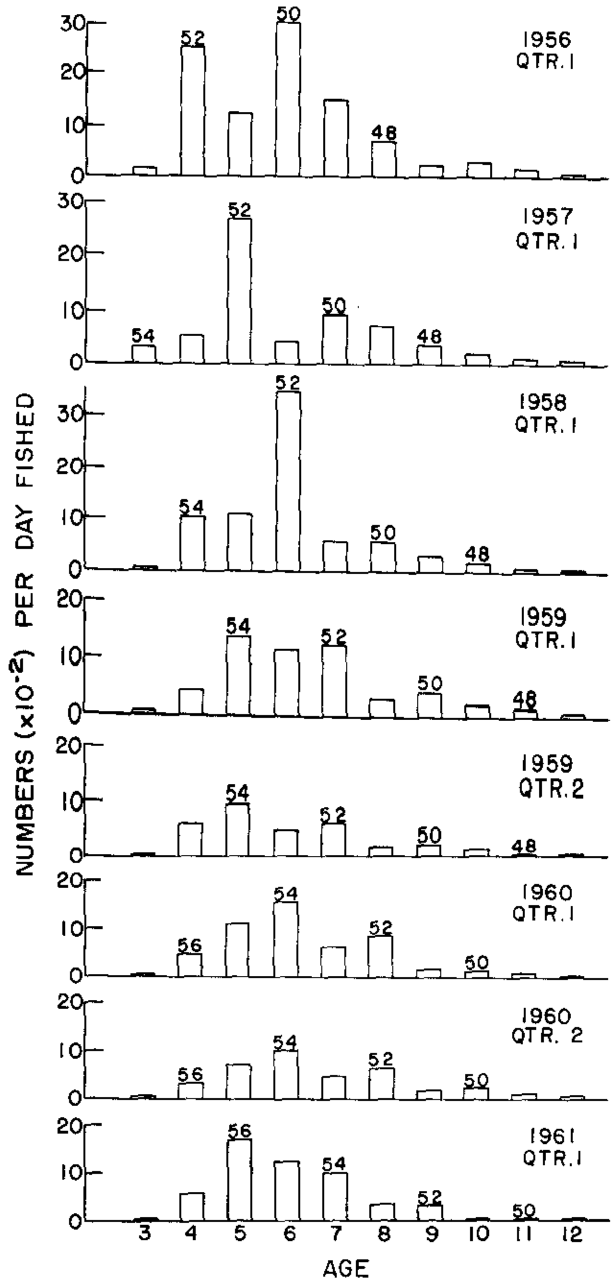

Fig. 5. Relative abundance of age groups in landings of haddock caught by otter trawlers in Sampling Area 42 of Division 4X. Numbers over bars denote year classes.

Age	4	5	6	7	8	9	10
Even years/ odd years	2.4	1.7	2.8	1.2	1.5	1.3	1.3

Age	3	4	5	6	7	8	9	10	11	12	13+
%	2	14	24	28	15	9	4	3	2	<1	<1

Age	3	4	5	6	7	8	9	10	11	12
Qtr. 1	1	9	24	26	18	11	5	4	2	1
Qtr. 2	1	14	23	20	15	11	6	6	3	1

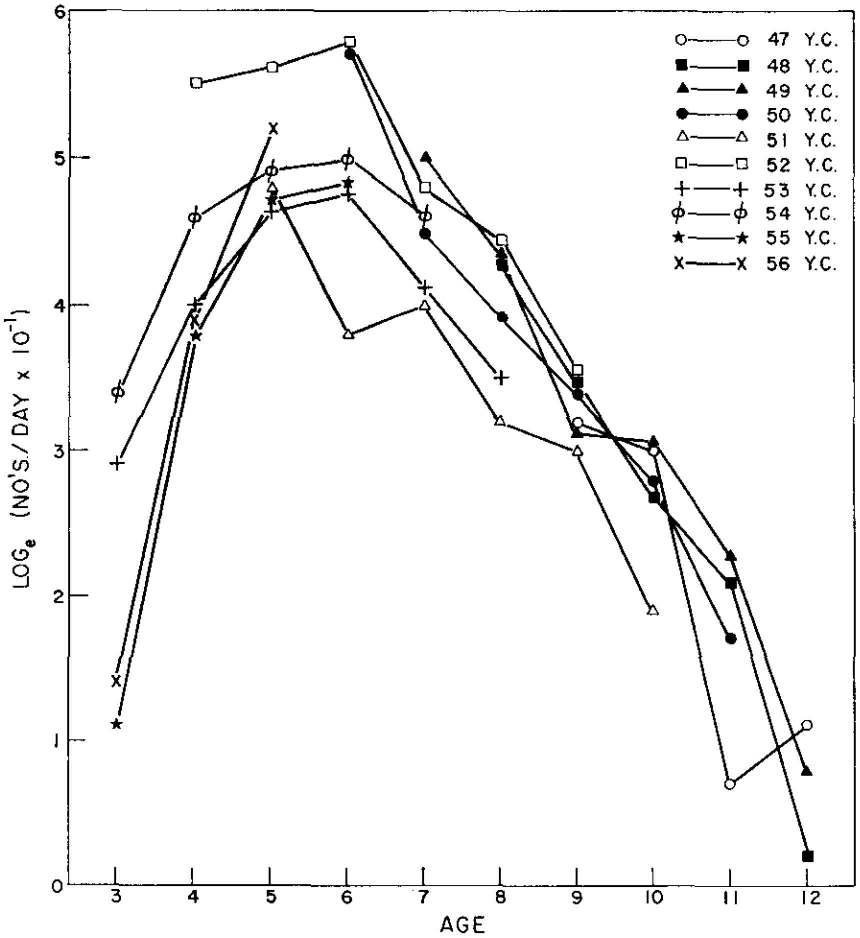

Fig. 6. Plot of logarithm of abundance on age for various year classes in landings by otter trawlers from Sampling Area 42, Division 4X.

1.4 Estimates of total mortality

The natural logarithms of numbers-per-day in the first quarter landings have been plotted against age for various year classes (Fig. 6). The peak of these curves occurs between 5 and 6 years of age, and recruitment is taken to be essentially complete by age 6. There is no observable departure from linearity between age groups 6 and 10, but the decrease in apparent abundance between age groups 10 and 12 appears somewhat greater. We might also note that the degree of homogeneity among the curves is rather satisfactory, considering the variety of data employed.

In order to estimate annual survival rates and examine variations thereof among years and ages, we have calculated the individual ratios

$$r_{ij} = \frac{N_{i+1,\, j+1}}{N_{ij}},$$

and the ratios of the means (i.e., ratio of sums of numerator and denominator above); $r_{\cdot j}$, $r_{i\cdot}$, and $r_{\cdot\cdot}$, where N_{ij} is the estimated number-per-day in age group j, and year i, i = 1956,. . ., 1961, and j = 3,. . ., 12 years, and where the dot indicates the subscript over which the sums have been taken. The ratios $r_{i\cdot}$ and $r_{\cdot\cdot}$ include only age groups 6 through 12. The ratios are set forth in Table 7.

There is considerable variation among the r_{ij}, which is not unexpected considering all the possible sources of variation. The row and column totals are somewhat more informative.

Examination of the $r_{\cdot j}$ reaffirms our previous observation that recruitment is essentially complete by age 6; the validity of this observation depends, of course, on constant mortality rates from age 6 onwards. We might conclude this is

TABLE 7. Estimates of total survival rate of haddock in first quarter otter-trawl landings from Sampling Area 42, Division 4X.

	Age Group									
Year	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	Age 6-12 Avg ($r_{i}.$)
1956-57	2.90	1.06	0.38	0.32	0.52	0.46	0.89	0.39	0.32	0.41
1957-58	3.08	1.83	1.29	1.26	0.51	0.37	0.44	0.10	0.20	0.54
1958-59	15.40	1.39	1.10	0.34	0.45	0.62	0.68	0.57	1.43	0.42
1959-60	12.46	2.32	1.11	0.52	0.74	0.80	0.55	0.52	0.15	0.62
1960-61	60.2	3.43	1.17	0.66	0.54	0.38	0.35	0.36	0.22	0.52
Avg ($r._{j}$)	5.21	1.57	1.06	0.45	0.56	0.47	0.58	0.38	0.29	0.48 ($r..$)

so for ages 6-10, since there is no trend in the survival ratios. As mentioned earlier, the lack of age assessments for some of the larger length intervals has been responsible, to some extent, for the lower apparent abundance at ages 11 and 12.

The row averages, $r_{i}..$, indicate large differences in survival among years. Changes in annual fishing intensity, show a general inverse trend to survival, but the series of data are too short and the yearly deviations are too small to permit a precise evaluation.

The overall pooled ratio, r.., of 0.48 provides an estimate of survival which is equivalent to a total instantaneous mortality rate, Z, of 0.73. This may not be the "best" estimate of mortality in the statistical sense of no bias and minimum variance, but it seems as good as any with the data at hand. Other estimators (e.g., Robson and Chapman, 1961, and slope of the catch curve) have produced similar estimates in trial comparisons.

2. Hook and line fishery

The hook and line fishery in Sampling Area 42 is exclusively Canadian and employs both longlines and handlines. Longlines produce about two-thirds of the landings. Longliners use, on the average, 11 lines per tub and 50 hooks per line, or approximately 550 hooks per tub, (usually Pfleugers 6/0 or equivalent hook). Varying numbers of tubs per day are set depending upon fishing ground. Inshore vessels (0-25 gross tons) land catches daily whereas offshore vessels (above 25 gross tons) land after several days fishing. Handliners (0-25 gross tons) use 6/0 hooks most frequently and fish the inshore grounds exclusively.

Landings from offshore areas (Subareas N and P, see Fig. 1) are at a peak in the first quarter, drop to a low level in the second and third quarters, and rise slightly again in the fourth quarter (Table 8). In contrast, landings from inshore areas (Subareas M, O, and Q) usually are highest in the second and third quarters. Consequently, total hook and line landings remain fairly steady throughout the year. Haddock landings from inshore areas constitute about three-fourths of the total hook and line landings of haddock each year.

Most hook and line landings were graded into market categories of large and scrod at the time of sampling. Some fish were landed as ungraded, but the actual amount cannot be determined, because the total landings of the small longline vessels (0-25 gross tons) were listed as ungraded in the statistics, even though most of these landings actually were graded. Another deficiency in the statistics is that handline and longline landings usually were not recorded separately. Because complete statistics were lacking it was necessary to use special records of landings of Lockeport longline vessels from Subareas N and O combined. The special records listed Lockeport landings as large and scrod for all classes of longliners, and this breakdown was used to prorate the total hook and line landings into large and scrod for each month. This procedure requires several assumptions.

First, we have assumed that the length-frequencies of graded and ungraded catches are equal. This appears to be a valid assumption

TABLE 8. Haddock landings (gutted weight in lb. x 10^{-3}) and numbers of fish measured and aged for hook and line fishery, Sampling Area 42, Division 4X.

		Landings				
Year	Qtr.	M, O, Q (Inshore)	N, P (Offshore)	Total	Number measured	Number aged
1956	1	1515.1	978.4	2493.5	1100	260
	2	1554.5	191.3	1745.8	—	—
	3	1473.7	167.6	1641.3	200	—
	4	1115.6	357.0	1472.6	800	200
	Total	5658.9	1694.3	7353.2		
1957	1	933.7	1507.4	2441.1	998	200
	2	1879.7	233.2	2112.9	1015	135
	3	2765.8	174.3	2940.1	290	50
	4	965.4	371.6	1337.0	2370	340
	Total	6544.6	2286.5	8831.1		
1958	1	796.2	1669.9	2466.1	400	56
	2	1627.4	161.8	1789.2	1515	227
	3	1475.7	270.1	1745.8	—	—
	4	1321.5	383.1	1704.6	1664	288
	Total	5220.8	2484.9	7705.7		
1959	1	883.0	1383.3	2266.3	332	55
	2	2681.1	290.9	2972.0	—	—
	3	2280.9	72.7	2353.6	425	331
	4	1420.7	124.4	1545.1	500	196
	Total	7265.7	1871.3	9137.0		
1960	1	590.7	1000.7	1591.4	230	47
	2	1553.9	437.7	1991.6	1000	192
	3	1754.0	91.1	1845.1	—	—
	4	736.4	311.2	1047.6	600	129
	Total	4635.0	1840.7	6475.7		
1961	1	1121.4	942.3	2063.7	—	—
	2	1612.1	263.3	1875.4	—	40
	3	2053.2	106.3	2159.5	—	79
	4	704.2	90.9	795.1	200	40
	Total	5490.9	1402.8	6893.7		

(Fig. 7). Also, we have assumed that the large scrod ratio of Lockeport longliners as well as the length frequency of each market category was the same as that of the entire hook and line fleet. Supporting this assumption are the facts that most of the hook and line landings of haddock comes from Subareas N and O, and the size frequencies of both large and scrod are similar for these two Subareas (Fig. 8).

However, the proportion of scrod in offshore landings (Subarea N) tended to be lower than that of inshore landings (Subarea O), particularly in the first quarter (Table 9). Furthermore, Lockeport longliners land more haddock from offshore grounds than from inshore grounds in the first part of the year and less from offshore grounds in the fourth quarter, than does the fleet in general (Table 10). Consequently, by using the combined landings from Subareas N and O in the Lockeport records we have obtained a slightly lower estimate of the proportion of scrod in the total hook and line landings for the first two quarters, than that which would have been obtained by treating each area separately (Table 11). With the exception of 1958 the reverse is true for the fourth quarter (Table 11).

Finally our procedure assumes that the length-frequency of haddock landings is the same

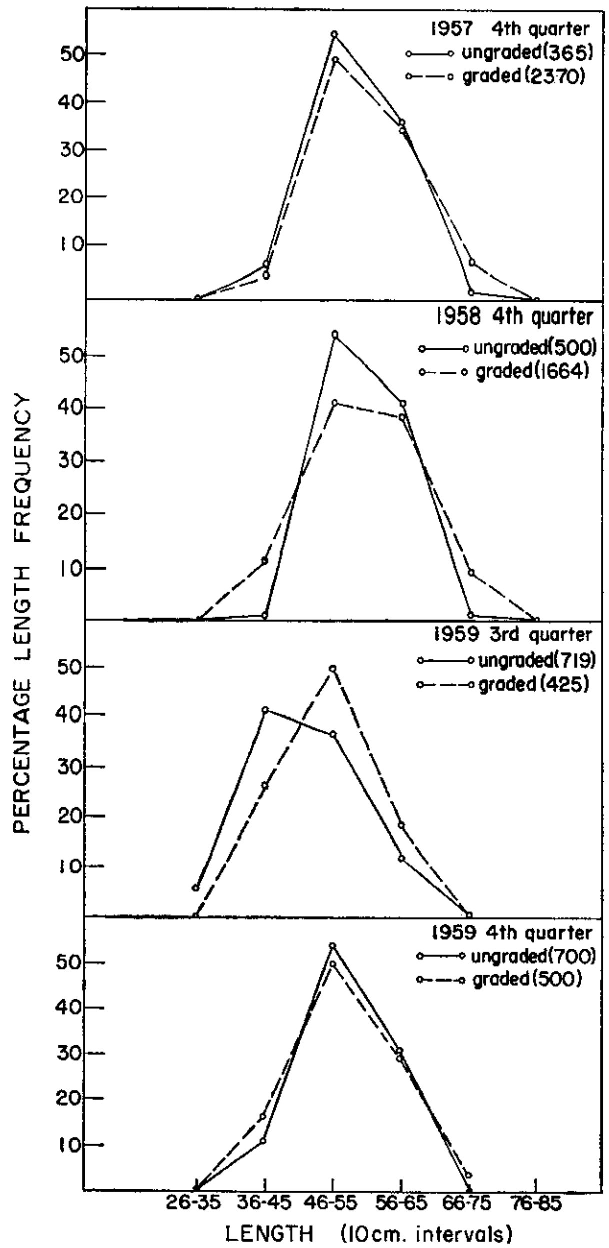

Fig. 7. Comparisons of graded (large and scrod combined) and ungraded length-frequencies of Canadian longline landings of haddock caught in Sampling Area 42, Division 4X.

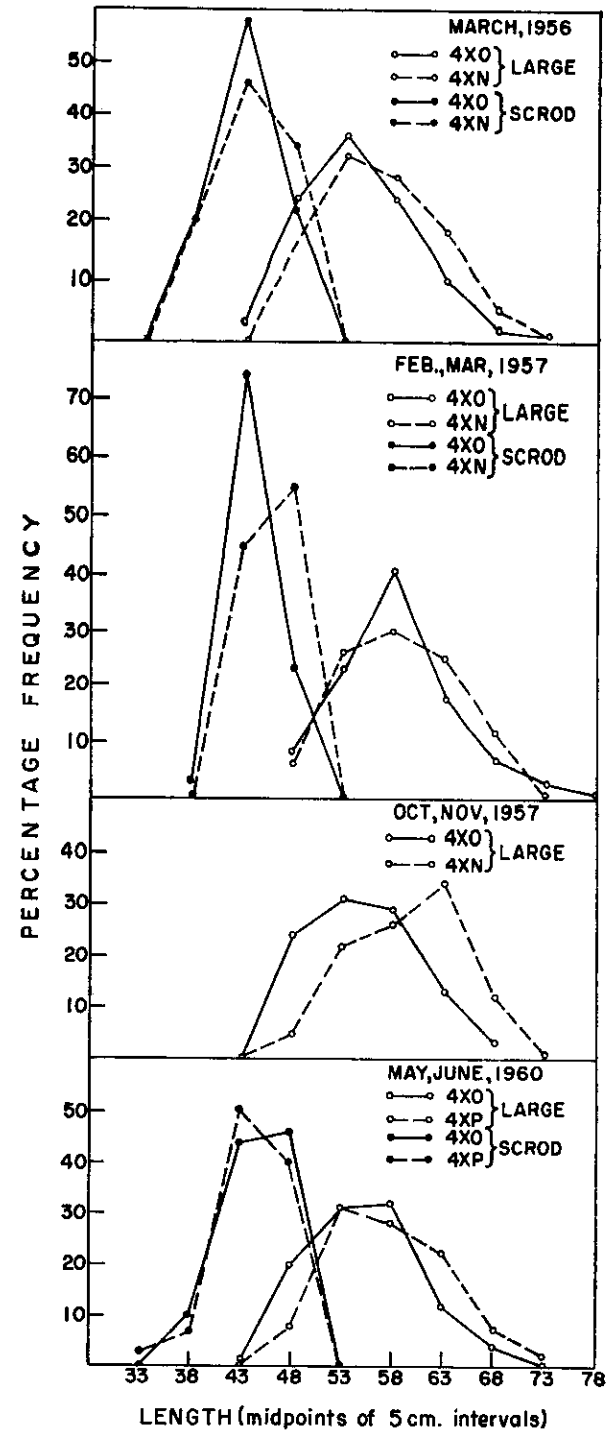

Fig. 8. Comparison of length frequencies of haddock in landings by longliners fishing in Subarea O (inshore) and Subareas N and P (offshore) of Sampling Area 42, Division 4X.

TABLE 9. Percentage (by weight) of scrod in landings from offshore (Subarea N) and inshore (Subarea O) grounds by Lockeport longliners, Sampling Area 42, Division 4X.

	1956		1957		1958	
Qtr.	O	N	O	N	O	N
1	15	5	23	9	11	5
2	5	5	15	9	8	6
3	6	6	15	9	10	9
4	12	6	7	5	9	5

TABLE 10. Percentage contribution of offshore haddock landings to total haddock landings by Lockeport longliners, and to total haddock landings by entire hook and line fleet in Sampling Area 42, Division 4X.

	1956		1957		1958	
Qtr.	Lockeport line trawlers	Total hook and line	Lockeport line trawlers	Total hook and line	Lockeport line trawlers	Total hook and line
1	84	39	86	62	86	68
2	88	11	67	11	31	9
3	80	10	20	6	10	15
4	5	24	4	28	8	22

TABLE 11. Percentages (by weight) of scrod in hook and line landings, estimated by using Lockeport Co. statistics of longline landings from Subareas N and O separately and combined.

	1956		1957		1958	
Qtr.	N and O Combined	N and O Separate	N and O Combined	N and O Separate	N and O Combined	N and O Separate
1	7	11	10	14	6	7
2	5	5	11	14	7	8
3	6	6	14	15	10	10
4	12	10	7	6	7	8

for handlines and longlines. Only two comparisons are available between length frequencies of landings by handline and longline vessels, and these indicate that there is some similarity between them (Fig. 9). Also the estimated proportion of scrod is about the same for handliners as for longliners in the Lockeport Company records as shown below:

Year[6]	Longliners	Handliners
1957	13	11
1958	8	14
1959	16	18
1960	17	16
1961	25	18

Age-length frequencies of the hook and line landings were estimated in the manner described earlier. Length samples were used from graded longline landings only, but age samples were used regardless of grading or type of gear[7]. Inaccuracies because of lack of age assessments for all length intervals were negligible in this segment of data (see totals of Table 14).

2.1 Average length and weight at age

Mean length and weight at each age in hook and line landings are shown in Table 12 and Fig. 10. Mean length and weight in the fourth quarter was somewhat less in 1959 and 1960 than in the earlier years. In contrast, the means

[6]) Only summer months with substantial handline landings were used in the comparison. Figures are arithmetic means of monthly percentage contributions of scrod landings to total landings.

[7]) Some samples were available from ungraded longline landings and a few samples were taken from handline landings.

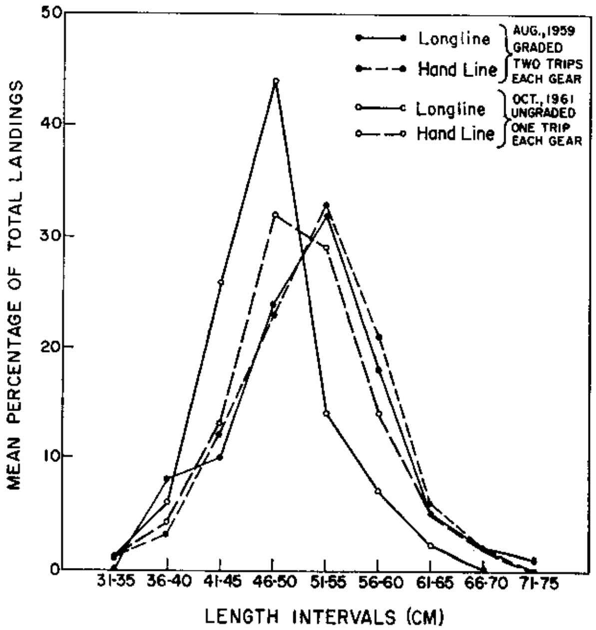

Fig. 9. Comparison of length frequencies of haddock in handline and longline landings from Sampling Area 42, Division 4X.

in the first and second quarters are somewhat greater in later years than in earlier years, but it seems likely that these differences lie within the limits of sampling error. In the first quarter only one age sample was obtained in each of the years 1958, 1959, and 1960; therefore, the means of lengths and weights at age for the first quarter are less reliable estimates than for the fourth quarter. Kohler (1960) presented data for inshore haddock landings at Lockeport during the period 1946-1954. Mean lengths at age in his study were approximately 1 cm higher than in the present study.

Lengths at age in fourth quarter longline landings were compared with those of the same year classes in the first quarter otter-trawl landings of the following year (Fig. 21). Haddock taken by otter trawls in the first quarter at ages 4 and 5 were larger than the corresponding age groups and year classes taken by longlines in the previous fourth quarter. From age 6 onward, haddock taken in the fourth quarter by longlines tended to be progressively larger than members of the same year classes and corresponding age groups taken by otter trawls in the following quarter. These differences are partly due to bias in estimating mean length of youngest and oldest age groups in otter-trawl landings. Differential selectivity by the two types of gear may also contribute to the differences. However, the comparison may reflect real differences in length at age between inshore and offshore grounds; the former represented by longline landings, and the latter by otter-trawl landings.

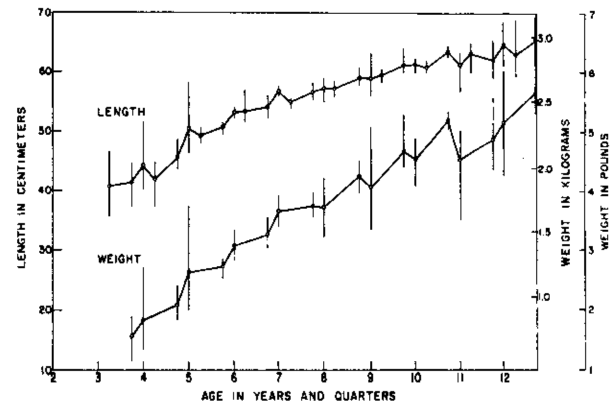

Fig. 10. Mean length and weight (gutted) of haddock in landings of longline vessels fishing in Sampling Area 42, Division 4X.

2.2 Index of relative abundance

Indices of relative abundance of haddock in terms of landings-per-line are based on special records of longliners landing at the Lockeport Company. The Lockeport Company data on landings, lines fished, and landings-per-line are given by quarters for inshore and offshore grounds in Table 13. The inshore indices are based on landings and effort of small (0-25 gross tons) and medium (26-50 gross tons) vessels fishing only in Subarea O. Offshore indices are based on data for medium longliners fishing mainly in Subarea N. No effort data are available for Subareas M, P, Q, and we have assumed that data for N are representative of P, and data for O representative of M and Q.

