INTERNATIONAL COMMISSION

FOR THE

NORTHWEST ATLANTIC FISHERIES

RESEARCH BULLETIN
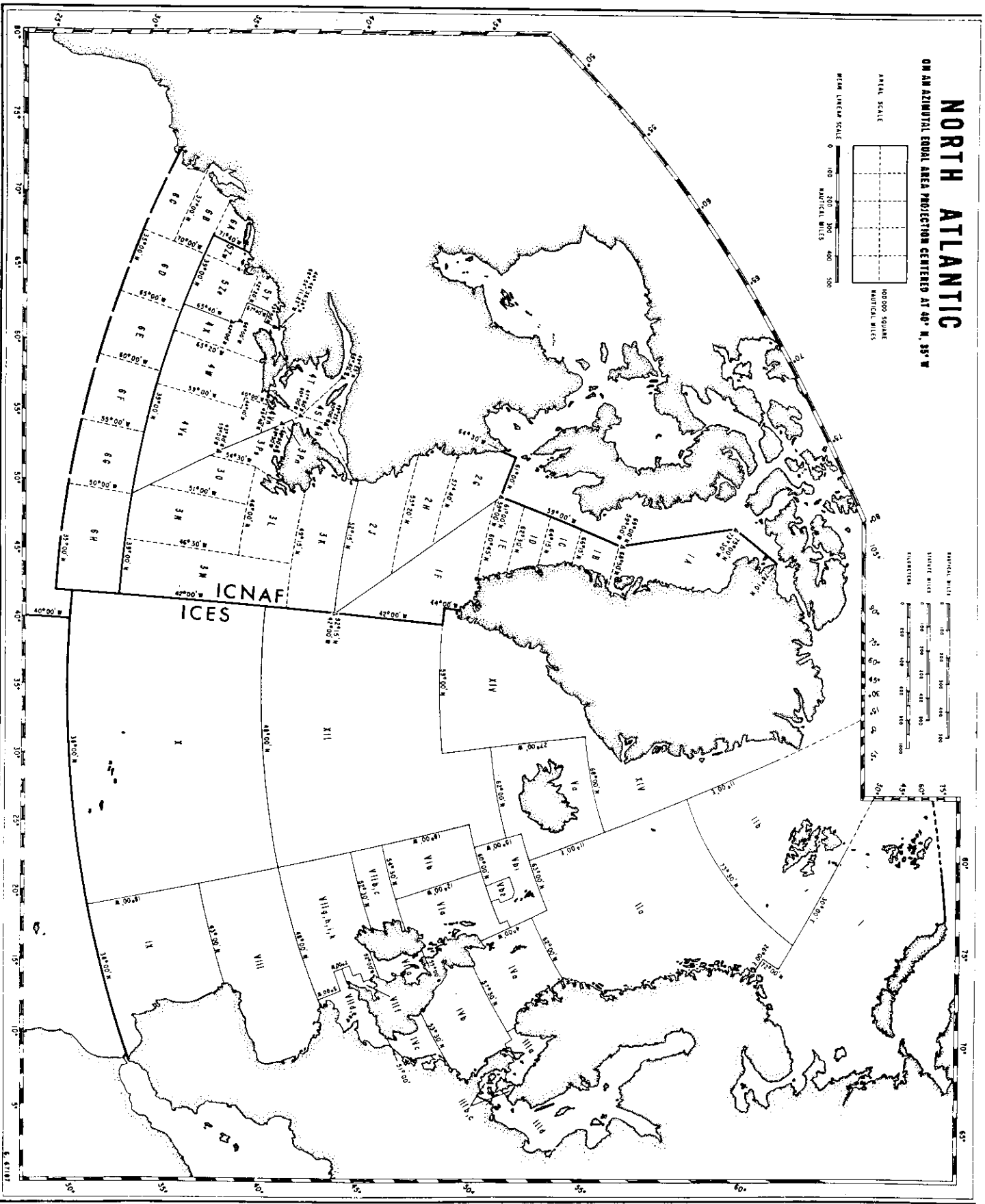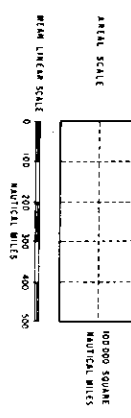
NUMBER 5

NORTH ATLANTIC

ON AN AZIMUTHAL EQUAL AREA PROJECTION CENTERED AT 40° N, 35° W

AREAL SCALE

100 000 SQUARE NAUTICAL MILES

MEAN LINEAR SCALE

0   100   200   300   400   500
NAUTICAL MILES

NAUTICAL MILES
STATUTE MILES
KILOMETRES

ICNAF

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Biology and Fishery of the West Newfoundland Cod Stock

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Abstract

Biology of the West Newfoundland cod stock, based on sampling from 1947 to 1966, is described in relation to changes in fishing. Where practical, Divisions 4R and 4S are considered separately. Catches increased since the early 1950's in Division 4S, but fluctuated irregularly in Division 4R.

Research vessel samples exhibit a decline in relative numbers of old and large fish since the early 1950's. This is also reflected in commercial size and age distributions and in increased estimates of total mortality from the various gears. Average size at age has recently increased, particularly in the older age-groups. These changes in growth could have resulted from a combination of increased fishing and hydrographic warming. Size and age at maturity, weight-length and girth-length relationships are described. Evidence supporting the validity of the otolith method of age determination is presented.

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Introduction

The "West Newfoundland" cod stock is restricted within the geographical boundaries shown in Fig. 1. Distribution varies with the season (Templeman, 1962). Tagging returns (Templeman and Fleming, 1962) and seasonal changes in the cod fisheries of the Quebec North Shore and the west and southwest coasts of Newfoundland indicate that in summer distribution is mainly in the northern and northeastern Gulf of St. Lawrence, but in winter and early spring is predominantly around southwestern Newfoundland (Templeman, 1962). In summer, the western Newfoundland and Quebec North Shore-Anticosti fish are to some extent separated by the Esquiman Channel into at least two populations, but these intermingle while wintering off south-western Newfoundland (Templeman, 1962). Cod along the northern shore of the Strait of Belle Isle form part of the West Newfoundland stock and are little mixed with cod from the more northerly Labrador coast. Although the range of movements of Straits cod into the northern and northeastern Gulf of St. Lawrence is incompletely known, it is likely that most of the Straits population winters off southwestern Newfoundland.

This study presents data relating to the biology of cod in the northeastern Gulf from collections made by the St. John's Biological Station of the Fisheries Research Board of Canada during 1947–66. Recent trends in the fishery are analyzed in detail and related to changes in age, size composition, growth, and mortality of the stock.
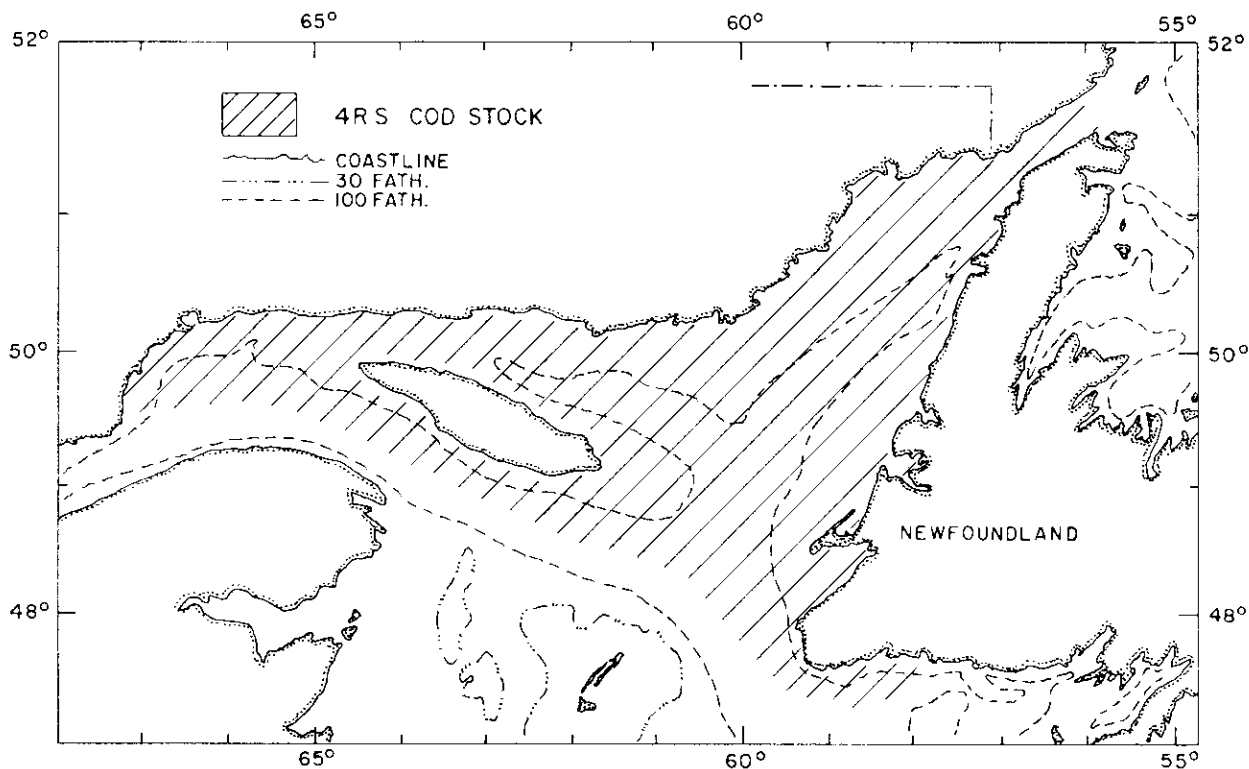

Fig. 1. Distribution of the West Newfoundland cod stock (adapted from Templeman, 1962).

The Fishery

Introduction

The extensive migrations in this area support a winter to early spring fishery off southwestern Newfoundland (Division 3Pn) and a summer fishery along the Newfoundland west coast (Division 4R), northern shore of the Strait of Belle Isle (Division 4R) and the Quebec North Shore (Division 4S). In summer, the partially separated populations are in essence confined to Div. 4R and 4S, lying to the east and west of the Esquiman Channel respectively. The summer fisheries based on these two populations are thus best treated separately and in relation to statistics for Div. 4R and 4S. The offshore and inshore fisheries are also considered separately.

The cod fisheries along the west coast of Newfoundland, the Quebec North Shore, and the northern shore Strait of Belle Isle were traditionally based on inshore gears and, to a lesser extent, offshore line fishing from Canadian dory vessels on parts of the Quebec North Shore. However, in Div. 4R and 4S annual catches by inshore boats (less than 25 tons) have tended to decline in recent years and the dory vessels ceased operations in 1959. Whereas the Quebec North Shore and Strait of Belle Isle are traditionally cod fishing regions, on the Newfoundland west coast lobsters are of more importance and many fishermen begin fishing for cod only at the end of the lobster season. Thus the northeastern Gulf of St. Lawrence is not generally regarded as a good cod fishing area and despite recent increases in otter trawl fishing, catches have not been large in comparison to those in most other ICNAF Divisions around Newfoundland.

The earliest otter trawl exploitation of cod was probably by France and Portugal in 1954, and since that time France, and to a lesser extent Portugal and Spain, have fished for cod more or less regularly. Catches by these countries have gradually increased since 1954 and accounted for about half the cod landed in Div. 4R and 4S during this period. It is difficult to estimate the extent to which increased otter trawl catches of cod in Div. 4RS are due to the redfish fishery which has expanded dramatically in the area since 1954 (Templeman, 1959), but it is probable that almost all effort by Canada, USA, and Newfoundland was directed towards redfish rather than cod.

Trends in landings 1953-65

Statistics for Div. 3Pn are available only since 1959. Landings rose from 7,000 tons in 1959 to a peak of 38,000 tons in 1961, declining to 17,000 tons in 1965. The fishery depends mainly on the winter and early spring concentrations. Because of the short data series and present uncertainty as to the degree of mixing of West Newfoundland and Burgeo Bank (Div. 3Ps) stocks (Templeman, 1962), no detailed analysis of the 3Pn fishery is presented here.

The total and trawler cod landings, in metric tons round fresh weight for 1953-65, are given by countries for Divisions 4R and 4S in Table 1. Offshore catches of all countries were taken by otter trawlers, except for very small amounts taken by Portuguese and Spanish dory vessels using line gears, and some caught by Canadian dory vessels during 1953–59. These dory vessel landings were combined in Fig. 2 which shows the percentage contribution to the total cod landings of the major gear components during two periods, 1953–59 and 1960–65.

Division 4R. From 1953 to 1965 total cod landings fluctuated irregularly around a mean of about 50,000 tons (Fig. 5). Annual variations in catches were largely due to fluctuations in otter trawl catches (Table 1). These reflected varying otter trawl effort, particularly by France and Portugal (see below).

The mean annual catch by otter trawlers for 1953–65 was about 25,000 tons and during this time otter trawlers accounted for, on the average, about half of the total catches of cod in Div. 4R. Most of the trawl caught cod was taken by France and Portugal, with small amounts by Spain and Canada (Mainland). Offshore catches by other countries were very small. Almost all the remaining cod was caught by Newfoundland inshore fishermen (41% of the total during 1953–65). About 1% of the catches were taken by Canadian Danish Seiners fishing for greysole, *Glyptocephalus cynoglossus*, and Portuguese or Spanish dories fishing for cod. Canadian (Mainland) dory vessel catches averaged 7% of the total for 1956–59, but this fishery ceased after 1959.

Since ICNAF statistics were published by Subareas rather than by Divisions prior to 1953, the year in which otter trawling started in Div. 4R is not known with certainty. The different
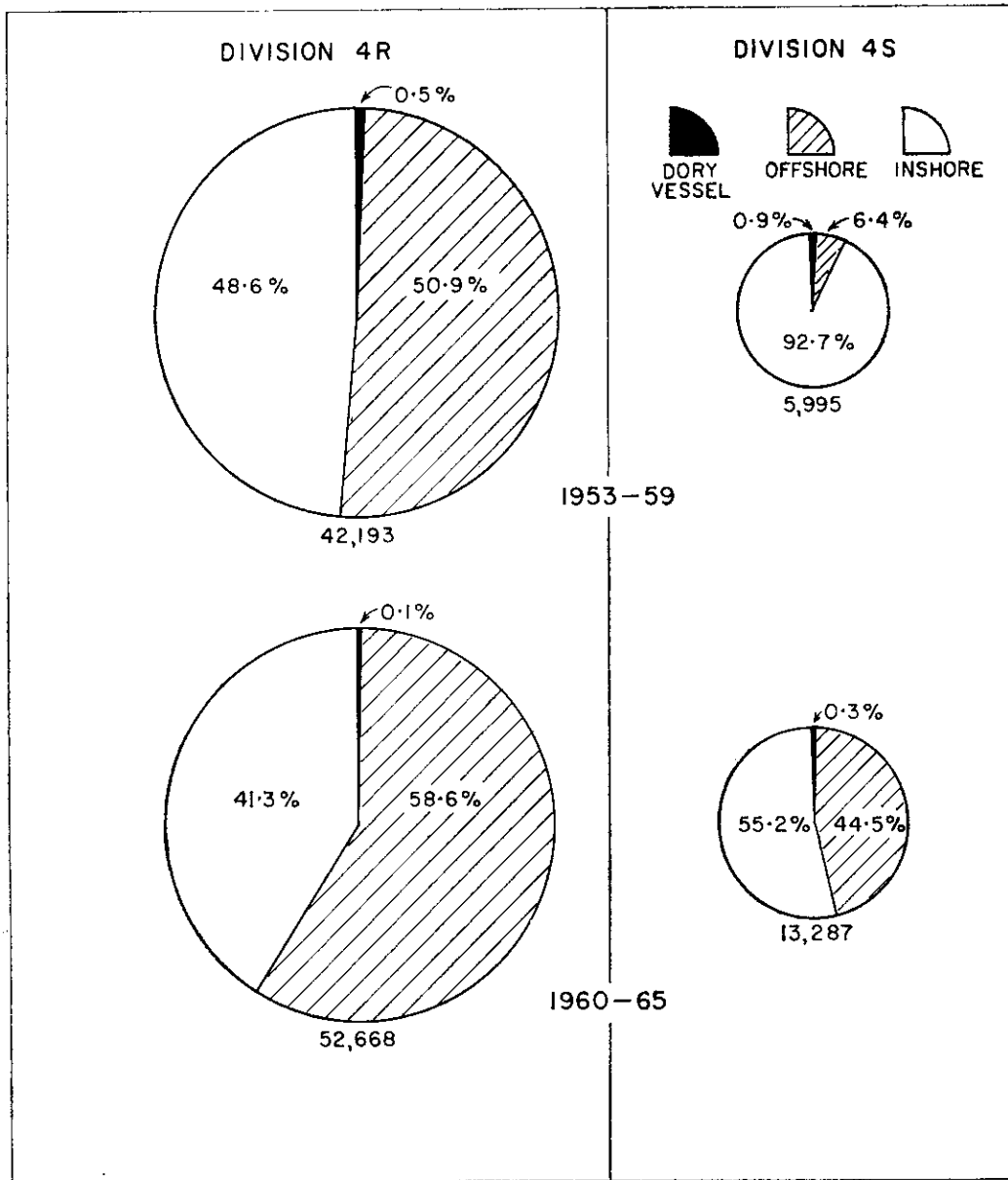
TABLE 1. Cod catches (thousands of tons) for each country by otter trawls and all gears combined, Divisions 4R and 4S, 1953–65 (+ indicates amounts less than 50 tons).

Division	Year	All Gears							Otter Trawl						
		Canada (N)	Canada (M)	Portugal	Spain	France	Other	Total	Canada (N)	Canada (M)	Portugal	Spain	France	Other	Total
4R	1953	17.3	+	—	—	—	—	17.4	+	+	—	—	—	—	+
	1954	16.0	0.6	1.6	—	14.0	+	32.2	+	0.1	1.6	—	14.0	+	15.8
	1955	15.6	0.3	9.6	+	20.6	+	46.2	+	0.2	9.6	+	20.6	+	30.6
	1956	15.6	4.1	8.7	+	10.6	+	39.1	0.3	1.0	8.7	+	10.6	+	20.7
	1957	25.1	2.0	7.3	—	13.5	+	47.9	0.1	1.2	7.3	—	13.5	+	22.1
	1958	18.8	7.1	15.3	0.3	30.0	—	71.5	0.6	2.4	15.3	0.3	30.0	—	48.7
	1959	26.1	7.2	0.2	0.4	7.1	—	40.9	0.2	4.6	0.1	0.4	7.1	—	12.4
	1960	17.3	5.9	13.4	7.3	22.0	0.6	66.6	0.2	5.8	13.4	7.3	22.0	0.6	49.3
	1961	15.7	2.9	7.6	2.4	18.7	—	47.3	0.1	2.7	7.3	2.4	18.7	—	31.2
	1962	22.0	3.5	10.1	5.5	7.0	—	48.1	0.5	—	10.1	5.5	7.0	—	23.1
	1963	26.8	3.0	7.9	3.0	1.6	—	42.4	0.1	—	7.9	3.0	1.6	—	12.7
	1964	20.2	3.2	12.5	6.8	16.3	+	59.0	1.2	—	12.5	6.8	16.3	—	36.8
	1965	20.0	1.7	11.7	0.2	10.1	0.1	43.8	3.2	1.6	11.7	0.2	10.1	—	26.8
4S	1953	—	7.2	—	—	—	—	7.2	—	—	—	—	—	—	—
	1954	—	2.9	—	—	—	—	2.9	—	+	—	—	—	—	+
	1955	+	4.5	0.7	—	+	—	5.2	+	0.1	0.7	—	+	—	0.8
	1956	+	2.3	—	—	0.3	—	2.6	+	0.1	—	—	0.3	—	0.5
	1957	+	5.4	0.1	—	0.3	—	5.8	+	0.2	0.1	—	0.3	—	0.6
	1958	0.2	7.6	+	—	+	—	7.8	0.2	0.4	+	—	+	—	0.6
	1959	+	10.2	—	0.1	+	—	10.4	+	0.4	—	0.1	+	—	0.6
	1960	—	16.1	—	0.4	+	—	16.5	+	8.9	—	0.4	+	—	9.3
	1961	+	13.8	0.1	0.1	0.5	—	14.4	+	6.6	0.1	0.1	0.5	—	7.2
	1962	—	13.2	—	—	—	—	13.2	—	4.3	—	—	—	—	4.3
	1963	+	11.8	0.4	—	+	—	12.2	+	4.6	0.4	—	+	—	5.0
	1964	+	10.1	+	—	+	—	10.1	+	3.4	+	—	+	—	3.5
	1965	0.1	7.3	1.0	—	—	—	8.4	+	3.0	1.0	—	—	—	4.0

Fig. 2.   Average percentage composition of cod catches by gear components in Divisions 4R and 4S during 1953–59 and 1960–65.   The average annual catch in metric tons during each period is given below the circles.

fishing countries probably did not instigate otter trawling at exactly the same time, but before 1953 catches were negligible. The available data show that cod were taken on redfish trips by Canada (Mainland) and Newfoundland in 1953, on cod trips by Portugal and France in 1954, and on cod trips by Spain in 1955.

Division 4S. Total catches of cod in Div. 4S have remained at a low level relative to catches in Div. 4R (Table 1). From 1953 to 1958 total catches varied around a mean annual level of 5,300 tons. During 1959–65 catches were somewhat higher than previously and averaged 12,800 tons annually. The highest yearly catch was

taken in 1960 (16,500 tons), but catches subsequently declined to 8,400 tons in 1965.

Catches by the different countries fishing in Div. 4S are given in Table 1. From 1953 to 1965 Canada (Mainland) accounted for 96% of the total catch. The remaining amount was shared by Portugal, France, Spain, and Newfoundland. About 57% of the Portuguese catches were taken by otter trawl and the remainder by dory vessels, whereas 95% of the Spanish catches and all of the French catches were taken by otter trawlers. Roughly 70% of Newfoundland catches in Div. 4S were by otter trawl, the remainder being caught by small longliners. For Canada (Mainland) 74% was caught by inshore Quebec fishermen and 26% by trawlers.