In inshore areas, abundance appears to have increased in the latter half of the period 1956-61 but chiefly in the second and third quarters (Table 13). Abundance indices in both the first and fourth quarters were about the same throughout the period except for the first quarter in 1961, which was about twice the average first-quarter value. While there is some basis for suggesting an overall increase in abundance on inshore grounds, the evidence is much less convincing than if all quarters had shown increases. Note also that abundance was higher on the average in the third and fourth quarters in all years.

TABLE 12. Average length (cm) and weight (lbs. gutted) of haddock age groups in longline landings. Sampling Area 42, Division 4X. Average weights in parentheses are in kilograms.

		Age Group										
		3	4	5	6	7	8	9	10	11	12	Grand Mean
Year	Qtr.						Length					
1956	4	44.7	46.7	51.4	55.1	57.2	59.6	61.4	63.9	61.4	67.1	54.6
1957	4	41.6	48.8	51.0	56.0	58.1	60.8	64.2	64.5	64.7	59.9	54.4
1958	4	42.7	44.6	50.7	53.9	56.9	58.9	60.2	63.0	60.4	69.4	54.8
1959	4	41.5	45.9	49.7	53.2	56.5	60.0	60.9	63.7	65.8	64.5	52.7
1960	4	37.4	43.7	51.4	52.4	55.5	57.9	60.1	64.5	59.4	68.0	51.9
Average		41.6	45.9	50.8	54.1	56.8	59.4	61.4	63.9	62.3	65.8	
1956	1		45.4	51.4	53.3	56.6	58.9	60.0	61.2	63.6	64.2	55.9
1957	1		43.2	48.4	54.0	56.5	59.1	63.2	62.1	62.4	62.8	55.6
1958	1		40.5	47.2	54.0	57.6	56.1	56.0	62.5	61.6	68.5	56.2
1959	1		40.5	46.5	52.5	56.1	56.6	59.7	60.8	56.8	61.2	56.2
1960	1		51.6	58.5	52.2	57.6	55.0	56.2	61.9	62.8	67.6	58.2
Average			44.2	50.4	53.2	56.9	57.1	59.0	61.7	61.4	64.9	
1957	2	35.6	37.3	50.5	57.0	55.3	58.7	60.8	60.6	65.1	69.2	50.4
1958	2	40.5	45.0	49.1	52.5	54.0	56.1	58.7	60.0	60.1	59.5	54.4
1960	2	46.5	43.8	48.2	51.7	55.6	57.2	59.5	62.2	65.0	60.9	55.0
Average		40.9	42.0	49.3	53.7	55.0	57.3	59.7	60.9	63.4	63.2	
							Weight					
1956	4	1.89	2.14	2.78	3.40	3.77	4.26	4.62	5.15	4.59	5.99	3.41 (1.55)
1957	4	1.56	2.41	2.75	3.57	3.98	4.51	5.31	5.36	5.38	4.35	3.40 (1.54)
1958	4	1.71	1.93	2.76	3.24	3.81	4.16	4.48	5.05	4.50	6.53	3.50 (1.59)
1959	4	1.55	2.04	2.53	3.06	3.65	4.36	4.55	5.13	5.59	5.30	3.10 (1.41)
1960	4	1.16	1.82	2.86	3.04	3.58	3.99	4.42	5.30	4.39	6.15	3.05 (1.38)
Average		1.57	2.07	2.74	3.26	3.76	4.26	4.68	5.20	4.89	5.66	
		(0.71)	(0.94)	(1.24)	(1.48)	(1.70)	(1.93)	(2.36)	(2.22)	(2.57)		
1956	1		1.95	2.77	3.04	3.57	4.00	4.19	4.42	4.98	4.95	3.52 (1.60)
1957	1		1.73	2.48	3.34	3.73	4.23	5.09	4.88	5.02	4.96	3.70 (1.68)
1958	1		1.45	2.24	3.33	3.93	3.66	3.70	4.90	4.70	6.15	3.73 (1.69)
1959	1		1.35	2.01	2.81	3.40	3.52	4.07	4.19	3.50	4.29	3.50 (1.59)
1960	1		2.72	3.75	2.90	3.62	3.21	3.37	4.43	4.66	5.62	3.82 (1.73)
Average			1.84	2.65	3.08	3.65	3.72	4.08	4.56	4.57	5.19	
			(0.83)	(1.20)	(1.40)	(1.65)	(1.69)	(1.85)	(2.07)	(2.07)	(2.35)	

The annual trend in abundance is less noticeable on offshore grounds, but the lowest abundance indices occurred in 1956 and 1957 as was the case for inshore grounds. In each year there is a marked peak of abundance in the first quarter, and on the average the lowest abundance occurs in the third quarter.

Abundance estimates for the offshore grounds are probably less reliable than for inshore grounds because fewer interviews for offshore trips were recorded, particularly in the third and fourth quarters.

Nevertheless, the fact that the peak offshore abundance occurs in the first quarter of both otter trawl and longline fisheries, and that the third and fourth quarters show highest abundance in the inshore longline fishery, suggests again that haddock move offshore in winter and inshore in summer.

Total hook and line effort, in terms of lines, was estimated by dividing total hook and line landings from each ground by estimated landings per line (Table 13). The total estimated number of lines fished has declined steadily.

TABLE 13. Estimates of apparent abundance and total effort of hook and line vessels (in terms of lines) in Sampling Area 42, Division 4X. Abundance estimates based on records of Lockeport Company.

		Inshore (M, O, Q) Lockeport Co. Special Records						Offshore (N, P) Lockeport Co. Special Records						
Year	Qtr.	No. Trips	Lines Fished	Landings (lb.)	Landings per Line	Total Landings (lb. $\times 10^{-3}$)	Total Lines $\times 10^{-4}$	No. Trips	Lines Fished	Landings (lb.)	Landings per Line	Total Landings (lb. $\times 10^{-3}$).	Total Lines $\times 10^{-4}$	Grand Total† Lines $\times 10^{-4}$
1956	1	182	14575	65065	4.5	1515.1	33.7	29	11121	331055	29.8	978.4	3.3	37.0
	2	68	3553	4675	1.3	1554.5	119.6	24	10593	53760	5.1	191.3	3.8	123.4
	3	89	4741	23010	4.8	1473.7	30.7	35	13409	95590	7.1	167.6	2.4	33.1
	4	235	24750	285880	11.6	1115.6	9.6	4	1342	14640	10.9	357.0	3.3	12.9
	TOTAL		47619	378630	$\bar{x}$ = 8.0		193.6		36465	495045	$\bar{x}$ = 13.6		12.8	206.4
1957	1	162	15928	89090	5.6	933.7	16.7	46	16258	413750	25.4	1507.4	5.9	22.6
	2	112	6952	29275	4.2	1879.7	44.8	22	6941	59140	8.5	233.2	2.7	47.5
	3	127	6226	84090	13.5	2765.8	20.5	18	4499	20860	4.6	174.3	3.8	24.3
	4	235	22770	234715	10.3	965.4	9.4	3	1166	9750	8.4	371.6	4.4	13.8
	TOTAL		51876	437170	$\bar{x}$ = 8.4		91.4		28864	503500	$\bar{x}$ = 17.4		16.8	108.2
1958	1	105	9966	65015	6.5	796.2	12.2	43	14091	414895	29.4	1669.9	5.7	17.9
	2	175	11902	75025	6.3	1627.4	25.8	15	4433	34165	7.7	161.8	2.1	27.9
	3	169	11286	102160	9.0	1475.7	16.4	5	1650	11505	7.0	270.1	3.8	20.2
	4	210	22275	223480	10.0	1321.5	13.2	6	2046	32315	15.8	383.1	2.4	15.6
	TOTAL		55429	465680	$\bar{x}$ = 8.4		67.6		22220	492880	x = 22.2		14.0	81.6
1959	1	70	7029	37815	5.4	883.0	16.4	44	16654	424063	25.5	1383.3	5.4	21.8
	2	108	4873	53290	10.9	2681.1	24.6	12	4499	57865	12.9	290.9	2.2	26.8
	3	125	3245	45585	14.0	2280.9	16.3	0	–	–	–	72.7	0.5*	16.8
	4	77	8646	105715	12.2	1420.7	11.6	0	–	–	–	124.4	1.0*	12.6
	TOTAL		23793	242405	$\bar{x}$ = 10.2		68.9		21153	481928	$\bar{x}$ = 22.8		9.1	78.0
1960	1	58	5489	33055	6.0	590.7	9.8	35	12694	390145	30.7	1000.7	3.2	13.0
	2	55	1771	17130	9.7	1553.9	16.0	14	7040	182905	26.0	437.7	1.7	17.7
	3	71	1683	22735	13.5	1754.0	13.0	2	528	3585	6.8	91.1	1.3	14.3
	4	88	8459	86160	10.2	736.4	7.2	10	3454	38925	11.3	311.2	2.8	10.0
	TOTAL		17402	159080	$\bar{x}$ = 9.1		46.0		23716	615560	$\bar{x}$ = 26.0		9.0	55.0
1961	1	56	6908	95270	13.8	1121.4	8.1	15	5203	179510	34.5	942.3	2.7	10.8
	2	60	2255	24635	10.9	1612.1	14.8	11	4642	42730	9.2	263.3	2.9	17.7
	3	150	3421	73570	21.5	2053.2	9.5	2	935	5955	6.4	106.3	1.7	11.2
	4	49	4884	53060	10.9	704.2	6.5	10	2541	15580	6.1	90.9	1.5	8.0
	TOTAL		17468	246535	$\bar{x}$ = 14.1		38.9		13321	243775	$\bar{x}$ = 18.3		8.8	47.7

†Inshore plus offshore.

*Estimated by using inshore catch/line.

TABLE 14. Estimated numbers of fish (x 10^2) landed per line by age groups,[1] Sampling Area 42, Division 4X.

		Age Group										Totals of	
Year	Qtr.	3	4	5	6	7	8	9	10	11	12	Age groups	Length groups
1956	4	15	59	32	79	65	40	21	10	3	5	4280	4322
1957	4	12	29	109	29	52	17	13	5	9	2	3917	3935
1958	4	5	39	33	103	27	42	25	14	8	4	4844	4873
1959	4	20	76	82	53	88	22	31	4	6	2	4981	4990
1960	4	5	96	47	74	24	64	17	4	7	2	3398	3434
Avg		11.4	59.8	60.6	67.6	51.2	37.0	21.4	7.4	6.6	3.0		
1956	1		17	15	52	37	24	15	20	4	4	7089	7089
1957	1		8	85	27	48	43	28	26	13	8	6606	6606
1958	1		2	16	126	33	85	37	6	48	4	6492	6617
1959	1		6	30	19	87	39	35	35	11	10	6148	6367
1960	1		19	9	39	53	51	27	70	30	23	4169	4169
Avg			10.4	31.0	52.6	51.6	48.4	28.4	31.4	21.2	9.8		

[1])Note that fish of a given year and age group in Quarter 4 are just ½ year younger than the next older age group in Quarter 1 of the following year.

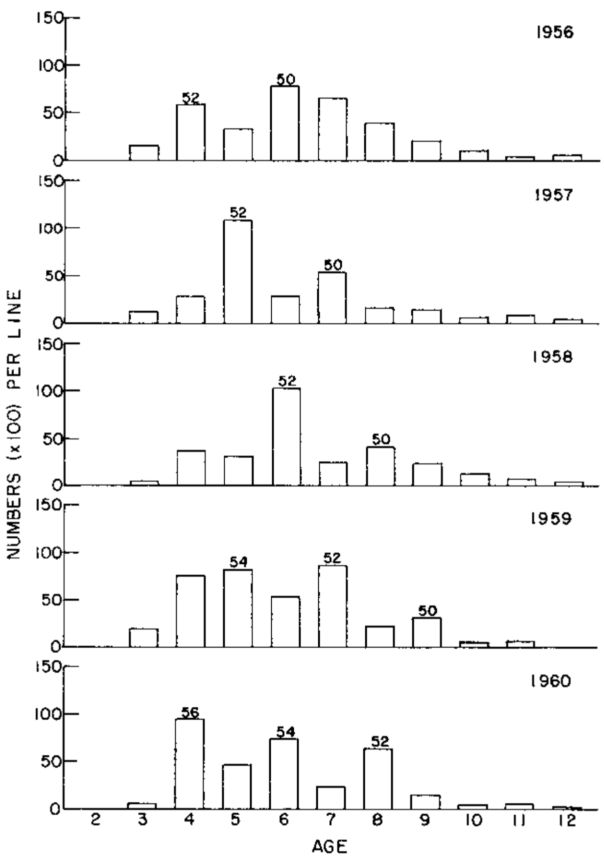

Fig. 11. Relative abundance of age groups in landings of hook and line vessels fishing in Sampling Area 42, Division 4X. Numbers above bars denote year classes.

2.3 Relative abundance of age groups

Estimated numbers landed at each age in the first and fourth quarters were divided by the estimated total lines fished (inshore and offshore grounds combined) to obtain estimates of abundance at each age (Table 14 and Fig. 11).

The fourth quarter was the only one in which age sampling was at all adequate for more than two successive years. Data for the years 1958, 1959, and 1960 in the first quarter are rather inadequate, and estimates of abundance at age are less reliable than for the fourth quarter.

Relative numbers landed per line in the fourth quarter show the alternating strengths of even and odd year classes which was shown previously in the otter trawl landings. The 1952 year class appears to have been a particularly strong year class and the early estimates indicate that the 1956 year class may be of comparable size. In general, the estimates of relative abundance of year classes derived from otter-trawl and longline landings agree very favourably.

The percentage age composition shown below indicates a maximum contribution to longline landings at age 6, which is the same as that for otter trawl landings. Age groups 10 and older contributed an average of nearly 15 per cent to hook and line landings, as compared to less than 6 percent of first quarter otter-trawl landings.

	Percentage of longline landings at age										
Period	3	4	5	6	7	8	9	10	11	12	13+
Qtr. 1 (1956-1960)	–	4	11	18	18	16	10	11	6	3	2
Qtr. 2 (1957, 1958, 1960)	4	6	15	19	14	19	9	5	4	2	3
Qtr. 4 (1956-1960)	3	18	19	21	15	11	6	2	2	1	1

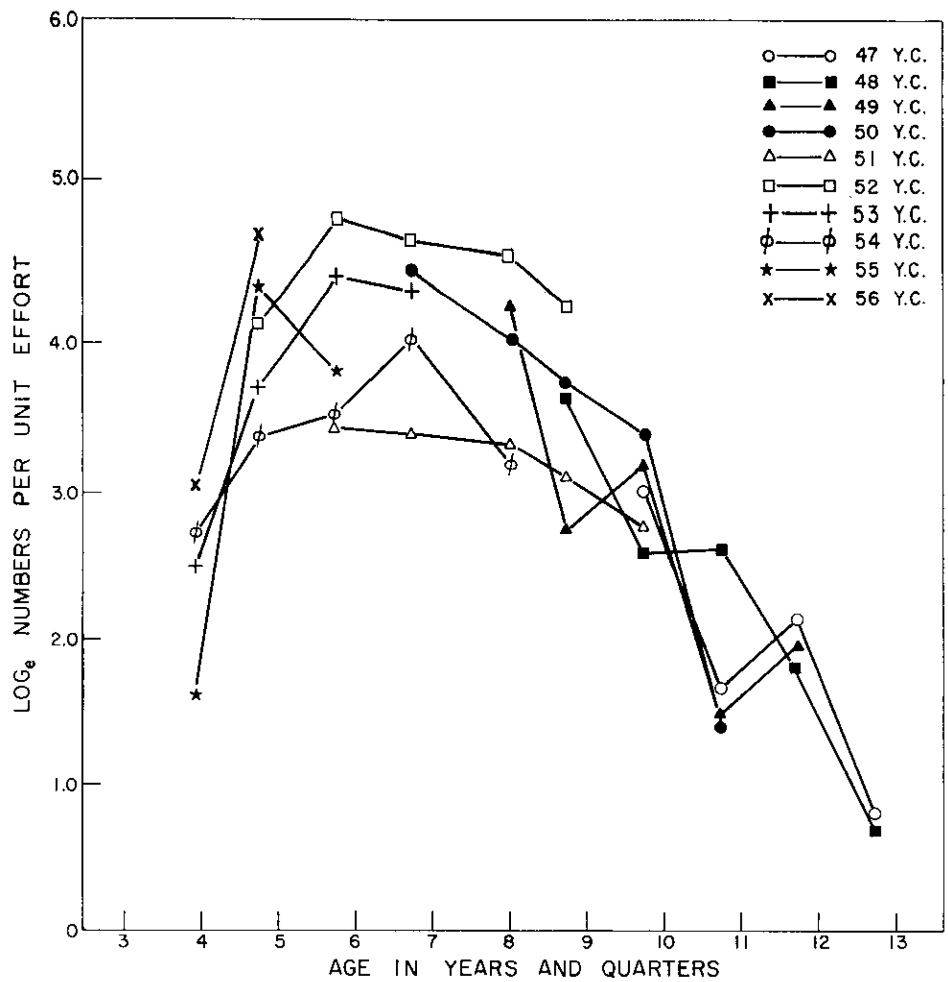

Fig. 12. Logarithmic abundance of haddock year classes at age in landings of longliners fishing in Sampling Area 42, Division 4X.

2.4 Estimates of total mortality

Catch curves based on fourth quarter longline landings were plotted for individual year classes (Fig. 12). The rather wide scatter of points between different year classes and also by the same year class in successive years indicates a fair degree of sampling variation and does not provide a good basis for judging linearity of the right hand limb of the curves. However, the wide dome, and apparent convexity of the curve over a large range of ages may be indicative of a rather gradual recruitment, which is probably not complete until age 8. In contrast, recruitment was found to be nearly complete at age 6 in otter-trawl landings.

Estimates of survival from age 6 on were made using the ratios $r_{ij\cdot}$, $r_{i\cdot\cdot}$, $r_{\cdot j\cdot}$, and $r_{\cdot\cdot}$ as defined in the previous section, and are set forth in Table 15. The estimated survival ratio of 0.96 for 1957-58 is unrealistic and therefore, the value of $r_{\cdot\cdot}$ = 0.64 is considered to be high also.

TABLE 15. Estimates of total survival rate of haddock in fourth quarter hook and line landings, Sampling Area 42, Division 4X.

Year	Age Group									Mean ($r_{i\cdot}$)
	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	Age 6-12
1956-57	1.93	1.85	0.91	0.66	0.26	0.32	0.24	0.90	0.67	0.45
1957-58	3.25	1.14	0.94	0.93	0.81	1.47	1.08	1.60	0.44	0.96
1958-59	15.20	2.10	1.61	0.85	0.81	0.74	0.16	0.43	0.25	0.70
1959-60	4.80	0.62	0.90	0.45	0.73	0.77	0.13	1.75	0.33	0.58
Mean ($r_{\cdot j}$)	4.62	1.33	1.01	0.72	0.62	0.71	0.30	0.91	0.38	0.64 ($r_{\cdot\cdot}$)

We believe the rather wide fluctuation in survival estimates between years is caused by errors in abundance estimates, which would affect all age groups in a given year. It should be recalled that in the fourth quarter about one-fourth of the total hook and line landings were from offshore grounds (N, P) but usually there were never more than 10 offshore trips recorded in the fourth quarter for any year, and there were only 3 and 6 trips in 1957 and 1958, respectively (Table 13). Rather large errors might be expected, therefore, in estimating offshore abundance in the fourth quarter, and these errors could significantly affect the estimate of total effort.

Under these conditions, a more accurate estimate of mortality probably is obtained by plotting natural logarithms of the mean numbers-landed-per-line at each age for the fourth quarter (Fig. 13). Linear regression of the points from ages 7-12 gives a slope of − 0.58, i.e., Z = 0.58.

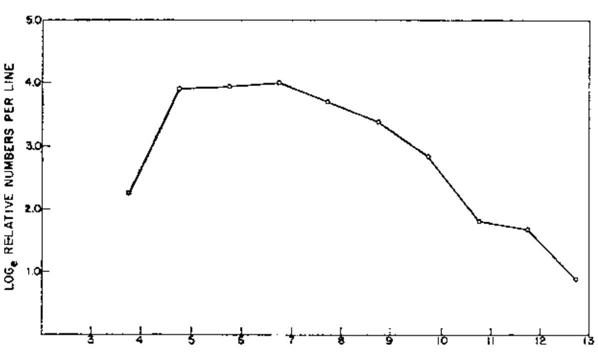

Fig. 13. Logarithms of mean numbers-landed-per-line on age for haddock in hook and line landings from Sampling Area 42, Division 4X.

3. Comparison of mortality estimates from line and trawl landings

For purposes of comparison, we have computed the difference between $\log_e$ of mean numbers per unit effort of successive age groups, i.e., the instantaneous total mortality, for both longlines and otter trawls in the years 1956-1960. Plotting these differences against age groups (Fig. 14) indicates that estimates of mortality in both sets of data approach the same value at older ages. However, while the estimates from otter trawl landings vary around a nearly constant value from ages 6-7 onward, the estimates from longline landings approach the limiting value more slowly, and can be considered as estimates of a constant value only from ages 8-9 onwards.

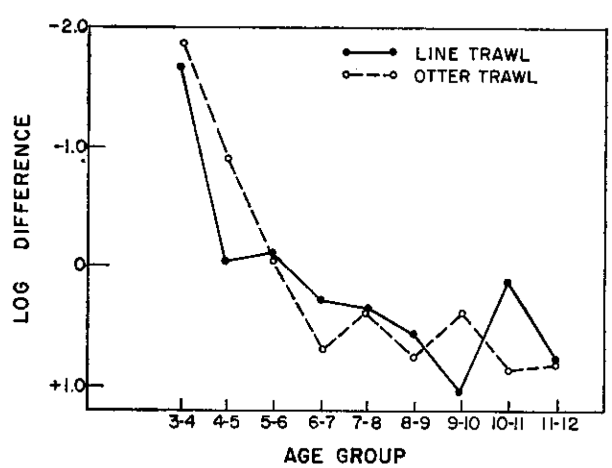

Fig. 14. Estimates of instantaneous total mortality (log difference) between successive ages of haddock in longline and otter-trawl landings.

Although the data are somewhat variable for firm conclusions, the overall picture is what we might expect with a more gradual recruitment to hook and line gear producing a lower fishing mortality among the younger age groups. A total instantaneous mortality rate, Z, of about 0.7 for ages 8 onwards for the whole haddock stock of southern Nova Scotia is considered a reasonable estimate, while the overall rate would decrease in age groups 6 and 7 in proportion to the amount of hook and line catch. Below age 6, the fishing mortality is drastically reduced because of incomplete recruitment to both kinds of gear.

Sampling Area 41, (Bay of Fundy)

The fishery within this area is carried on primarily by Canadian small and medium otter trawlers in the second and third quarters (Table 16). The smaller U.S. otter-trawl fishery is carried on in the third and fourth quarters. The longline fishery accounted for 47 percent of the landings in 1956, but this share of the landings had dropped to 25 percent in 1957, and to 10 percent by 1961.

No otoliths were collected in 1956, thus analysis of that year's landings is not possible. Length and age samples are available only for Canadian otter-trawl landings in the second quarter of the four years, 1958-1961 (Table 16), and it has been necessary to prorate the U.S. landings in the second quarter by the Canadian length-frequency data. Comparison of the length frequencies of haddock in landings of the two countries for the third quarter indicate that Canadian landings are composed of smaller fish (Fig. 15). This probably applies to all seasons. However, because of the small amount of U.S. landings in the second quarter (1.5 percent on the average), the bias introduced by the proration is negligible. Both U.S. and Canadian length-samples are available for the third quarter of 1957-59, and 1961; and for the fourth quarter

TABLE 16. Landings of haddock (gutted weight, lb. x 10^{-3}) and numbers of fish measured and aged for otter-trawl fishery, Sampling Area 41, Division 4X.