Catches by otter trawlers were negligible before 1955 and from 1955 to 1959 averaged only 580 tons per annum. In 1960 a peak catch of 9,300 tons was made but since then catches have levelled off to about 4,000 tons annually.

Otter trawl fishing in Div. 4S apparently started in 1954 when 36 tons were caught by Canadian vessels. European catches were first reported in 1955 but the fishery has operated at a very low level (Table 1). Canadian otter trawl catches (Maritimes, Quebec, and Newfoundland), which commenced in 1954, remained steady around 235 tons per annum until 1960 when a relatively high catch of about 8,900 tons was made. Since 1960 however, catches have gradually declined and were around 3,000 tons in 1965. As in Div. 4R, the extent to which offshore cod catches have been incidental to redfish catches is not precisely known, particularly during the 1950's, but it is likely that at least up to 1960 offshore effort was concerned primarily with redfish. The available evidence in ICNAF Statistical Bulletins suggests that, since 1960, only 25% of trips made by Canada (Mainland) were primarily for cod.
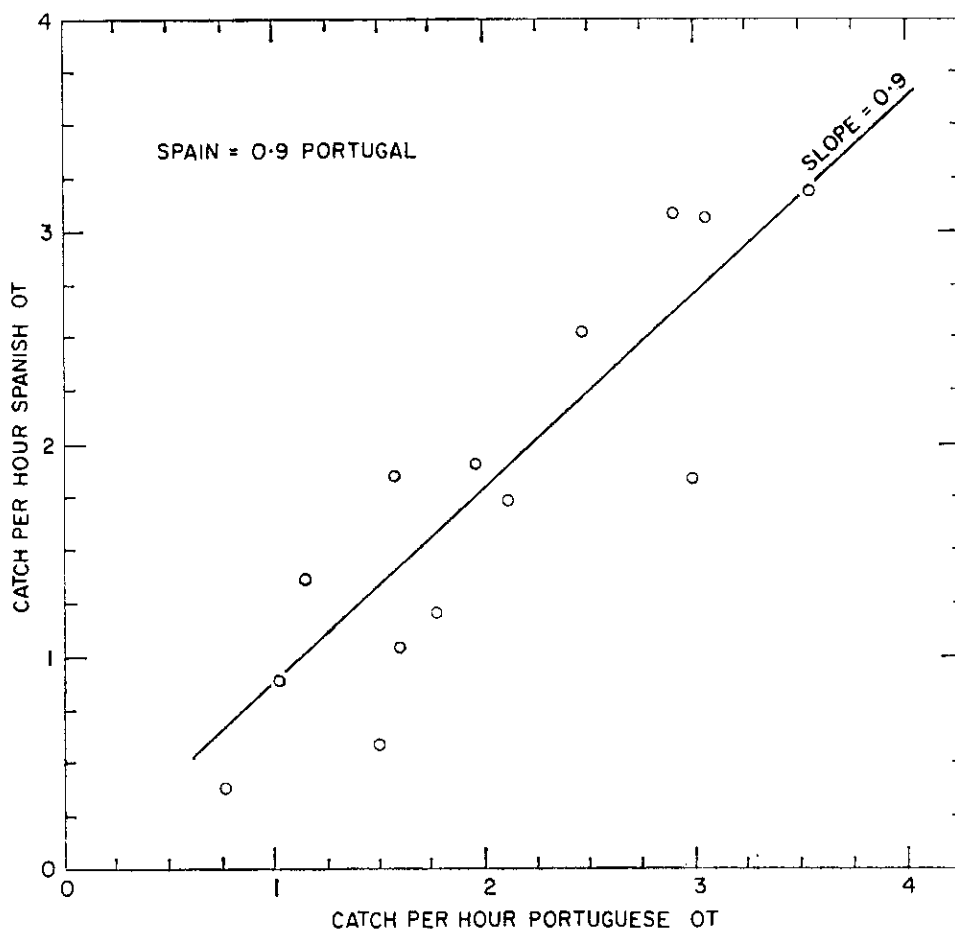

Fig. 3.   Relation of cod catches per hour fished (averaged on a semi-annual basis) by Spanish otter trawlers and the corresponding catches per hour of Portuguese otter trawlers in Division 4R, 1954–65.

Trends in otter-trawl effort and catch per effort

When considering changes in catches in a fishery it is necessary to distinguish the effects of changes in the amounts of effort from effects of changes in catch per unit effort. In this paper the methods used to analyze trends in effort and catch per unit effort (C/E) are similar to those used by Hodder (1965).

Among the different nations reporting effort in hours fished, Portugal fished most consistently and most heavily during 1954–65. Hence the Portuguese otter trawler hour was selected as the standard unit of effort. In a few half-yearly periods no Portuguese effort was expended and to fill these gaps catch and effort data for Spanish trawlers were used after conversion of Spanish effort to the standard Portuguese otter trawler hour. For Division 4R, this conversion was effected by comparing graphically half-yearly

values of C/E for Spain with corresponding half-yearly values for Portugal. A line fitted by eye to the data points, and passing through the origin, gave a slope of 0.9 (Fig. 3). In Div. 4S there were so few Spanish data that these were simply combined with corresponding Portuguese half-yearly catch and effort data. In Div. 4R and 4S there were no catches by Portugal or Spain in a few half-yearly periods. Since Canada (Mainland) had catches in these periods, these effort data were used after conversion to the standard Portuguese hour for the appropriate half-yearly periods. The conversion factors were calculated by comparing Canadian catch per unit effort values with Portuguese-Spanish values in those periods when catches were made by all three countries (Fig. 4). The slope of the line was 0.1 in 4R and 0.08 in 4S. Trawl catches and effort for Spain, Portugal, and Canada (Mainland) were next combined for Div. 4R after adjusting Spanish effort by 0.9 and Canadian effort
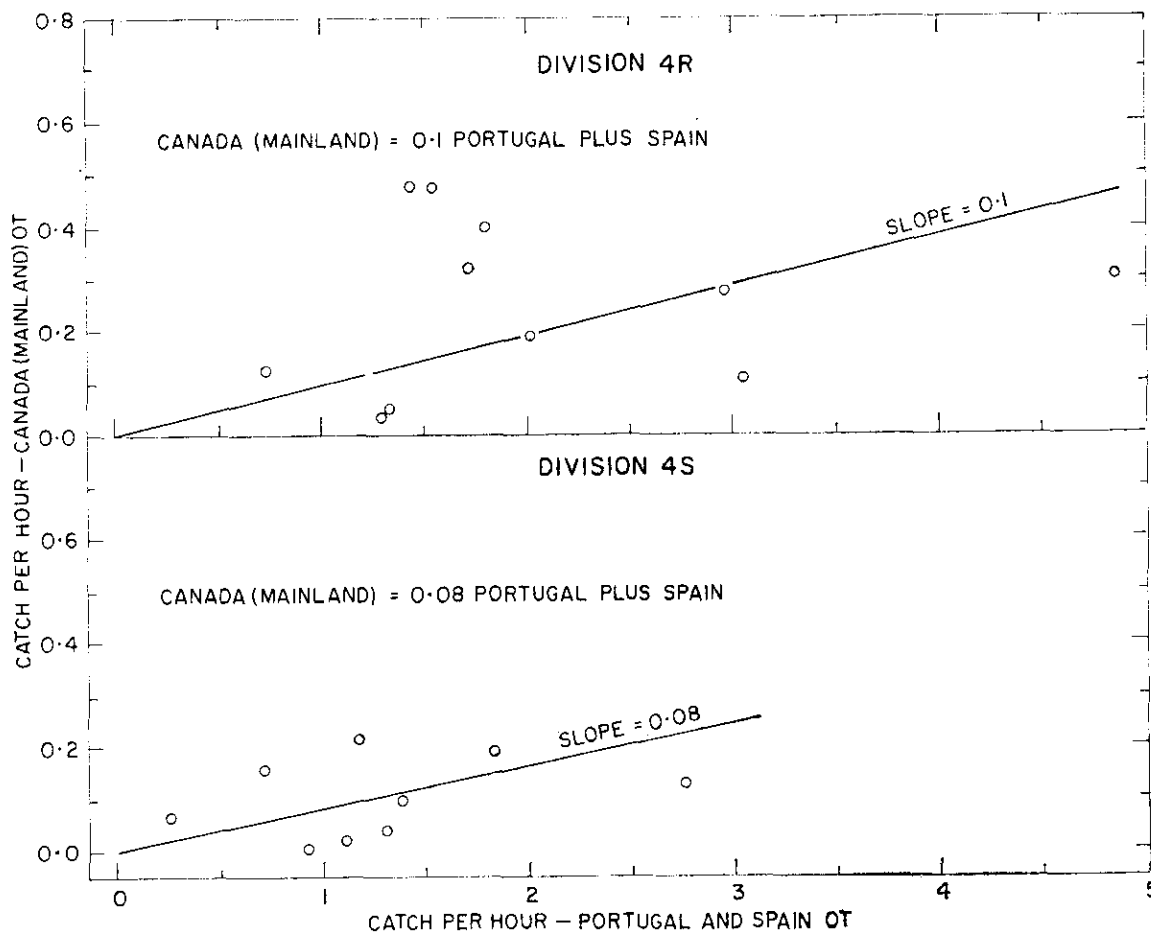

Fig. 4.   Relation of cod catches per hour fished (averaged on a semi-annual basis) by Canadian (Mainland) otter trawlers and the corresponding catches per hour of Portuguese and Spanish otter trawlers in Divisions 4R and 4S, 1954–65.
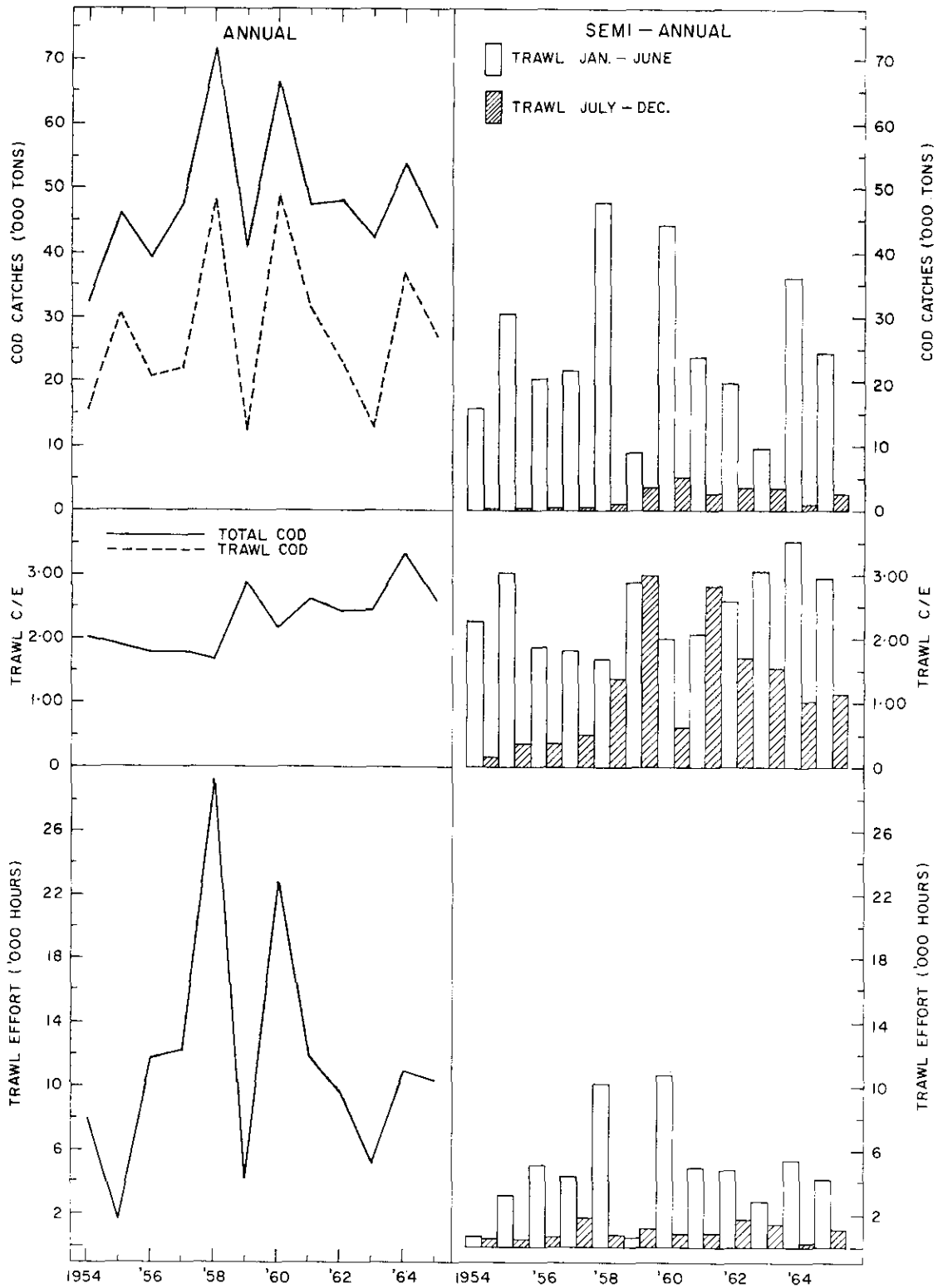
Fig. 5.   Trends in catches, effort and catches per unit effort by trawlers in Division 4R, annually and semi-annually, 1954–65.

by 0.1; in Div. 4S, Spanish effort was used without conversion but Canadian effort was adjusted by 0.08. The average standard catch per hour (C/E) in each half-yearly period from 1954 to 1965 was then calculated by dividing the combined catches of Spain, Portugal, and Canada by the adjusted effort. Effort for cod by **all** trawlers in each period was derived by dividing the total semi-annual trawler catches by the standard C/E value for that 6-month period.

Division 4R. Total cod catches from 1954 to 1965 fluctuated irregularly on an annual basis from a low of 17,000 tons in 1953 to a record high of 72,000 tons in 1958 (Fig. 5). The variations were largely due to changes in both otter trawl catches, which were at a low of 45 tons in 1953 and reached peaks at 49,000 tons in 1958 and 1960, and otter trawl effort which was only 8,000 hr in 1953 but reached high levels of 29,000 and 23,000 hr in 1958 and 1960 respectively. Catch per hour declined from 2 tons in 1954 to 1.7

tons in 1958 but increased during 1959–65 to an average of 2.5 tons.

On a semi-annual basis (Fig. 5), most of the cod were caught in the first half of the years 1954 - 65. For 1954–58 C/E values for January–June declined from 2.3 to 1.7 tons per hour but from 1959 to 1965 rose to about 3 tons. On the other hand, in the second half of these years, 1954–58 C/E values increased from 0.1 to 1.4 tons but during 1959–65 declined from about 2.5 tons in 1959–61 to about 1 ton in 1964–65. Trawler effort remained relatively stable in both semi-annual periods, with isolated increases during January–June of 1958, 1960, and 1964 producing increased catches in the first halves of these years.

Division 4S. Total catches of cod rose steadily from about 3,000 tons in 1954 to 10,000 tons in 1959 mostly as a result of increasing catches in the inshore cod fishery (Fig. 6). In 1960, relatively high otter trawler catches of about 9,000 tons contributed largely to a high total
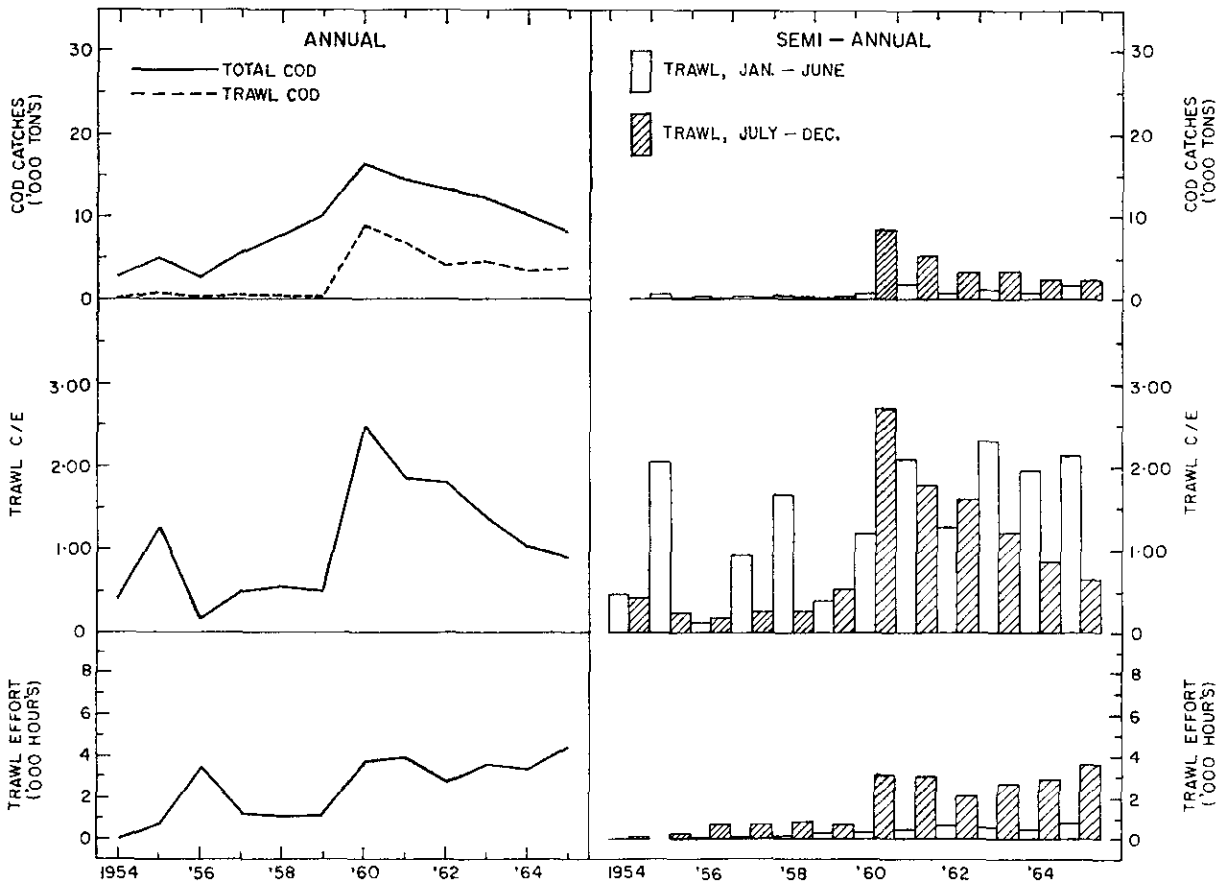

Fig. 6.   Trends in catches, effort and catches per unit effort by trawlers in Division 4S, annually and semi-annually, 1954–65.

catch of 16,500 tons. During 1961–65 a decline in total catches occurred, due to decreases in both inshore and trawler catches. However, since trawler effort steadily increased during 1956–65 from less than 1,000 hr in 1954–55 to 4,500 hr in 1965, the standard trawler C/E increased from 1954 to 1960 but declined from 1960 to 1965.

Most trawler effort was expended from July to December resulting in larger catches for this half of each year. Variations in annual C/E values were thus mainly due to semi-annual fluctuations in catches per hour during the second half of each year. Values of semi-annual C/E for this period rose from 0.25 to 0.5 tons per hour during 1954–59, reached a peak of 2.7 tons in 1960 and gradually declined to about 0.6 tons by 1965. Changes in C/E for the first halves of the years 1954–65 were irregular, with isolated high values in 1955 and 1958, but they remained relatively high after 1960.

The inshore fisheries

In Div. 4R, the inshore cod fishery is carried on exclusively by Newfoundland fishermen, and in Div. 4S by Quebec fishermen. In both areas a variety of gear is used including cod traps, jiggers, handlines, longlines, and gillnets, so that an estimate of effort in terms of the amounts of gear used is very difficult to obtain. The best available indicator of relative annual effort is the number of inshore cod fishermen. In Newfoundland, at least, changes in numbers of men does not necessarily result in corresponding changes in total fishing effort in terms of amounts of gear used (Templeman, 1966) but even so such data are of value in indicating trends if a sufficient number of years are considered. In Newfoundland, the Canada Department of Fisheries has obtained estimates of numbers of inshore cod fishermen (on boats of 25 tons or less), by settlement, for a number of years. For Quebec, numbers of inshore groundfish fishermen are available annually by district in the Dominion Bureau of Statistics, Industry Division publication "Fisheries Statistics-Quebec". The Quebec "groundfish" fishermen fish essentially for cod in those districts within Div. 4S (Bérubé, personal communication), and landings of species other than cod are relatively small.

Division 4R. The trends in catch, number of men and catch per man for the inshore cod fishery in Div. 4R (1956–65) and Div. 4S (1953–64) are shown in Fig. 7. In Div. 4R, catches were relatively steady, averaging around 20,000 tons per annum with a minimum of 15,000 tons in 1956 and 1961 and a maximum of 26,000–27,000 tons in 1959 and 1963. The number of men increased from 1,512 in 1956 to 2,810 in 1965. Since inshore catches did not generally increase, catch per man declined from 10.1 tons per man in 1956 to 5.9 tons in 1965.

Division 4S. Inshore cod landings fluctuated irregularly in Div. 4S during 1953–64 averaging 6,300 tons per annum. There was a decline of about 2.8% per annum in the number of fishermen, which resulted in the loss of about 300 men from 1953 to 1964. Thus catch per man has tended to vary erratically with a period of decline from 1953 to 1956, followed by an increase from 1956 to 1961 and a decline from 1961 to 1964. The recent decline in C/E is a marked one, since annual values fell from about 13 tons per man in 1961 to 7.3 tons in 1964.