		Landings			Measured		Aged
Year	Qtr.	CAN.	U.S.	Total	CAN.	U.S.	
1956	1	81	—	81	—	—	—
	2	1542	49	1590	—	—	—
	3	1556	908	2464	—	1501	—
	4	443	457	900	—	280	—
1957	1	78	—	78	—	—	—
	2	1604	20	1624	—	63	—
	3	2614	442	3056	200	445	142
	4	783	395	1178	—	150	—
1958	1	144	—	144	202	—	40
	2	2310	34	2343	3815	—	445
	3	3003	592	3595	2753	434	233
	4	497	164	661	—	159	34
1959	1	222	—	222	—	—	—
	2	2320	30	2350	2060	—	166
	3	3233	855	4088	2100	647	372
	4	417	244	661	173	522	35
1960	1	338	—	338	—	—	—
	2	2287	29	2316	1800	—	267
	3	3036	636	3672	—	267	—
	4	470	302	772	3000	194	472
1961	1	181	—	181	—	—	—
	2	2116	26	2142	2500	—	268
	3	3890	683	4572	567	433	194
	4	833	18	851	150	—	30

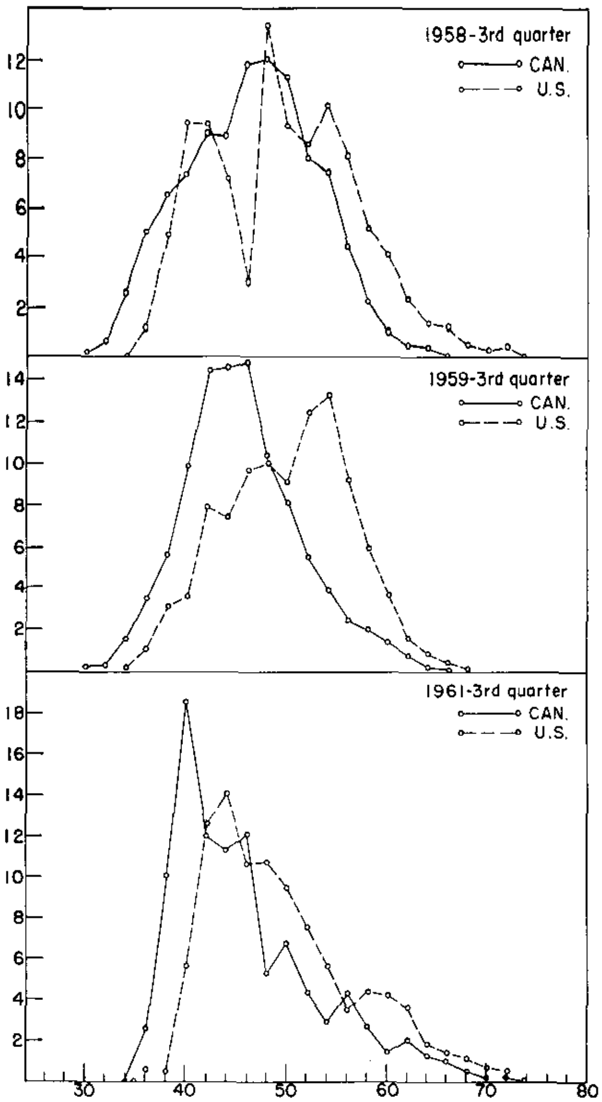

Fig. 15. Comparison of length frequencies of haddock in Canadian and U.S. landings from Sampling Area 41, Division 4X.

of 1960. Biostatistics of the landings of each country were computed in the standard manner for these quarters, and pooled to form total figures for analysis.

Data on length and age frequency of longline landings were not obtained. Therefore, it is not possible to estimate length and age composition of these landings.

1. Average length and weight

The mean lengths and weights of each age group are presented in Table 17 and Fig. 16. The means for the third and fourth quarters of each year were obtained by weighting the estimates of mean length and weight at age in landings of each country by the estimated numbers and weights landed, respectively, in each country. Annual estimates are simple arithmetic averages. Vertical bars in Fig. 16 represent the range of quarterly estimates.

The lengths and weights of the 2- and, to a lesser extent, 3-year-old age groups are biased upward because of incomplete recruitment. Length and weight at age seems fairly consistent throughout the study period, and the apparent growth rate fairly rapid. Asymptotic maximums appear to be about 70 cm or 6 pounds (2.7 kg).

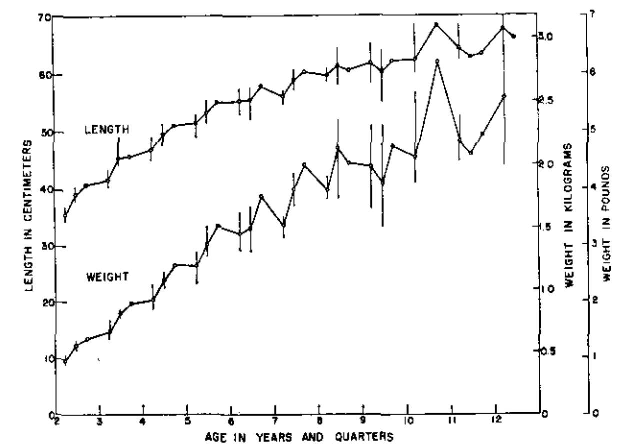

Fig. 16. Mean length and weight (gutted) of haddock in landings of otter trawls fishing in Sampling Area 41, Division 4X.

2. Index of relative abundance

Estimates of relative abundance for the second quarter were based on Canadian log-book records of small otter trawlers. These logs give the number of hours the trawl net was fishing, and the corresponding catch. From these data an estimated apparent abundance index in terms of catch-per-hour of fishing was obtained. The total effort was estimated by dividing the total landings (including those of longlines) by the above index (Table 18).

A similar procedure was used for the third and fourth quarter indices. The data employed were from interview records of medium-sized otter trawlers landing in the U.S. and the index is in terms of landings-per-day fished. These estimates are also found in Table 18.

The two sets of indices are not directly comparable, because of the different effort units and vessel class.

TABLE 17. Average length (cm) and weight (lb., gutted) of haddock age groups in otter-trawl landings, Sampling Area 41, Division 4X. Average weights in parentheses are in kilograms.

		Age Group											
Year	Qtr.	2	3	4	5	6	7	8	9	10	11	12	Grand Mean
							Length						
1957	3	40.3	49.2	51.5	53.3	57.7	—	58.5	64.1	58.5	—	60.5	49.79
1958	2	36.8	41.7	49.1	52.6	56.3	57.3	59.0	65.1	60.5	62.5	—	45.65
1958	3	37.9	44.4	50.1	51.8	55.4	—	64.5	55.0	—	—	—	47.22
1959	2	34.5	40.6	45.4	49.3	53.4	55.1	59.7	58.5	68.5	68.5	64.5	44.40
1959	3	38.7	44.6	47.8	53.1	52.3	57.5	58.5	58.5	—	—	72.5	46.76
1960	2	—	43.6	47.1	53.0	57.8	57.0	61.2	63.2	61.0	64.0	62.5	50.43
1960	4	40.8	45.9	51.1	55.2	58.1	60.5	60.3	62.2	68.4	63.1	—	50.69
1961	2	35.9	40.8	45.4	50.6	53.8	55.3	59.8	61.1	60.5	66.0	72.5	44.84
1961	3	40.4	44.2	49.0	55.5	57.7	60.9	64.3	63.9	—	62.5	—	46.88
Avg	2	35.7	41.7	46.8	51.4	55.3	56.2	59.9	62.0	62.6	64.2	67.5	
Avg	3	39.3	45.6	49.6	53.4	55.8	59.2	61.4	60.3	—	62.8	66.5	
							Weight						
1958	2	1.05	1.49	2.32	2.83	3.43	3.52	3.83	5.10	4.11	4.49	—	1.98 (0.90)
1958	3	1.17	1.81	2.57	2.81	3.39	—	5.05	3.35	—	—	—	2.25 (1.02)
1959	2	0.87	1.38	1.88	2.36	2.92	3.18	3.85	3.65	5.70	4.80	—	1.83 (0.83)
1959	3	1.24	1.85	2.26	3.02	2.88	3.72	3.93	3.87	—	—	—	2.18 (0.99)
1960	2	—	1.68	2.09	2.88	3.61	3.50	4.23	4.54	4.33	4.78	4.40	2.60 (1.18)
1960	4	1.37	1.99	2.72	3.37	3.90	4.46	4.43	4.78	6.25	4.91	—	2.94 (1.33)
1961	2	0.99	1.40	1.87	2.56	3.00	3.24	4.03	4.28	4.10	5.26	6.80	1.89 (0.86)
1961	3	1.36	1.77	2.39	3.37	3.73	4.29	5.20	5.11	—	4.60	—	2.21 (1.00)
Avg	2	0.97	1.49	2.04	2.66	3.24	3.37	3.98	4.39	4.56	4.83	5.60	
		(0.44)	(0.67)	(0.93)	(1.21)	(1.47)	(1.53)	(1.80)	(1.99)	(2.07)	(2.19)		
Avg	3	1.26	1.81	2.40	3.06	3.33	4.00	4.72	4.10	—	4.60	—	
		(0.57)	(0.82)	(1.09)	(1.39)	(1.51)	(1.81)	(2.14)	(1.86)		(2.09)		

Fishing effort, landings, and apparent abundance have remained fairly steady throughout the period. Although we have no measure of the reliability of these estimates, the amount of data upon which they are based is small and therefore the variability may be large.

3. Relative abundance of age groups

The estimated numbers of each age group landed in each quarter were divided by the corresponding total effort to estimate the relative abundance of age groups in terms of numbers-per-day or hour of fishing. The two sets of these data are presented in Table 19. Because the abundance indices are not comparable, the second quarter estimates must be treated independently of those of the third and fourth quarters.

Examination of abundance of 3-year-old age groups in the third quarter (Fig. 17) reveals comparatively strong 1954, 1956, and 1958 year classes, the latter being the largest of those included in the data. The 1952 year class also appears strong, although only the remnants from age 5 onwards are observable in the years under study. The 1959 year class, just entering the fishery as 2-year-olds in 1961, is larger at this age than any in previous years. Fluctuations in relative abundance of year classes are dampened in the older age groups.

Abundance data for the second quarter follow similar trends, but reflect less variability among year classes.

Plots of natural logarithms of abundance against age for various year classes in the second quarter (Fig. 18), and in the third and fourth quarters (Fig. 19) indicate maximum abundance occurs at age 3 in all cases except for year class 1957 in the fourth quarter. There is no observable departure from linearity in either of the catch curves beyond age 3; in fact, they are remarkably straight. Also, with proper adjustment of abundance magnitude, the two sets of curves are nearly coincident. We shall assume, therefore, that haddock are fully recruited to the otter trawl fishery by age 3. Considering the many possible sources of variation in the estimation of abundance, the catch curves of the various year classes reflect a marked degree of homogeneity. This homogeneity provides a measure of confidence in the final results.

TABLE 18. Estimation of apparent abundance of haddock and total effort in otter-trawl-days or hours for Sampling Area 41, Division 4X.

Year	Qtr.	Interviewed Fleet: Landings (lb. x 10^{-3})	Interviewed Fleet: Days or hours[1]	Interviewed Fleet: Landings/day or hour (lb. x 10^{-3})	Total landings OT plus LT (lb. x 10^{-3})	Total effort (days or hours x 10^{-2})
1957	1	—	—	—	—	—
	2	—	—	—	—	—
	3	240.0	35.0	6.8	3413	502
	4	—	—	—	—	—
1958	1	—	—	—	—	—
	2	28.5	173.0	0.17	3147	185
	3	445.3	80.6	5.5	4228	769
	4	—	—	—	—	—
1959	1	—	—	—	—	—
	2	38.9	207.0	0.19	2803	148
	3	560.6	93.9	6.0	4567	761
1960	1	—	—	—	—	—
	2	61.1	307.0	0.20	2668	133
	3	379.1	59.5	6.4	4024	629
	4	180.4	33.9	5.3	983	185
1961	1	—	—	—	—	—
	2	33.6	357.0	0.10	2419	242
	3	209.0	29.9	7.0	4831	690
	4	—	—	—	—	—

[1])U.S. med. OT's for Qtr. 3 and 4 - days
Can. small OT's for Qtr. 2 - hours

TABLE 19. Numbers of haddock landed per day or hour fished by otter trawlers for various years and quarters, Sampling Area 41, Division 4X.

Year	Qtr.	2	3	4	5	6	7	8	9+	Totals of Age groups	Totals of Length groups
		Numbers per day fished at age									
1957	3	264	1139	472	408	47	—	12	34	2376	2382
1958	3	258	741	630	237	148	—	5	32	2051	2090
1959	3	264	1041	671	318	87	60	26	8	2453	2477
1960	4	382	416	349	164	151	36	59	38	1596	1617
1961	3	550	1412	559	194	112	41	50	85	3003	3019
		Numbers per hour fished at age									
1958	2	2.5	33.4	17.2	5.0	3.8	0.6	0.6	0.5	63.6	64.0
1959	2	0.6	37.8	29.8	7.0	2.6	4.5	0.4	1.0	83.8	86.6
1960	2	0	16.0	21.3	14.0	4.6	1.3	5.3	3.2	66.5	67.0
1961	2	0.9	22.5	11.0	5.9	3.2	1.4	0.9	0.8	45.9	46.8

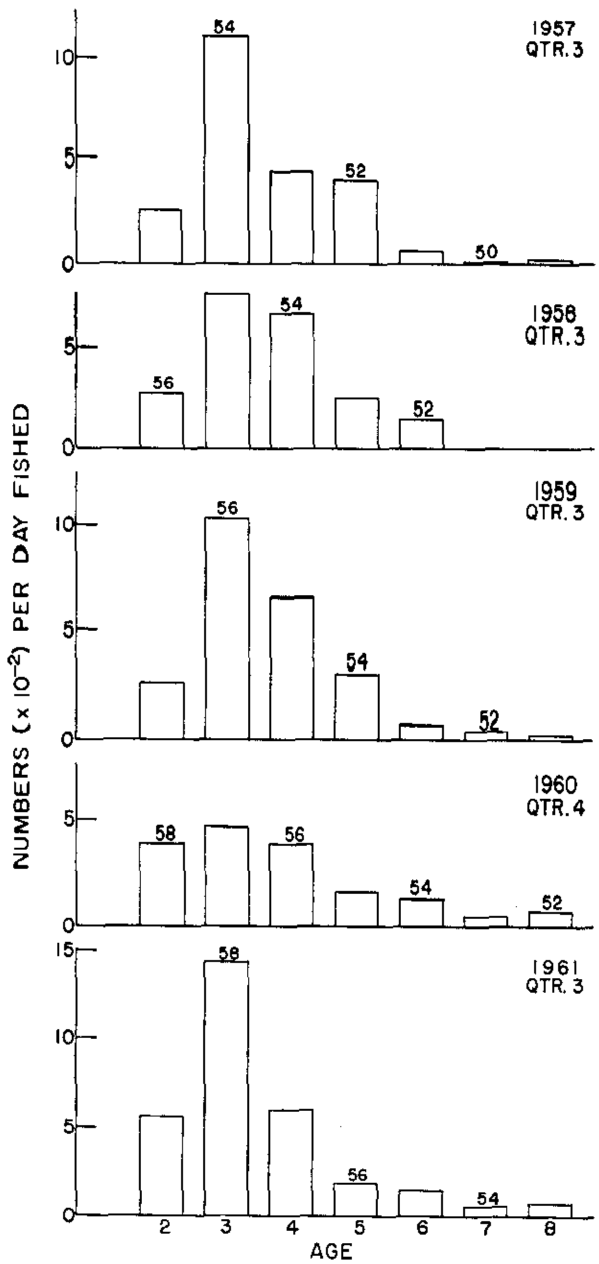

Fig. 17. Relative abundance of age groups of haddock in otter-trawl landings from Sampling Area 41, Division 4X. Numbers above bars denote year classes.

The average percentage age composition for both seasons is presented below:

Age	2	3	4	5	6	7	8	9+
Qtr. 2	2	42	30	13	5	3	3	2
Qtr. 3	15	41	23	12	5	1	1	2

The greater proportion of 2-year-olds in third quarter landings probably reflects recruitment to the fishery at this time. There are few fish over 6 years of age in the landings.

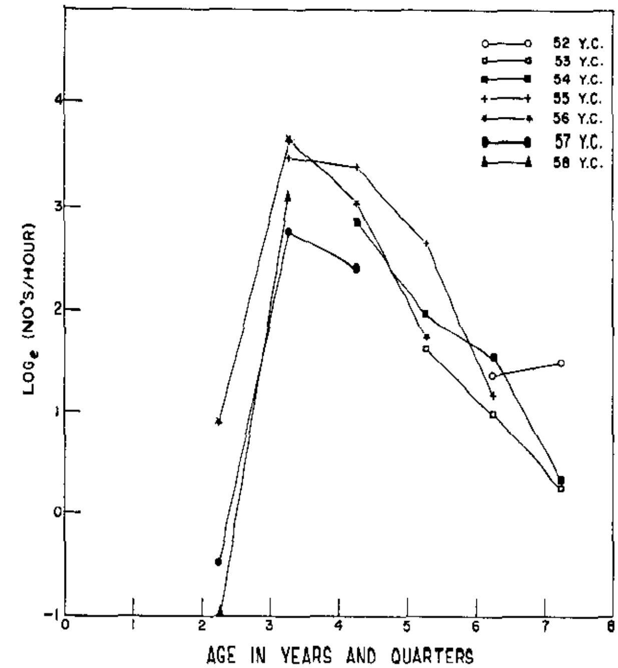

Fig. 18. Logarithms of abundance of haddock on age for otter-trawl landings from Sampling Area 41 in the second quarter.

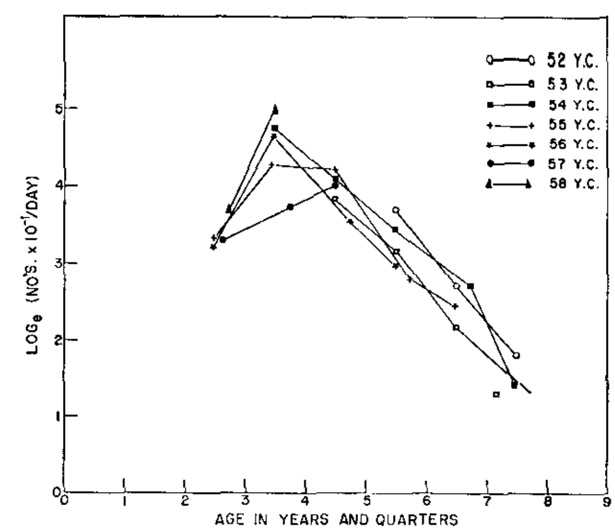

Fig. 19. Logarithms of abundance of haddock on age for otter-trawl landings from Sampling Area 41 in the third and fourth quarters.

4. Estimated survival rate

Survival rates were estimated from both sets of data as outlined in previous sections (Table 20). The estimates of average total annual survival rate were based on age groups 3 through 7, except for the period 1960, fourth quarter, to 1961, third quarter, where age groups 4 through 7 were used.

Estimates of abundance were not determined for quarter three in 1960, but those for quarter

TABLE 20. Estimated annual survival rate and corresponding instantaneous mortality rate, Z, Sampling Area 41.

Year (Qtr.)	Age Group 2-3	3-4	4-5	5-6	6-7	Avg Age groups 3-7	Z
1957(3rd.)-1958(3rd.)	2.81	0.55	0.50	0.36	—	0.50	
1958(3rd.)-1959(3rd.)	4.03	0.90	0.50	0.37	0.40	0.65	
1959(3rd.)-1960(4th.): 5/4 year	1.58	0.34	0.24	0.47	0.41	0.33	
Convt'd to annual rate		(0.42)	(0.32)	(0.55)	(0.50)	(0.41)	
1960(4th.)-1961(3rd.): 3/4 year	3.70	1.34	0.56	0.68	0.27	0.52*	
Convt'd to annual rate			(0.49)	(0.62)	(0.19)	(0.44)	
					Arith. Avg	0.50	0.69
1958-1959 (2nd.)	15.1	0.89	0.41	0.52	1.18	0.74	
1959-1960 (2nd.)	26.7	0.56	0.47	0.66	0.50	0.53	
1960-1961 (2nd.)	—	0.69	0.28	0.23	0.30	0.38	
					Pooled Avg	0.55	
					Arith. Avg	0.55	0.60

*Ages 4-7 only

four were used to provide continuity in the survival estimates. The survival ratios for the period from third quarter, 1959 to fourth quarter, 1960 represent therefore, 5/4 of a year, and the ratios were converted to the corresponding annual rates. Similar adjustments were made in the 1960-61 period, which represented 3/4 of a year, to indicate annual rates.

The average annual survival rate, estimated from data of the third and fourth quarters, was 0.50, corresponding to an instantaneous total mortality rate, Z, of 0.69; the survival and mortality rate estimates for quarter two are very similar, 0.55 and 0.60, respectively. The somewhat higher estimate of survival of the period 1958-59 in both seasons results almost entirely from the apparently higher survival rate of the 1955 year class from age 2 to 3 (0.90 and 0.89). This could be due to a number of causes, e.g., less complete recruitment of 3-year-olds in 1958, inaccurate estimates of abundance index or numbers landed, or erroneous age assessment, but the data do not allow us to distinguish among them.

5. Comparisons between Subareas R and S, Sampling Area 41

For landings of haddock caught by hook and line, Needler (1930) reported similar length compositions, but greater average length-at-age off Campobello (Subarea S) than off Digby (Subarea R). To examine this aspect with current data, we have computed length and age frequencies, and mean age per 2 - cm length intervals for three periods in which sample data were available from both sides of the Bay of Fundy (Subareas R and S).

Most samples from Subarea S, the inland side of the Bay, came from around Grand Manan Island, where much of the fishing occurs. Those from Subarea R, the Nova Scotian side, were mainly from off Digby Neck and St. Mary Bay (Fig. 1). All samples are from otter-trawl landings.

The length and age frequencies of landings (Fig. 20), illustrate a marked difference between the two subareas, with R having the greater proportion of smaller and younger haddock. However, estimates of mean age-per-length interval (Table 21) were nearly the same for both subareas, at least for lengths well represented in landings (up to 60 cm). It appears from our data that the growth rate is similar in the two subareas. That smaller, younger fish are landed from the Nova Scotia side of the Bay of Fundy (Subarea R) than from the New Brunswick side (Subarea S) may be related both to differential distribution of stock and to differences in marketability. Our data do not provide a basis for separation of these two factors.

Comparison of Growth, Length, and Age Composition Among Areas

It is of interest to compare the length and age characteristics of haddock landings between the Bay of Fundy and southern Nova Scotia (Sampling Areas 41 and 42 respectively), and among these and adjacent fishing areas of Division 4V-W to the north, and Divisions 5Z and 5Y to the south (see Fig. 1).

Quarterly estimates of mean length at age in landings of the three components of the 4X

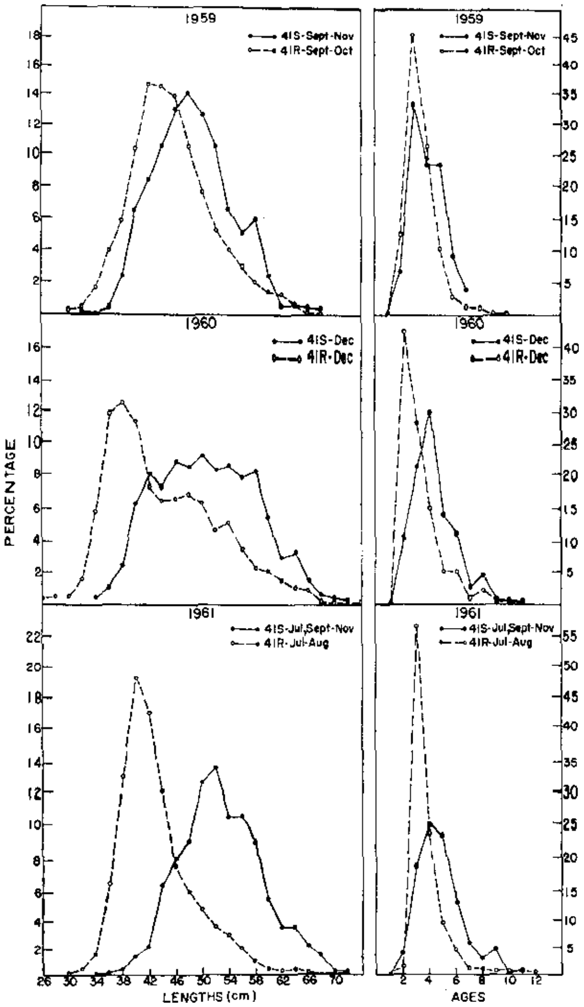

Fig. 20. Comparison of length and age frequency composition of landings from Subareas R and S, Sampling Area 41.

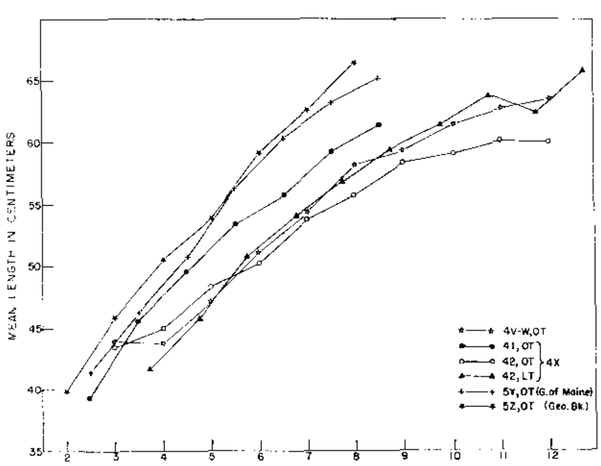

Fig. 21. Comparison of average length-age curves of haddock in landings from various fishing areas.

haddock fishery, which have been obtained in this study, and similar estimates from the otter-trawl landings from Georges Bank (Division 5Z), the Gulf of Maine (Division 5Y), and central Nova Scotia Banks region (Divisions 4V and 4W), have been plotted in Fig. 21. Scales rather than otoliths were used for age assessments in Divisions 5Y and 5Z, but the two methods have been shown to yield similar results for haddock of 5Z up to age 7 (Kohler and Clark, 1958). Furthermore, Jensen and Wise (1962) have presented evidence of the validity of scale age assessments for younger haddock from Georges Bank (Division 5Z). Consequently comparisons among the Divisions are valid at least for younger age groups making up the bulk of the haddock landings. In general, mean length at age is greatest for Georges Bank and Gulf of Maine, intermediate for the Bay of Fundy, and lowest for southern and central Nova Scotia. Mean length at age for haddock in otter trawl landings from central Nova Scotia, and in longline landings from southern Nova Scotia are very similar, but somewhat greater than those for otter trawl landings from southern Nova Scotia, particularly at older ages. The interarea comparisons above yield quite different results than those presented by Needler (1930), who reported similar growth rates for Georges Bank, Digby (Subarea R), Lockeport, and central and eastern Nova Scotia, the highest growth rate for Campobello Is. (Subarea S), and the lowest for Brown's Bank. These discrepancies might be related to differences in sampling and analysis. In particular it should be noted that Needler used scales for all areas and, as noted by Kohler and Clark (1958), haddock scales probably have a tendency to overestimate growth somewhat in southern Nova Scotia waters. In any case the present study is more intensive.