Standardization of total effort

In order to analyze the data for Div. 4R and 4S with a view to assessing the combined effort of the major gears, it was necessary to combine catch and effort data for trawlers of the different countries with that from the inshore fishery. This was done by first graphically comparing annual values of catch per man with the corresponding standard C/E for all trawlers as calculated previously (Fig. 5 and 6). Lines fitted to the data and passing through the origins gave conversion factors of 3.9 and 6.9 in Div. 4R and 4S respectively (Fig. 8). The effort data (number of fishermen) for the inshore fisheries in each area were then adjusted by the appropriate factor and added to corresponding estimates of effort by trawlers to give an estimate of total effort in standard otter trawler hours for the whole fishery in each division. Figure 9 shows the trends in total cod landings, estimated standardized effort, and resultant standard C/E values, all relative to standard trawler effort units.

In Div. 4R, catches varied irregularly around a mean level of about 51,000 tons largely as a result of corresponding fluctuations in total effort which averaged about 22,500 standard otter trawler hours per year. As a result standard annual C/E values showed no definable trend, averaging 2.3 tons per otter trawler hour.
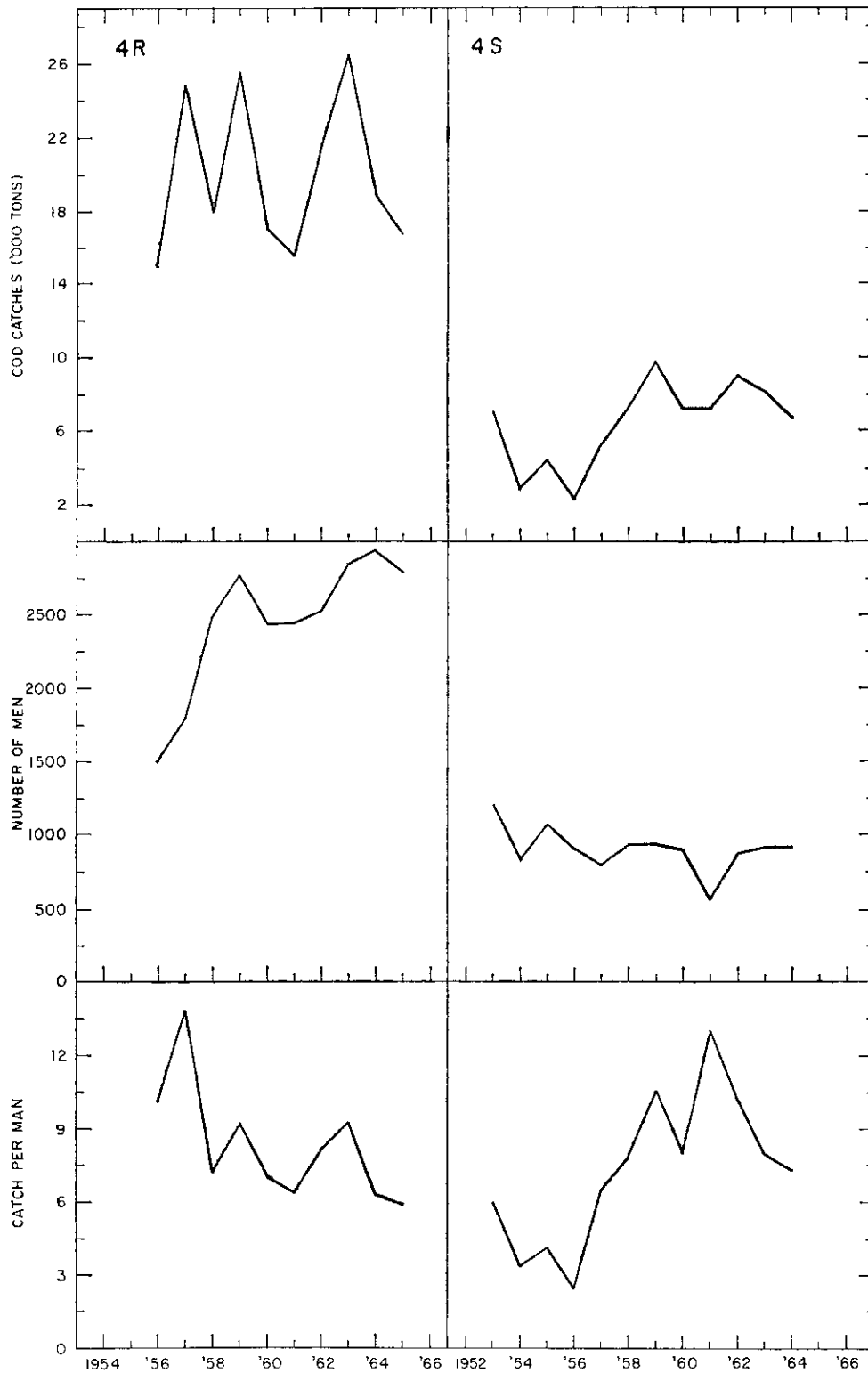
Fig. 7. Trends in catches, effort and catch per man for the inshore cod fishery in Division 4R during 1956–65 and in Division 4S during 1953–64.

Fig. 8.   Relation of annual catch per inshore fisherman and the corresponding catch per
hour (averaged on an annual basis) by all trawlers in Divisions 4R and 4S during
1954–65.

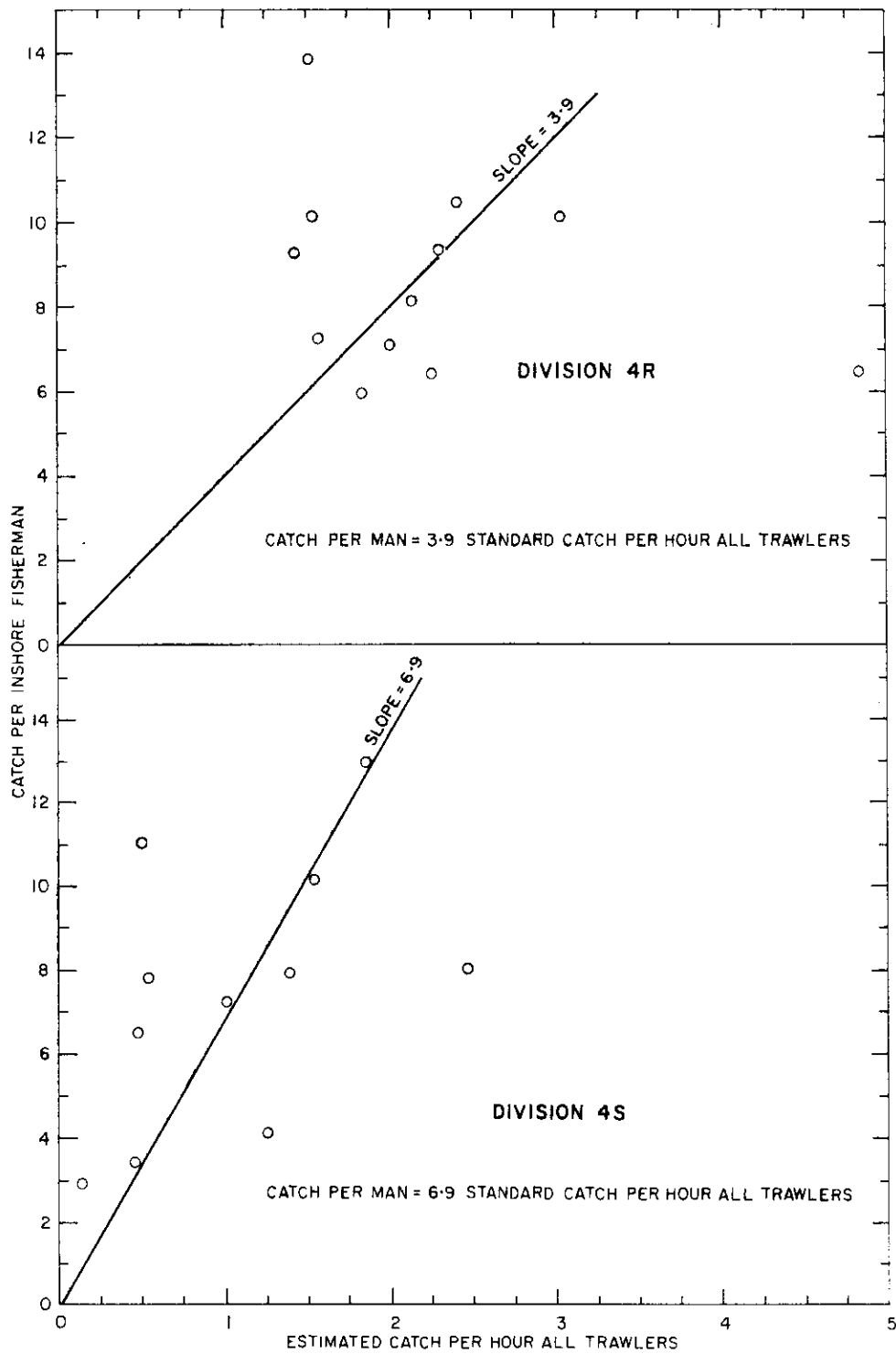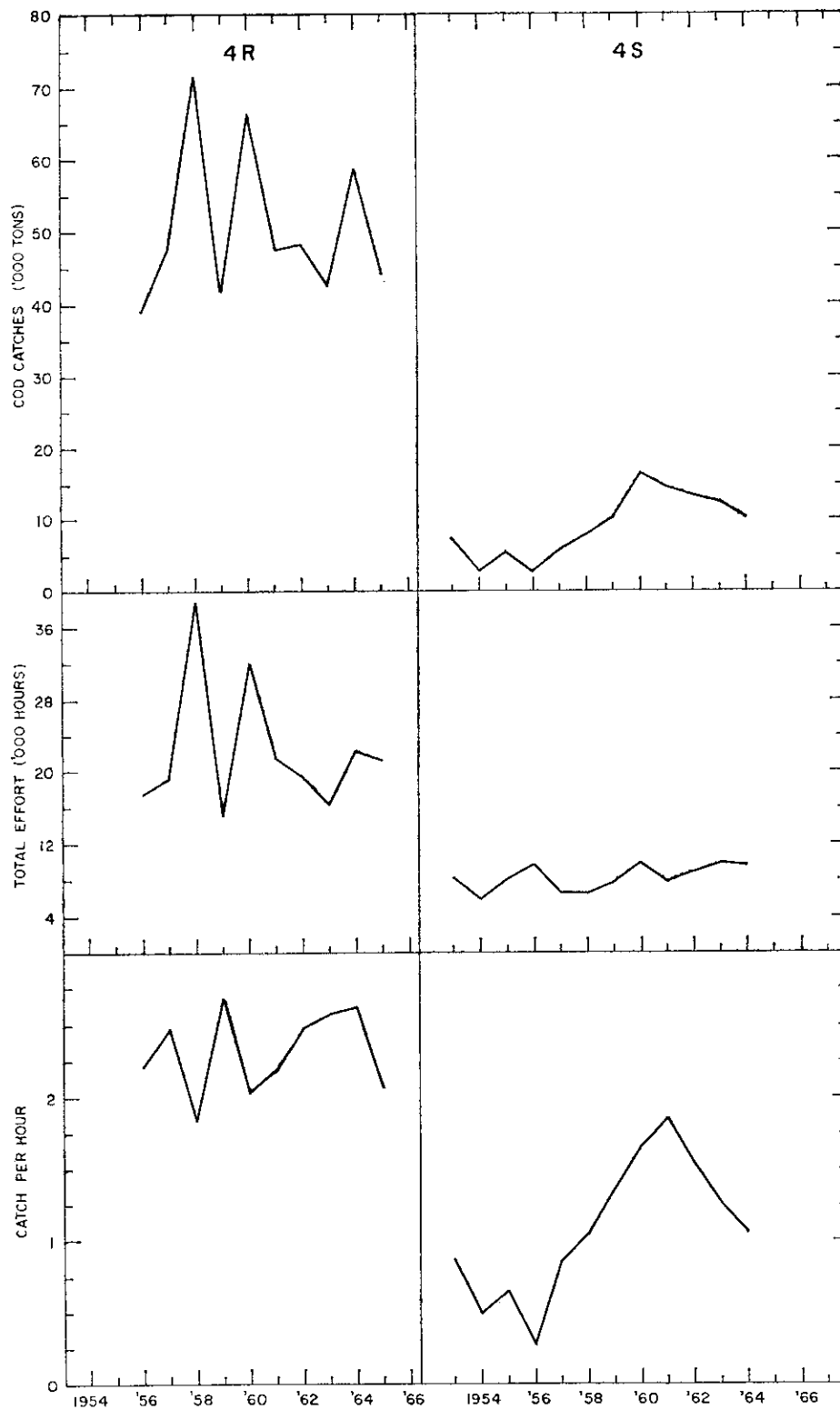Fig. 9. Trends in total catches, effort, and catches per unit effort in standard trawler
units for the cod fishery in Division 4R during 1956–65 and in Division 4S
during 1953–64.

In Div. 4S, catches rose from about 4,500
tons in 1953–56 to a peak of about 16,500 tons
in 1960 but declined during 1961–64 to around
10,000 tons in 1964.   The overall trend in catches
was upward whereas effort increased only margin-
ally over the period, averaging about 8,000 otter
trawl hours per year.   C/E values followed the
trend in total landings, declining from 0.9 to 0.3
tons per hour during 1953–56, doubling from 0.9
to 1.8 tons during 1957–61 and then declining to
about 1 ton per hour by 1964.   The mean C/E
in Div. 4R from 1956 to 1965 was 2.26 tons per
hour compared with 1.08 tons in Div. 4S during
1953–64.

Length and Age Composition
of Catches

The trawl fishery

Length and age compositions of samples of
commercial catches are published annually in
ICNAF Sampling Yearbooks.   Both length and
age frequency data are available from 1956 to
1966 for Div. 4R, but only length data for Div.
4S.   For both divisions monthly length fre-
quencies of the different countries were generally
similar within any 1 year.   Since in Div. 4R,
no one country reported trawler data each year
during 1956–64, data from different months and
countries were combined on a yearly basis to pro-
vide a suitably long series.   In Div. 4S, Canada
(Maritimes) and Canada (Quebec) provided
frequencies for certain months in each year from
1960 to 1964 and these also were combined on an
annual basis.   Portuguese data for 1956 were
included to extend the series.

Before monthly frequencies of any one
country were combined for each year, their *per
mille* figures were converted to actual numbers
and then adjusted proportionately according to
the ratio between that country's monthly landing
and the smallest monthly landing by any country
for which a frequency was given.   The adjusted
numbers of all countries were then totalled on an
annual basis and totalled adjusted numbers con-
verted to *per mille* figures to produce composite
annual length frequencies.   Age frequencies were
fewer in number; Portuguese data for 1956–58
were combined for each year after conversion of
per mille frequencies to actual numbers aged,
addition of these numbers and final calculation
of a composite *per mille* distribution.   Figure 10
shows the adjusted length frequencies of trawler
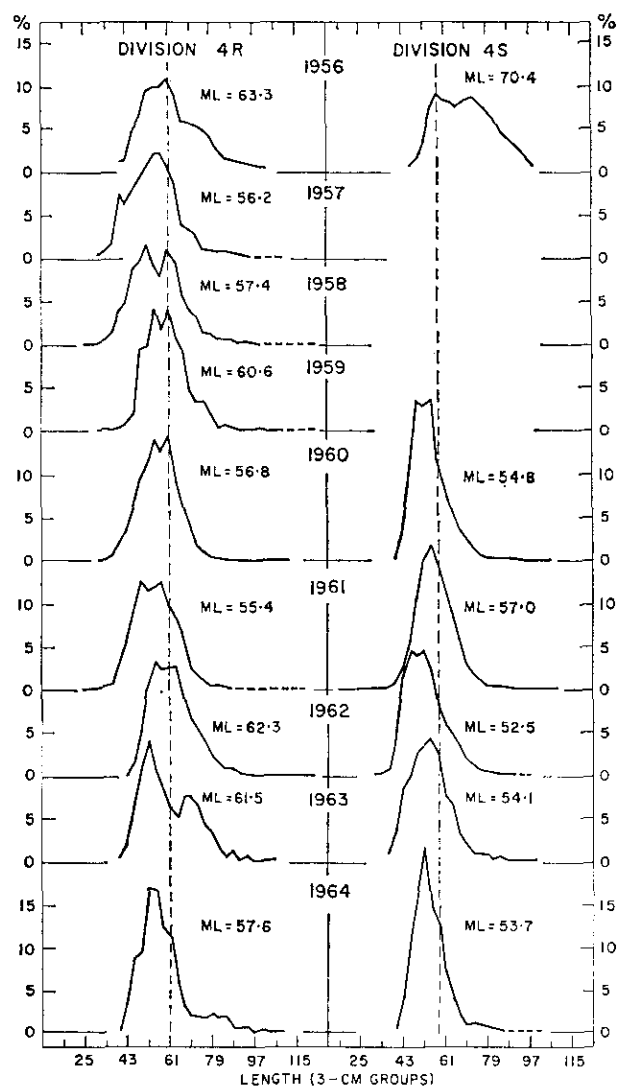
Fig. 10.   Trends in length composition of cod caught by
otter trawlers in Division 4R during 1956–64
and Division 4S in 1956 and 1960–64.   The
vertical broken line for 4R represents the aver-
age mode in 1956–60 and that for 4S the mode
in 1956.

cod catches based on Portuguese, Spanish, Can-
adian (Mainland), and French data of 1956–64
for Div. 4R, and, for Div. 4S, Canadian (Main-
land) data of 1960–64 and Portuguese data of
1956.

These data show that in Div. 4R length com-
positions were similar during 1956–60, having
modes at 61 cm and the majority of fish within
the range 45–65 cm.   However, there is an indi-
cation that larger fish became less plentiful over

this period. After 1960 the fish were grouped around a mode of 52–55 cm and the trend for comparative scarcity of larger fish continued. This is indicated more clearly in composite length frequencies for 1956–60 and 1961–64 (Fig. 11 A).

In Div. 4S a difference is evident between the length composition for 1956, having a mode at 58 cm and a large proportion of fish between 50 and 88 cm, and those for 1960–64 which have modes of 48–55 cm and a smaller range of predominant sizes (45–65 cm). The greatest reduction is apparent in the larger size groups over about 65 cm. To illustrate this trend a composite frequency for 1960–64 is compared with that for 1956 in Fig. 11 A.

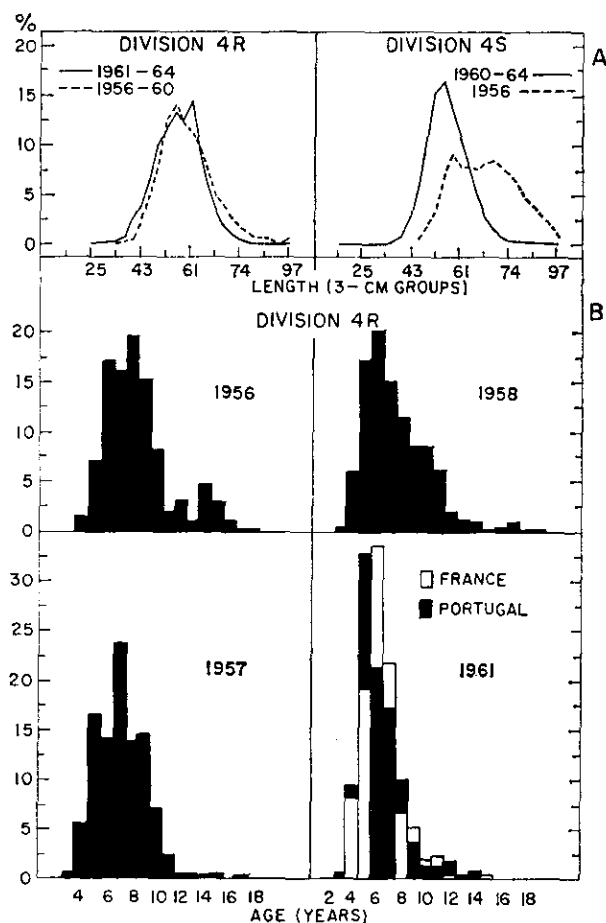Fig. 11.   (A) Comparison of length compositions of cod caught by otter trawlers, averaged for 1956–60 and 1961–64 in Division 4R and 1956 and 1960–64 in Division 4S.   (B) Trends in age composition of cod caught by otter trawlers in Division 4R by Portugal in 1956–58 and France in 1961.

Division 4R age frequencies for Portugal in 1956–58 and for Portugal and France in 1961 (Fig. 11B) indicate that during 1956–58 there was a reduction of fish aged 12 and above followed by a reduction of 9-to 11-year-old cod after 1958. Portuguese data also demonstrate a progressive drop in the dominant age-group from 8 years in 1956 to 5 years in 1961. The differences in age compositions of catches by Portugal and France in 1961 may be due to differences in mesh sizes (114 and 120 mm respectively), but data by both countries are included to emphasize the low proportion of fish aged 9 and above in this year. However, the actual decline in older fish is probably not as great as indicated in Fig. 11B. An unusually large 1955 year-class appeared in most areas of the Northwest Atlantic, resulting in relatively large numbers of 6-year-olds in 1961. Since the age distributions are plotted from *per mille* values, the effect of a strong year-class is to reduce the proportion of older fish.

The inshore fishery

In Div. 4S a sufficiently long series of length or age composition data on inshore catches is not available, so that reliable conclusions on trends cannot be drawn. In Div. 4R regular sampling of cod trap catches has been carried out since 1962 by the St. John's Biological Station, but only along the northern shore of Belle Isle Strait. Age and length frequency compositions of cod trap landings from 1962 to 1966 are considered later (Fig. 16), but can be mentioned at this point. These data show that the trap fishery is dependent on 4-year-old cod with a mean length of about 40 cm. A larger average size in 1962 was due to a strong 1957 year-class (relatively more age 5 fish). There was a decline in the relative proportion of older fish during 1962–66, particularly for ages 11 and above which were virtually absent from the 1965–66 samples.