The age frequency curves for otter-trawl landings segregate quite clearly into two groups (Fig. 22). The modal age in landings from Georges Bank (5Z), Gulf of Maine (5Y), and Bay of Fundy (4X, Sampling Area 41) is between 3 and 4 years, with the Bay of Fundy having proportionately more younger fish than the other two. The modal ages for southern (4X, Sampling Area 42), and central (4V-W) Nova Scotia are 6 and 5 years, respectively. Longline landings from southern Nova Scotia have proportionately more older haddock than the others.

The differences in age composition between the Georges Bank-Gulf of Maine and southern-

TABLE 21. Comparison of average age of haddock per length interval in landings from Subareas R and S of Sampling Area 41. Numbers of fish aged are in parentheses.

Length Interval	Sept. - Nov. 1959		Dec. 1960		Jul. - Nov. 1961		Totals	
	41-R	41-S	41-R	41-S	41-R	41-S	41-R	41-S
36	2.4 (10)		2.2 (12)		3.0 (11)	2.0 (6)	2.5 (33)	–
8	2.5 (15)	2.0 (2)	2.3 (18)	2.5 (2)	3.0 (26)	2.0 (6)	2.6 (59)	2.1 (10)
40	2.8 (27)	2.9 (8)	2.1 (27)	2.9 (7)	3.2 (27)	– (11)	2.7 (81)	2.9 (15)
2	3.2 (42)	2.9 (7)	2.7 (18)	2.8 (11)	3.1 (26)	2.3 (8)	3.1 (86)	2.7 (26)
4	3.4 (42)	3.0 (2)	2.7 (16)	3.2 (11)	3.6 (28)	2.7 (12)	3.3 (86)	2.9 (25)
6	3.5 (50)	3.6 (8)	3.3 (22)	3.5 (15)	3.8 (26)	3.2 (13)	3.5 (98)	3.4 (36)
8	3.9 (35)	4.1 (12)	3.5 (22)	4.0 (20)	4.6 (25)	3.1 (13)	4.0 (82)	3.8 (45)
50	3.9 (36)	4.7 (8)	3.5 (33)	4.5 (17)	4.6 (25)	3.8 (19)	3.9 (94)	4.2 (44)
2	4.6 (21)	5.0 (8)	4.3 (26)	4.2 (15)	5.3 (16)	4.5 (13)	4.6 (63)	4.2 (36)
4	4.5 (22)	5.3 (3)	4.3 (20)	4.7 (18)	5.4 (18)	4.4 (16)	4.7 (60)	4.6 (37)
6	4.7 (16)	4.7 (3)	5.3 (15)	5.4 (16)	5.9 (15)	5.1 (12)	5.3 (46)	5.2 (31)
8	6.6 (7)	4.4 (5)	5.0 (11)	5.7 (22)	7.0 (6)	5.1 (14)	6.0 (24)	5.3 (41)
60	6.1 (7)	7.0 (2)	6.4 (8)	7.1 (12)	8.0 (4)	6.4 (9)	6.6 (19)	6.8 (23)
2	6.0 (3)		6.5 (6)	5.5 (11)	7.7 (3)	6.2 (6)	6.7 (12)	5.7 (17)
4			8.0 (5)	7.1 (11)	9.0 (5)	7.3 (8)	8.5 (10)	7.2 (19)
6			8.0 (4)	7.2 (4)	8.5 (2)	7.1 (4)	8.2 (6)	7.1 (8)
8				8.3 (4)	9.0 (1)	8.0 (2)	9.0 (1)	8.2 (6)
70				11.0 (2)		6.0	–	(2)
		Average age for length intervals			40-48 cm		3.32 (433)	3.26 (147)
					50-58 ,,		4.62 (287)	4.68 (189)
					60-68 ,,		7.27 (48)	6.80 (73)

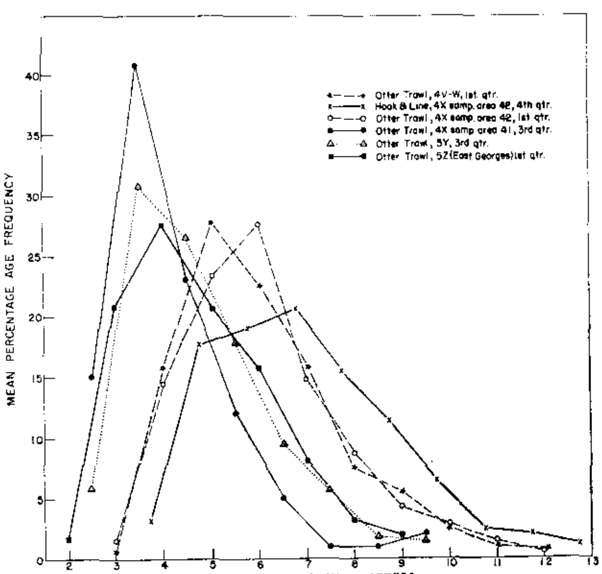

Fig. 22. Age frequencies of haddock in landings from various fishing areas.

central Nova Scotia areas are due mainly to differences in apparent growth rate, because the length compositions are generally similar (Fig. 23). In fact, the higher average age of central Nova Scotia landings occurred in spite of a slightly larger proportion of small fish in the landings. Landings from the Bay of Fundy have the youngest age composition, despite intermediate growth rate, because of the substantially greater proportion of small fish in the landings. The greater proportion of large fish in hook and line landings from southern Nova Scotia is also evident.

While these data on landings are subject to fishing selectivities, the magnitude of differences among some areas is sufficiently large to indicate real differences in the underlying populations. Therefore it seems desirable for some management purposes, to consider haddock in Divisions 5Z, 5Y, and Sampling Area 41 of 4X as a unit stock. The same concept might be applicable to haddock of Sampling Area 42 of 4X, and Division 4V-W.

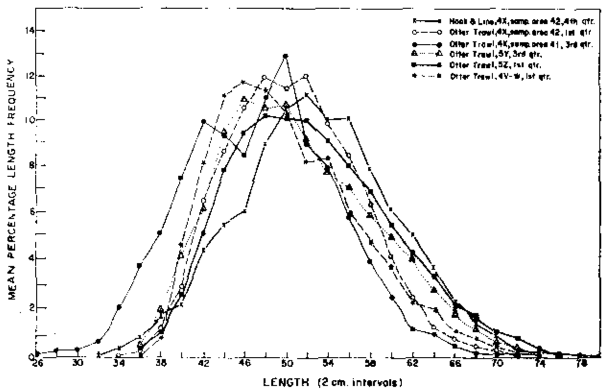

Fig. 23. Length frequencies of haddock in landings from various fishing areas.

In spite of the differences in age and length frequency of haddock landings between fishing areas, similarity in the relative abundance of some year classes suggests that annual brood strength may be controlled by factors common to the entire region. For comparisons among areas, year classes were ranked according to abundance indices of the three most abundant ages (ages 3-5 for 5Z and 4X, Sampling Area 41; and ages 5-7 for 4X Sampling Area 42). A mean rank was computed for each year class. The rankings are presented below.

Of the four year classes (1952-1955) which are represented in all of the areas, the 1952 year class is consistently of highest rank, and the 1954 year class consistently of second highest rank; the 1955 year class was ranked third in three of the areas and fourth in one area. In otter-trawl landings from 5Z and 4X (Sampling Area 41) the 1956 year class appeared weak, but in otter-trawl landings from Sampling Area 42 of Division 4X the 1956 year class at age 5 appears to be on a par with the 1952 and 1954 year classes.

An analysis of year-class strengths in landings from central Nova Scotia (Division 4W) has not been completed, but it is obvious that the 1952 year class was relatively strong, and predominant in the fishery for several years (unpublished Canadian data).

	5Z				4X, Area 41				4X, Area 42 OT				4X, Area 42 LT			
	rank at age				rank at age				rank at age				rank at age			
Year Class	3	4	5	mean rank	3	4	5	mean rank	5	6	7	mean rank	5	6	7	mean rank
1949											6	6.0			4	4.0
1950										5	3	4.0		4	3	3.5
1951			3	3.0					3	1	1	1.7	1	1	2	1.3
1952		6	6	6.0			5	5.0	6	6	5	5.7	5	5	5	5.0
1953	1	3	5	3.0		2	3	2.5	1.5	2	2	1.8	2	2	1	1.7
1954	5	5	4	4.7	4	4	4	4.0	4	4	4	4.0	4	3		3.5
1955	3	2	2	2.3	2	5	1	2.7	1.5	3		2.2	3			3.0
1956	2	4	1	2.3	3	1	2	2.0	5			5.0				
1957	4	1		2.5	1	3		2.0								
1958	6			6.0	5			5.0								

Summary

In 1956, Canadian and United States scientists initiated a cooperative study of the haddock fishery in Division 4X of ICNAF convention waters. This paper presents estimates of mean length and weight at age, abundance of year classes, and total mortality obtained from analysis of data on landings, fishing effort, and samples of length frequencies and otoliths from haddock in landings for the period 1956-61.

Annual landings varied between 28 and 40 million pounds during the period. The major share of the landings, on the average 17 million pounds per year (8 thousand metric tons) or 51 percent, was taken by otter trawlers fishing off southern Nova Scotia, primarily on Browns Bank in the first half of the year. The otter trawl fishery within the Bay of Fundy took place during the latter half of the year, and produced an average of 8 million pounds (4 thousand metric tons)

annually, or 21 percent of the total. Fishing effort and landings by longliners, which fish mostly off southern Nova Scotia, declined steadily through the period, accounting for about 8 million pounds (4 thousand metric tons) annually, or 28 percent of the average total annual landings.

The 6 year old fish contributed the maximum numbers of haddock to otter-trawl landings from southern Nova Scotia, and had attained an average length of 50 cm and weight of 2.5 pounds (1.1 kg) at this age. At age 10 the fish average 60 cm or 4 pounds (1.8 kg). Less than 3 percent of the fish in the landings were older than 10 years. Longline landings contained proportionately more larger and older fish than did the otter trawl landings. This is due to the different size selectivities of the two kinds of gear. The average annual survival rate of the southern Nova Scotia stocks was estimated to be 48 percent, which is equivalent to a total annual instantaneous mortality rate of about 0.7.

In landings from the Bay of Fundy area, the age of maximum frequency was 3 years, at which time the fish averaged 46 cm or 1.8 pounds (0.8 kg). There were very few fish over age 6 in the landings, at which age they averaged 56 cm or 3.3 pounds (1.5 kg). The average survival rate was estimated to be 50 percent, corresponding to an instaneous mortality rate of about 0.7.

Thus, there was found to be a striking contrast between length at age and age composition of haddock in landings from the Bay of Fundy and southern Nova Scotia fishery grounds, the former area having much faster growing and younger fish. Making the reasonable assumption that fish in the landings are representative of the stocks beyond the age of full recruitment, the data provides evidence of autonomy of adult populations in the two areas.

Apparent growth rate and age composition of haddock in landings were compared among Division 4X, Division 5Z (Georges Bank) to the South, and Division 4V and 4W to the North. The age structure of stocks in the Bay of Fundy area was very similar to that of 5Z, although the growth rate in 5Z was somewhat greater. Growth rate and age composition in Division 4V-W was quite similar to that of the southern Nova Scotia area.

In spite of the observed differences in growth and age compositions, the relative abundance of year classes was found to be quite similar in all Divisions, indicating that perhaps some general, common condition controls success of year classes, or that the stocks of the various divisions are mixing at the egg, larval or pre-recruit stages. The 1952 year class was the most abundant of those included in the data.

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Discrepancies Between Auto-Lab and N.I.O. Salinometers

BY R. A. COX[1] AND A. R. FOLKARD

Abstract

The recent NORWESTLANT surveys of the International Commission for the Northwest Atlantic Fisheries have revealed certain small but appreciable differences in salinities determined on the same water with Australian (Auto-Lab) and British (N.I.O.) salinity meters. The discrepancies reach a maximum at salinities below 33‰, and at 30‰ are about 0.02‰ The reasons for these discrepancies are analysed; it is shown that the two instruments give almost identical conductivity readings, and that the differences lie in the tables used to convert the readings to salinity. A correction table is given which when applied to the salinity results will make them comparable. It is shown that both meters give results closely approximating to the true salinity, as at present defined. The N.I.O. instrument is fractionally more accurate above 35‰, and the Auto-Lab meter is better below 34‰.

Various types of conductivity salinometer are currently in use for routine determinations of salinity. The methods of calibration of the various types of instrument are quite different, and it is not surprising that at times they fail to give concordant readings. All these instruments use Copenhagen Standard Sea Water (with a salinity of almost exactly 35‰) as reference standard. Thus it is only when samples differ considerably from this salinity that errors of calibration can become serious. The differences are most likely to be large when measuring salinities above 37‰ or below 33‰.

Fortunately, it is only when investigating large water masses with relatively uniform properties that very small variations in salinity, less than 0.01‰, have any significance. Almost all such water masses have salinities within the range 33.5‰ - 35.5‰, so the errors due to salinometer calibrations are minimised, and can usually be neglected. There are a few exceptions to this rule. Certainly the most important is the Mediterranean Sea, where two large, exceptionally homogeneous water masses exist with salinities of 38.4‰ and 38.7‰. Other areas are the Black Sea, the Red Sea, and certain polar regions.

The problem of calibration is complicated by the variations in chemical composition of the sea water, which affect the relationship between chlorinity and conductivity. This means that it is not possible to convert conductivity into chlorinity within the precision of measurement of either parameter (Cox, Culkin, Greenhalgh and Riley, 1962). To overcome this difficulty, and facilitate the precise comparison between salinometers, it is proposed to abandon the current use of the expression

$$S‰ = 1.805\ Cl‰ + 0.03$$

proposed by Forch, Knudsen and Sorensen (1902) which has been generally interpreted as defining salinity. An international committee has recommended that salinity instead shall be defined as a function of density (sigma-O) which is very closely related to conductivity (UNESCO, 1962). This recommendation was endorsed by the International Association of Physical Oceanography at their meeting held at Berkeley, Calif. in August 1963, and will be implemented as soon as the necessary tables are available. This it is hoped will be during 1964. It will then be quite a simple matter to put salinometer calibrations on a more fundamental basis; those instruments (the majority) which give the answer as a ratio of the conductivity of the unknown to that of standard sea water will be particularly simple. The new oceanographic tables will include conversion tables appropriate to all such salinometers, based on the new definition of salinity and measurements of conductivity and density of natural sea water samples. These measurements are under way at the National Institute of Oceanography (N.I.O.). Thus providing only that the various instruments give true conductivity ratios the results will be directly comparable.

Since this general solution to the problems will shortly be available, there is little point in attempting to "correct" individual salinometer tables at the moment. Such tables certainly do not entirely agree, but it is impossible to say

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which is correct and which is not. However, this paper is concerned with a particular example of disagreement between salinometers revealed during the NORWESTLANT surveys around Greenland during 1963. We have included below a "correction" table which will enable results taken on N.I.O. thermostat salinity meters and on Auto-Lab Industries salinometers to be made directly comparable. This will allow the data collected during these surveys to be processed. We do *not* make any claim that the results so modified are necessarily more nearly correct, neither do we suggest that at the moment other users of these instruments should apply these "corrections" unless they wish to make direct comparison between highly precise salinities taken on both types. We think it highly desirable that oceanographers should wait until the new tables are available next year before any general re-calibration is made, otherwise much confusion will be added to an already difficult situation.

During the NORWESTLANT surveys all ships taking part used salinometers; some were N.I.O. salinometers and others the Auto-Lab instrument. All participants were issued with a low-salinity sub-standard to check their instruments in the region of 30‰. This sub-standard (known as EQUALANT A[1]) was kindly provided by the co-ordinator of the International Co-operative Investigations in the Tropical Atlantic; it was originally prepared as a check on salinometers used in the recent EQUALANT I and II surveys. The salinity of this standard, as determined by chlorinity titration and on the various salinometers, is shown in Table 1.

TABLE 1. Salinity values given by various instruments for EQUALANT sub-standard sea waters

Method	Standard A	Salinity found for Standard A[1]	Standard B
Chlorinity titration	29.947	29.430	37.088
NIO salinometer	29.936	29.426	37.084
MAFF salinometer		29.426	
Auto-Lab salinometer		29.447	
Hytech salinometer (USNOO)	29.950	29.437	37.082
Hytech salinometer (USS Explorer)	29.937		37.051

It is clear from Table 1 that there are discrepancies in the values given by the various instruments for the low salinity sub-standards. To resolve these discrepancies we have made certain comparative trials of the two types. A series of samples of salinity ranging from 29.4‰ to 40.5‰ was measured on both instruments, and the conductivity ratios converted to "salinity" by the tables used with the two machines. Significant differences were apparent both at high and low salinities, as shown in Table 2; the table omits certain of the highest salinities, which were outside the range of the respective tables.

It will be seen that with the exception of two results, on samples 9 and 15 (which are probably reading errors on one machine or the other), the two sets show a fairly clear pattern. The higher salinity samples agree within 0.01‰, but there is a larger discrepancy below 33.5‰, where the Auto-Lab instrument reads about 0.013‰ higher than the N.I.O. one.

These differences could be due to two causes. Either the instruments could be giving different ratios of conductance, or the two conversion tables could be giving different salinities from the same ratio. Unfortunately it is not possible to compare the two tables directly; the N.I.O. tables are based on the thermostat temperature of 15°C, while the Auto-Lab ones are based on the room temperature of 22.5°C.

Accordingly we applied a temperature adjustment factor to the ratios given by the Auto-Lab salinometer. The factor was based on measurements by Cox (1962). These measurements are in close agreement with those of Hamon (1960) on which the Auto-Lab tables are based. The adjusted value gives us the ratio which the Auto-Lab meter would have given had the room temperature been 15°C, and both the standard water and the samples at this temperature. The conductivity ratios are given in Table 3, and it will be seen that the agreement is very good.

TABLE 2. Difference between duplicate samples measured by N.I.O. salinometer and Auto-Lab salinometer.

Sample No.	N.I.O. Salinometer (A)	Auto-Lab Salinometer (B)	B - A
2	39.960	off scale	
3	39.484	off scale	
4	39.050	39.053	−0.003
5	38.584	38.584	0
6	38.141	38.139	−0.002
7	37.681	37.673	−0.008
8	37.241	37.239	−0.002
9	36.846	36.828	−0.018?
10	36.730	36.722	−0.008
11	36.021	36.021	0
12	35.626	35.626	0
13	35.808	35.802	−0.006
14	34.805	34.803	−0.002
15	34.376	34.397	+0.021?
16	33.972	33.974	+0.002
17	33.560	33.575	+0.015
18	33.171	33.184	+0.013
19	32.764	32.779	+0.015
20	32.395	32.414	+0.019
21	32.022	32.034	+0.012
22	31.670	31.683	+0.013
23	31.337	31.345	+0.008
24	31.008	31.018	+0.010
25	29.423	29.437	+0.014

TABLE 3. Conductivity ratios at 15°C on actual samples.

Salinity (nominal)	N.I.O. (A) (at 15°)	Auto-Lab (B) (corrected to 15°)	Difference A - B	Equivalent salinity difference ‰
40.5	1.13745	1.13756	−011	−003
40.0	1.12586	1.12607	−021	−006
39.5	1.11369	1.11375	−006	−002
39.1	1.10267	1.10265	+002	+001
38.6	1.09082	1.09085	−003	−001
38.2	1.07960	1.07967	−007	−002
37.6	1.06797	1.06793	+004	+001
37.2	1.05687	1.05691	−004	−001
36.8	1.04686	1.04659	+027	+008
36.7	1.04396	1.04389	−007	−002
36.0	1.02599	1.02607	−008	−002
35.6	1.01595	1.01601	−006	−002
35.8	1.02058	1.02051	+007	+002
34.8	0.99507	0.99500	+007	+002
34.4	0.98417	0.98464	−047	−013
34.0	0.97391	0.97380	+011	+004
33.6	0.96340	0.96354	−014	−004
33.2	0.95346	0.95345	+001	−000
32.8	0.94300	0.94304	−004	−001
32.4	0.93346	0.93355	−009	−002
32.0	0.92379	0.92371	+008	+002
31.7	0.91471	0.91460	+011	+003
31.3	0.90604	0.90580	+024	+007
31.0	0.89750	0.89731	+019	+006
29.4	0.85606	0.85596	+010	+003

In only one case does the disagreement represent a difference of as much as 0.01‰, which is quite satisfactory in the circumstances; measuring samples of very widely varying salinities, as here, tends to increase rinsing errors, so the standard deviation of 0.004‰ is acceptable. There appears to be a slight tendency for the N.I.O. meter to give higher ratios than the Auto-Lab at low salinities, and possibly lower ratios at high salinities. These trends could be due to very slight imperfections in one or other of the transformer bridges, or they could be due to minor errors in the temperature correction factor.

Our troubles, then, are not instrumental, but are due to inconsistent tables. Here the "shape" of the discrepancy shows the cause. The Auto-Lab tables are based on a series of measurements of conductivity by Hamon, made on one sample of water, diluted by weight. The N.I.O. tables are in two sections. The lower section is the older, and is based on the conductivity measurements of Thomas, Thompson and Utterback (1934). The values above 35‰, however, were replaced in 1961 by a new table based on more recent measurements, including those of Hamon, so the good agreement here is not coincidence. It seems that the lower N.I.O. table, based on Thomas *et al.*, is wrong.

The final stage in our investigation was to prepare a table of relative conductivities (conductivity ratios) from the N.I.O. measurements of conductivity and chlorinity. These conductivities are in each case an average, based on from five to eighty samples in the respective ranges. The "salinity" here is computed from the chlorinity by the Knudsen relationship. Table 4 shows these average values in the second column; they are certainly very close to the best which can be derived using the present definition of salinity, and will closely approximate to the new tables which will be published next year. They apply to measurements at 15°C.

TABLE 4. Conductivity ratios at 15°C.

Salinity	Correct	N.I.O. tables	Auto-Lab tables
31.5	(not enough	0.91026	0.90986
32.0	results for	0.92322	0.92283
32.5	reliable figure)	0.93616	0.93571
33.0	0.94876	0.94906	0.94869
33.5	0.96160	0.96186	0.96158
34.0	0.97450	0.97460	0.97440
34.5	0.98730	0.98730	0.98723
35.0	1.00012	1.00000	1.00000
35.5	1.01272	1.01275	1.01277
36.0	1.02536	1.02546	1.02551
36.5	1.03806	1.03812	1.03819
37.0	1.05080	1.05076	1.05087
37.5	1.06350	1.06340	1.06351
38.0	1.07615	1.07605	1.07612
38.5	1.08880	1.08870	1.08873
39.0	1.10150	1.10140	1.10129
39.5	1.11422	1.11412	off table
40.0	1.12697	1.12687	off table

It will be seen that at low salinities, from 33.0 to 34.0‰, the ratios in the Auto-Lab tables are slightly low; that is, the tables would give a salinity a little high. The N.I.O. tables err, more considerably, in the other direction. At a salinity of 33‰ the Auto-Lab tables would read 33.002‰ and the N.I.O. 32.992‰. At first sight the "correct" ratio given for 35‰ will appear unlikely; it arises in this way. In the "group" of results from which this value is calculated are many observations on deep samples. Many of these contain rather more calcium than surface samples, so their conductivity is slightly greater, relative to the chlorinity. Thus on average a sea water of chlorinity 19.374‰ shows a slightly higher conductivity than standard sea water, which is surface sea water. At higher salinities both instruments agree very well with the "correct" ratios, the N.I.O. tables being rather nearer.

Finally, Table 5 gives corrections applicable to the observations in the NORWESTLANT surveys. Below 35‰, observations on the N.I.O. salinometers should be increased as shown. Above 35‰, observations on the Auto-Lab instruments should be increased. This will make the two sets comparable and also give a close approximation to the N.I.O. "best values".

TABLE 5. Corrections to salinometer results on NORWESTLANT surveys.

A. Low salinities, below 35°/₀₀

Increase all observations on N.I.O. salinometers as follows:

Salinity	Increase
30.0	0.021
30.5	0.020
31.0	0.019
31.5	0.018
32.0	0.016
32.5	0.014
33.0	0.012
33.5	0.010
34.0	0.008
34.5	0.004
35.0	nil

B. High salinities, above 35°/₀₀

Increase all observations on Auto-Lab salinometers as follows:

Salinity	Increase
35.0	nil
35.5	0.001
36.0	0.002
37.0	0.003
38.0	0.002
39.0	0.002

Addendum

Salinity samples from Russian vessels that participated in NORWESTLANT III were analysed by a salinometer of South African manufacture. This was the I.M.C. Electronic Salinometer manufactured by Jayco Instruments (Pty) Ltd. The calibration of this instrument was based on the formula of Thomas, Thompson and Utterback. Eight analyses of the EQUALANT A[1] sub-standard all gave salinities between 29.422‰ and 29.424‰. These are comparable with those obtained with the N.I.O. salinometer. Salinity data from the I.M.C. instrument during NORWESTLANT III will therefore be corrected in the same way as those from the N.I.O. salinometer.