Collections and Methods for Biological Studies

Collections

Details of the collections are listed in Table 2. All measurements were of fork length to the nearest centimeter and were taken at random. Offshore material comprised length and otolith collections of fish caught by Canadian research vessels using No. 36 or 41-5 otter trawls with small-meshed codends, in certain years during

1947–66. Usually, but not always, the codend was lined or covered with fine mesh nylon netting. The measured fish were subsampled for collection of otoliths and determination of sex and maturity. Before 1962 such subsamples were simply random samples of the measured fish. From 1962 to 1966 additional sampling was performed on "category" sizes (fish above about 65–70 cm).

Inshore measurements were of trap catches from the North Shore Strait of Belle Isle, collected during 1962–66, and of catches by research vessel or commercial line gears from 1953 to 1966. Line gear samples were normally from close to shore in various areas of the northeastern Gulf of St. Lawrence (Fig. 12). Trap subsamples were random during 1962–64 and stratified (approxi-

mately equal numbers from each 3-cm length group) from 1965 to 1966, whereas for line gears subsampling was random during 1953–64 and stratified in 1966, when catches at a fish plant on the northwest coast of Newfoundland were sampled.

Age determinations

Age determinations were from sacculus otoliths read according to the method given in the summary by Keir (MS, 1960). Age distributions for each year were obtained after adjustment of random, random plus category or stratified otolith subsamples to number caught using age length keys based on the otolith ages.

TABLE 2.   Otolith collections of cod caught by inshore gears and offshore research vessels during 1947–66 in Divisions 4R and 4S.   Research vessel collections were taken by otter trawl having the codend lined with small-meshed netting, except as indicated.

Year	Locality	Month	ICNAF Division	Gear	Otoliths collected	Lengths measured
1947	Bonne Bay, St. Georges Bay	Nov.	4R	OT[a]	159	250
1948	Anticosti	Aug.	4S	OT[a]	48	48
1950	West Nfld.	Oct.–Dec.	4R	OT[a]	457	860
1953	West Nfld.	July–Sept.	4R	Longline	473	10,916
1955	Port aux Choix, Flowers Cove	Sept.–Oct.	4R	Longline	225	2,255
1957	West Nfld.	Dec.	4R	OT	58	342
1961	West Nfld.	Nov.	4R	OT	62	352
	Anticosti	Nov.	4S	OT	141	1,327
1962	West Nfld.	Jan.	4R	OT	665	6,321
	North Shore Strait of Belle Isle	July	4R	Trap	392	1,500
	North Shore Strait of Belle Isle	Sept.	4R	Hook[b]	61	61
	Quebec North Shore	Oct.	4S	OT[a]	122	890
	Belle Isle Strait	Oct.	4R	OT[a]	154	172
1963	North Shore Strait of Belle Isle	July	4R	Trap	485	1,143
	Quebec North Shore	Sept.	4S	Longline	372	497
1964	North Shore Strait of Belle Isle	July	4R	Trap	130	130
	North Shore Strait of Belle Isle	July	4R	Hook[b]	25	25
	Port aux Choix	Sept.	4R	Longline	123	1,751
	Quebec North Shore	Oct.	4S	Longline	205	2,867
	Bay of Islands	Nov.	4R	Longline	121	1,761
1965	North Shore Strait of Belle Isle	June	4R	Trap	198	495
	West Nfld.	Nov.	4R	OT	532	828
	West Nfld.	Nov.	4S	OT	78	447
1966	North Shore Strait of Belle Isle	June	4R	Trap	211	603
	Port aux Choix	June–July	4R, 4S	Linetrawl	418	1,989
	Port aux Choix	Sept.	4R	Linetrawl	225	844
	West Nfld.	Oct.	4R	OT	327	441
	Quebec North Shore and Anticosti	Oct.	4S	OT	458	1,447

[a] non-lined codend.
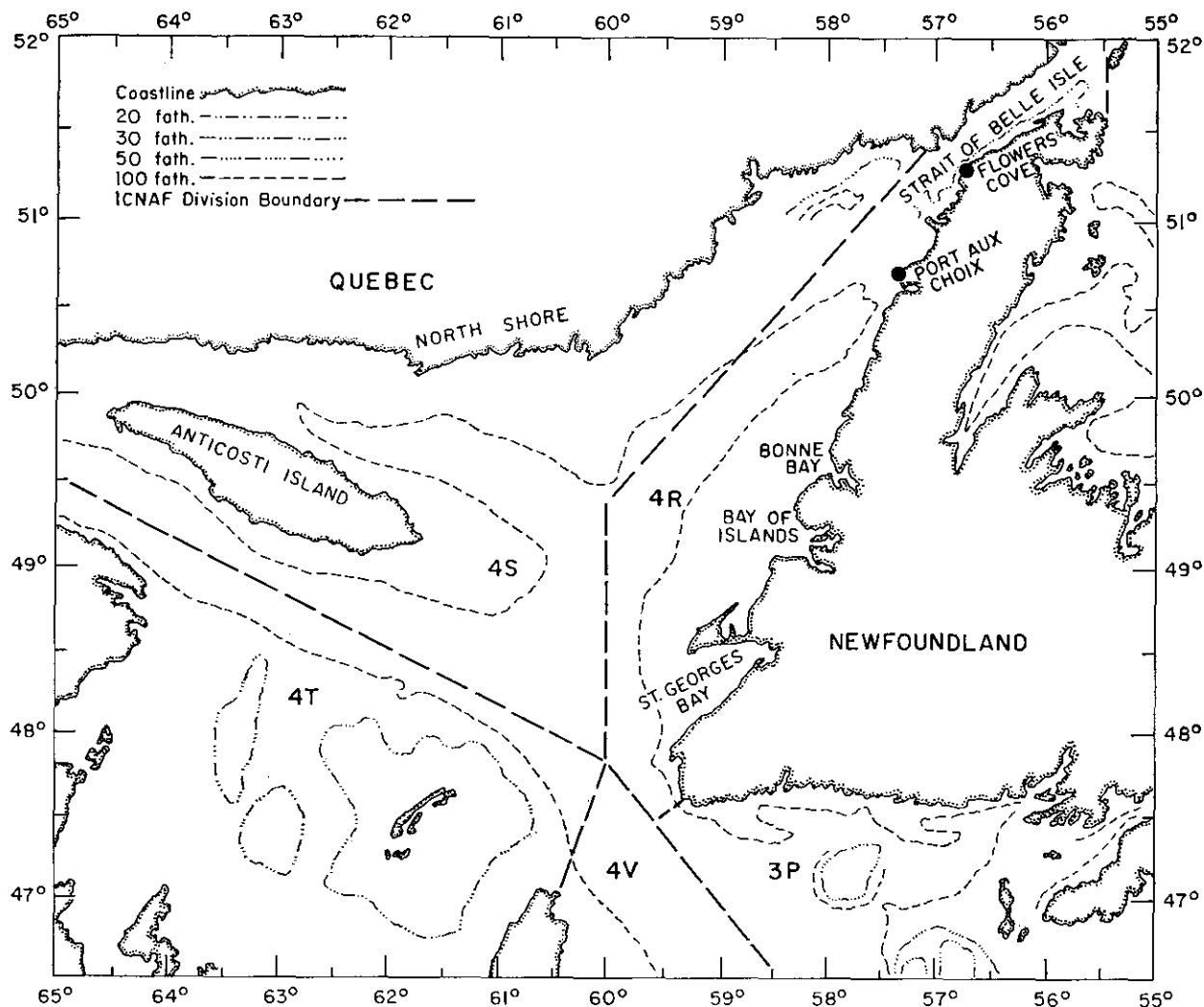[b] special collections of small cod.

Fig. 12.   Gulf of St. Lawrence showing areas mentioned in text.

Collections were made in every month of the year except February, April, and May. To compensate for seasonal growth differences and to prevent an error of 1 year being made in otolith ages in the September-December period, otolith edge deposits were recorded at the time of reading and 1 January used as the fishes' "birthday". Hyaline zones apparent in the autumn were regarded as the next annual hyaline zones and were not counted for ageing purposes until 1 January of the next year. Ages so determined were used to compile annual adjusted age distributions from which estimates of total mortality were calculated. The incidence of opaque otolith edges was used in a study of the validity of the otolith readings. (Fleming, 1960; Kohler, 1964; Williamson, MS, 1965; May, 1967).

The age-length keys were also used to calculate mean length at age, from which growth curves were plotted. Since data were taken at different times of the year, annual collections were not comparable because of seasonal growth differences. In preparing growth figures, the convention of adding $\frac{1}{4}$ to the otolith age for each quarter of the year beyond January–March was adopted. Thus a fish of t years collected in April–June was called $t + \frac{1}{4}$ in July–September $t + \frac{1}{2}$, and in October–December $t + \frac{3}{4}$.
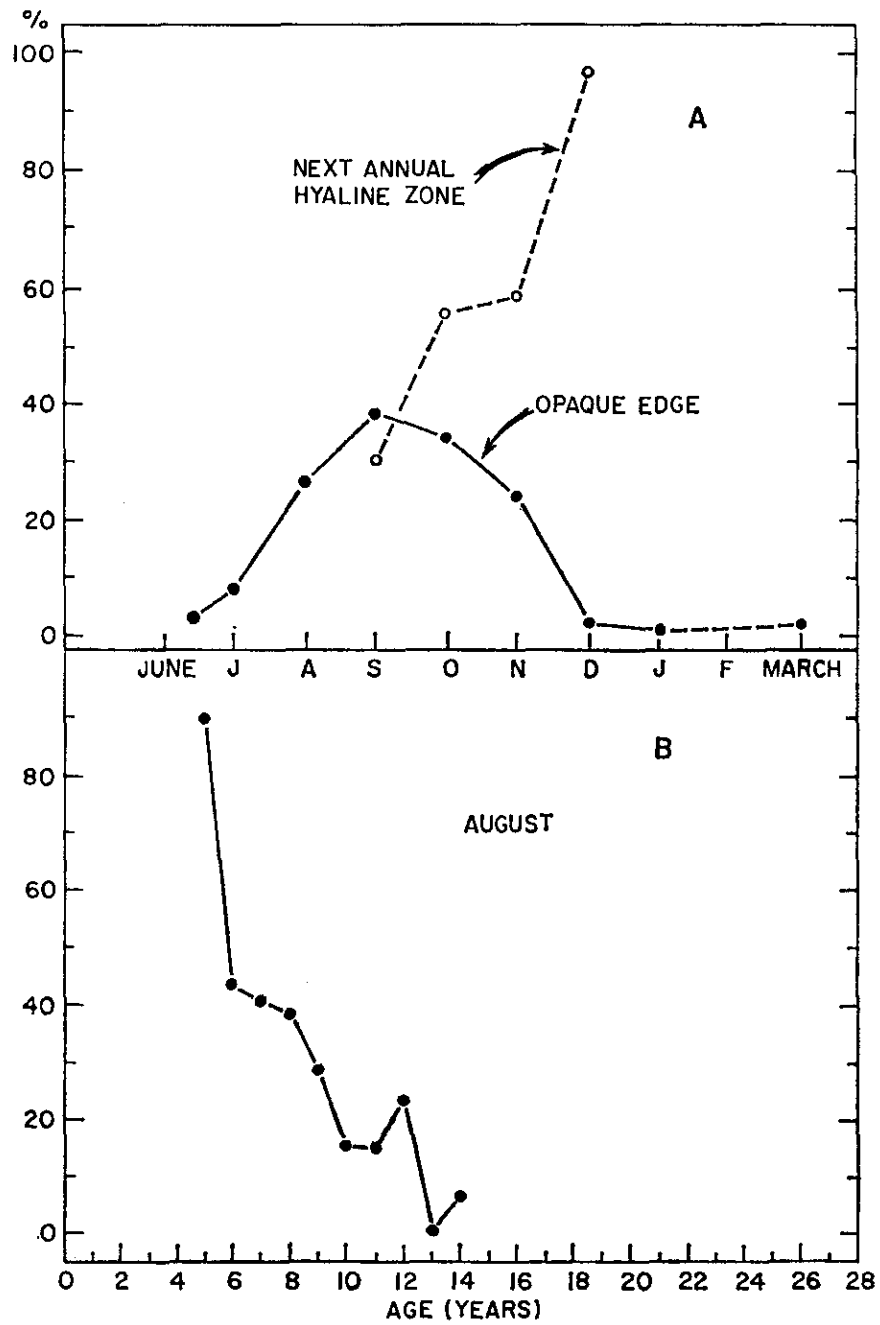
Fig. 13.   (A)   Monthly incidence of opaque edge on otoliths of cod from the
          northeastern Gulf of St. Lawrence.   (B)   Incidence of opaque edge in
          cod otoliths of different ages in August.

Age Validation

Introduction

Recent workers (Saetersdal, 1953; Kohler, 1964; May, 1967) have reiterated and emphasized Dannevig's (1933) observation that a critical approach is essential to age determination procedures. Examination of skeletal structures for estimations of age involves some interpretation rather than simple counting of annual growth markings. Hence validation studies assume importance in determining the correctness of these interpretations.

For the purposes of this study, offshore research vessel material was combined with commercial and research samples taken inshore from line gears. Data from traps were not used because they consisted predominantly of very young fish whose opaque zones appeared very early in the year. Their inclusion would elevate incidence values of opaque edge in June–July to non-representative levels. Age and edge data for all years were combined by month and also analyzed by age-group for August samples. The opaque zones represent the period of greatest growth (Fleming, 1960). Hyaline zones begin to form when otolith (and hence bodily) growth slows down. As they are more distinct than opaque zones they were used for age determinations.

An empirical assessment of the age reading technique can be made by observing seasonal changes in the otolith edge and by comparing mean lengths of otolith ages so derived with modes in the length frequency distribution. Observations on both these methods are given below.

Results

Otolith Edges. Figure 13A shows the occurrence of opaque edge in the otoliths of cod from the northeastern Gulf of St. Lawrence during 9 months of the year. Opaque edges were present at least as early as March, but only in younger fish aged 3–7 years. In June and July the percentage of fish with opaque edges was still low, and mostly confined to 4- to 7-year-olds. By September, about 40% of fish exhibited opaque

edges and the shape of the curve (Fig. 13A) clearly demonstrates that only one opaque zone is formed each year. However, beginning in September, some fish showed a narrow hyaline zone at the otolith edge. In later months this increased in thickness and became more common, being particularly well developed from late October to December (Fig. 13A). This zone was regarded as the next annual hyaline zone and was omitted from age estimations of fish collected before 1 January. This is standard procedure at the St. John's Biological Station and prevents an error of 1 year being made in readings of autumn and early winter samples. The hyaline edge was also predominant from January to July, when it was counted for age determinations.

The otoliths of most very old fish exhibited no recognizable opaque edges at any time of the year. A similar observation was made for Labrador cod by May (1967) who attributed this apparent lack to an inability to see extremely thin opaque zones at the very edge of the otolith. May's interpretation seems to be equally applicable to otoliths from the northeastern Gulf of St. Lawrence.

The opaque zone appeared earlier in the year in younger fish than it did in older ones, an observation also made by Williamson (MS, 1965) for Grand Bank cod and May (1967) for Labrador cod. The occurrence of opaque edges in fish of different ages is shown in Fig. 13B, for August, when the development of the opaque zone was almost at a maximum. The occurrence of opaque edge ranged from 90% at age 6 to about 30% at age 8 and less than 10% at age 14.

Length Frequencies and Mean Lengths From Otoliths. The modes of length distributions of catches taken by line gears and otter trawl during 1947–66, together with mean lengths of strong age classes from the corresponding age-length keys are listed in Table 3. These data show that there was good agreement between most modes in length compositions and the corresponding calculated mean length of strongly represented ages. Conformity was best for younger fish but in several samples a high degree of consistency was evident even for fish aged 10–12 years.

TABLE 3. Modes in length frequencies of catches compared with mean lengths of dominant ages in corresponding age frequencies.

Sample year	Gear	Age	Mean length	Mode	Age	Mean length	Mode	Age	Mean length	Mode	Age	Mean length	Mode
1947	Lines	4	47	49	5	52	55	10	65	73	—	—	—
1947	OT	3	34	34	6	54	52	12	78	58	—	—	—
1948	OT	4	43	43	7	59	61	10	67	70	—	—	—
1950	OT	2	26	25	4	45	43	8	65	67	—	—	—
1953	Lines	7	58	61	—	—	—	—	—	—	—	—	—
1953	Lines	6	52	61	8–9	68	70	10–12	73	76	—	—	—
1955	Lines	6	62	63	7	68	72	—	—	—	—	—	—
1957	OT	2	23	25	5	51	52	—	—	—	—	—	—
1961	OT	4	41	43	7	63	61	—	—	—	—	—	—
1961	OT	4–5	48	49	6	58	58	—	—	—	—	—	—
1962	OT	6–7	55	54	—	—	—	—	—	—	—	—	—
1962	OT	1	15	13	5	49	49	6–7	58	59	—	—	—
1962	OT	7	55	59	—	—	—	—	—	—	—	—	—
1963	Lines	7	57	58	9	64	64	—	—	—	—	—	—
1964	Lines	8	58	55	9	62	61	—	—	—	—	—	—
1964	Lines	7	58	61	10	66	67	—	—	—	—	—	—
1965	OT	3–4	37	37	5	48	49	7	54	55	—	—	—
1965	OT	2	23	25	3	34	34	4	40	43	6	51	52
1966	OT	1	16	16	3	32	37	4	45	43	5	50	52
1966	OT	2	27	25	3	38	40	5	53	58	—	—	—
1966	Lines	11	79	73	12	82	82	—	—	—	—	—	—
1966	Lines	8	61	61	10	75	76	12	82	82	—	—	—
1966	Lines	8	66	61	9	73	70	10	75	79	—	—	—

Length and Age Composition of Samples

In the study of age and length compositions, data for each of offshore otter trawl and inshore line gears were combined for several years to compensate for scarcity or lack of data in some years and to reduce effects of annual variations in recruitment.

Offshore samples were combined into three 5 year periods 1947–51, 1957–61, and 1962–66. For inshore line gears, data were combined for 1953–55, 1963–64, and compared with 1966 collections. Material from the summer trap fishery on the northern shore Strait of Belle Isle, was analyzed on a yearly basis since samples were available for every year from 1962 to 1966.

Composite age and length frequencies for offshore samples are shown in Fig. 14. During 1947–51 catches were composed of a wide range of age-classes, fish 2–8 years old being dominant. Fish 9–13 years, and to a lesser extent those 14–

17 years were relatively well represented. The wide range of ages is reflected in the length frequency for 1947–51 which had no well-defined mode and a large number of fish 25–70 cm in length. From 1957 to 1961 ages 2 and 4–7 were dominant but ages 8–14 were relatively reduced in comparison to the 1947–51 sample. There were no fish older than 14. The corresponding length frequency for 1957–61 had two distinct modes at 25 and 47 cm but fish greater than 65 cm were uncommon. The mode at 25 cm was caused by a strong 1955 year-class collected in 1957 (2-year-olds).

From 1962 to 1966, collections from ICNAF Div. 4R and 4S were kept separate. The age frequency for Div. 4R had a relatively restricted range of ages composed largely of 4- to 7-year-olds. Cod less than age 3 and greater than age 9 were relatively poorly represented and there were virtually no fish older than 11 years in the sample. In the 4S sample, ages 3–7 were dominant and 8- and 9-year-olds well represented, but there were few fish less than 3 or greater than

%

20

10

0

30

20

10

0

20

10

0

20

10

0

1947—51 4RS

(1158)

(662)

1957—61 4RS

(2961)

(261)

1962—66 4R

(7821)

(1734)

1962—66 4S

(2006)

(654)

O   16   34   52   70   88   106 124
LENGTH (3 – CM GROUPS)

2   6   10   14   18
AGE (YEARS)
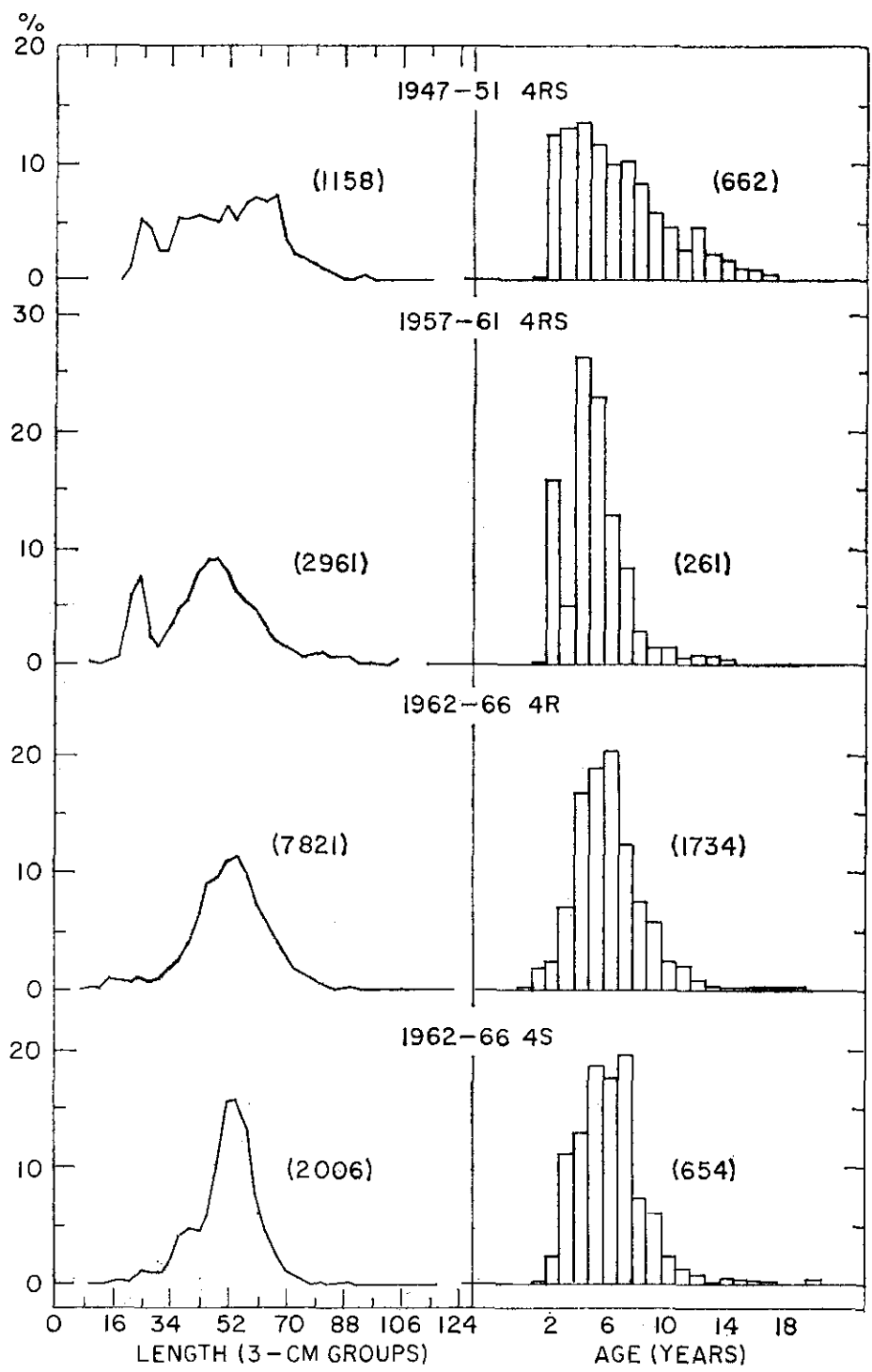
Fig. 14.   Length and age compositions of cod taken by small-mesh-otter trawl in three
5-year periods in Divisions 4R and 4S.   Numbers of fish measured or aged
are in parentheses.

Fig. 15.   Length and age compositions of cod taken in 1953–55 and 1963–64 by experimental long-
lining and in 1966 by commercial linetrawl in Divisions 4R and 4S.   Data for 1953 are
extended from Templeman and Fleming (1956), the otoliths being read by the senior author.
Numbers of fish measured or aged are in parentheses.

Fig. 16.   Age and length distributions from the inshore trap fishery.   Numbers refer
to measured fish.

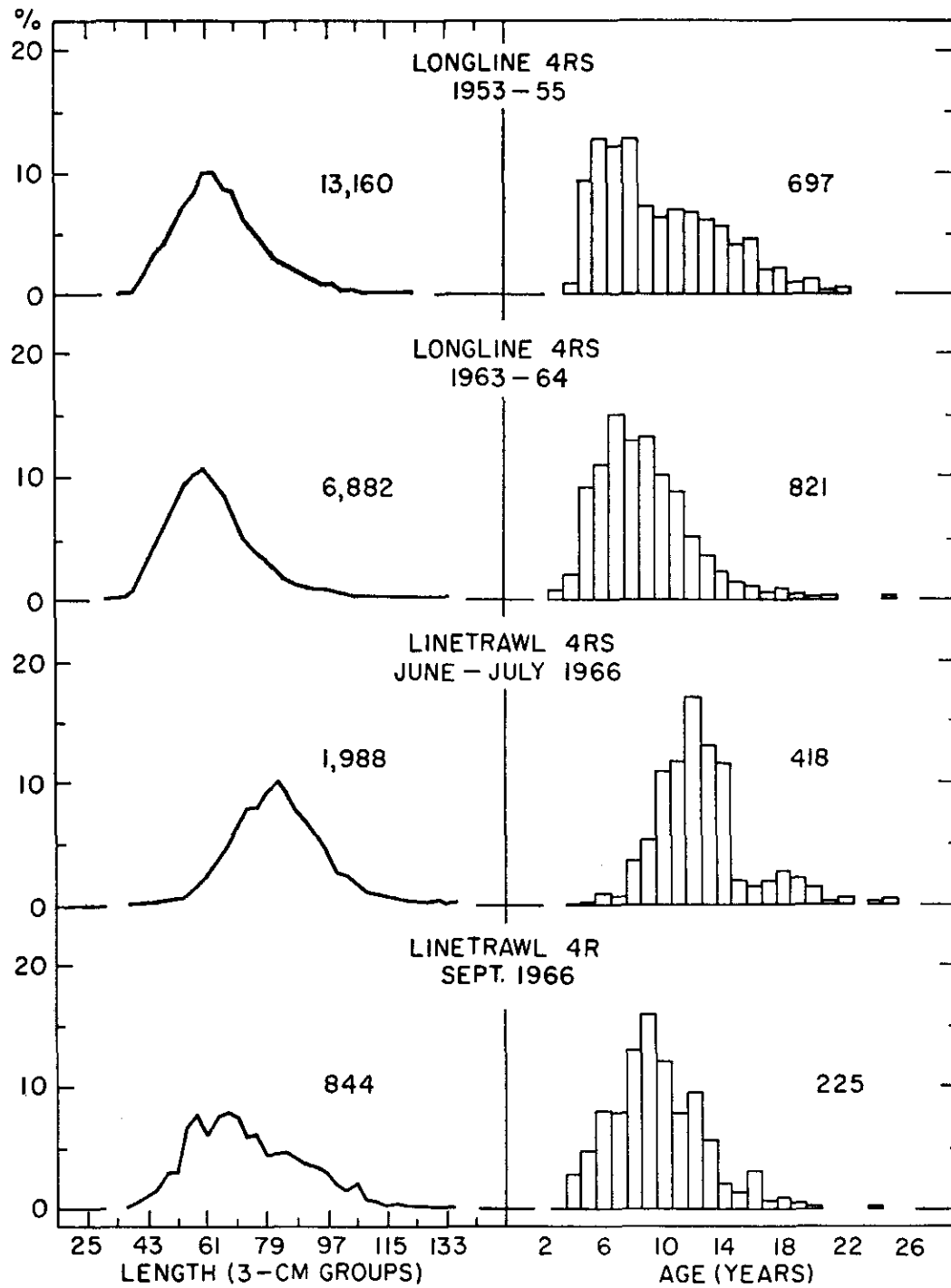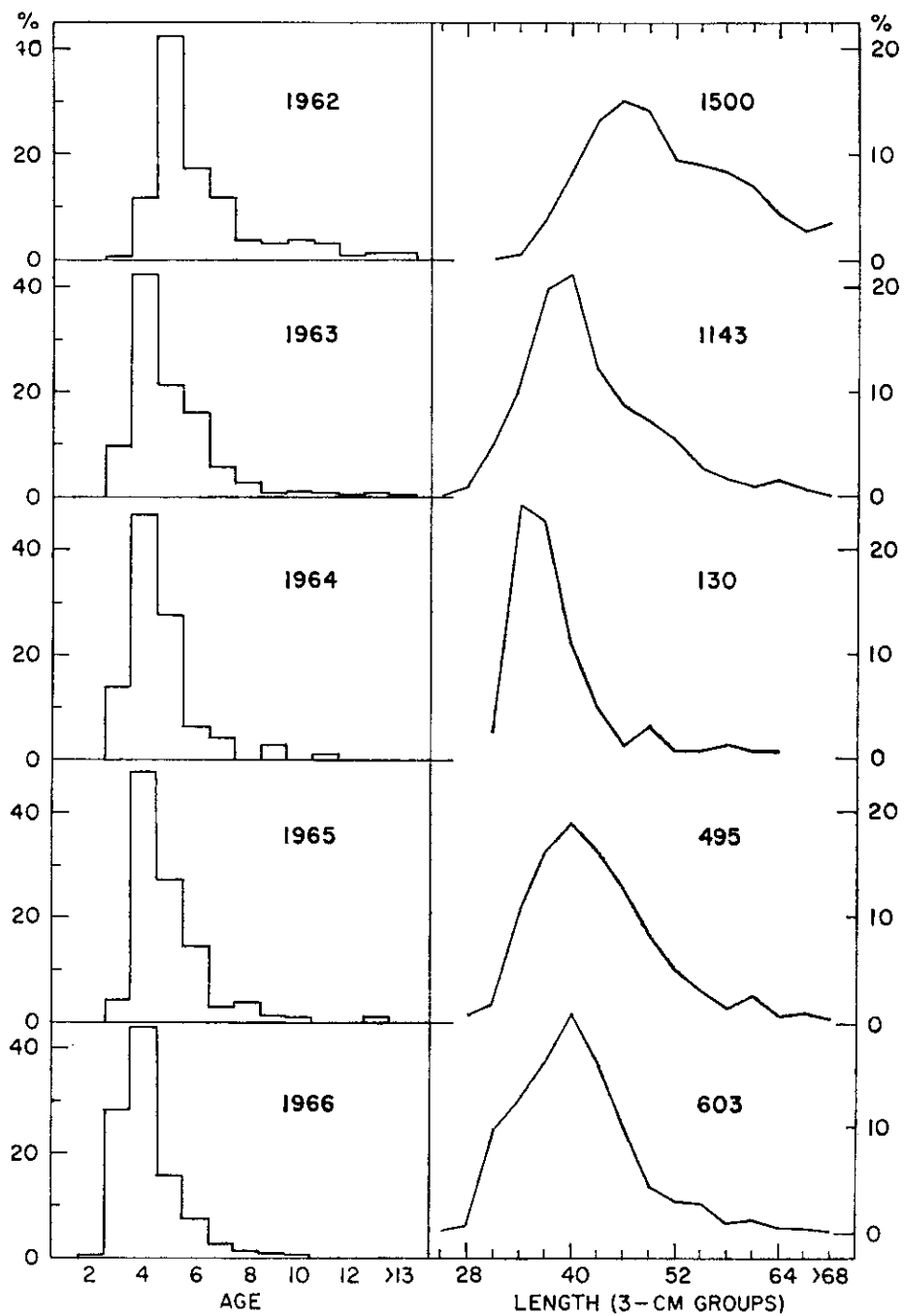10 years old. From 1962 to 1966, length fre-
quencies for Div. 4R and 4S had similar modes at
55 cm but the frequency for 4S had a secondary
mode at 40 cm corresponding with the abundant
3-year-olds.

Age and length frequencies of line gear
samples are shown in Fig. 15. During 1953–55
catches were composed of a wide range of ages.
Ages 5–8 were dominant, followed in importance
by ages 9–16 and to a lesser extent ages 17–22.
The corresponding length frequency had a mode
at 64 cm but was skewed to the right by the
quantity of larger and older fish in the sample.

In 1963–64 ages 5–11 were dominant but fish
older than 12 years were poorly represented in
comparison to the 1953–55 sample. The length
frequency for 1963-64 had a mode at 61 cm
(*cf* 64 cm for 1953–55) and approached a normal
distribution more closely than that of 1953–55.
In June–July 1966, old fish were again predomin-
ant, with ages 12–14 forming the bulk of the
sample, but younger and smaller fish predomin-
ated in September.

Age and length distributions from the trap
fishery (Fig. 16) were similar from year to year,
being made up largely of very young and small
fish. In each year, except 1962, almost half the
fish were 4-year-olds. In 1962, 5-year-olds were
dominant but this was an anomalous observation
caused by relatively great survival of the 1957
year-class. In all years most of the fish were less
than 50 cm in length. Very few fish older than
10 years or longer than 70 cm were taken, and
these were relatively less numerous in 1965–66
than in 1962–63.

Mortality

Introduction

Fishery assessments were not made for cod
of ICNAF Div. 4R and 4S by the ICNAF work-
ing group on fishery assessments (Beverton and
Hodder, eds., 1962). For these Divisions few
data are published on age compositions of fish
caught by the major gears in the cod fishery and
no information is available on gear selectivity,
ratio of fishing mortality to total mortality, or
natural mortality of fish within the selection
ranges of the gears. In the present study total
mortality estimates were derived to see whether
reduction of older fish noted above was accom-
panied by significant increases in mortality.

Estimates of total mortality for otter trawl,
line gears, and trap samples were calculated from
least squares regressions fitted to the descending
limbs of catch curves based on percentage age
distributions. For these estimates, offshore data
were combined for 1947–61 and 1962–66. Samples
from line gears were combined for 1953–64 and
compared with 1966 samples while those for trap
were combined for 1962–63 and compared with
1965–66.

Results

Offshore catch curves are shown in Fig. 17.
From 1947 to 1961 and 1962 to 1966 Z increased
from 0.39 (ages 5–16) to 0.65 (ages 7–15). The
catch curves for line gears (Fig. 18) indicate that
Z changed from 0.18 for ages 8–16 and 0.50 for
ages 16–22 in the former period to 0.22 for ages
13–20 in 1966. For traps the age at full recruit-
ment was low, remaining at 4 years during the
whole period of sampling (Fig. 19). The value
of Z for ages 4-16 increased from 0.46 in 1962–63
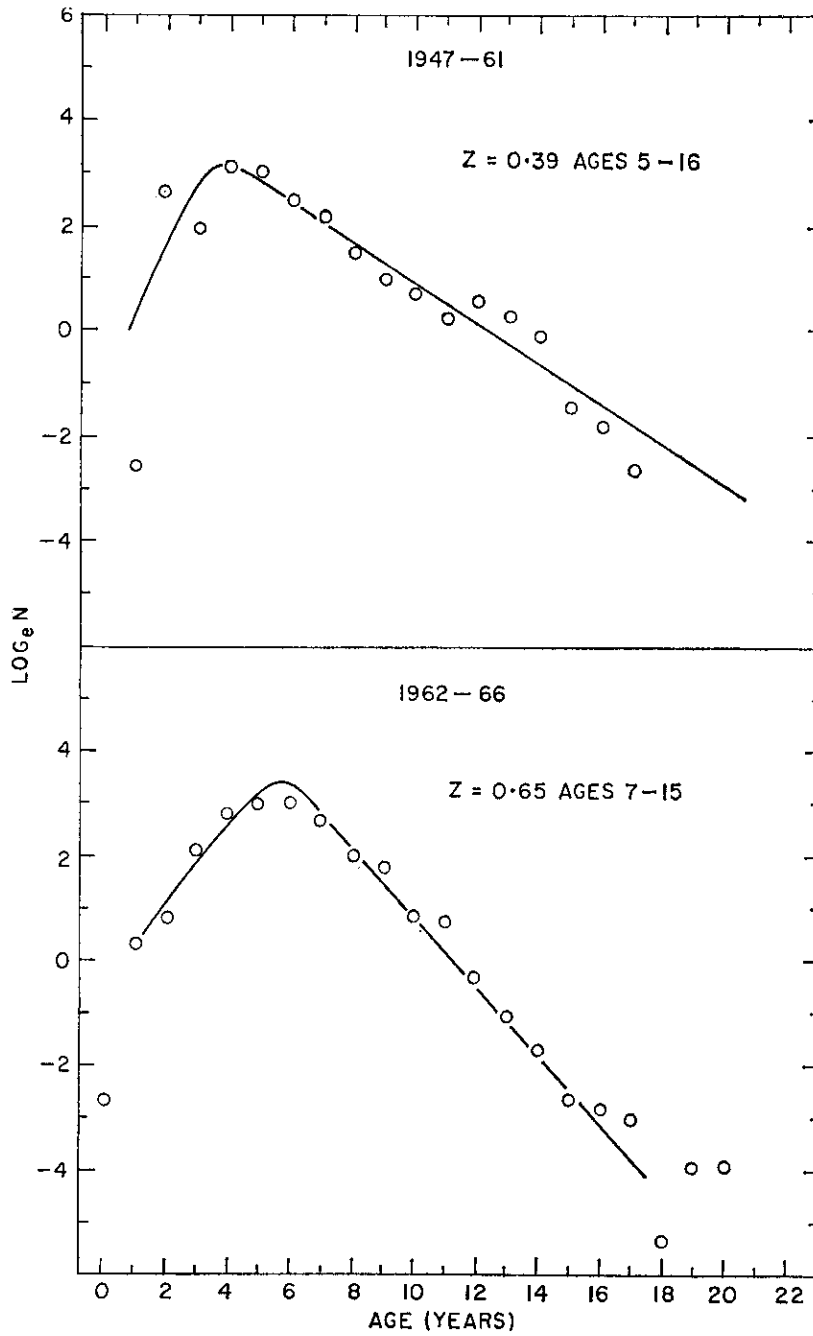to 0.68 in 1965-66, averaging 0.54 for the whole
period.

Fig. 17. Catch curves for combined age distributions of cod taken by small-mesh-otter trawl in Divisions 4R and 4S.
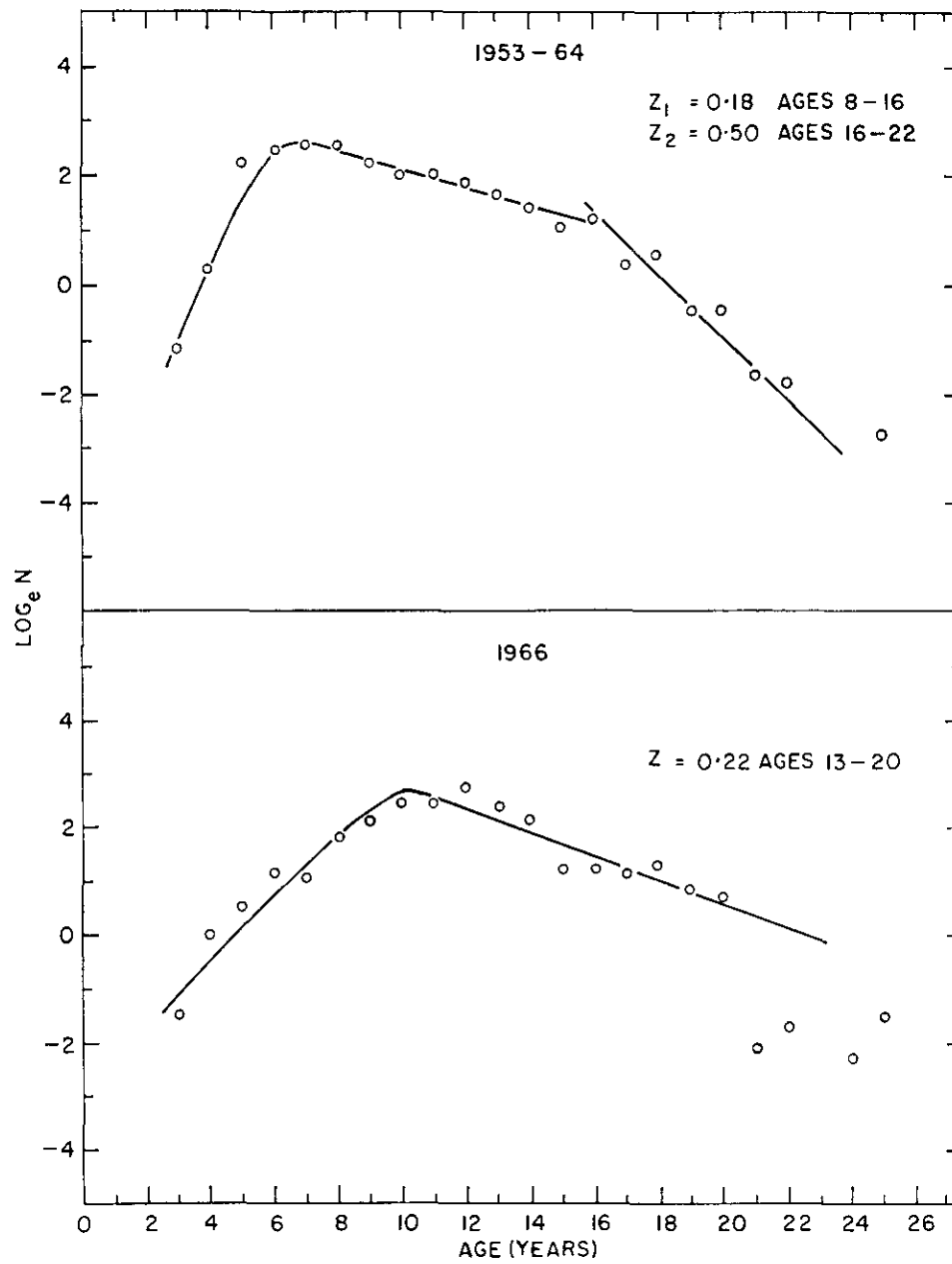
Fig. 18.   Catch curves for combined age distributions of cod taken by line gears in Divisions
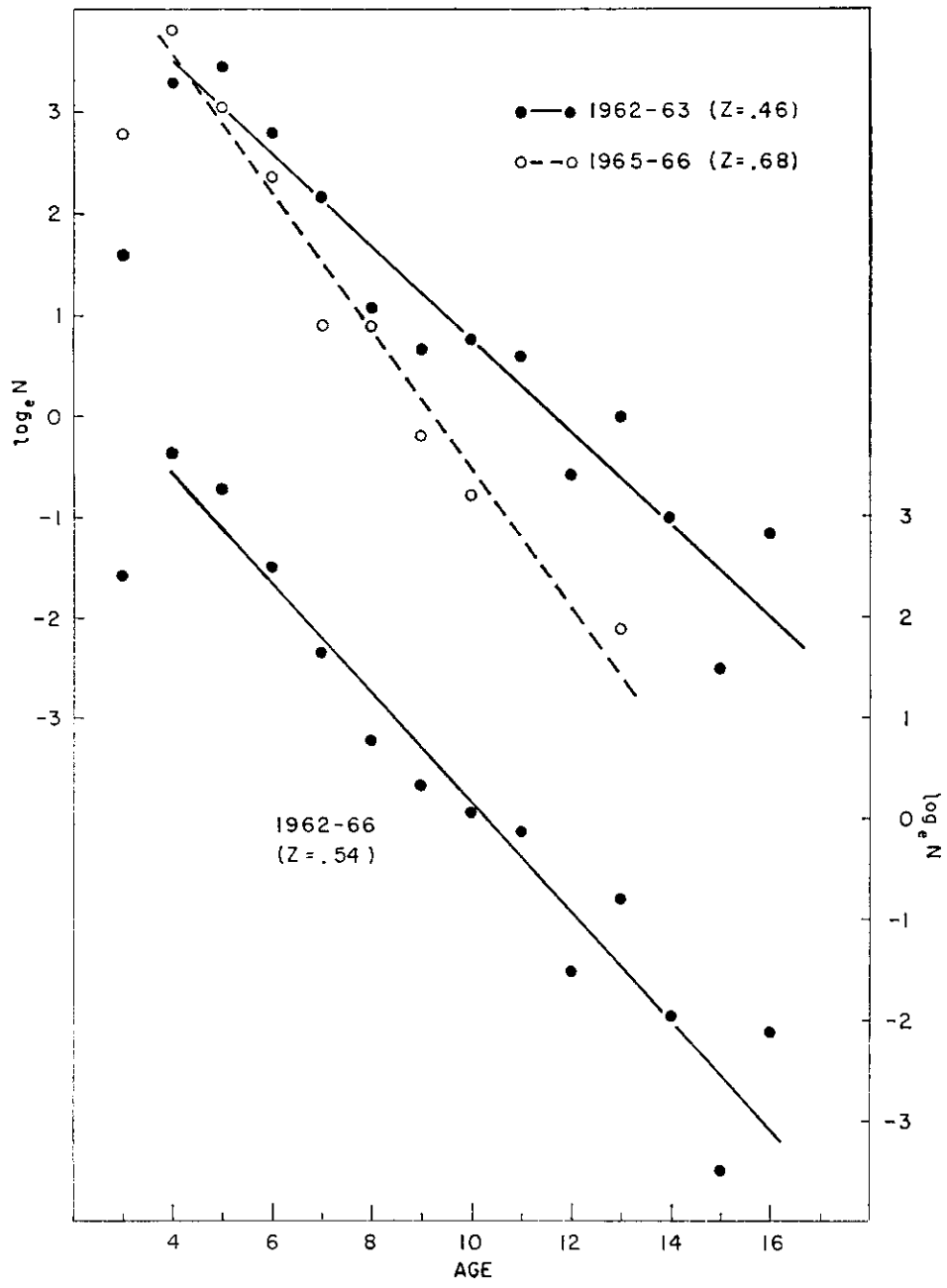4R and 4S.