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Two Mechanical Aids for Otolith Reading

BY B. C. BEDFORD [1]

Abstract

Mechanical devices are described for preparing quickly, an almost standard section of each otolith and for controlling the illumination of the section surface.

Introduction

Two problems confront the otolith reader. The first of these is to view the ring structures satisfactorily, and the second is to interpret what is seen. It is obvious that the first of these considerations may well affect the second.

Most gadoid fish otoliths are too dense and thick to view whole and the most common method used to read them is as follows. A section is made (usually through the plane of least area) and this is viewed by mounting the piece of otolith in plasticine with the section horizontal. The otolith is then illuminated from the side and the sectioned surface placed in shadow. The effect of this is to show on the surface the dense opaque rings as dark areas and the hyaline rings as light areas.

The usual method of producing the section of the otolith is to break it with pressure of the thumbs or with a cutting tool. Where interpretation of the zones is easy the section thus produced is often good enough, provided that the break is reasonably square and through the centre of the otolith. However, many otoliths are more difficult to interpret and a good flat surface is needed on the section to view it satisfactorily.

This note describes two mechanical devices which have been developed at Lowestoft. The first of these enables the reader to prepare quickly an almost standard section of each otolith. The second enables him to control the illumination of the section surface.

Grinding/Polishing Machine (Fig. 1)

This is simply a small fine carborundum wheel fitted to a fairly high-speed motor. Grinding of otoliths has been tried before and rejected because (a) the heat generated damages the otolith, (b) clouds of dust harmful to the operator are produced, and (c) the time taken to get a good surface is too long.

These disadvantages are overcome by fitting a water supply which drips directly on to the point of contact of the otolith on the wheel. Heating is prevented, there is no dust, and a good surface is produced very rapidly. The wheel itself is completely screened from the electrical parts of the machine to prevent danger from water spraying. The shields fitted are very effective and the machine is considered to be completely safe.

The machine is usually positioned with the drip tray overhanging a sink to carry away waste water. If, however, no sink or water supply is available, the drip tray can be used as a reservoir and water from it can be brushed on the wheel while the otolith is being ground.

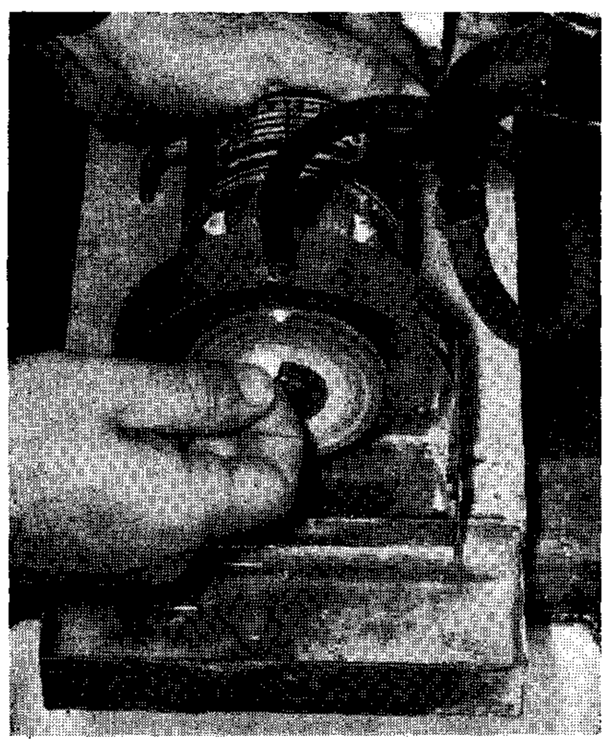

Fig. 1. Grinding machine in use.
N.B. The on-off switch of the machine is controlled by the second finger of the left hand of the operator.

[1]) Fisheries Laboratory, Lowestoft, England.

It is generally agreed that the best position for the section to be made is at the "V" shaped interruption of the *sulcus accusticus*. Using the grinding wheel this can always be achieved. The otolith is broken by pressure of the thumbs and the part containing the "V" shape is selected for grinding. The broken surface is held against the wheel with moderate pressure, care being taken to hold it square to the longitudinal axis of the otolith. Surplus material is removed very rapidly from even the largest otoliths and a flat surface bisecting the "V" is produced in approximately twenty seconds. Some slight striations and a deposit of dust are left on the surface and these can be clarified when the otolith is read, by brushing on a little Xylene.

Details of the Machine

Motor 1/20 H.P. 2,800 R.P.M.: 230/250 v A.C. Single phase.

Wheel 3 inches diam. x $\frac{3}{4}$ inch thick; abrasive texture, fine or very fine. It has been found that the wheels made for grinding valve seatings are ideal. These have a threaded centre which allows it to be screwed on to a brass boss fitted to the spindle of the motor.

Water shields These are made of 18 S.W.G. brass and are of such size that the hoop-shaped guards clear the outside rim of the wheel by one inch.

Assembly The apparatus is mounted on a 12 mm thick bonded plywood baseboard approximately 12 x 8 inches. This is supported by two pieces of wood fixed to the two long edges. These supports are tapered so that the water tray end is lower than the other end. A plywood or rigid plastic cover is fitted to the bottom of the apparatus.

The Microscope Light Screen (Fig. 2)

Not all readers of gadoid fish otoliths use the method of side illumination and resultant transmitted light for viewing the section. The origin of this technique is probably to be found in the early Norwegian work on the otoliths of the cod and in the author's experience the majority of readers do use this method, certainly in Europe.

It is apparent from the many and varied methods used to put the section surface in shadow – pencils, the observer's finger, a match stick mounted in a second piece of plasticine are but a few – that this has always been something of a problem. It may indeed be one of the reasons why the method of direct illumination of the surface has been adopted by some observers.

However, it is the author's opinion that the method of transmitted light is preferable, as it enables the reader to see more of the detailed structure of the otolith. Also, by this method the dense opaque zones are in fact seen as dark zones and the light hayaline zones as light zones, a not unimportant consideration when describing structures, particularly to trainees.

The light screen used at Lowestoft provides the reader with a simple tool that enables him to put the surface into any degree of shadow that he desires. The degree of shadow required may well be different for different parts of the same otolith, and the fact that the bar can easily be moved up and down allows each part of the otolith to be examined under conditions most suitable to itself. Once the state of shadow is fixed the observer can leave the bar and have his hands free to brush on clearing agents, adjust focus and move the stage of the microscope.

The screen is simply an adjustable height bar. A brass base plate supports a vertical pillar in which is housed a captive threaded rod. By turning this thread the bar is raised or lowered to

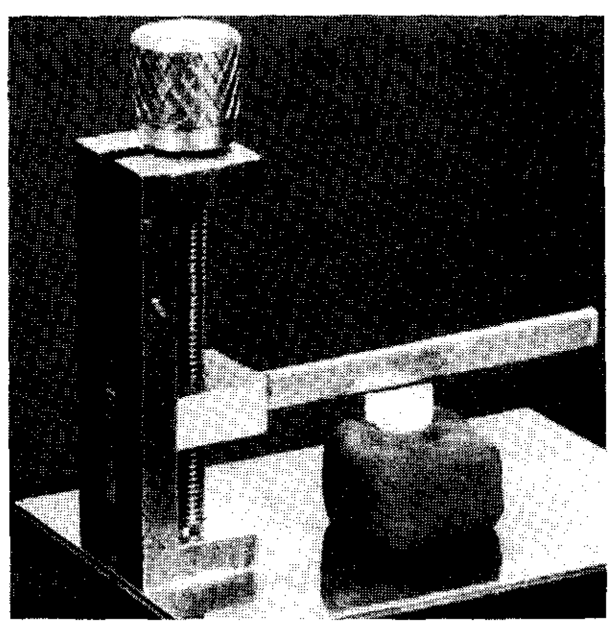

Fig. 2. View of light screen with otolith mounted.

the height required. The vertical pillar is sited in the centre of the shorter side of the base plate so that the screen may be used both right and left handed.

Materials and Dimensions

The base plate is of 16 S.W.G. plate brass, size 3 inches by 2 inches.

The vertical pillar is machined from $\frac{5}{8}$ inch square brass and is 2 inches high.

The bar is $\frac{3}{16}$ inch deep and is soldered to a brass block which has a hole threaded to fit the vertical threaded rod.

The brass block is keyed into a $\frac{1}{8}$ inch slot in the vertical pillar.

A Method of Preparing Photographs and Transparencies of Cod Otoliths

BY J. MESSTORFF [1]

Abstract

A photographic technique of preparing satisfactory black and white transparencies and prints of cod otolith structures, is described and two examples are given. A corresponding set of transparencies have been successfully demonstrated to experts. The results, obtained by this technique, show rather the same pictures of otolith structures as at microscopic viewing under the usual conditions, but have the advantage of enabling several people to examine and discuss the same otolith at the same time.

Introduction

Some sets of transparencies of cod otolith photographs, both black and white prepared by the author and coloured prepared by Blacker (1963), have been demonstrated at the meeting of the ICNAF Working Group on Age Reading Techniques in Bergen in November 1962 as well as at the Annual Meeting of the Research and Statistics Committee of ICNAF in Halifax in May 1963. The great value of this type of photographs for the training of otolith readers, as well as for the discussion of certain otolith structures, was recognised by all participants of these meetings, since it enables a large number of people to examine the same otholith and to discuss the same structure with certainty. Considering these advantages, the Research and Statistics Committee recommended that future co-ordination of age reading techniques take the form of exchange of selected otolith samples, accompanied by corresponding sets of photographs (transparencies and /or prints), to be marked by each country in the way they would read them. Because of the fundamental importance of the reliability of age data, all member countries of ICNAF agreed to participate in this programme, which offers a promising way for the detection and perhaps reduction of persistent discrepancies in age determinations between different readers.

Considering the lack of special information on suitable photographic techniques, the writer was asked to give a description of his method, for obtaining the satisfactory black and white transparencies of cod otolith structures mentioned above.

Materials and Methods

To be useful an otolith transparency should show the same picture by projection, as the same otolith viewed under the usual conditions by transmitted light and by means of a binocular microscope. Therefore the arrangements for taking photographs, as illustrated in Fig. 1, should be nearly the same as for routine age determination.

The otolith to be photographed is mounted in plasticine in the usual manner. For illumina-

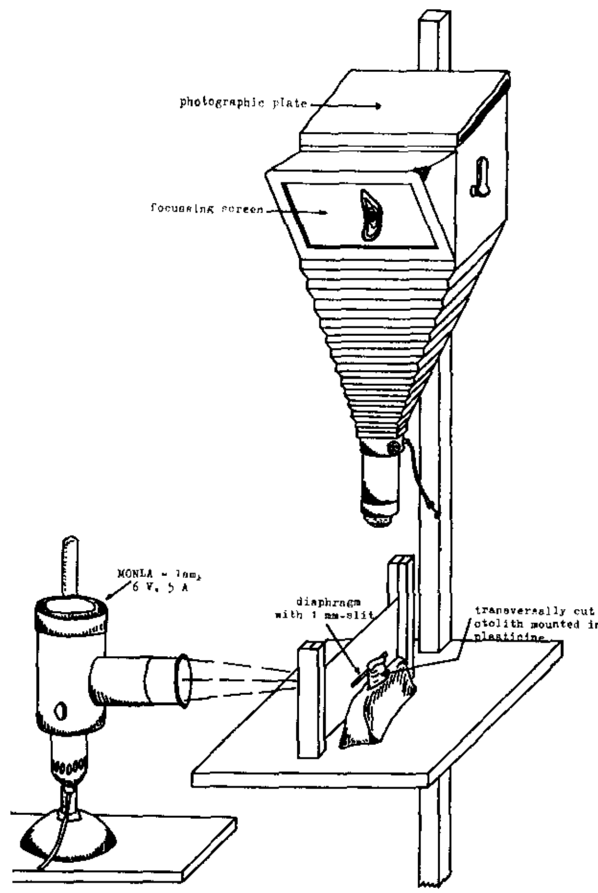

Fig. 1. Sketch of the photographic arrangement. Camera system: Panphot, Leitz.

[1])Institut für Seefischerei, Aussenstelle Bremerhaven, Federal Republic of Germany.

tion the same MONLA-lamp (Leitz, 6 v, 5 amp) as for microscopic viewing is used. To avoid reflected light, which obviously causes more trouble in photography than in microscopic viewing, and also to obtain sharper contrasts between the growth zones, the transversally-cut surface of the otolith[2] is shaded from the laterally-directed light beam by an adjustable horizontal slit-diaphragm situated rather close to the otolith. After focussing, the enlarged and illuminated picture of the otolith surface appears on the ground glass screen of the camera system (Panphoth, Leitz) without any disturbing light effects.

Because of the relatively low light intensity of the photo-object and of the screen picture respectively, the room should be darkened during focussing and exposure. For the same reason the diaphragm of the camera lens must be wide open for focussing, whereas for exposure a smaller aperture is recommendable (about 12 on the scale). The time of exposure was about 10 to 15 seconds. This, however, should be tested because the light source as well as the camera system and the photomaterial used may be different.

For the above technique photographic plates (9 x 12 cm, two exposures each) were used. From these negatives, 1:1 transparencies were made on 24 x 36 mm film. Of course the technique could be improved by avoiding plates and using a 36 mm single reflex camera, fitted with a suitable bellows extension for enlargement, such as described by Blacker (1963), if available. Using reversal film, transparencies could then be produced directly.

Fig. 2. 47 cm male cod from ICNAF Statistical Division, 4 V North, 25 April 1960. Interpretation depends on counting or discounting the two innermost hyaline zones. After own interpretation five years old (as indicated to the right), first hyaline zone discounted as being a checkring.

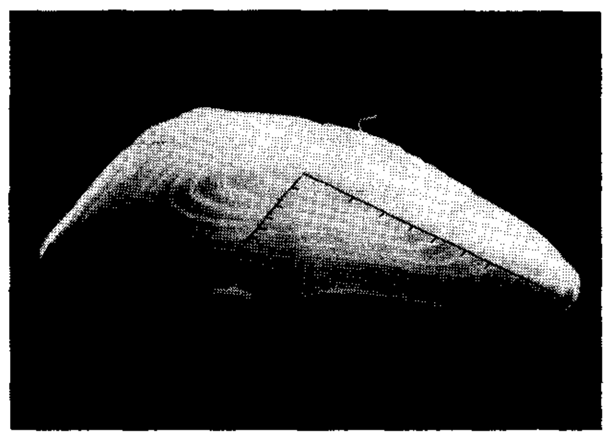

Fig. 3. 72 cm female cod from ICNAF Statistical Division, 4 R, 22 April 1960, ten years old, advanced gonad condition. Fish was going to spawn for the second time. Spawning zones on the otolith indicate first spawning in the year before (1959).

Results

The two prints in Figs. 2 and 3 show that no disturbing light effects appear around the sharp contours of the otolith surface. The photographs are not retouched! The growth structures stand out as clear and contrasting as when viewed through the microscope.[3] The illuminative effect is of course still better and more natural by projection of the corresponding transparencies. Compared with the colour prints submitted by Blacker (1963) the possibility of exact interpretation of these black and white prints is not less satisfactory. The advantage of Blacker's method is perhaps a somewhat quicker and easier production of photographs but black and white photos are less expensive.

The use of electronic flash with black and white film would, it is felt, not give as good results as Blacker obtained using flash with his colour

[2])For ageing German workers routinely cut all cod otoliths transversally by means of a specially designed electric circular saw, a description of which has been submitted by Dr. A. Meyer to the 1964 Annual Meeting of ICNAF and will appear in Research Bulletin No. 2.

[3])This refers to the original photographs. The printed reproductions (Figs. 2 and 3) are less clear.

film. This is because of the very high light intensity produced by the electronic flash. For the same reason it is expected that electronic flash, used with black and white film, would not give as good results as those obtained by using the method described above with black and white film.

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Hydrographic Conditions off the Coasts of Labrador and Newfoundland in November - December 1962

BY J. W. RAMSTER [1]

Abstract

Temperature and salinity conditions in the Seal Islands - Hamilton Inlet Bank and Grand Bank - Flemish Cap areas for the "early winter" period of 1962, are shown by vertical sections. The T-S curves for each station sampled are compared with 13-year mean T-S curves for the Labrador Current, Atlantic Current, and Mixed Water, drawn from observations made around the Grand Bank during the iceberg seasons (April-July) in 1948-60.

Introduction

The Research Vessel *Ernest Holt* of the Fisheries Laboratory, Lowestoft, cruised off the coasts of Labrador and Newfoundland between 22 November and 6 December 1962. As well as making groups of trawl hauls between 52°20′N and 55°30′N, two of the standard hydrographic sections of the Biological Station of the Fisheries Research Board of Canada, St. John's, Newfoundland were worked. The resulting temperature and salinity diagrams provide, as far as can be ascertained, the first description of the water-mass conditions off these coasts during "early winter."

Seal Islands - Hamilton Inlet Bank Section

This section was worked during the period 26-27 November in relatively good weather conditions. Owing to a strong cross-current and poor Loran coverage, however, the line of stations sampled diverged from the standard section of the Biological Station at St. John's as the coast was approached. The temperature and salinity sections based on these data (Fig. 1) show that the water over and adjacent to the main bank had a simple structure, which followed the general lines of the bottom topography, the only unusual feature being a warm pocket situated seaward of the coastal zone and lying between 200 and 300 m depth.

The T-S diagram for each station has been drawn and compared with those, beginning at 50 m, of the Labrador Current, Atlantic Current

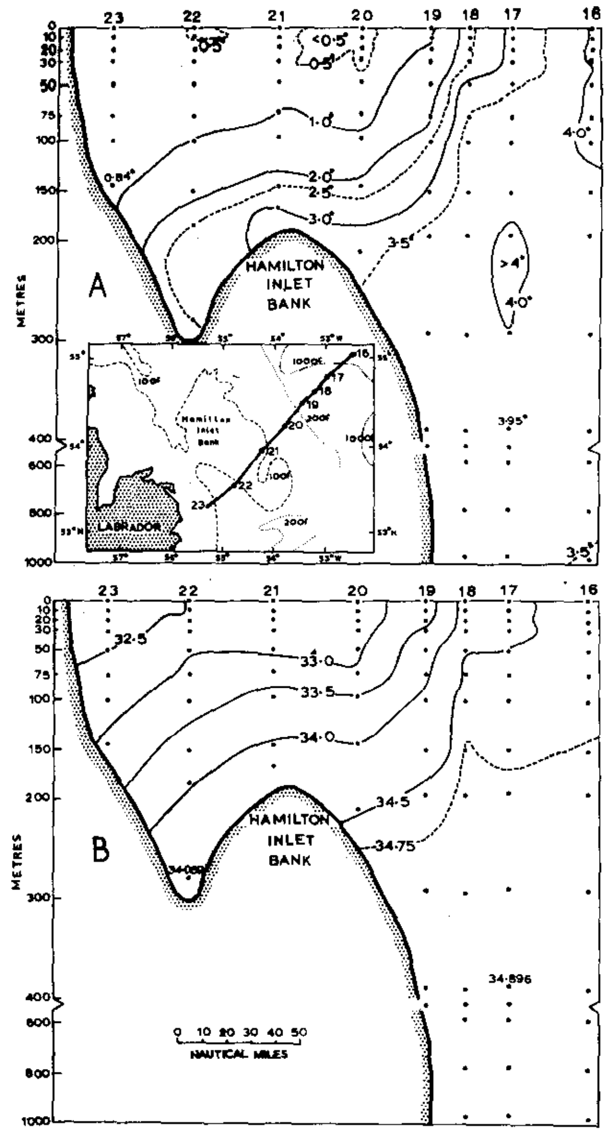

Fig. 1. Temperature and salinity distributions: Hamilton Inlet Bank Section: 26-27 November 1962.

and Mixed Water in the Grand Bank area, as drawn by Soule, Morrill and Franceschetti (1961) from data collected during the iceberg seasons (April-July approximately) of the period 1948-60 (Fig. 2). The curves for the 5 inshore stations (23-19) are very similar in shape to that typical of

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the Labrador Current, and lie between it and that identifying the Mixed Water; those for the offshore stations (18-16) are closer both in shape and position to the Mixed Water curve. The Labrador Current would seem therefore to be restricted to the shallow shelf zone at this time of year, while the deeper water seaward of the Hamilton Inlet Bank is essentially a mixture of the Labrador and Atlantic Currents.

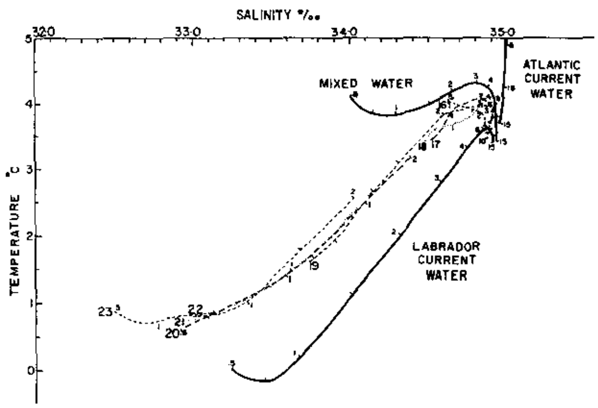

Fig. 2. Temperature-salinity diagrams for Hamilton Inlet Bank Section compared with 13-year mean values for Labrador Current, Atlantic Current and Mixed Waters. Depths in hectometres.

The temperature section obtained in November 1962 is very different to that reported by Templeman (1963) for the preceding August. The "early winter" situation is one of temperature increasing steadily with depth over the Hamilton Inlet Bank and of an absence of sub-zero water; winter cooling has only just begun, apparently. In "summer" however, a core of very cold water, less than 0°C and attaining -1.5°C in parts, surviving presumably from the previous winter and spring, lies over the coastal zone between slightly warmer bottom water and a relatively warm surface layer that is found at all stations.

Grand Bank - Flemish Cap Section

The standard stations of the St. John's Biological Station on this section were worked between December 4 and 6, although bad weather prevented complete sampling at stations 46, 47 and 48, so that in the Flemish Cap area the 34.75°/₀₀ isohaline cannot be completed. The structure of the water over the line of stations was complicated (Fig. 3) and unusual in that while temperature decreased sharply with depth salinity gradually increased. This is not, in fact, simply a case of the cold, relatively fresh water of the Labrador current appearing beneath water typical of the warm, saline North Atlantic Drift. Comparison

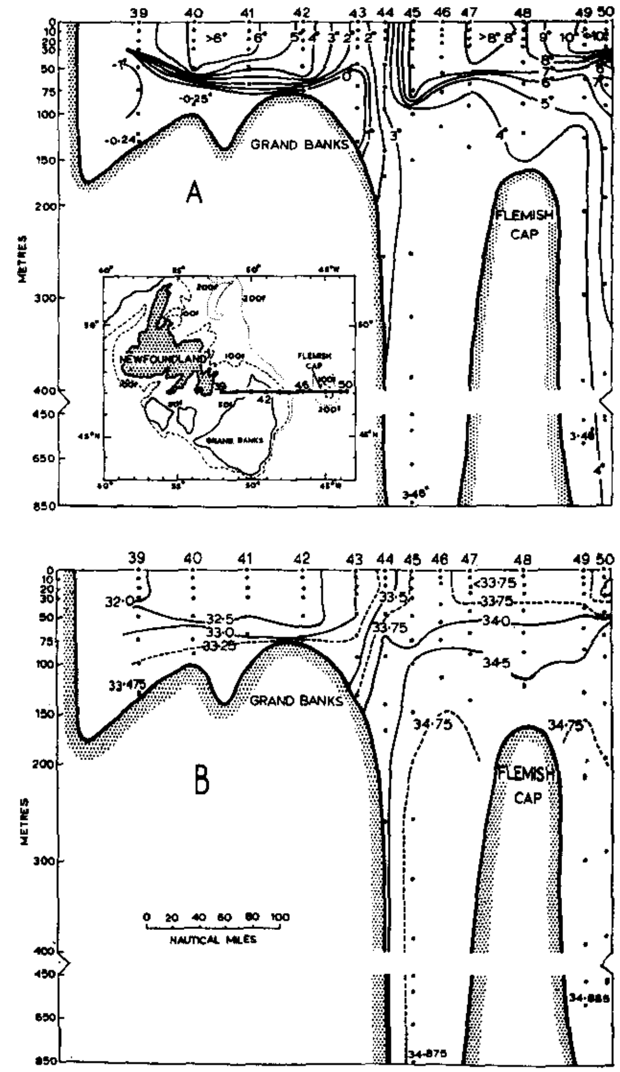

Fig. 3. Temperature and salinity distributions: Grand Bank - Flemish Cap Section: 4-6 December 1962.