Fig. 19. Catch curves from the inshore trap fishery, north shore of the Strait of Belle Isle.

Growth

Introduction

Variations in cod growth can arise from changes in hydrographic conditions (Hermann and Hansen, 1965) or changes in stock abundance. In the first case the variations are regulated by external (physical) factors and in the second case by biotic factors involving population stability. When considering the biology of a commercially exploited fish species it is therefore useful to know the trends in the fishery which the species supports, as well as temporal changes in the hydrography of the area in which the stock lives. Knowing these an assessment of any changes in growth rate can usually be made.

The preceding detailed study of the commercial cod fishery indicates that generally increasing otter trawl effort in Div. 4R and 4S has apparently resulted in a reduction in the abundance of larger and older fish in trawler and inshore catches (increased total mortality). In this section growth is examined to determine whether reduction of older fish was accompanied by increased growth rates in the cod stock complex of 4RS.

Growth was expressed as average fork length at age. Data were analyzed according to the von Bertalanffy (1938) growth curve equation,

$$l_t = l_\infty\ (1 - e^{-K(t-t_o)})$$ where l_t is mean length at

age t years, l_∞ is average "maximum" or asymptotic length, K is a constant determining rate of change in length increment, and t_o is the theoretical age at which the fish would be of zero length. Growth curves were fitted using the "trial l_∞" method of Ricker (1958).

Results

A detailed preliminary analysis of growth data for otter trawl and line gear samples showed that there were usually no differences in growth rate between fish from Div. 4R and 4S. Since samples were mostly small and scattered in time, data for Div. 4R and 4S were combined by years up to 1961 but kept separate after 1961. Offshore otter trawl, inshore line gear and trap collections were treated separately because of differences in gear selectivity. For plots of mean length at age the data were treated as yearly samples. However, examination of the composite yearly collections showed that it was neces-

sary to combine data from different years for purposes of growth rate calculations. For offshore material, data were combined in three 5 year periods: 1947–51, 1957–61, and 1962–66. Material from Div. 4R and 4S were treated separately in the most recent period. Inshore line gear data were less extensive than offshore and were combined as follows: 1953–55, 1963–64, June–July 1966, and September 1966. Trap samples were combined for 1962–66.

Average Sizes at Age. Otter trawl fish show no discernible trends in average size at age from 1947 to 1961 (Fig. 20). From 1962 to 1966 in Div. 4R an upward trend was observed for ages 10–13. No consistent trend was evident in Div. 4S. Plots of average sizes at age for inshore line gear samples indicate a decline in all ages during 1955–63 followed by an upward tendency for most ages during 1964–66 (Fig. 21). Attained sizes at age of trap fish were quite variable from year to year. The average sizes of the most abundant age groups (Fig. 22) generally declined from 1962 to 1964 but increased from 1964 to 1966.

Growth Curves. Curves fitted to offshore data combined in the 5 year periods indicated that no consistent trends occurred in growth rate of all ages sampled during 1947–66. Consequently, offshore data for the whole period were combined as shown in Fig. 23. Only mean lengths based on 10 or more fish within each 5 year period were used to calculate the average mean lengths at age for 1947–66. The growth equation for ages 1–14 was as follows:

$$l_t = 93\ (1 - e^{-0.14\,(t\,+\,0.2)}).$$

Inshore line gear growth curves for 1953–55 and 1963–64 indicated that in the latter period growth decreased slightly for ages 4–9 but increased for ages 10 and above. Growth curves for June–July and September 1966 demonstrated a higher growth rate in 1966 of most ages sampled. Data for 1953–64 were therefore combined and compared with the 1966 material as shown in Fig. 24 which indicates that growth of most ages was greater in 1966 than it had been previously, the fitted curves being as follows:

$$1953\text{--}64\ \ l_t = 91\ (1 - e^{-0.14\,(t\,+\,0.3)}).$$

$$1966\ \ l_t = 110\ (1 - e^{-0.13\,(t\,-\,0.8)}).$$

Growth rate of trap fish for 1962–66 is shown in Fig. 25. Included also are fish of ages 1 and 2 taken close inshore by baited hook. The von
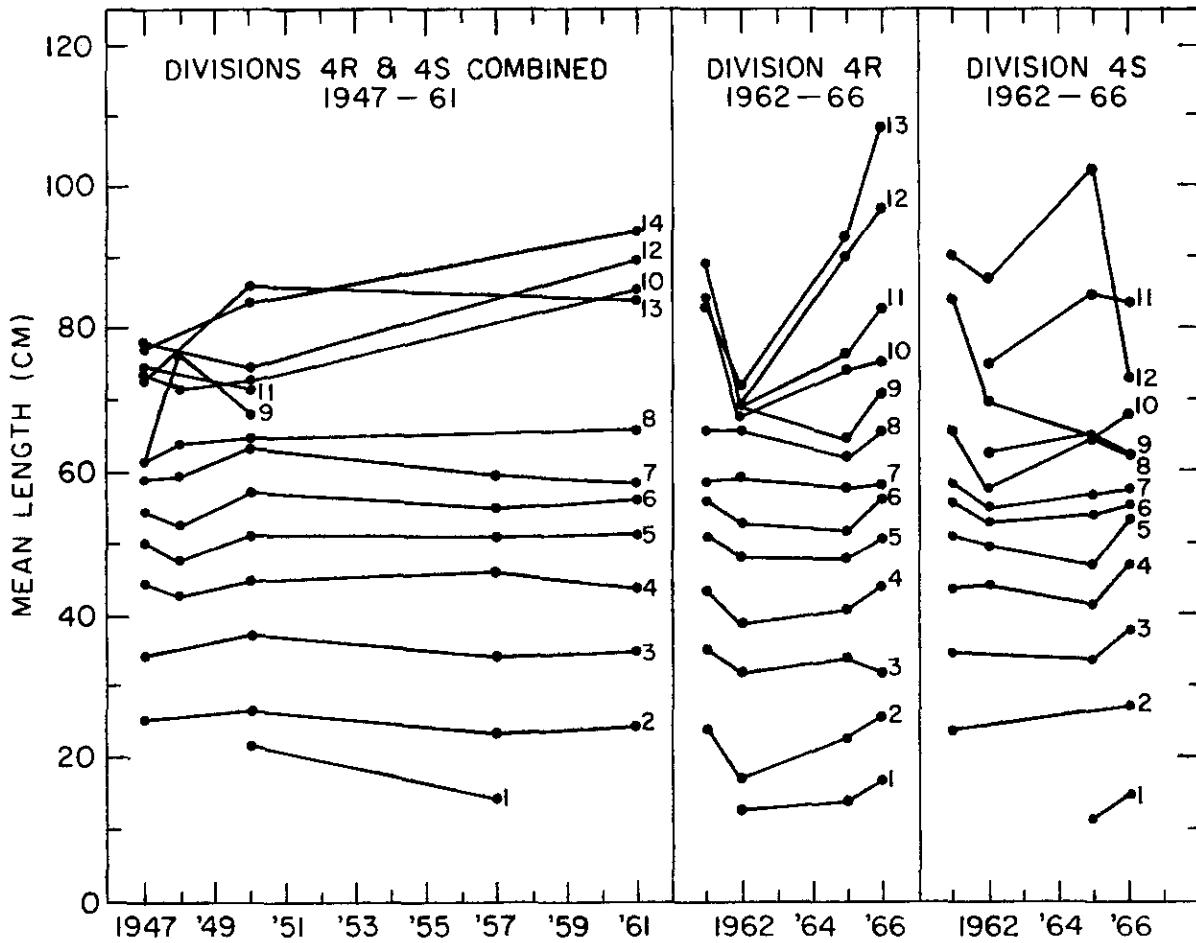
Fig. 20.   Trends in mean length at age of offshore cod caught by small-mesh-otter trawl during 1947 66, Divisions 4R and 4S.

Bertalanffy growth curve shown in the figure gave a reasonable fit to the data, though the common "levelling-off" at the older ages followed by increased growth for the very oldest ages (May *et al.*, 1965) was very much in evidence. Average lengths for ages 1 and 3 were artificially high because of hook selection in the former group and trap mesh selection in the latter.

Weight-Length and Girth-Length.   Weights of whole cod, and with viscera and gills removed, were obtained for all trap fish sampled during 1962–64.   All weights were made in the field and recorded to the nearest ounce (1 oz = 28 g). Weight-length curves of the form $W = kL^n$ were fitted to the data (about 1,000 observations)

and are shown in Fig. 26. Plotted averages of both whole and gutted-gilled weights adhered closely to a logarithmic straight line though there was some tendency for the largest sizes to depart from the regression.   Points above 60 cm were better fitted by regressions employing greater exponents.   Thus values of n for fish greater than 60 cm in length were 3.43 for the whole weight curve (3.01 for all sizes) and 3.37 for the gutted-gilled weight curve (2.91 for all sizes). A similar phenomenon was described for Labrador cod by May (MS, 1966).

Measurements of girth at the posterior edge of the operculum were obtained from 874 trap fish from 1962 to 1964.   These measurements
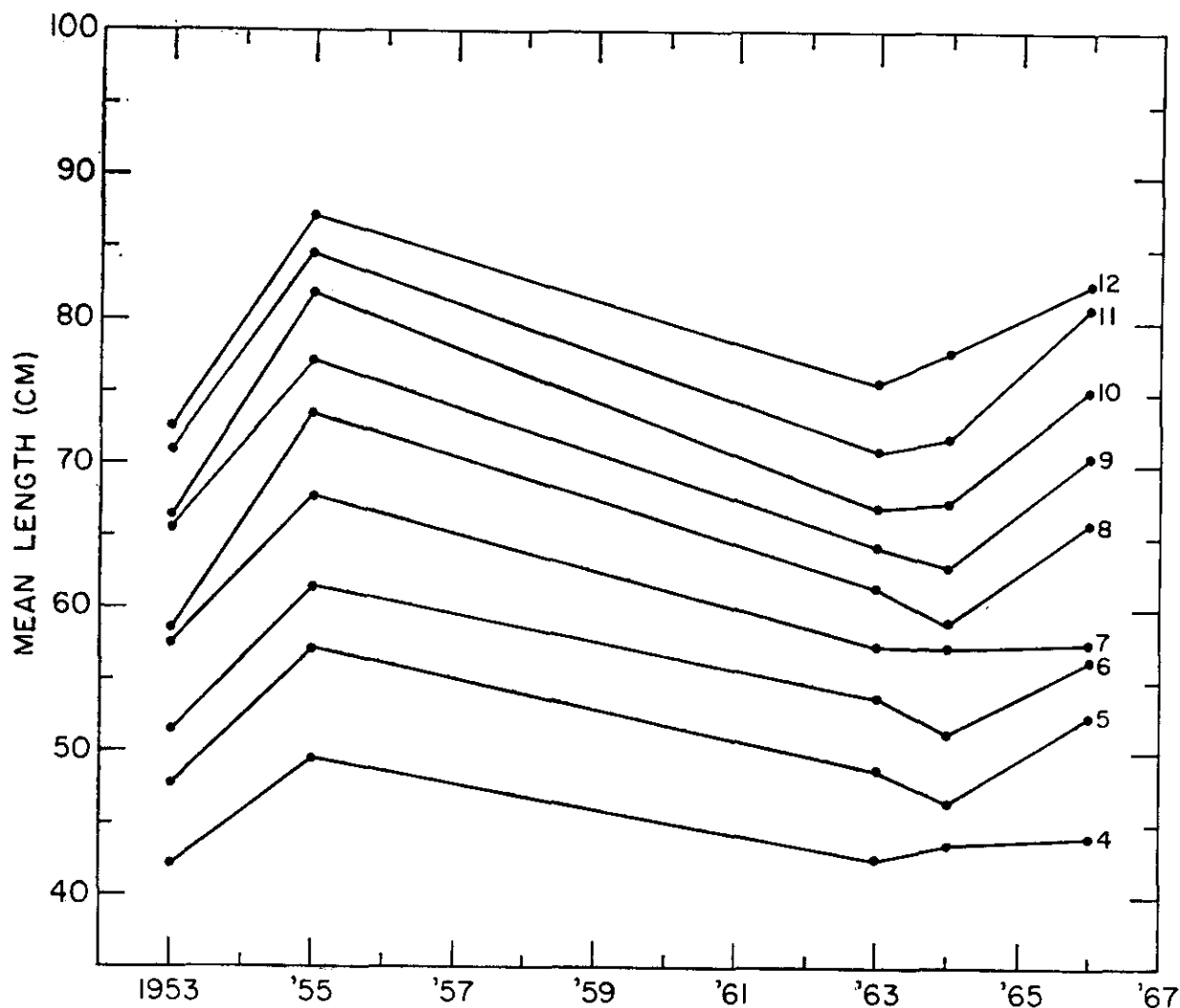
Fig. 21.   Trends in mean length at age of inshore cod caught by line gears during 1953 -65, Divisions 4R and 4S.

were originally made in millimeters using a flexible tape, and later combined into 1-cm groups.   Preliminary analysis revealed no sex differences. Combined averages for 1962–64 are plotted in Fig. 27.   A weighted straight line fitted to the data gave the regression,

$$G = 0.56L - 0.87$$

where G = opercular girth in cm and L = fork length to the nearest cm.

Maturity and Spawning

Observations on stage of maturity were made by gross examination in the field of gonads of all fish sampled.   For present purposes data collected by otter trawl, line gears, and traps were combined.   Moreover, various stages were combined as immature, pre-spawning, spawning, and spent-recovering.   Spawning was completed by virtually all fish by June when 95% of the mature
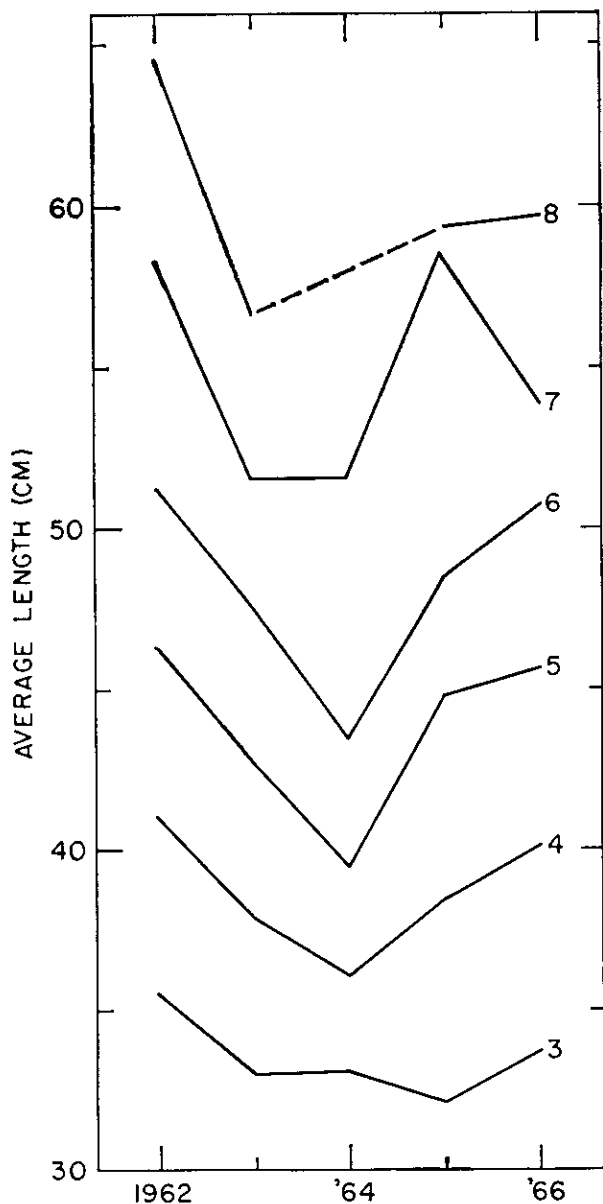
Fig. 22. Trends in mean length at age of inshore cod caught by traps during 1962-66, Division 4R (north shore Strait of Belle Isle).

males were spent-recovering; 2% spawning; and 3% pre-spawning. Mature females in June were 92% spent-recovering and 8% pre-spawning. A very few individuals appeared to spawn late in the year, even in October.

The proportion of mature fish in each 3-cm length group and at each age were determined for the combined data (Fig. 28). Males were first

mature at 31 cm and age 2; females at 40 cm and age 3. All males were mature at 67 cm and age 9; all females at 76 cm and age 11. Sizes and ages at 25%, 50%, and 75% maturity, estimated from the plotted curves (Fig. 28), are tabulated below.

Size at maturity (cm)

	25% mature	50% mature	75% mature
Male	42.0	45.5	48.4
Female	47.3	49.7	56.3
Combined	44.0	47.5	52.8

Age at maturity

	25% mature	50% mature	75% mature
Male	4.1	5.1	5.9
Female	5.3	6.1	6.9
Combined	4.6	5.6	6.6

Discussion and Conclusions

The fishery

Statistics from 1954 to 1965 show that cod catches by trawlers from the northeastern Gulf of St. Lawrence varied somewhat but generally increased relative to inshore catches since 1960, particularly in Div. 4S. Whereas effort by trawlers increased since 1960 in the first half of the year in Div. 4R, similar upward trends in effort in 4S occurred in the second half of the year. Thus, in Div. 4R C/E values for January–June varied but tended to rise in 1960–65 while those for July–December declined. In Div. 4S, on the other hand, July–December C/E values decreased and January–June values were variable. On an annual basis, C/E values in Div. 4R increased after 1960 whereas those in Div. 4S declined showing that effects of increased trawler effort on the stock have been most marked in Div. 4S.

For the inshore fishery in Div. 4R, catches remained relatively stable during 1956-65 while annual catch per man declined due to increasing numbers of fishermen. In Div. 4S during 1953–64, catches rose while number of men declined
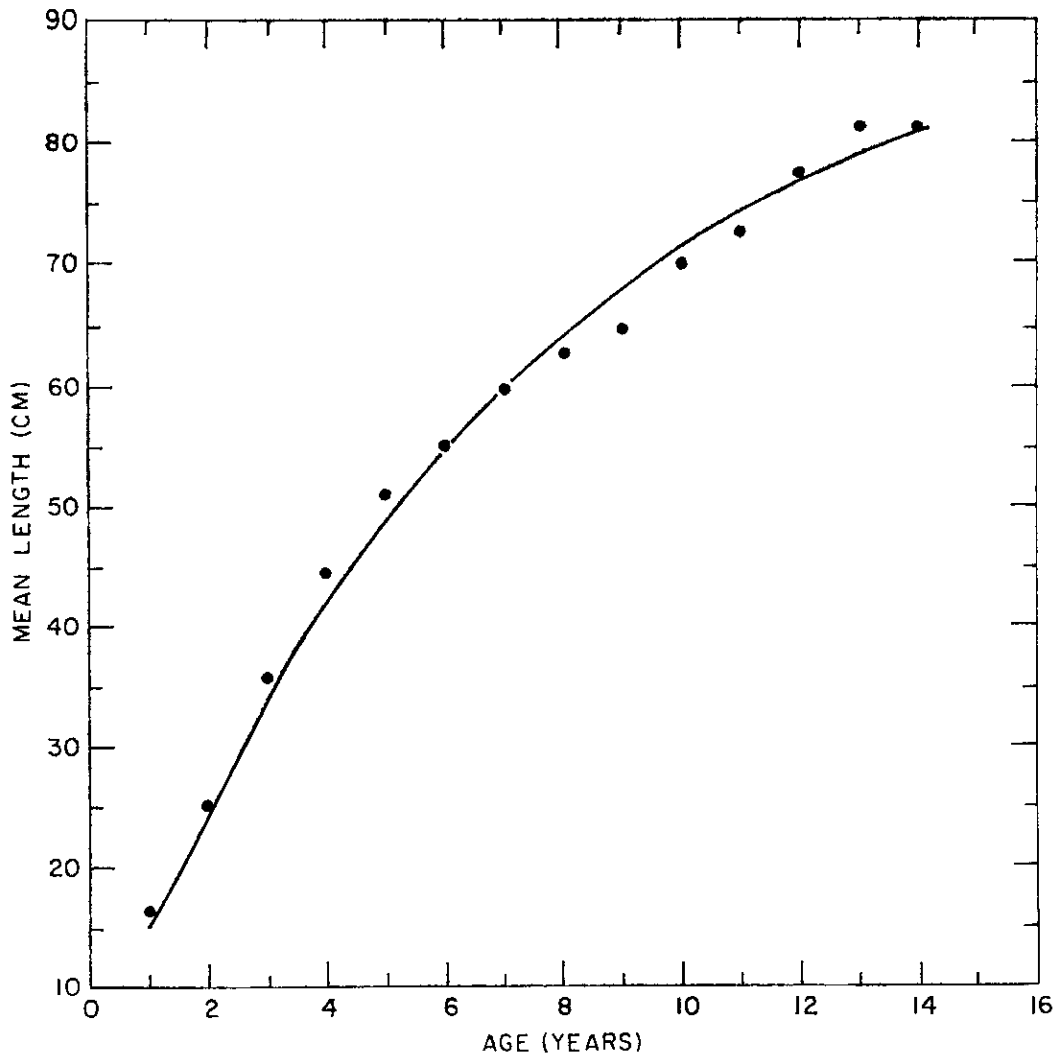
Fig. 23.   Fitted growth curve for combined 1947–66 otter-trawl collections, Divisions 4R and 4S.

and this resulted in an improved annual catch per man up to 1961.   From 1962 to 1966 however, catch per man declined, probably as a result of stock depletion by increased trawler catches.

Trends in the whole fishery were determined by converting inshore effort to standard trawler hours based on statistics of Portuguese and Spanish otter trawlers.   This treatment showed that annual catches, effort and C/E values fluctuated irregularly in Div. 4R during 1956–65, whereas in Div. 4S increased catches and

effort resulted in improved C/E values from 1956 to 1961 but a decline in C/E during 1961–64 which may be due to increased trawler effort since 1960.

Length and age composition data for trawlers indicate a trend towards smaller and younger fish in the catches and, in particular, decline in the oldest age groups.   For the inshore trap fishery of the North Shore Strait of Belle Isle older fish became less abundant but average size of fish caught did not alter appreciably.
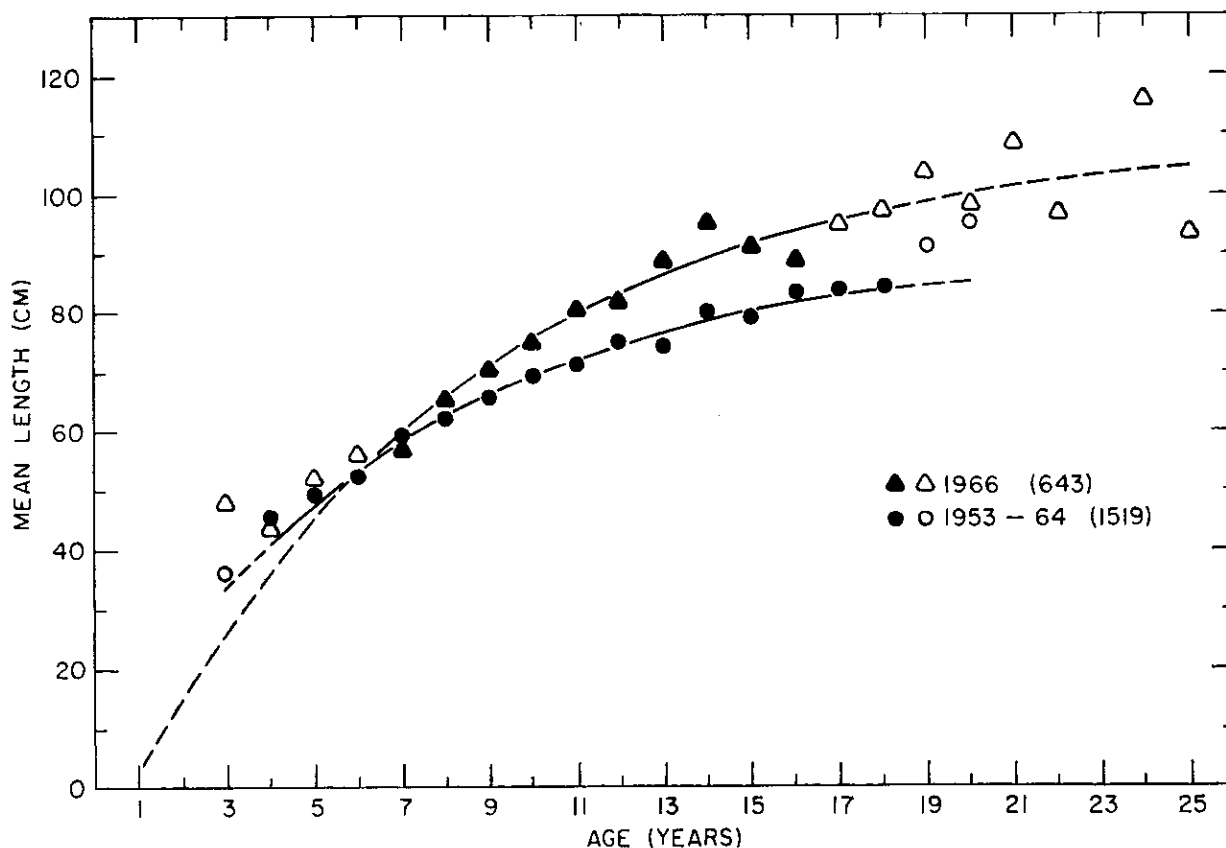
Fig. 24. Fitted growth curves of inshore cod taken by linetrawl, Divisions 4R and 4S, 1953–64 and 1966. Shaded symbols indicate ages used in growth calculations, and open symbols those not so used. Numbers of fish are in parentheses.

Up to 1965, any effect on annual C E of increased trawler landings and effort occurred only on that part of the stock complex being fished within Div. 4S. In Div. 4R no marked changes in the cod fishery were detectable.

Age validation

The study of seasonal changes in otolith edges shows that one opaque and one hyaline zone are formed each year. Hyaline zones appeared first in September and persisted until July when they were almost completely replaced by a broader opaque zone. An opaque zone was present in varying degrees of development from March to November. Thus, there was appreciable overlap in the time of formation of the two types of edge, caused mainly by the early (March) appearance of opaque edges in young fish, and its persistence in some individuals of all but the oldest

ages even into early December. The period of greatest deposition of opaque material was August–November, indicating that the growing season in the northeastern Gulf is about 4 months compared to about 3 months in Labrador as indicated by May's (1967) data and 5 months or more on the Grand Banks (Williamson, MS, 1965). In this connection it is interesting to note that growth of cod in Div. 4R and 4S is greater than that of Labrador cod but less than that of stocks on the Grand Banks (May et al., 1965). Hence, observations on the seasonal changes in otolith edges of cod from the northeastern Gulf are consistent with conclusions derived from growth studies.

In the general Newfoundland area, "checks" or false (weak) rings are commonly found in otoliths. Checks were often seen in the present study, mostly in the first 3 years of growth but

Fig. 25.   Fitted growth curve for inshore cod taken by
          trap in Division 4R, June and July, 1962–66.

particularly in the second year, which often ex-
hibited a bright, many banded hyaline zone.
Such checks sometimes confused an age reading,
but since they usually conformed to a distinctive
pattern, they were early recognized as false rings
and were not counted for ageing purposes. They
usually formed "double", incomplete or weakly
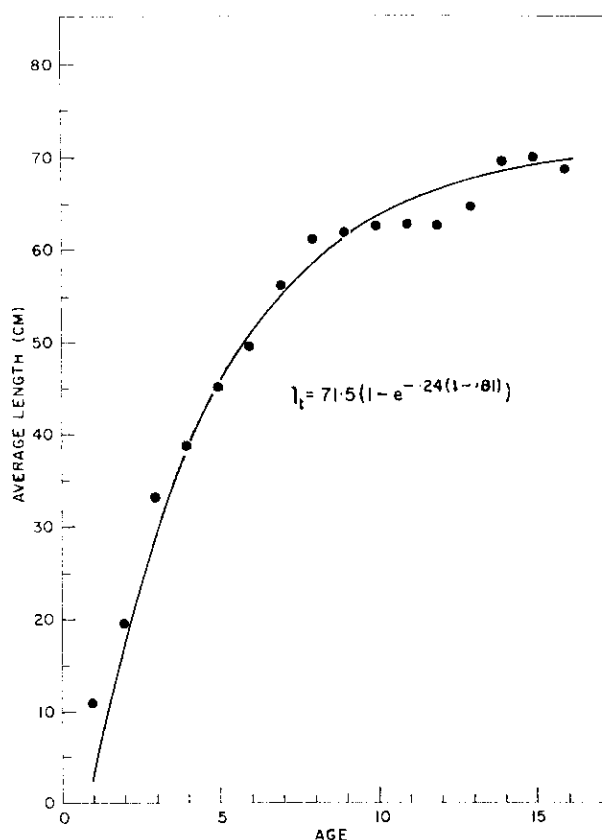developed zones which did not fit into the pattern
of decreasing opaque zone width which was re-
lated to increasing age. In fact, sometimes a
check was recognized by its anomalous position
or unusual spacing, rather than its appearance.

For validation purposes length compositions
of samples were compared with age distributions
based on otolith ages, but only dominant ages
were considered. Poorly represented ages did
not generally produce recognizable modes, the ex-
ceptions being the very youngest fish (1-to 3-
year olds). Therefore the method of comparison
used was not truly an application of Peterson's
method, which utilizes the recognition of separate

modes of successive ages, but rather an indirect
deductive one where no attempt was made to
prove that a particular mode was formed by fish
of a particular age. Reliance was placed on find-
ing good agreement between dominant modal
values and mean lengths and the fairly high de-
gree of correlation found is a good indication of
the validity of the otolith ages, particularly since
a reasonable number of samples were available
for analysis.

Age and length distributions of samples

Assuming that an otter trawl with a small
meshed codend provides a random sample of most
of a fish population on the sea bed, the offshore
research vessel data on age and length composi-
tions indicated that prior to 1957 the cod stock
in the northeastern Gulf of St. Lawrence was com-
posed of a wide range of ages and sizes, a good
proportion of which were more than 10 years old
and 70 cm in length. A decline in older and
larger fish occurred sometime during 1951–57.
This may be related to the inception of otter trawl
fishing in Divisions 4R and 4S in 1954. The de-
cline became more marked by 1962–66 and so
probably occurred in 1961 or 1962, which coin-
cides with the increase in growth rate of cod aged
10 or 11 and older as noted above. Thus, re-
duction of larger and older fish in offshore samples
may have been due to the introduction and gen-
eral increase of trawler fishing in this area.

The data for line gears show that although a
decline of older and larger fish occurred some-
time from 1956 to 1962, by 1966 at least ages 12–
14 were again well represented. However, the
samples for the earlier period were from shallow
(33–104 m) water and mostly at depths less than
90 m, whereas those for 1966 were from deeper
(51–269 m) water usually below 90 m. Thus the
two sets of data may indicate that proportionately
more older and larger fish are found in deeper
water.

Data on the trap fishery demonstrate that old
fish were relatively less numerous in 1965–66
than in 1962–63 and probably reflect recent in-
creased fishing on the 4RS cod stock as a whole.

Mortality

The increases in total mortality (Z) for off-
shore trawl and inshore trap samples and a con-
cavity between ages 5 and 11 on the catch curve
for trap are a reflection of the decline in older
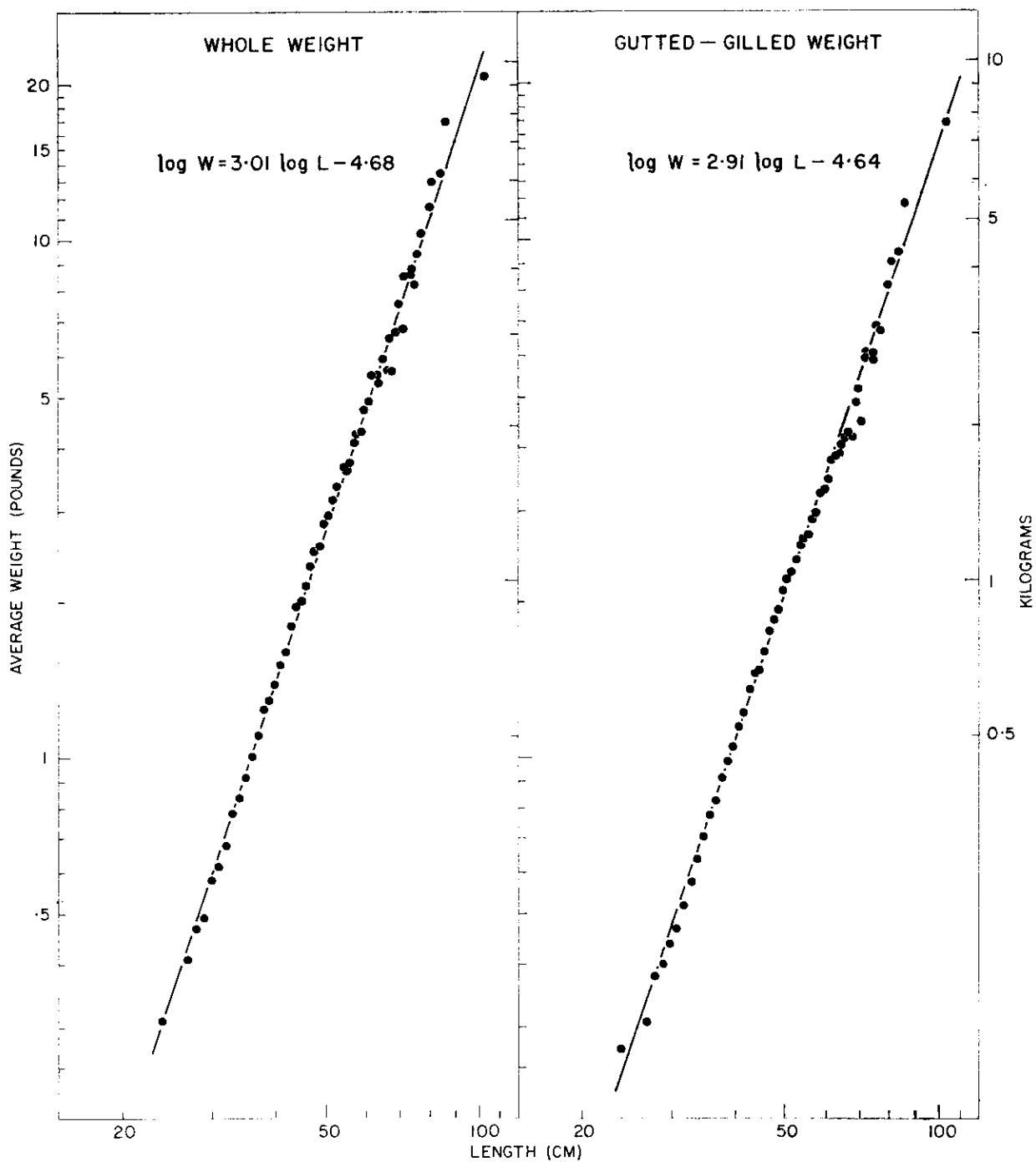
Fig. 26.   Weight-length relationship for inshore cod taken by trap in Division 4R, July, 1962-64.
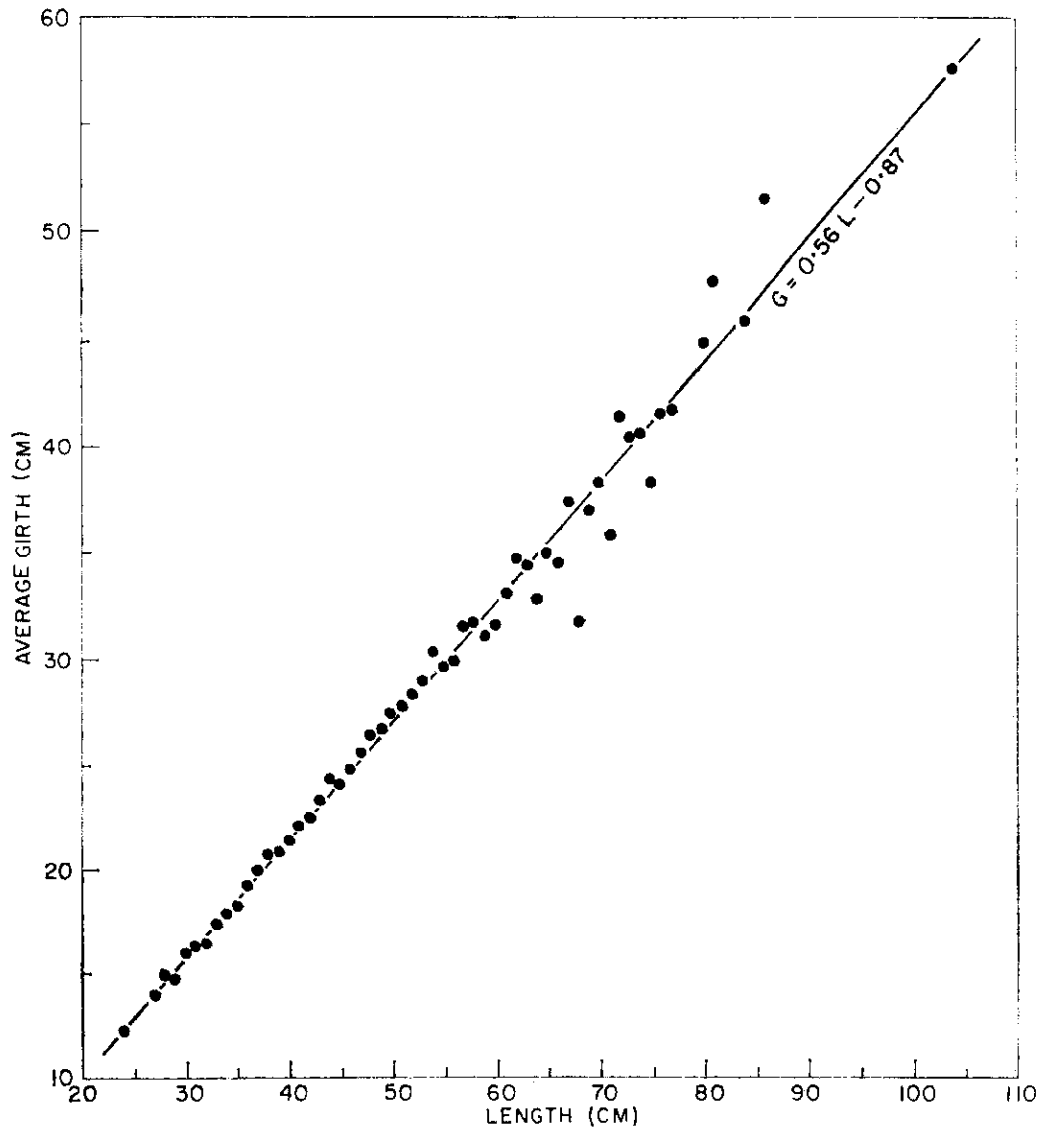
Fig. 27. Girth-length relationship for inshore cod taken by trap in Division 4R, July, 1962–64.

fish which occurred in recent years (1962–66) in the respective samples. The probable cause of increased total mortality was the introduction, in the mid-1950's, and continuance of, otter-trawl fishing in Div. 4R and 4S. For line gear samples Z was about the same for younger ages (8–16 years) in 1953–64 and 1966, while older fish had a lower value of Z in 1966 than in 1953–64. A convex descending limb on a catch curve such as was obtained for 1953–64 is indicative

either of natural mortality simply increasing with age or of a period of low fishing intensity following one of greater fishing intensity (Ricker, 1958). The fact that values of Z for the younger ages were almost identical in the early and recent periods, averaging 0.2 over the whole period of sampling, indicates that the effort put into the line gear fishery has not changed appreciably from 1953 to 1966, although there may have been a decrease from the early 1940's to the 1950's.
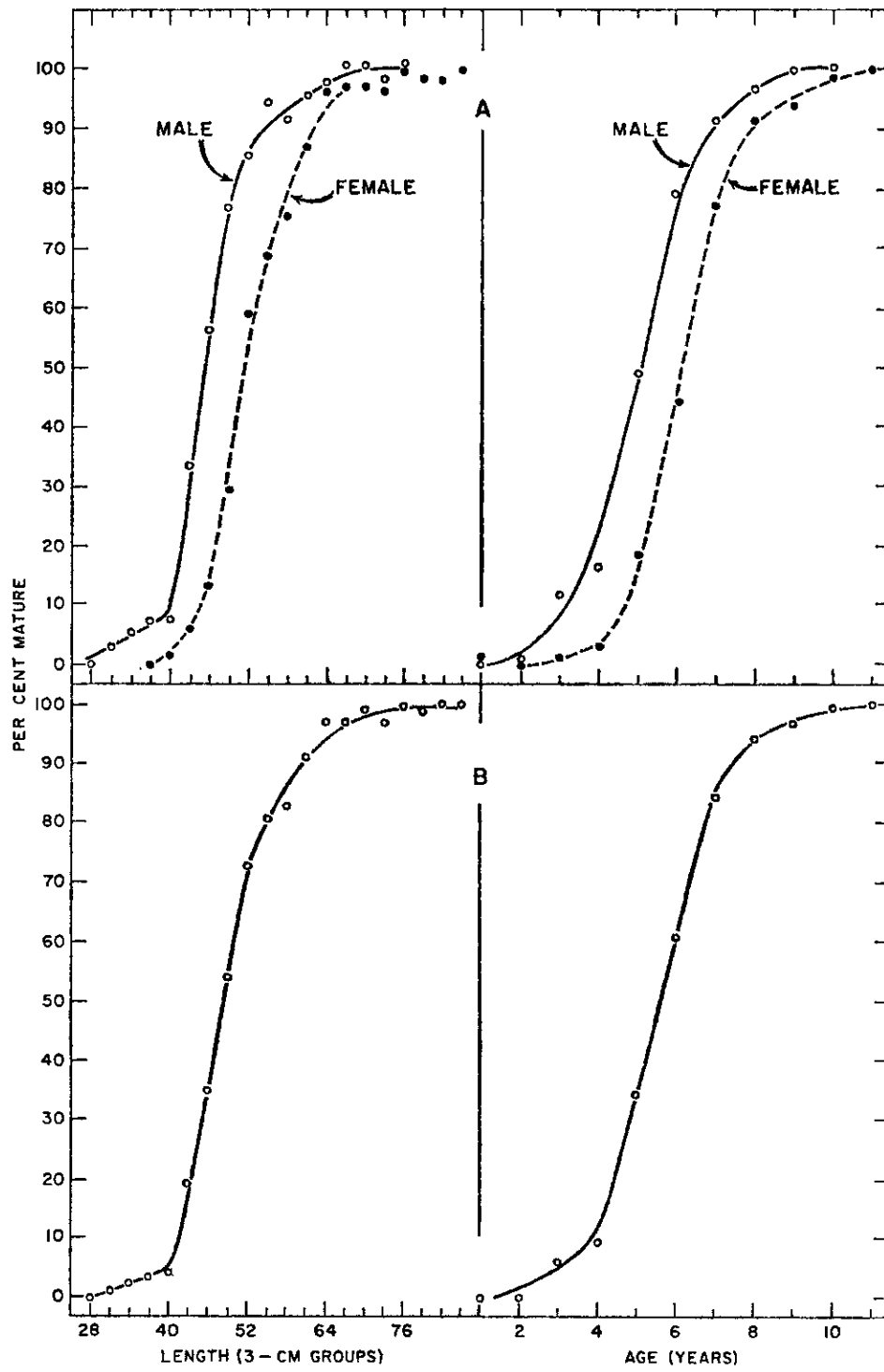
Fig. 28.   Size and age at maturity of otter trawl, line gear and trap fish combined, 1947–66.
(A)   Sexes separate.   (B)   Sexes combined.