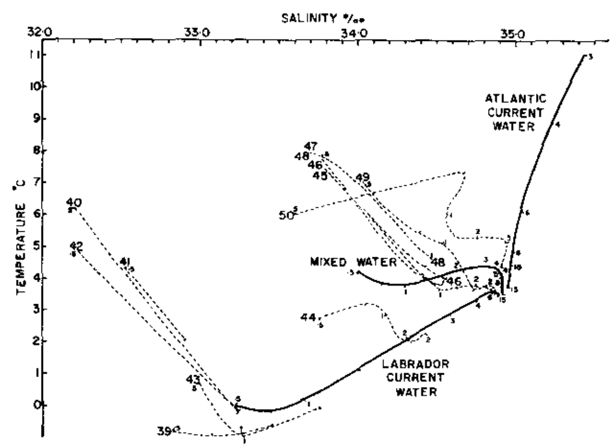

Fig. 4. Temperature-salinity diagrams for Grand Bank-Flemish Cap Section compared with 13-year mean values for Labrador Current, Atlantic Current and Mixed Waters. Depths in hectometres.

of the temperature-salinity relationship for each station with those given by Soule, Morrill and Franceschetti (1961) bears this out (Fig. 4). By this means not only is the water over the Grand Bank, stations 39-43, sharply distinguished from that seaward of it, stations 44-50, but also both groups of curves are seen to be rather different in the 50-70 m layer to those given as being typical of the three main types of water during the iceberg season, 1948-60. There seems little doubt, however, that the Labrador Current covers the Grand Bank and gives way eastwards to Mixed Water.

Marked differences in structure are seen when the temperature section is set alongside that shown by Templeman (1963) for the previous July. Both sections show sub-zero water lying, in particular, over the seaward edge of the Grand Bank, but in July this region has a core of colder water which seems better defined insofar as its presence has altered the form of the isotherms throughout the surface layer. There is a suggestion in December of a body of water, even colder than that found on the Grand Bank, lying close to the shore and below 50 m to match that found in July. These, therefore, may be pockets of cold water that stay in position throughout the year and have temperatures just below or relatively well below 0°C according to the season. The general cooling of the surface layers with the coming of winter is implied by the fact that the 10°C isotherm just appears at the eastern end of the December diagram, whereas in July it extended over most of the section.

The presence of sub-zero water in December over the Grand Bank is in contrast with the conditions on the Seal Islands - Hamilton Inlet Bank section, where such water was found in August but not in December. Below 75m depth, in fact, the inshore water of the more northerly section is warmer than that over the Grand Bank area.

The salinity sections are very similar both in shape and range of the isohalines to those used by Templeman (1961) to describe conditions during the summer of 1960.

Summary

In November-December 1962:—

1. The Labrador Current was restricted to the relatively shallow inshore zones of the Hamilton Inlet Bank and Grand Bank regions.
2. Below 75 m depth the water of the Labrador Current flowing in the Hamilton Inlet Bank area was warmer than that some 400 miles further south moving over the Grand Bank of Newfoundland.
3. Between 50 and about 70 m depth the Mixed Water and Labrador Current water flowing over the Grand Bank - Flemish Cap section was much warmer and less saline than the mean values of temperature and salinity, for the iceberg seasons 1948-60, lead one to expect.

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Estimating the Natural Mortality Rate of the Sea Scallop
(Placopecten magellanicus)

BY ARTHUR S. MERRILL[1 2] AND J. A. POSGAY[1]

Abstract

A method is described for estimating the natural mortality of sea scallops. The method is based on the percentage occurrence of the persistent paired valves of scallops that died from causes other than fishing collected along with live animals. Estimates of the average length of time that the paired valves remain attached at the hinge are calculated by determining the age in years and months when the animals died, and by measuring the time difference between modal groups in frequency distributions of live and dead animals. The possible causes of natural mortality are discussed. It is concluded that the average instantaneous natural mortality rate of the stocks in Subarea 5Z during the years 1959-1963 was about 0.10.

Introduction

Estimating the natural mortality rate for any wild population is a difficult task. In fishery investigations, it is frequently done by estimating total mortality rate from an analysis of the relative decline in numbers of several year classes as they pass through the fishery and then subtracting the fishing mortality rate which has been estimated by marking experiments.

This method is not feasible in the sea scallop fishery since only the shucked meats are landed, and it is not possible to collect data on the age composition at the time of landing. Since the animal is sedentary and the fishing grounds wide spread, it would be prohibitively expensive to collect a long series of samples for analysis of the age structure of the fished stock. Marking experiments are difficult to interpret for mortality rate estimates since the marked animals do not distribute themselves at random through the population, but remain where they are released (Posgay, 1963).

By fortunate circumstance, however, it is possible to identify a sea scallop which has recently died from causes other than fishing. When a fisherman shucks a scallop, he separates the two valves in order to get at the edible adductor muscle. Shells of sea scallops which die from other causes are left with the hinge intact. The soft parts decompose or are eaten by scavengers, but the paired valves, called "clappers" or "cluckers" by the fishermen, persist for some time.

This fact led Dickie (1955) to propose a direct method of estimating the natural mortality rate. He reasoned that, if the rate is constant, the number dying and adding to the clapper population should be equal to the number being removed by the hinge ligament decomposing. Knowledge of the average time required for the valves to separate would provide an estimate of deaths per unit time. In his calculations for the Bay of Fundy stocks he used the results of some unpublished tank experiments which gave an average time of 100 days required for separation of clappers larger than 96 mm. Relating the number of clappers to the number of live scallops in the population would give an estimate of the mortality rate.

Realizing the importance of Dickie's method for determining natural mortality, investigators at this Laboratory have kept records of clapper-live shell relationships on all sea scallop research cruises since 1958.

It is apparent that the accuracy of Dickie's clapper method for estimating natural mortality is dependent, among other things, on the accuracy of estimating the number of days the valves hold together. It was our desire to increase the reliability of his method by obtaining an estimate of the time required for separation on the fishing grounds. To do this we have actually aged live and clapper shells from samples to determine how long the clappers had been dead. Aging was accomplished by reading the annual rings on the

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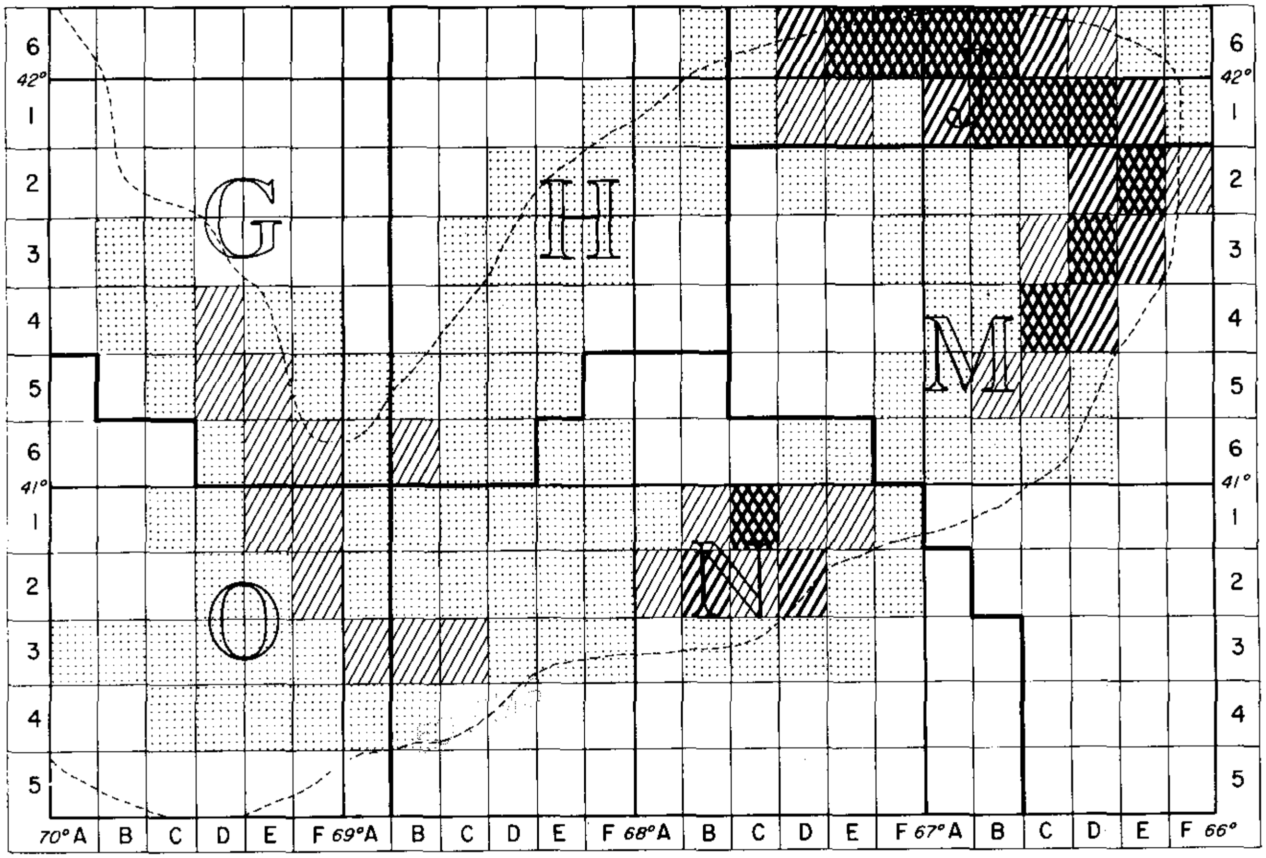

Fig. 1. The sea scallop grounds of Georges Bank showing the division into unit areas and Statistical Subareas. The shading of the unit areas represents the relative productivity of the different areas. The lightly shaded areas produced average annual landings of less than 100,000 pounds (45 metric tons) of meats during the years 1944-1961. The next darker areas supplied between 100,000 and 200,000 pounds (45-90 metric tons). The areas with the next darker tone supplied between 200,000 and 300,000 pounds (90-135 metric tons). The 11 areas with the darkest tone supplied more than 300,000 pounds (135 metric tons) per year. In all, there were about 250 million pounds (113,636 metric tons) of sea scallop meats, 39 percent from the most heavily shaded areas, landed during the 18 years.

shell. We have full confidence in this method of aging, having recently validated the reading of annual marks on the shell of the sea scallop (Merrill, Posgay, and Nichy, in press).

This paper presents the clapper shell and live scallop data collected from all the Georges Bank (Fig. 1) fishing grounds during the years 1958-1963. From the available evidence, it appears that clappers hold together for varying periods of time depending upon the conditions of the environment. Ways and means of determining most accurately the probable average length of time clappers hold together in particular areas are discussed. It is concluded that, (1) natural mortality varies considerably on Georges Bank, and (2) natural mortality is low over most of the Bank.

Area of Investigation

Although the sea scallop is known and fished from the Gulf of St. Lawrence to the offing of the Virginia Capes, it occurs in greatest abundance on Georges Bank off the coast of Massachusetts. In our investigation of the ecology of the sea scallop and the effects of the fishery on the stocks, we have, therefore, concentrated our efforts on these grounds. They are in ICNAF Subarea 5Z.

In reporting our data we have used the unit area, 10 minutes of latitude by 10 minutes of longitude, as our basic unit. These are named by the degree square in which they occur; the letters A to F from west to east, and the numbers 1 through 6 from north to south. For example, 41/66 E-2 is located between 41°40′ and 41°50′ N and 66° 10′ and 66° 20′ W. In these latitudes they have an area of about 75 square miles (194 sq km). The next larger unit is the subarea as defined by the North American Council on Fishery Investigations (Rounsefell, 1948). These are lettered G, H, O, J, M, N. We have also combined subareas G. H, and O into what we will call Area Group 1, Subarea N into Area Group 2, and Subareas J and M into Area Group 3. Fig. 1 shows the Georges Bank fishing grounds with these divisions outlined.

The three Area Groups are not equal in area. Area Group 1 has 60 unit areas fished for sea scallops: Area Group 2 has 36 unit areas fished; Area Group 3, 49 unit areas. In all, the exploited grounds on Georges Bank total 145 unit areas, approximately 11,000 square miles (28,490 sq km).

Collection of Data

We have made 11 cruises to Georges Bank during the past 6 years concerned directly with sea scallop research. The cruises were designed for specific purposes; the recording of clapper-live shell length-frequencies often was incidental. On some cruises only a few areas were sampled while on others a large portion of the Bank was surveyed. In general, however, stations within the three major Area Groups were sampled every year. In addition, a valuable set of clapper-live scallop data from a 1961 research cruise to Georges Bank made by Canadian scientists was kindly given us for incorporation into this report. In 1960 and 1961 samples of clappers and live shells from an area of high clapper ratio were brought back to the laboratory for analysis.

Distribution of Live and Clapper Shells on Georges Bank, 1958-1963

Table 1 lists the number of 10-minute tows taken and the number of live scallops and clapper shells found in the unit areas investigated during each cruise. The clapper ratios are the result of dividing the number of clapper shells taken by the number of live scallops. For *Delaware* cruise 60-8, and all subsequent United States cruises, there is an additional column headed "density index." These data were obtained by towing an odometer behind the dredge to measure the distance traveled over the bottom and then reducing all catches to the common base of numbers of live scallops caught per 10,000 square feet (929 sq m) dredged.

Figs. 2-7 show the clapper ratios measured for each of the unit areas sampled during each year. If a unit area had been sampled during more than one cruise in the year, the clapper ratio was calculated by pooling the catches of all the samples collected during the year. A dot has been placed in each unit area which was sampled but yielded no scallops. A brief summary of each cruise is presented below.

1958

Albatross III Cruise 113

Albatross III cruise 113 (Table 1), June 1958, surveyed Georges Bank adequately. No clappers were found in Area Group 1, and no scallops were taken in Area Group 2. The clapper ratios were very low in Area Group 3.

Dartmouth Cruise 1

Dartmouth cruise 1 (Table 1), September 1958, worked mostly in Area Group 3. The clapper ratios were low, the highest .0351 in one unit area to the east.

1959

Whaling City Cruise 3

Whaling City cruise 3 (Table 1), May 1959, covered eight scattered unit areas. The first evidence of rather high clapper ratios was discovered on this cruise.

Whaling City Cruise 4

Whaling City cruise 4 (Table 1), September 1959, was restricted to concentrated sampling in four unit areas. However, at least one unit area was in each Area Group. As with the earlier cruise, the clapper ratios were low in Area Groups 1 and 2, higher in Area Group 3.

1960

Delaware Cruise 60-8

Only one cruise was made in 1960. *Delaware* cruise 60-8 (Table 1), May 1960, sampled rather adequately the three Area Groups. As usual, few clappers were found in Area Groups 1 and 2. Large numbers of clappers were found in Area Group 3; the highest ratio, .4406, in one unit area on the Northern Edge.

1961

Delaware Cruise 61-7

Delaware cruise 61-7 (Table 1), May 1961, surveyed Georges Bank quite thoroughly especially in known scallop producing areas. Again few clappers were found in Area Groups 1 and 2, while large numbers were taken in Area Group 3. One unit area on the Northeast Peak had a clapper ratio of .4585.

Delaware Cruise 61-13

The purpose of *Delaware* cruise 61-13 (Table 1), August 1961, was to do gear selection work.

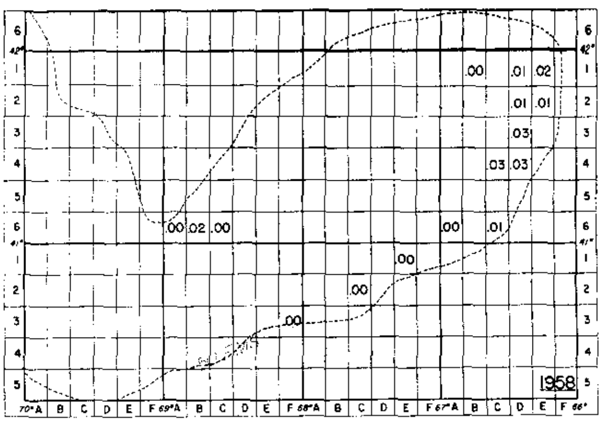

Fig. 2. Clapper ratios observed in 1958.

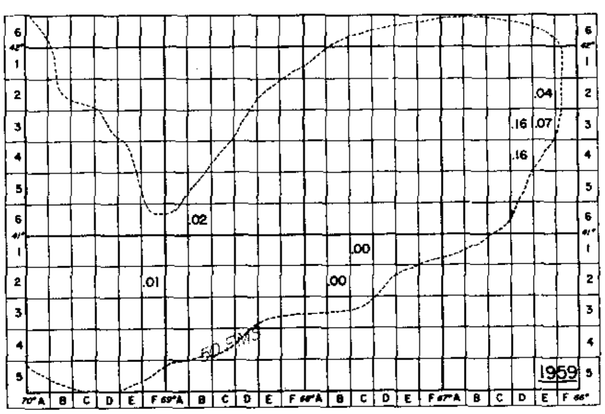

Fig. 3. Clapper ratios observed in 1959.

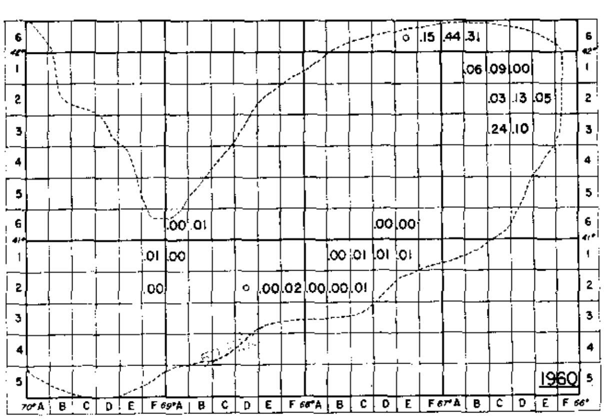

Fig. 4. Clapper ratios observed in 1960.

Most of this was done in a limited area in Area Group 3.

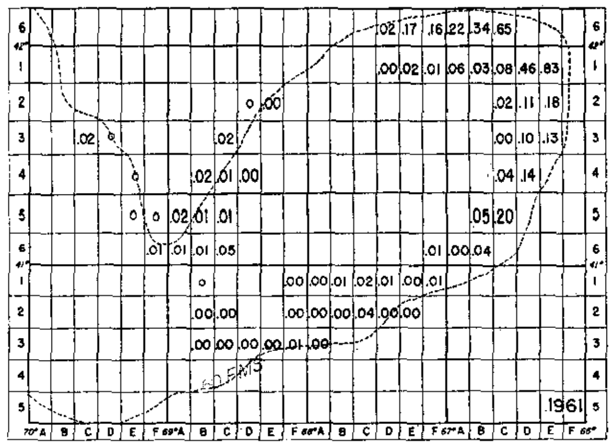

Fig. 5. Clapper ratios observed in 1961. Notice the high ratios in some of the northern and eastern unit areas. These are the same areas shown in Fig. 1 as being the most highly productive.

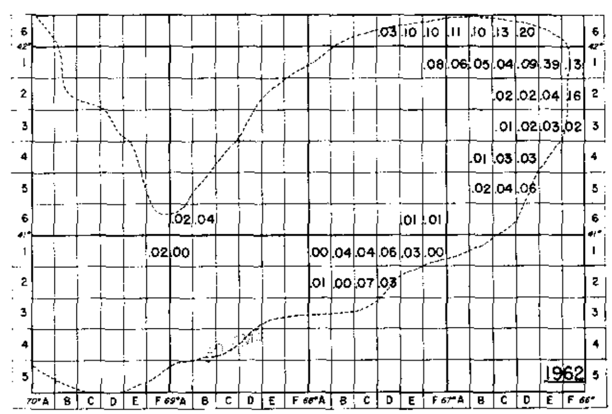

Fig. 6. Clapper ratios observed in 1962.

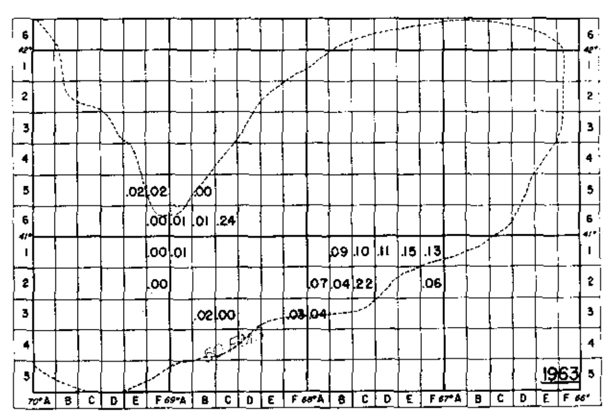

Fig. 7. Clapper ratios observed in 1963.

Cape Eagle Cruise

Cape Eagle cruise (Table 1), September 1961, concentrated efforts in three selected unit areas in Area Group 3. Each unit area was subdivided into many smaller units and systematically sampled. The clapper ratios resulting from this Canadian cruise in which many samples were taken from a unit area compare favorably with clapper ratios from United States cruises in 1961 where only a few samples were taken from the same unit area.

Delaware Cruise 61-16

Delaware cruise 61-16 (Table 1), September 1961, surveyed a large area of Georges Bank. The clapper ratios were similar to the May cruise with few clappers in Area Groups 1 and 2. One unit area in Area Group 1 showed a high ratio of clappers, but the ratio was based on only a few live and clapper shells. Area Group 3 showed large numbers of clappers. Two unit areas on the Northeast Peak had extremely high ratios, .8300 and .6476.

Delaware Cruise 62-6

Delaware cruise 62-6 (Table 1), May 1962, again surveyed a large area of Georges Bank. The clapper ratios were low as usual in Area Group 1, but in Area Group 2 there were more clappers than usual, the highest ratio was .0734 in one unit area. Clapper ratios continue generally high in some unit areas in Area Group 3, although the data indicate that ratios were lower than in the preceding 2 years in many unit areas.

Delaware Cruise 62-10

Delaware cruise 62-10 (Table 1), September 1962, concentrated effort in Area Group 3. Sampling was extended to include a number of additional unit areas, and more tows were made in each one of them. Although clapper ratios are still high in some unit areas, the number of unit areas with high ratios is fewer, and not generally as high as in the preceding 2 years.

Albatross IV Cruises 63-1 and 63-3

These two cruises were made in late May and early June 1963. Cruise 63-1 was interrupted because of equipment breakdown, and the station plan completed on Cruise 63-3. Samples were collected only in Area Groups 1 and 2. Clapper ratios were moderately high in some locations; the highest was .2433.

Examination of the data of Table 1 produces two interesting facts. In general, high clapper ratios did not occur before 1960. Pooling all the samples collected in 1958 gives a ratio of .0133; the 1959 samples a ratio of .0208, although two unit areas, 41-66 D3 and D4, had ratios greater than .15. The average clapper ratio in the samped areas rose to .1131 in 1960 and then dropped to .0723 in 1961; it was .0620 in 1962, and .0845 in 1963. The other point, seen most clearly in Fig. 5, is that all of the higher clapper ratios occur in those unit areas which are along the northeastern rim of the Bank.

Analysis of Shell Samples

The amount of time that has passed since any individual clapper was formed can be estimated by a study of the shell. A clapper can be aged by reading annual rings on the shell just as a live specimen can. By this means it is possible to estimate the month in which it died. Further information regarding time of death can be gathered by observing the clapper shells for kinds and degrees of fouling, and for the degree of erosion to shell and hinge ligament. Gunter, Dawson, and Demoran (1957) undertook experiments along these lines in Texas and Mississippi waters to determine time of oyster mortality. They described the initial fouling complex and dominants at different levels below the surface at various seasons of the year and concluded the rate of fouling to be strongly dependent upon temperature. Conditions differ somewhat in deeper, colder water where sea scallops are found, because bottom temperatures are more uniform and the season of setting of fouling organisms is shorter. Moreover, we are interested in fouling succession as well as initial setting in determining the period of time a clapper holds together. The two valves of a sea scallop gape at each side even when fully closed; as soon as it dies, the adductor muscle relaxes, and they gape fully. This enables minute organisms to enter and utilize the interior shell substrate of a clapper as soon as the animal matter has deteriorated or has been eaten by another organism. Thus, it is possible to study the fouling organisms that settle on the interior part of a clapper shell to help determine how many years have passed since the scallop died.

In August 1961 (*Delaware* cruise 61-13), a sample from unit area 42/66 B-6 in Area Group 3, which contained live and clapper scallops, including associated fouling organisms, was quick-frozen aboard ship and brought back to the laboratory for study. Two dredges were towed simultaneously on this station. The live scallops from both dredges totalled 1125, the clappers 516 (clapper ratio .4587). The length frequencies of these are shown in Fig. 8. The live scallops from one dredge (about half, 508) and all the clappers (516) were studied in the laboratory. About 60 percent of the live scallops were of the same year class (Fig. 8, mode at about 110 mm).

Before the scallops could be aged, the exterior of the shells had to be thoroughly scrubbed to remove foreign growths and expose the annual rings. The interiors of the clappers were left untouched as far as possible to study the degree and complexity of fouling. The cleaned shells revealed exceptionally clear rings, particularly those which had formed in 1959, 1960, and 1961 (Fig. 9).

The length that each of the live scallops had attained at the time that each annual ring had formed was measured. The average size at each ring is shown in Table 2 and Fig. 10. These results agree very well with other samples that we have analyzed from the same general area.

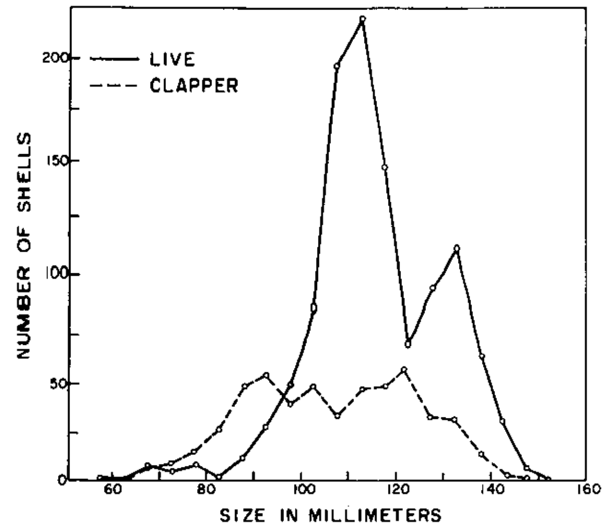

Fig. 8. Length frequency distribution of the live and clapper shells collected in August 1961 from unit area 42/66 B-6.

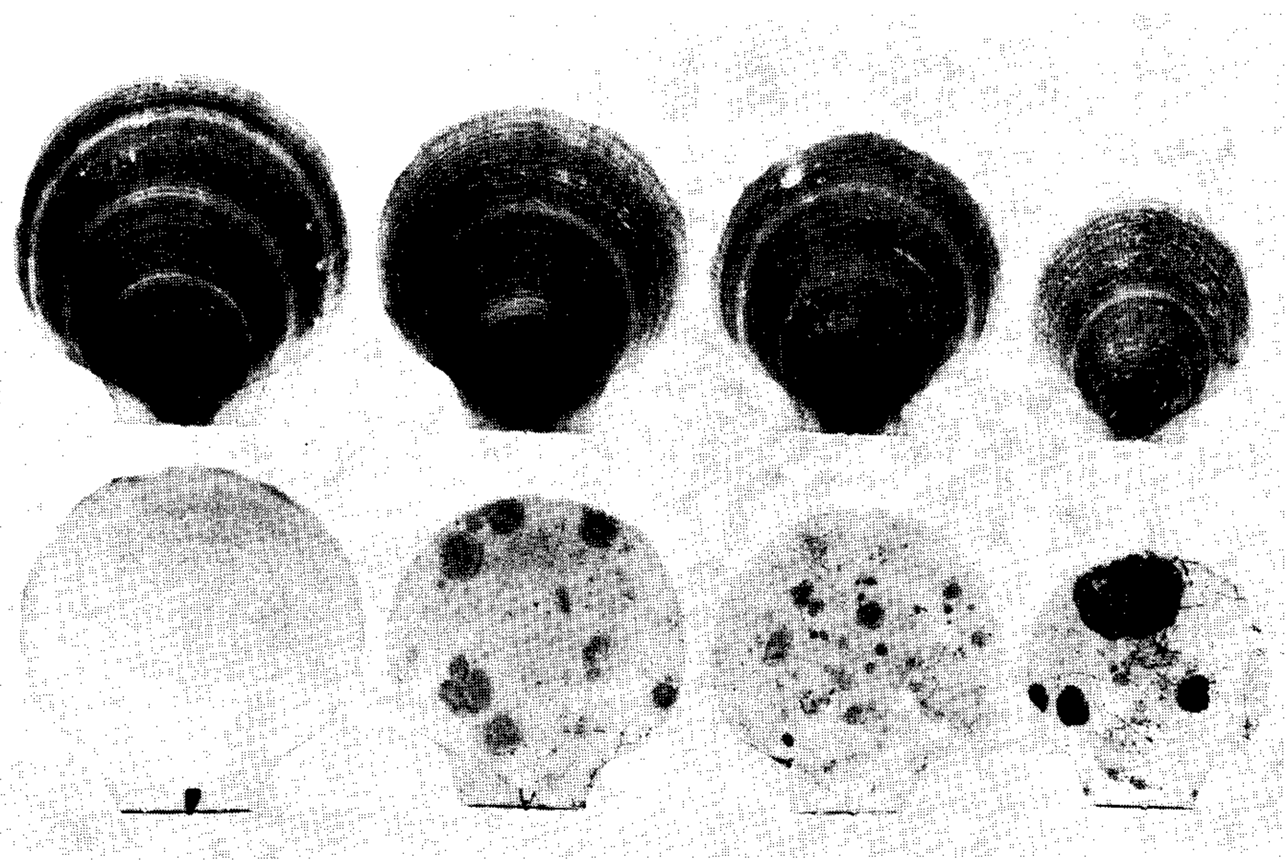

Fig. 9. Exterior (top row) and interior (bottom row) surfaces of the left valves of some clapper shells collected in August 1961 from unit area 42/66 B-6.

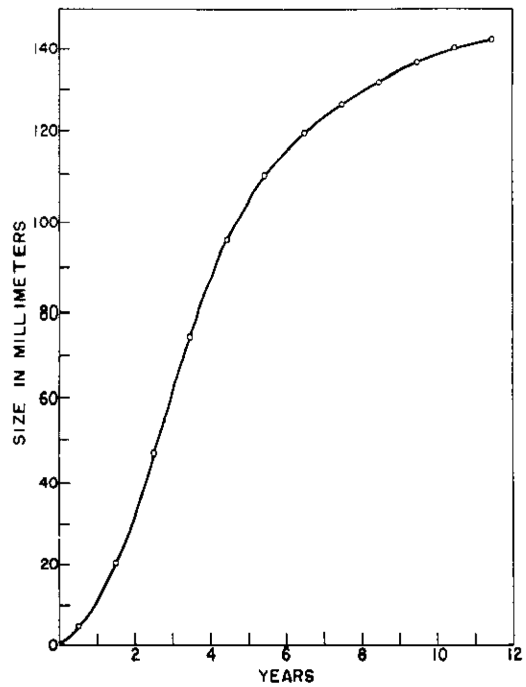

Fig. 10. Growth curve of a sample of 508 live sea scallops collected in August 1961 from unit area 42/66 B-6.

The annual ring forms on the sea scallop in the spring time (Merrill, Posgay, and Nichy, in press). For the purpose of this paper we have arbitrarily chosen March 1st (6 months before the sample was taken) as the exact date the ring finished forming each year. We well understand, however, that it may vary from year to year and even from shell to shell in the same year. By doing this we have a constant with which to compare rates of growth between rings for any part of the year. At the same time the fouling growth on the shells was studied to determine the intensity of fouling, the kinds of organisms involved, and their probable time of setting.

The clappers were first separated into their respective ring groups. The amount of shell added since the formation of the last ring was then used to estimate the amount of time that had elapsed between ring formation and death. A scallop with three rings, for example, that had grown 7.5 mm after the third ring had formed, was assigned July as its month of death since the average rate of growth between the third and fourth ring was 1.76 mm per month. The following criteria were then used to assign a specific year of death to each clapper. A clapper had died within 6 months if:

1. The last three rings were extremely clear.
2. Little to moderate fouling growths were on the interior of the valve.
3. The hinge ligament showed little deterioration.
4. The interior of the shell was glossy.

A clapper had been dead between 6 months to 18 months if:

1. Only the last two rings were extremely clear.
2. Fouling growths were extensive with new encrusting growths overgrowing old ones.
3. The hinge ligament was completely deteriorated.
4. The interior of the shell had lost its high gloss.

A clapper had been dead 18 months to 30 months if:

1. Only one ring was extremely clear.
2. Fouling growths were not only extremely extensive but succession in fouling was evident.
3. The valve showed evidence of actual decay.
4. The interior of the shell was stained and discolored.

The clappers, after being aged and having a time of death assigned to them, were arranged by year class in the order of the month and year that they had died (Table 3). Here can be seen clappers that had remained together for as long as 2 years. This was the time when we first noticed large clapper ratios. The mean period of time clapper valves in this sample had remained together was 36 weeks. These data also show that clappers from the three youngest year classes had been dead less than 18 months. This may be due to the fact that small clapper scallops separate sooner than the larger ones. Dickie (1955) states that scallops under 96 mm hold together on the average only half as long as those larger. Examination of the clapper frequency distributions also show few clappers under 80 mm which also suggests either that small clappers separate quickly or perhaps fewer die.

Some of the clappers were so heavily overgrown with fouling organisms that the valves could not have separated even had total deterioration of the hinge ligament allowed them to. This points out the difficulty of estimating an average length of time that clappers hold together from tank experiments. Conditions of the natural environment must be taken into consideration.

If epizooty or predation had caused mass mortality most of the scallops would have died about the same time. The data in Table 2 show this not to be the case. Fig. 11 shows a plot of the data of Table 3 grouped by quarter years. The total numbers show a progressive rise in the number of clappers formed each quarter from the time the sample was taken back to the fourth quarter. Further back in time the numbers are lower each quarter.

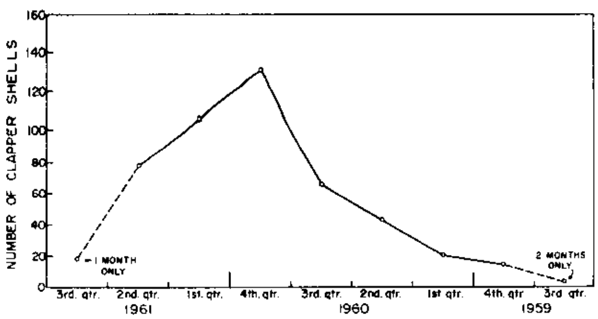

Fig. 11. Dates of death for the clapper shells collected in August 1961 from unit area 42/66 B-6. The modal group had died about 36 weeks before collection.

Using the size of the clapper shell when it was collected, the estimated time that it had been dead, and the average growth rate (Fig. 10), we were able to estimate the size that each clapper shell would have attained had it lived to the time of collection. The results of these calculations are shown in Fig. 11 which compares the length frequency distributions of the live scallops and the clapper shells, (adjusted for unrealized growth). It is apparent that the younger group, with a mode at about 110 mm, have a smaller clapper ratio than the group with a mode at about 132 mm. The close coincidence of the modes of the adjusted lengths of the clappers with those of the live scallops is, in our opinion, strong evidence of the reliability of this method of estimating the time of death of a clapper shell.

A sample of 236 clappers, taken in May 1960 (*Delaware* cruise 60-8) from the same unit area, was studied to determine when they had died and how long they had held together. Fig. 13 shows the results lumped into quarter-year units. The graph is similar to that of the first sample analyzed. The oldest clapper in this sample had died 14 months previously. The mean length of time clapper valves held together in this sample was 26 weeks.

In summing up it is apparent that it is possible to determine the length of time clapper valves remain together by a study of their shells. Samples of shells can be aged by using the technique of reading annual rings. The time of death of a clapper can be determined by noting the position of the shell edge in relation to the latest ring, the general condition of the ligament and shell, and the kinds and degree of fouling on them. Analysis of results using these methods show that scallops had died in all months of the year, thus discounting possibilities of sudden mass mortality. Clappers were found that had remained together for as long as 2 years.

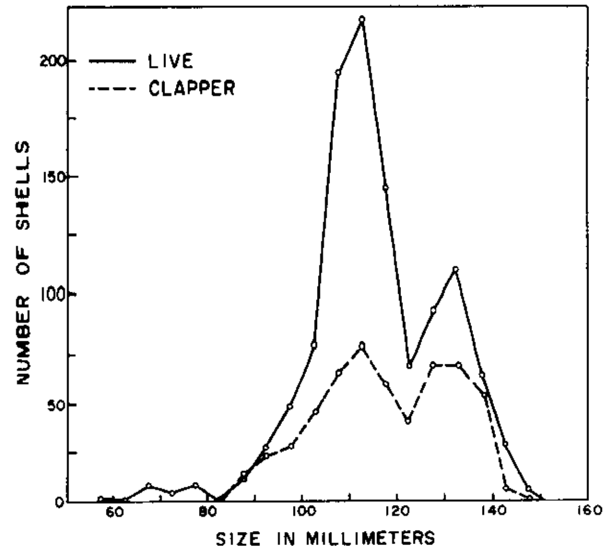

Fig. 12. Length frequency distribution of the live and clapper shells collected in August 1961 from unit area 42/66 B-6. The lengths of the clappers have been adjusted to the size that they would have attained if they had lived to the date of collection.

Analysis of Clapper and Live Shell Length-Frequency Distribution

The length-frequency distributions of both live and clapper shells from areas with high clapper ratios frequently show pronounced modes (Fig. 14). The modes in the clapper distribution almost always lag behind those in the live scallop distributions. This phenomenon coupled with the good agreement obtained between the live and adjusted clapper modes shown in Fig. 12, suggested that measuring the difference in length between the live and clapper modes and converting this to time using the average growth rate would give us another estimate of the time that clappers persist.

We, therefore, selected the samples shown in Table 4, located the modes, and converted the length differences to time. The average is 37 weeks. Using three different, if interrelated, methods, we thus have estimates of 36, 26, and 37 weeks as the average time that clappers persist after death of the scallop; the grand average is 33 weeks.

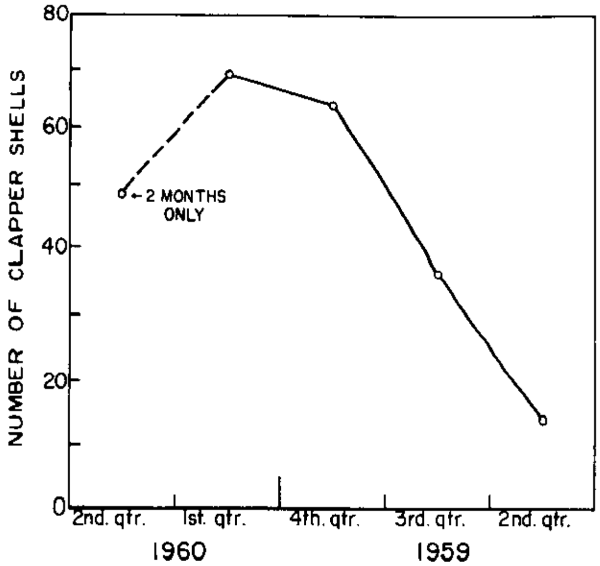

Fig. 13. Dates of death for a group of clapper shells collected in May 1960 from unit area 42/66 B-6.

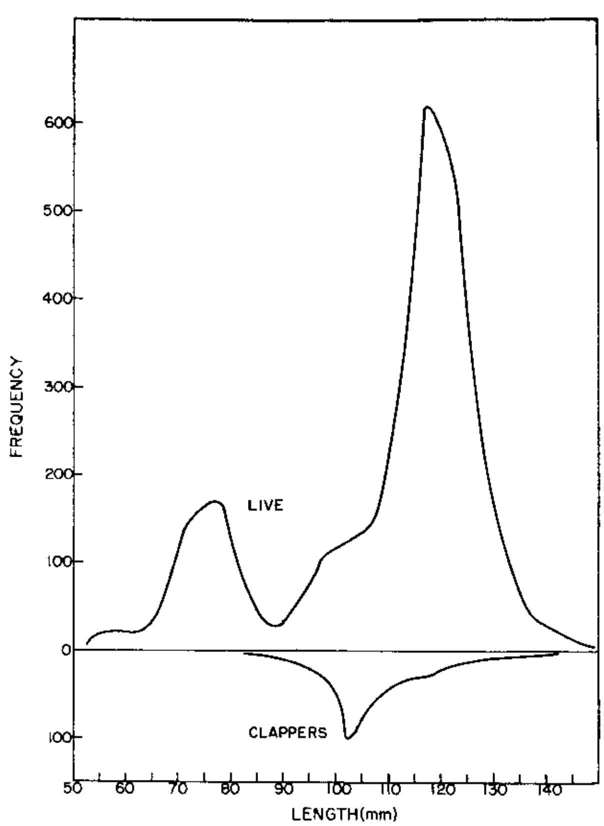

Fig. 14. Length frequency distribution of the live and clapper shells collected in May 1961 from unit area 42/67 E-6.

Calculating the Natural Mortality Rate

Dickie (1955) in his calculations used the formula:

$$a = 1\text{-}e^{-(C/t)(1/L)(365)}$$

in which a is the annual rate of natural mortality, C is the number of clappers in the sample, t is the average time in days required for the shells of the clappers to separate, and L is the number of live scallops in the sample. The exponent above is equal to the instantaneous mortality rate, so we may write:

$$M = (C/L)(52/t)$$

where M is the instantaneous annual coefficient of natural mortality, C and L as above, and t the average time in weeks that the clappers persist.

We have presented above in detail the data we have available for calculating an average clapper ratio for all of Georges Bank over the years we sampled. Table 5 summarizes these data by Area Group and year. The last column gives weighting factors derived from the average density index for each Area Group over the 4 years that they are available. We have calculated a weighted average clapper ratio, an unweighted clapper ratio, and a raw clapper ratio.

Inserting the weighted average clapper ratio into the equation, we have: M = (.0662) (52/33) = .1045. The unweighted average gives a clapper ratio of .0463 and M = .0731. The raw clapper ratio is obtained by lumping all the collections of clapper shells and live scallops together. We have collected in all 47,811 clapper shells and 643,470 live sea scallops. This gives a raw clapper ratio of .0743 and M = .1172. It would appear, therefore, that in our further studies of yield of a year class under various conditions of fishing pressure we can use .10 as a reasonable value of M with a spread of about ± .02.

Causes of Natural Mortality in Adult Sea Scallops

Medcof and Bourne (in press) discuss in some detail the causes of mortality in stocks of sea scallops. They identify a number of things that can affect the well being of scallops during specific periods of their life history. In this study we make no attempt to determine the natural mortality of young scallops under 80 mm. This is because we relate clappers to live scallops and few clappers under 80 mm are to be found. In effect, we are dealing with adult scallops from about the time they enter the fishery.

Among the more important causes of natural mortality mentioned by Medcof and Bourne that would affect adult scallops are predators, parasites, semi-parasites (boring sponges and annelids) which may weaken scallops and leave them susceptible to predators, and sudden rises in water temperature which occasionally produces mass mortality. Other causes (attributed by them to *fishing* mortality) have to do with damage to scallops during dredging and handling operations. Scallops may be injured by the dredge scraping over them without actually catching them, or the turmoil in the dredge during the drag and haul may kill or injure many scallops, some of which are shoveled overboard as discards or overlooked in the trash when it is returned to the sea. A putative cause is mentioned by Medcof and Bourne: returning of refuse (empty shells and waste body parts) to the beds may "sour" the bottom or otherwise cause fouling of the beds.

On Georges Bank, sea scallop mortality due to extreme temperature fluctuations can be discounted because of the deep waters where scallops are taken. We have determined earlier, using certain clapper data (Table 3; Figs. 12, 13), that there is no evidence of mass scallop mortalities such as that discussed by Dickie and Medcof (1963) in the Gulf of St. Lawrence. We have also been unable to find any concrete evidence of predation on sea scallops. We have a fair idea of species relationship on Georges Bank for dominant species are listed each time a tow is made. The only possible predator of which we are aware is the starfish, but starfish are rather scarce on Georges Bank and they are not excessively numerous in areas with high clapper ratios. There is some boring activity by sponges and annelids on Georges Bank, but the scallop appears to be able to cope with them.

We have tested the degree to which density of sea scallops affects the clapper ratios. A regression line fitted to all the data for which a density index is available has the formula: C/L = .0308 + .00038 (d.i.). The slope is positive, but the correlation coefficient is only .21 so it appears that density alone is not an important factor in causing mortality. Inspection of Table 1 shows many instances of low clapper ratios in arears of high density and vice versa.

The same situation applies to fishing activity. We have correlated the clapper ratios obtained in *Delaware* cruise 61-16 with the number of days fished in each unit area sampled during the previous 9 months. The regression equation is: C/L = .0062 + .00063 (d. f.). The correlation coefficient is .28. Fishing activity of itself, therefore, does not seem an important cause of mortality among the uncaught scallops.

A possible explanation of the positive, although weak, correlation of high density and heavy fishing pressure with high clapper ratios lies in the fact that high density of sea scallops attracts heavy fishing pressure by the fleet. Under conditions of high density, a low rate of natural mortality will still cause the formation of a large number of clapper shells. As shown above, some of these clappers may persist for as long as 2 years. During this time the fleet is constantly reducing the numbers of live scallops but returning the clapper shells that they catch to the sea. When we sample the area some time later, we collect all the clappers that were formed during the past year or so but only those live scallops that remain after heavy exploitation. The density of those that remain may still be high as compared with other areas of the Bank but we will obtain a clapper ratio that is too high because we do not know the density of the original stock from which the clappers were formed.

There appears to be more than scallop density or fishing activity involved to produce high natural mortality. Probably the general environment, the bottom structure, and the general community relationships of an area are all involved. Unusually high clapper ratios have been found only in Area Group 3. Here conditions are such that year classes of some strength enter the fishery each year. Consistently, over the years, more scallops are taken from this part of Georges Bank than anywhere else (Fig. 1). The bottom sediments are composed generally of gravel and/or medium coarse sand (Wigley, 1961). Usually a good assortment of invertebrates, shell, and other debris is brought up with the scallops. The dredge hauls with high clapper ratios usually contain a high percentage of invertebrates, particularly fouling types. The substrate is effectual for larval settlement of all kinds. Returning the shucked remains of scallops to the bottom year after year possibly helps enrich the fauna of this area. For instance, in a 1200-square-mile (3108 sq km) area in Area Group 3 in 1961, over 18 million pounds (8,182 metric tons) of scallop meats were taken. The adductor muscle, which is the only meat utilized, makes up approximately one third of the body weight. Thus, two thirds of the body meat or about 36 million pounds (16,364 metric tons) of scallop waste meat were returned to the sea in this area during the year, an average of 2500 pounds per square mile (438 kg/sq km) each month. In 1961 an average of 22.5 scallops (45 shell valves) were shucked for each pound of meat yielded in Area Group 3. This means that over 800 million scallop valves were returned to the sea in this area that year as additional substrate for larval settlement.

On the other hand, when an exceptionally successful year class enters the fishery, sea scallops may also be found in large numbers elsewhere on Georges Bank. In 1959 a large year class entered the fishery in Area Group 2. The bottom sediments here are composed generally of medium and fine sand. The total invertebrate fauna was not rich in 1959 as inferred from the almost pure catches of scallops taken in the dredges. Only slightly more "trash" was recorded from hauls in 1960. In 1961, associated organisms had begun to increase and in 1962 they comprised a definite part of each haul. Significantly, in 1962 the number of clappers in Area Group 2 also was on the increase (Table 5). This suggests that an increase of invertebrates including fouling organisms may be responsible for increase in scallop mortality or vice versa.

Summary

The ratio of clapper shells to live sea scallops during the period 1958-1960 as observed in research vessel catches has been less than .10 in Subarea 5Z except for a restricted area in the northeast part of Georges Bank. Here, it was estimated at .19 in 1960 and .16 in 1961, but declined to .07 in 1962.

Two samples of clapper shells which were aged to determine the year and month of death, gave estimates of 36 and 26 weeks as the average time that clappers will persist after death from causes other than fishing. Analysis of 13 length frequency distribution samples of both live and clapper shells for the time that would have been required for a sea scallop to grow from the length at which a prominent mode occurred in the clapper distribution to the length at which a prominent mode occurred in the live distribution gave an average of 37 weeks.

Using a weighted average of the clapper ratios of .0662 and an average time required for clappers to separate of 33 weeks, it is concluded that the average instantaneous natural mortality rate of the sea scallop stocks of Georges Bank during the period of study was about .10.

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TABLE 1. Live and clapper scallops arranged by unit areas for all cruises, 1958-1963. The number of 10-minute tows, clapper ratios, and density index - when available - are also listed for each unit area.

Unit area	No. of tows	Live scallops	Clapper shells	Clapper ratio	Density index
ALBATROSS III CRUISE 113, JUNE 1958					
40/67 C-2	1	0	0	—	
40/67 E-1	1	0	0	—	
40/68 F-3	1	0	0	—	
41/66 A-6	1	0	0	—	
41/66 B-1	1	674	0	.0000	
41/66 C-4	1	93	0	.0000	
41/66 D-1	3	506	3	.0059	
41/66 D-2	9	1573	8	.0051	
41/66 D-3	4	3950	20	.0051	
41/66 D-4	4	4522	122	.0270	
41/66 E-1	2	2269	48	.0212	
41/66 E-2	19	12112	30	.0025	
41/66 C-5	2	408	0	.0000	
42/66 A-6	4	1936	0	.0000	
42/66 C-6	1	1028	3	.0029	
Total	54	29071	234		
DARTMOUTH CRUISE 1, SEPTEMBER 1958					
41/66 C-4	2	1267	39	.0308	384.5
41/66 C-6	5	7102	57	.0803	—
41/66 D-1	40	9469	113	.0012	143.9
41/66 D-4	6	5391	189	.0351	631.3
41/66 E-2	2	4489	103	.0229	1796.5
41/68 B-6	6	5004	87	.0174	—
Total	61	32722	588		
WHALING CITY CRUISE 3, MAY 1959					
40/67 C-1	4	7301	7	.0010	475.6
40/69 F-2	17	3286	15	.0046	61.7
41/66 D-3	2	1003	156	.1555	115.5
41/66 D-4	2	778	125	.1607	56.0
41/66 E-2	8	10671	173	.0162	410.3
41/66 E-3	2	1653	122	.0738	281.7
41/67 E-6	3	291	1	.0034	10.3
41/68 B-6	8	7599	159	.0209	261.3
Total	46	32582	758		
WHALING CITY CRUISE 4, SEPTEMBER 1959					
40/67 B-2	9	9139	16	.0018	
40/67 C-1	8	23638	79	.0033	
41/66 E-2	5	16010	834	.0521	
41/68 B-6	13	6512	142	.0218	
Total	35	55299	1071		

TABLE 1. (continued)

Unit area	No. of tows	Live scallops	Clapper shells	Clapper ratio	Density index
DELAWARE CRUISE 60-8, MAY 1960					
40/67 A-2	1	191	0	.0000	49.9
40/67 B-1	1	53	0	.0000	11.3
40/67 B-2	2	333	1	.0030	47.8
40/67 C-1	6	1681	23	.0137	72.2
40/67 C-2	3	611	4	.0065	52.0
40/67 D-1	4	1371	11	.0080	81.2
40/67 E-1	1	487	3	.0062	125.5
40/68 A-1	3	399	0	.0000	73.7
40/68 D-2	1	0	0	—	0.0
40/68 E-1	2	98	0	.0000	—
40/68 F-2	1	123	3	.0244	—
40/69 F-1	2	167	1	.0060	52.8
40/69 F-2	5	846	4	.0047	36.5
41/66 B-1	2	625	37	.0592	77.4
41/66 C-1	1	139	12	.0863	35.3
41/66 D-1	1	469	1	.0021	161.0
41/66 D-2	1	307	8	.0261	124.6
41/66 D-3	1	1426	337	.2363	449.4
41/66 E-2	7	2808	341	.1214	149.5
41/66 E-3	1	500	50	.1000	173.0
41/66 F-2	1	1556	84	.0540	—
41/67 D-6	1	106	0	.0000	36.1
41/67 E-6	1	358	1	.0028	107.0
41/68 A-6	1	758	1	.0013	198.8
41/68 B-6	1	798	6	.0075	188.2
42/66 A-6	2	2002	882	.4406	196.4
42/66 B-6	3	841	259	.3080	83.1
42/67 E-6	1	0	0	—	0.0
41/67 F-6	2	2447	364	.1488	402.1
Total	58	21500	2433		
DELAWARE CRUISE 61 - 7, MAY 1961					
40/67 A-1	3	241	0	.0000	22.3
40/67 A-2	5	674	9	.0134	37.5
40/67 B-1	4	958	4	.0042	80.1
40/67 B-2	4	816	0	.0000	68.8
40/67 C-1	12	4563	122	.0267	110.2
40/67 C-2	3	642	25	.0389	41.9
40/67 D-1	5	1877	23	.0123	101.0
40/67 E-1	5	2584	1	.0000	176.0
40/67 F-1	2	635	11	.0173	91.4
40/68 B-1	1	1	0	.0000	0.3
40/68 B-2	1	22	0	.0000	5.9
40/68 B-3	1	41	0	.0000	14.7
40/68 C-3	1	11	0	.0000	3.2
40/68 E-3	1	68	0	.0000	21.2
40/68 F-1	2	112	0	.0000	29.1
40/68 F-2	1	301	0	.0000	94.2
41/66 A-1	5	432	2	.0046	46.9
41/66 B-1	4	6068	416	.0686	370.3
41/66 B-5	1	56	0	.0000	21.9
41/66 C-1	4	3403	212	.0623	185.4
41/66 C-4	1	816	35	.0429	257.0

TABLE 1. (continued)

Unit area	No. of tows	Live scallops	Clapper shells	Clapper ratio	Density index
DELAWARE CRUISE 61 - 7, MAY 1961 (Continued)					
41/66 D-1	4	1457	668	.4585	94.3
41/66 D-3	4	1973	214	.1085	168.1
41/66 E-2	7	3038	784	.2581	129.3
41/67 A-1	2	448	6	.0134	64.2
41/67 D-1	2	517	1	.0019	78.7
41/67 E-1	4	333	8	.0240	42.5
41/67 E-6	1	370	3	.0081	125.4
41/67 F-1	4	574	4	.0070	59.2
41/67 F-6	1	53	1	.0019	14.4
41/68 A-5	4	483	2	.0041	48.6
41/68 A-6	6	1208	9	.0075	54.4
41/68 B-4	2	129	3	.0233	15.2
41/68 B-5	4	279	9	.0323	20.5
41/68 B-6	9	966	0	.0000	39.6
41/68 C-3	1	134	3	.0224	37.6
41/68 C-4	6	541	8	.0148	22.2
41/68 C-5	4	669	9	.0135	43.5
41/68 C-6	6	627	51	.0813	30.2
41/68 D-2	1	0	0	—	0.0
41/68 D-3	2	15	0	.0000	2.5
41/68 E-2	1	13	0	.0000	4.4
41/68 F-1	2	137	0	.0000	21.9
41/68 F-2	1	3	0	.0000	1.0
41/69 F-6	6	452	9	.0199	17.1
42/66 A-6	4	4146	1474	.3555	174.6
42/66 B-6	1	89	3	.0337	23.9
42/67 D-6	4	1641	29	.0177	128.3
42/67 E-6	4	2906	331	.1139	251.7
42/67 F-6	4	6650	1046	.1573	240.3
Total	167	54172	5535		
DELAWARE CRUISE 61 - 13, AUGUST 1961					
41/66 C-1	6	295	29	.0983	23.6
41/66 B-1	212	122341	2950	.0241	183.6
42/66 B-6	2	1125	516	.4587	169.2
Total	110	123761	3495		
CAPE EAGLE CRUISE, SEPTEMBER 1961					
41/66 C-1	38	9953	809	.0813	
41/66 E-2	50	19415	3065	.1579	
42/66 A-6	41	56864	11708	.2059	
Total	129	86232	15582		

TABLE 1. (continued)

Unit area	No. of tows	Live scallops	Clapper shells	Clapper ratio	Density index
DELAWARE CRUISE 61 - 16, SEPTEMBER 1961					
40/67 A-1	4	343	0	.0000	32.5
40/67 A-2	4	1308	1	.0008	81.3
40/67 A-3	4	40	0	.0000	0.3
40/67 B-1	4	874	13	.0149	45.7
40/67 B-2	4	1104	3	.0027	60.8
40/67 C-1	4	1857	18	.0097	79.6
40/67 C-2	4	810	28	.0346	43.6
40/67 D-1	4	3179	37	.0116	155.4
40/67 D-2	4	498	10	.0201	35.1
40/67 E-1	4	5014	14	.0028	271.6
40/67 E-2	4	48	0	.0000	5.7
40/67 F-1	4	2202	10	.0045	174.5
40/68 C-2	1	175	0	.0000	42.6
40/68 D-3	4	361	1	.0028	20.8
40/68 E-3	4	80	0	.0000	4.9
40/68 F-2	4	3444	2	.0006	116.5
40/68 F-3	4	78	1	.0128	4.3
41/66 A-1	4	1038	84	.0809	66.1
41/66 A-6	5	231	1	.0043	31.5
41/66 B-1	4	1378	48	.0348	123.3
41/66 B-5	4	325	18	.0554	21.9
41/66 B-6	4	159	7	.0440	14.2
41/66 C-1	5	111	9	.0811	10.1
41/66 C-2	4	64	1	.0156	5.9
41/66 C-3	4	14	0	.0000	0.5
41/66 C-4	4	1513	67	.0443	139.8
41/66 C-5	4	753	150	.1992	49.0
41/66 D-1	4	14	4	.2857	4.6
41/66 D-2	4	539	60	.1113	31.2
41/66 D-3	4	500	32	.0640	53.2
41/66 D-4	4	1427	198	.1388	134.7
41/66 E-1	5	4207	3492	.8300	280.4
41/66 E-2	4	1294	211	.1631	70.1
41/66 E-3	4	2031	271	.1334	140.6
41/67 E-6	4	205	1	.0049	14.8
41/67 F-6	4	126	1	.0079	9.8
41/68 A-5	4	22	7	.3182	3.7
41/68 A-6	4	353	3	.0085	36.3
41/68 B-5	4	563	0	.0000	19.7
41/68 B-6	5	2294	44	.0192	49.8
41/69 C-3	2	120	3	.0250	13.9
41/69 D-3	2	0	0	—	0.0
41/69 E-4	2	1	0	.0000	0.1
41/69 E-5	1	0	0	—	0.0
41/69 F-5	3	3	0	.0000	0.3
41/69 F-6	4	504	0	.0000	68.8
42/66 A-6	4	3421	685	.2002	783.8
42/66 B-6	4	943	213	.2259	57.6
42/66 C-6	4	647	419	.6476	56.5
42/67 E-6	4	2422	603	.2490	202.1
42/67 F-6	4	5724	986	.1723	382.1
Total	195	54361	7756		

TABLE 1. (continued)

Unit area	No. of tows	Live scallops	Clapper shells	Clapper ratio	Density index
DELAWARE CRUISE 62 - 6, MAY 1962					
40/67 A-1	4	176	1	.0057	12.2
40/67 A-2	4	801	8	.0100	62.8
40/67 B-1	4	305	13	.0426	19.9
40/67 B-2	4	786	3	.0038	56.9
40/67 C-1	9	6029	261	.0433	163.4
40/67 C-2	4	286	21	.0734	21.7
40/67 D-1	9	11797	578	.0490	205.7
40/67 D-2	4	349	11	.0315	27.0
40/67 E-1	9	12878	428	.0332	296.8
40/67 F-1	4	11298	58	.0051	309.0
40/68 A-1	4	429	1	.0023	33.1
40/69 F-1	4	530	9	.0170	44.9
41/66 A-1	4	20	0	.0000	1.8
41/66 B-1	3	1902	62	.0326	144.2
41/66 B-5	3	322	4	.0124	33.3
41/66 C-1	4	1478	46	.0311	111.4
41/66 C-2	4	535	7	.0131	41.5
41/66 C-3	4	211	3	.0142	17.6
41/66 C-4	4	1458	37	.0254	113.1
41/66 C-5	4	797	44	.0552	75.4
41/66 D-1	4	826	83	.1005	73.4
41/66 D-2	4	236	7	.0297	21.5
41/66 D-3	4	1156	24	.0208	85.7
41/66 D-4	4	4220	172	.0408	238.2
41/66 E-1	4	1359	393	.2891	175.5
41/66 E-2	4	706	61	.0864	84.1
41/66 E-3	5	4203	192	.0457	274.6
41/67 E-6	4	113	1	.0088	9.2
41/67 F-6	3	307	2	.0065	28.0
41/68 A-6	4	239	4	.0167	20.4
41/68 B-6	4	107	4	.0374	8.3
42/66 A-6	4	3892	336	.0863	195.8
42/66 B-6	4	2538	268	.1056	153.8
42/66 C-6	5	2631	253	.0962	96.1
42/66 D-6	4	1696	55	.0324	158.4
42/66 E-6	4	2563	219	.0854	180.1
42/66 F-6	4	2000	199	.0995	104.5
Total	162	81179	3868		
DELAWARE CRUISE 62-10, SEPTEMBER 1962					
41/65 A-2	5	642	12	.0187	46.5
41/66 A-1	8	366	22	.0601	24.5
41/66 B-1	6	1929	114	.0591	90.9
41/66 B-4	5	462	6	.0130	43.2
41/66 B-5	6	246	5	.0203	22.2
41/66 C-1	6	1254	68	.0542	95.1
41/66 C-2	5	650	22	.0338	44.1
41/66 C-3	7	557	8	.0144	25.5
41/66 C-4	6	2551	88	.0345	137.4
41/66 C-5	6	1254	34	.0271	81.2
41/66 D-1	5	1382	118	.0854	96.8
41/66 D-2	5	668	9	.0135	42.0

TABLE 1. (continued)

Unit area	No. of tows	Live scallops	Clapper shells	Clapper ratio	Density index
DELAWARE CRUISE 62-10, SEPTEMBER 1962 (Continued)					
41/66 D-3	7	1409	23	.0163	58.4
41/66 D-4	6	14112	460	.0326	392.8
41/66 D-5	6	3224	185	.0574	102.9
41/66 E-1	6	2904	1258	.4332	213.2
41/66 E-2	6	1215	23	.0189	58.2
41/66 E-3	6	6052	150	.0248	163.2
41/66 F-1	6	1947	259	.1330	75.5
41/66 F-2	6	2621	417	.1591	147.3
41/66 F-3	6	2577	64	.0248	92.7
41/67 F-1	4	112	9	.0804	12.3
42/66 A-6	5	1992	302	.1516	90.8
42/66 B-6	6	1659	155	.0934	114.1
42/66 C-6	6	1291	275	.2130	72.2
42/66 D-6	6	1524	300	.1969	66.3
42/67 D-6	7	2711	157	.0579	108.9
42/67 E-6	5	1881	221	.1175	85.4
42/67 F-6	7	1670	180	.1078	100.2
Total	171	60862	4944		
ALBATROSS IV CRUISE 63-1, MAY 1963					
40/67 A-2	6	940	68	.0723	47.7
40/67 B-1	6	515	44	.0854	22.9
40/67 B-2	6	583	22	.0377	31.2
40/67 C-1	6	713	74	.1038	37.1
40/67 C-2	6	409	90	.2200	19.1
40/67 D-1	6	1836	206	.1122	110.2
40/67 E-1	6	1525	234	.1534	91.9
40/67 F-1	6	4422	553	.1251	224.8
40/68 F-2	6	786	49	.0623	35.9
Total	54	11729	1340		
ALBATROSS IV CRUISE 63-3, JUNE 1963					
40/68 A-1	6	630	6	.0095	23.7
40/68 A-4	6	416	15	.0361	20.0
40/68 B-3	6	250	5	.0200	15.1
40/68 C-3	6	414	1	.0024	19.6
40/69 E-1	6	161	0	.0000	7.8
40/69 E-2	6	311	5	.0161	12.8
40/69 F-1	6	941	5	.0053	37.7
40/69 F-2	6	449	1	.0022	24.3
40/69 F-3	6	197	4	.0203	8.8
41/68 A-6	6	321	2	.0062	25.6
41/68 B-5	7	276	1	.0036	11.4
41/68 B-6	5	275	2	.0073	14.3
41/68 C-6	6	596	145	.2433	28.9
41/69 E-5	5	219	4	.0183	23.0
41/69 F-5	6	474	9	.0190	24.9
41/69 F-6	5	633	2	.0032	53.4
Total	94	6563	207		

TABLE 2. Average size at time of formation of the annual rings for the live sea scallops collected in August 1961 from unit area 42/66 B - 6

Ring no.	Average size	Measurements
	mm	*no.*
1	20.2	481
2	47.0	502
3	74.6	504
4	95.7	478
5	109.8	172
6	119.6	123
7	126.5	101
8	132.0	62
9	137.3	28
10	142.2	6
11	148.4	1
12	149.8	1

TABLE 3. Clappers arranged by year classes to show how many died each month.

Month clapper died	Year Class 59	58	57	56	55	54	53	52	51	50	Total
August 1961			1	1							2
July		2	6	1		4	4				17
June		1	11	3	5	4	1				25
May	1	2	12	4		4	1	1			25
April		2	12	4	4	4		1			27
March	1	3	15	4	2	5	3	3	1		37
February		5	15	5	5	1	1				32
January			23	3	5	4	1	1			37
December 1960		1	10	3	5	7	1	1			28
November		2	17	7	10	4	3				43
October		3	15	9	7	9	9	2	1		55
September	1	2	12	2	4	6	1	1			29
August			5	5	5	4	1	1			21
July			7	2	2	1	3	1			16
June			3	4	5	1	1	2	1		17
May			1	2		1	2				6
April			5	3	3	3	3	3		1	21
March			4	2		2		2			10
February					2	1		1			4
January					1	2	2	2			7
December 1959				1	2	3	1	1			8
November					3		1		1		5
October				1	2		1				4
September					2	1	1				4
Total	3	23	174	66	74	71	41	23	4	1	480

TABLE 4. Modal lengths of live and clapper shells in samples with high clapper ratios. The last column gives the average number of weeks required for a sea scallop to grow from the length at the clapper mode to the length at the live mode

Unit area	Date	Clappers	Live	Time
		mm	*mm*	*wks*
41/66 E-2	May 1960	93.0	107.4	48
41/66 D-3	May 1960	102.1	107.4	20
42/66 A-6	May 1960	92.2	97.9	17
42/66 B-6	May 1960	97.6	107.8	37
42/67 F-6	May 1960	102.3	106.6	17
41/66 D-3	May 1961	102.9	112.6	42
41/66 E-2	May 1961	102.6	112.7	44
42/66 A-6	May 1961	97.7	106.7	32
42/67 E-6	May 1961	108.3	118.2	43
42/67 F-6	May 1961	101.9	107.0	20
41/66 D-1	May 1962	117.5	122.6	32
41/66 E-1	May 1962	93.4	112.8	69
42/66 B-6	May 1962	117.6	126.8	66

TABLE 5. Summary of average clapper ratios by Area Group and year

Area group	1958	1959	1960	1961	1962	1963	Average	Factor
1	.0087	.0158	.0037	.0287	.0184	.0318	.0178	14
2	—	.0024	.0045	.0017	.0298	.0851	.0247	31
3	.0102	.0757	.1895	.1616	.0727	—	.1019	55

NOTES

Adult Redfish in the Open Ocean

(Interim Report on Fishing Trials at Ocean Weather Station 'A').

The Continuous Plankton Recorder survey has been operated over large areas of the central North Atlantic from 1955 onwards, and has been progressively extended further to the west in recent years (Glover, 1962, Fig. 6). The sampling, at the standard depth of 10 m, and at monthly intervals as far as possible, now covers a large area of the North Atlantic between the United Kingdom and Iceland, Greenland and Newfoundland. The work is supported by a grant from H. M. Treasury through the Development Fund, and by Contracts N62558-2834 and 3612 between the Office of Naval Research, Department of the United States Navy, and the Scottish Marine Biological Association.

The survey has shown the presence of large numbers of young redfish in the open ocean in the region south of Iceland and over the Reykjanes and mid-Atlantic Ridges, in the months April to July of every year. Details of the distributions of these young stages have been given by Henderson (1961, 1962) and a general outline of the extent of the distribution in May, the month of greatest abundance, is shown in Fig. 1, based on the material available from 1956-1962.

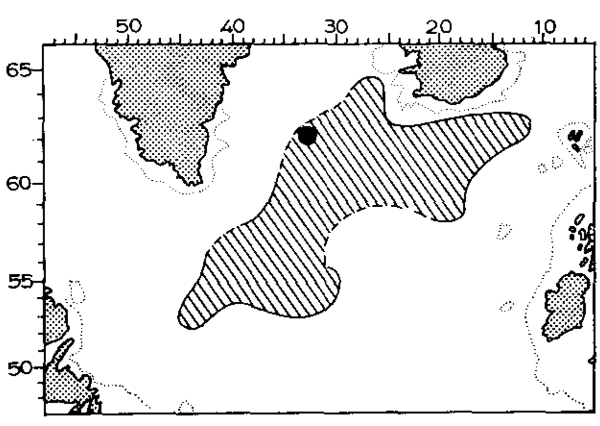

Fig. 1. The distribution of young *Sebastes* in the areas south of Iceland and over the Reykjanes and mid-Atlantic Ridges in May, based on sampling with Plankton Recorders during the years 1956-1962. Broken lines indicate regions in which the sampling was insufficient to determine the precise boundary of distribution.
The black circle shows the position of Ocean Weather Station 'A'.

The young stages found in this large oceanic area have been considered, in the light of the descriptions available, to be those of the large redfish, *Sebastes marinus* L., distinguished from the other viviparous *Sebastes* species by the absence of isolated melanophores below the root of the primordial caudal fin (Tåning, 1961 and Templeman and Sandeman, 1959). Doubts as to the reliability of this identification are growing, however, (Kotthaus, 1961, Raitt, 1962, and Graham, 1962) and it was evident that much more directly related information about parents and young was required. This oceanic stock is not fished commercially and it was, therefore, with special interest that a report from the Master of the Dutch weather ship *Cumulus* was received. He stated that 'plenty of redfish' (since ascertained to number about 400) were caught with rod and line while his vessel was on duty at Ocean Weather Station 'A' in 62°N. Lat., 33°W. Long. (Fig. 1) in May and June 1961. This seemed to offer an opportunity of sampling the adult stock in an area where the young stages were usually present from April to July and were nearly always very abundant in May (Henderson, 1961, Fig. 3).

Experimental fishing trials were carried out, with the help of British and Dutch weather ships occupying this station, from April to September, 1962. The objectives were: (a) to catch 'spawning' redfish; and (b) to obtain as much information as possible about the adult stock *in this area* from specimens preserved in formalin and returned to the laboratory. The trials were originally planned to cover the period April to early June, when extrusion of young occurs, but eventually they were continued until early September, well after the last of the young stages had been taken in Recorder samples. The limited results from these fishing trials in 1962 indicated the possibility that the presence of adult redfish was not restricted to the 'spawning' period, but that they might be present over a much greater part of the year. Further, no 'spawning' redfish had been caught, a finding in complete agreement with the statement by Kotthaus (1961) that "...all trials to catch adult (*spawning*) redfish in the open ocean by long line or floating trawls failed in the layers down to 450 m ...".

The fishing trials were, therefore, resumed in January, 1963 and, with the cooperation of the British, Dutch, French, and Norwegian weather ships occupying Ocean Weather Station 'A', it is hoped that the sampling will be continuous throughout the year. The ships were supplied with a seafishing rod, a reel and a line fitted with three triple-hooked spinners; they were asked to fish a sequence of depths down to 400 m at least once in each week during the period on station.

TABLE 1. Monthly record of number and overall length of adult redfish caught at Ocean Weather Station 'A'.

Month		Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept./Oct.	Totals
Number of fish caught	1962	P*	—	—	—	0	4	66	30	5	12*	400+
	1963	—	P	9	P	3	60	68	139	25	—	
Number of fish returned	♀	—	5	4	4	0	12	76	46	9	—	
	♂	—	2	1	4	0	1	5	2	1	—	
	Total	—	7	5	8	0	13	81	48	10	—	172
Mean overall length (cm)		—	39.6	38.2	36.1		37.2	37.4	37.6	37.7	—	37.5
Range of overall lengths (cm)		—	32.0—43.0	35.0—40.0	33.0—41.0		35.0—40.0	33.0—43.0	34.0—41.0	35.0—42.0		32.0—43.0

P reported as 'plentiful' or 'hundreds'. * ships fishing on own account — no fishing trial in these months.

Some details of the catches obtained during 1962 and 1963 are given in Table 1. Considerably more than 400 fish have been caught during the period of these trials although the exact figure cannot be determined as estimated numbers have been given in some reports.

Although the fishing lines were marked, the precise depth of capture may not always have been satisfactorily determined, due to drifting of the ship and the resulting variation in the angle of the line. However, from the available information, it seems most probable that the fish are not found above 200 m during the early part of the year, but in the summer months and also in December they may occur between 50 and 200 m. On the occasions when large numbers have been caught the depth of capture has generally been between 100 and 150 m.

The fact that a number of fish may be caught very easily by rod and line in a short time suggests that considerable aggregations must occur in this area at certain periods. Three examples of such catches are: 24 fish in 3 hours (May 1963), 21 fish in 3 hours (June 1963) and 40 fish in 13 hours (July 1963). In December 1962, the captain of the Norwegian weather ship *Polarfront II* reported that as many as seven fish were brought up on one cast.

A total of 172 specimens, preserved in formalin, has so far been returned to the Oceanographic Laboratory by the weather ships and all of these conform to the published criteria for *Sebastes mentella* Travin. Only 16 of the fish were males and in only one month (March 1963) was the sex ratio 1:1. Practically all the females have shown evidence of past spawning, or have had ovaries in various stages of ripening. In one specimen caught in late March 1963 it was observed that approximately one-third of the larvae had hatched. A very high proportion of the females caught in the period May-July, both in 1962 and 1963, had retained some larvae within the ovaries and oviducts. Many were found in perfect condition and all those so far examined were without sub-caudal melanophores; they are identical with the larvae sampled by the Plankton Recorder which have been considered to be *S. marinus*. This is a somewhat unexpected finding in the light of the results presented by Templeman and Sandeman (1959) for pre-extrusion larvae of *S. marinus* and *S. mentella*. They found that sub-caudal melanophores were absent in 76% of larvae from *S. marinus* parents, and when present were usually single; whereas these melanophores were absent in only 2.3% of larvae from *S. mentella* parents, and were usually 2 to 4 in number.

The problem is clearly one of more precise identification of stocks or populations in the oceanic area; to this end the oceanic samples are being subjected to detailed study. A series of measurements selected from those used by Kelly, Barker and Clarke (1961) has been taken from each fish after preservation. Before any final conclusions can be drawn about variation within the stock of redfish at station 'A', the series will have to be completed and analysed statistically. Observations on the present figures show, however, that there is little variation in overall length either throughout the period of the trials or from month to month (Table 1). The weight of individual fish varied from 0.5 to 1.2 kg with a mean of 0.82 kg and with 72.2% falling within the range 0.7 to 0.9 kg.

Work is continuing on other characters which may help in the elucidation of these problems of the biology of different stocks or populations. This includes observations on parasites (*Sphyrion lumpi*, nematodes and cestodes), gut contents, fecundity, maturation, age determination, and body pigmentation.

This account must be regarded as a preliminary statement of the results achieved so far, before the full year's sampling has, in fact, been completed, and it is hoped that material collected by participants in the NORWESTLANT surveys may be available for incorporation in the results.

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