Line gears select larger and older fish than otter trawl, which may explain the convexity of the curve for line gear samples in a period when trawl samples produced a straight catch curve.

It must be pointed out that values of Z given here for inshore gears probably do not represent true population values. Availability of older fish to traps probably decreases with age while younger fish are relatively unavailable to line gears. Hence, inshore catch curves contain a measure of availability as well as abundance and although they indicate the direction of change in total mortality, values of Z derived from them may not represent the stock as a whole.

Growth

Growth data used in this study have certain limitations: (1) a long series of collections was not available, there being years when data were lacking or so limited that they were of little use; (2) although a correction was applied to ages when combining material from different seasons, this may not completely compensate for seasonal growth differences; (3) since small numbers of fish were sampled at the very oldest ages, values of mean length derived for these may not be accurate, therefore interpretations of trends in mean length of the oldest fish are provisional; (4) it was found that small changes in the observed data, or differences in the ranges of ages used to determine the growth equations could result in large changes in calculated values of l_∞ and K. This was also noted by Jones (1962) and May *et al.* (1965). Thus the observed differences between l_∞ for 1953–64 and 1966 line gear samples may be artificially large and are of empirical value only. Furthermore, since temperature may well have had a significant influence on growth, the lack of hydrographic data limits the extent to which the effects of fishing on growth rates may be assessed.

Temperature and the growth rate of cod have been shown to be related in certain areas of the Northwest Atlantic (May *et al.*, 1965; Hermann and Hansen, 1965), and this relation is probably an indirect one working through effects on distribution of prey, feeding, and food assimilation (Kohler, 1964). Under relatively stable hydrographic conditions, growth rate changes may be at least partially due to reduced densities of fish on bottom caused by increased fishing (Kohler, 1964; Williamson, MS, 1965; May, MS, 1966). This reduces competition for prey and

allows some fish to take in more food and grow more rapidly. Temperature variations in the northeastern Gulf of St. Lawrence are not well documented, so the degree to which these are responsible for the growth rate changes observed in this study is unknown. In the absence of hydrographic data for the area, changes in fishing effort were examined to see whether increased fishing coincided with increased growth rate. Since 1930, increased otter trawler effort in Div. 4R and 4S appears to have reduced the number of older and larger fish in offshore and inshore catches. Otter-trawl samples from Div. 4R exhibited marked upward trends in average size at age for ages above 9 (Fig. 20). Data for older ages in Div. 4S were scanty and the data series for line gears was short (Fig. 21), though most ages exhibited increased average size from 1963 onward.

The changes are not as marked as those which have occurred in other parts of the Northwest Atlantic (Beverton and Hodder, eds., 1962) possibly because an intense offshore fishery has not yet developed to the same extent as in these other areas. The greatest increase in growth of otter trawl, line gear and trap fish occurred in 1966, which may indicate that the full effect of increased fishing is only now beginning to be felt.

On the other hand, May (MS, 1967) described parallel trends in air temperatures at selected localities and mean annual size at age of cod caught by traps on the North Shore Strait of Belle Isle. In particular, increased sizes in 1965–66 coincided with warmer than average air temperatures in those years. The possibility of hydrographically induced growth thus cannot be discounted. It is apparent that growth increases could have resulted from both increased fishing and hydrographic warming, but the available data do not allow a separation of the effects.

Acknowledgements

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Immunological Analysis of Serum Proteins of Redfish in Connection with Maturation

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Abstract

Sexual differences have been discovered in the serum proteins of redfish (genus *Sebastes*) by using the method of double immunodiffusion in agar gel. Antigen complex (ovovitellin) has been found in the blood of mature females and females maturing for the first time, but is absent in males and immature females. It is suggested that this approach be used to estimate the rate of sexual maturation in the redfish female population.

Introduction

Sexual differences in the serum proteins of the salmon *Oncorhynchus nerka* and *O. kisutch* have been discovered using both the paper electrophoresis (Vanstone and Ho, 1961) and the double immunodiffusion in agar gel (Ridgway *et al.*, 1962). This differentiation is associated with the process of sexual maturation and is expressed in the appearance in the blood of the first maturing females of the lipoprotein complex, named by Vanstone and Ho (1961) as serum vitellin. In the mature females the serum vitellin is always found in high concentration in salmon eggs, as has been shown by Krauel and Ridgway (1963). In the blood of males and immature females this complex is absent. In recent papers (Utter and Ridgway, 1967a, b) the existence of maturity antigens is shown in two other marine species, the English sole (*Parophys vetulus*) and the Pacific halibut (*Hippoglossus stenolepis*).

The present work is concerned with immunological studies of maturation in the viviparous redfishes of the genus *Sebastes*. These investigations were undertaken because the sensitivity and specificity of the immunological tests allow us to identify readily the complex of the sexual antigens. If they are present in the blood of redfish, it would be possible to determine in an objective experimental way the relative number of the first maturing females in the stock of this commercially significant fish.

Materials and Methods

The investigations took place in 1964-67 on board the R/V *Sevastopol* of the Polar Research Institute, and in the laboratory of Moscow University. Studies covered 209 samples of blood sera from *Sebastes marinus*, *Sebastes mentella*, and giants (specimens larger than 60 cm in length). Samples of blood from *S. marinus* and *S. mentella* were collected in September–October 1964, and from the giants in August 1965. Trawling for these took place in the locations shown in Fig. 1. Six samples of serum were taken from the Barents Sea. Four rabbits were immunized with a mixture of blood sera taken from five to six specimens of *marinus*- and *mentella*- types of redfish. Freund's 3-week cycle round of immunization with adjuvant was applied in the manner described in detail by Altukhov, Apekin, and Limansky (1964). Three highly reactive sera were obtained: two against the female serum proteins (anti-*marinus* No. 1 and No. 2) and one against the male proteins (anti-*mentella* No. 4).

Immunodiffusion proceeded in a moist chamber at 20° to 22°C in 1% agar Difco gel spread as a thin layer on the surface of a microscope slide. With the help of a special matrix, wells were cut in the agar gel and analyzed sera were put in them. After the formation of lines of precipitate was complete, the preparations were photographed with the aid of a special lighting set (Limansky, 1965).

The method of immunoelectrophoresis used is described in detail by Zilber and Abelev (1962).

Results

The results of the experiments are shown in Fig. 2. Figure 2A illustrates the character of the reactions between the anti-*marinus* No. 2 serum and the blood sera of males (well No. 2, 4, 6) and females (well No. 1, 3, 5) of *S. marinus*.

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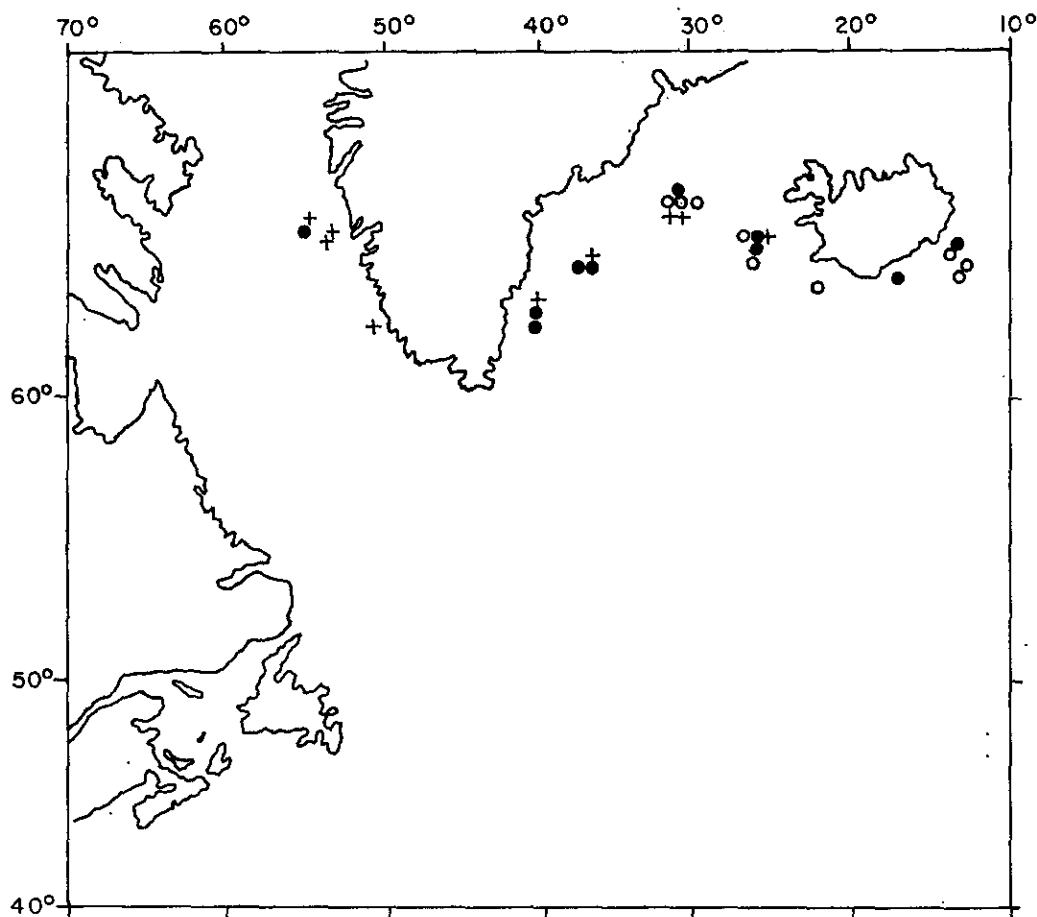
Fig. 1.   Redfish blood sampling locations : O = *Sebastes mentella*: ● = *Sebastes marinus*:
+ = giants.

In Fig. 2B, the antigen composition in the male and female blood of *S. mentella* is compared similarly with the precipitating anti-*marinus* No. 1 serum. These data reveal the sexual differences; namely, at the background of a greater number of connecting precipitate lines, showing the identity of the antigen components in the compared specimens, certain precipitate lines are seen, revealing antigens contained only in the female blood serum of *S. marinus* and *S. mentella*.

The association of these differences with sex is confirmed by the results of the experiment shown in Fig. 2C. Here the same sera as in Fig. 2B are in the peripheral wells, while in the central well is the immune anti-*mentella* No. 4 developed against the male serum. Anti-*mentella* serum does not show any specific antigens in the female blood, but rather shows only the

common components which are inherent in the blood of the specimens of both sexes. The apparent sexual antigen differences in the absorption experiments are also distinct. There results are shown in Fig. 2D and 2B. The difference is only that in the sets in Fig. 2A and 2B, whole antisera were used whereas in experiments in Fig. 2D and 2E they were absorbed by the male serum proteins according to the Björklund (1952) scheme (Fig. 2D) and to the conventional method of absorbtion (Fig. 2E). In the first case, male blood serum of *S. marinus* was put in the agar slide wells and the preparation kept in the moist chamber until complete absorption. After this, the same ingredients as in the set in Fig. 2A were put in the wells. The second variant of absorption was run by adding one part of a mixture of sera from several males of *S. mentella* to two parts
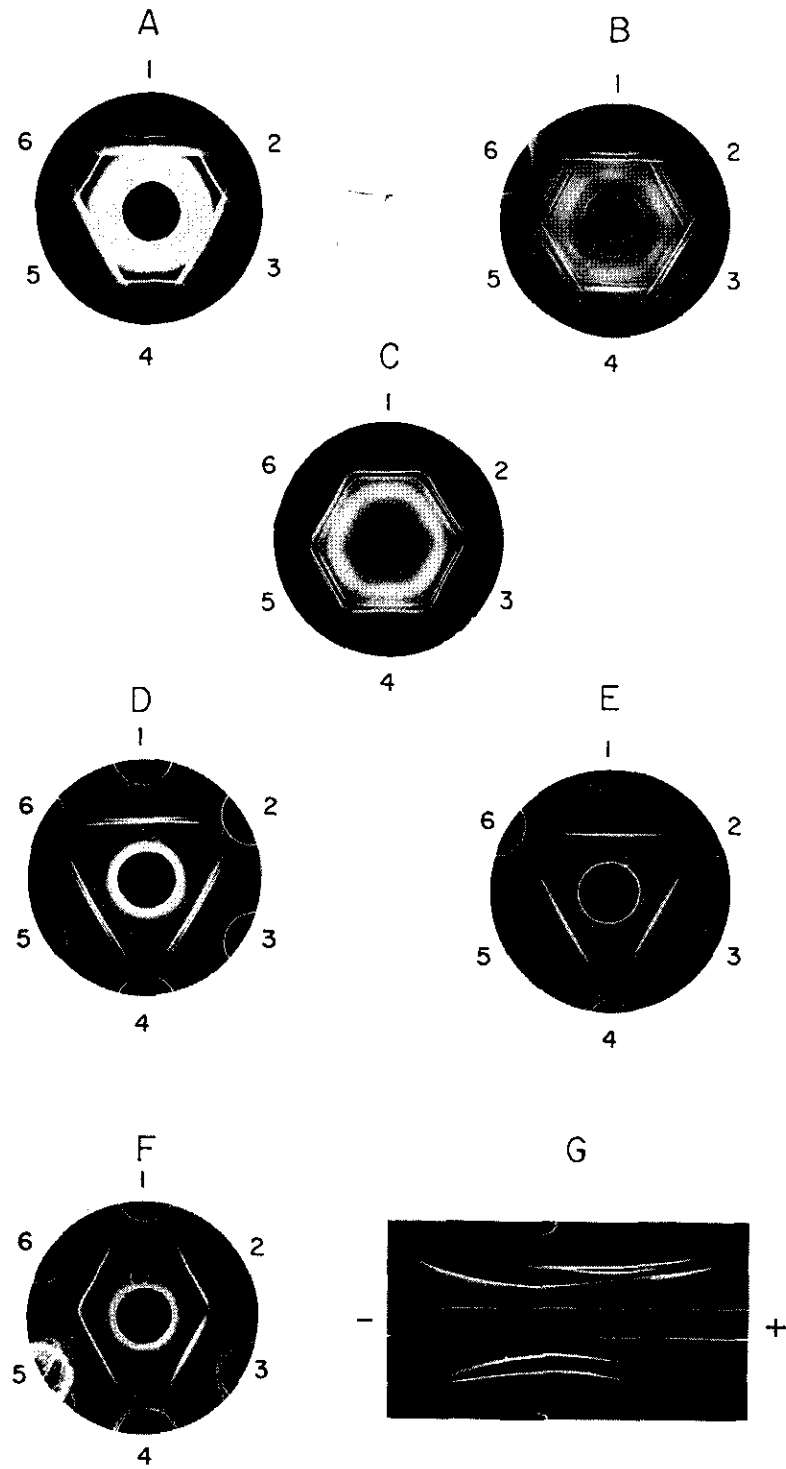
Fig. 2.   The antigen differences in blood sera of male and female redfish
of the genus *Sebastes*.   In each case, the central wells contain the
antisera and the peripheral wells contain the antigens.   For
further details see the text.

of the antiserum No 1. The mixture was placed in a refrigerator overnight, centrifuged and the reagent which is specific only against the blood antigens of the females was obtained.

On the other hand, the reactions with the absorption by antisera show that the specific female antigen is not homogenous, but consists of several components. It is possible to identify readily not less than three lines of precipitation, (Fig. 2D). The antigens in this experiment are arranged as a compact group; two of them which are recognizable near the equivalent zone, evidently prevail in quantity over the third antigen which is the nearest to the central well. The pattern shown in Fig. 2E actually does not differ from that described above, although the division of the first two precipitate lines is not so distinct. However, in the immunoelectrophoretic analysis of the antigen composition in the female blood sera, examined in the set in Fig. 2E, the number of precipitate arcs is also equal to three (Fig. 2G). Under the given methodical conditions, the antigens identified by the absorbed anti-*marinus* No. 1 serum, have a similar electrophoretic mobility.

The experiments described, in which the two absorbed anti-*marinus* sera behave as the specific reagents which are only female antigens, prove the presence of this complex regardless of whether the female belongs to the *marinus* - or to the *mentella* - type redfish. Therefore, the difference is possibly not species-specific. Such a supposition is confirmed by the experiment in Fig. 2F in which serum No. 1 is situated in the central well, and is absorbed by the mixture of anti-*marinus* male blood sera, while in the peripheral wells, the female sera of the *marinus* - (well No. 2, 6) and *mentella* - (well No. 3, 5) types of redfish are situated. For comparison the male blood sera were dropped in wells No. 1 and No. 4. These data show the merging of the precipitate lines, formed by the contact between the specific antibodies and the sexual antigens of females, this testifies to the identity of the compared components.

Thus, our investigations demonstrate clearly that the complex of specific antigens accompanying sexual maturation can be revealed by double immunodiffusion and immunoelectrophoresis. They are actually present in the blood of females,

which are visibly mature, and are also present in the ovaries of females which are in Stage II[3] of maturity, that is in females maturing for the first time. For example, wells No. 1 and No. 3 of the experiments in Fig. 2A and 2D contain the sera of the females in Stage II of maturity, and in well No. 5 is the serum of the mature female at the Stages IX–II of maturity. Not a single male from the 118 specimens of the three types of redfish studied possessed the sexual antigens. However for the females, which were mainly in Stages II, II–III, rarely in III and occasionally in IX–II, it is necessary to emphasize the following: (1) from 14 *mentella*-type females captured in East and West Greenland waters, the antigens of maturation were found in six specimens; (2) from 31 females of the *marinus*-type captured in the Iceland and East Greenland areas, the antigens of maturation were found in 17 specimens; (3) from 22 females of the West Greenland *marinus*-type antigens of maturation were found in only three specimens.

Twenty-four giant females caught in August 1965 in West Greenland waters were also studied. By their large size they might be expected to have reached maturity, yet their ovaries were in Stage II of maturity. The sexual antigen complex was found in only four fish, and it consisted of only two components instead of three.

From the 46 giant and West Greenland *marinus*-type females studied, sexual antigens were found in only seven specimens (15.2%), which is far less than its frequency in *marinus*-type females from the Iceland-East Greenland Area (54.8%). The difference found is statistically significant (P< 0.001). Therefore, it is possible that very slow rates of maturation are characteristic of the giants and *marinus*-type redfish caught off West Greenland.

Owing to the limited data collected a thorough discussion is not possible at the present time. Nevertheless, the data seem to deserve some further attention, since the cytophysiological and biochemical data reported on by Altukhov, Nefyodov, and Pajusova (1967) and Altukhov and Nefyodov (1968) point to the hybrid nature of the West Greenland *marinus*-type population and of the giants; moreover, the biological observations show a significant part of these fish, mainly females are juvenile. Until

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[3]The maturity scale adopted was developed for redfish by Dr. V. P. Sorokin (PINRO).

now such conclusions have been based upon the materials obtained by a visual examination of the sexual glands and identification of maturity co-efficients (Zakharov, 1962). Now such investigations can be conducted at the molecular level, moreover the discussed immunological data agree with the biological observations. Further accumulation of data would probably confirm the hypothesis that the juvenile nature of a considerable part of the West Greenland *marinus*-type population of females, including the giants, is connected with their hybrid origin. Therefore, with a certain degree of physiological incompatibility between the *marinus*- and *mentella*-types, these species would seem to be in the formative stage.

At the same time, although further investigations in this direction are necessary, the immunological data examined do show the immunological method suitable for early determination of the sexual maturation of females in the redfish populations of the North Atlantic. In addition, these data increase the number of fish species, in the blood of which, the sexual antigen complex can be identified.

Conclusions

The immunological analysis has revealed significant sexual differences in the antigenic composition of the blood serum of the genus *Sebastes* from the North Atlantic. It has been found that in the blood of the mature and first maturing females there is a specific antigen complex which is absent in males. The method of double immunodiffusion in agar gel is suggested for use in the early determination of sexual maturation in the female redfish population.

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Age, Length, and Gonadal Stages of Herring from Georges Bank and the Gulf of Maine

BY H. C. BOYAR [1]

Abstract

Age, length, and gonadal stages of adult herring, *Clupea harengus harengus* L., were determined from samples collected in 1960–65 from Georges Bank and the Gulf of Maine. Age-groups IV and V were the most abundant ages in the samples. The 1960 year-class dominated the samples from Georges Bank in 1963–65, and the samples from the Gulf of Maine in 1964–65. This year-class was the most abundant during the period of study. The 1959 year-class was extremely weak on Georges Bank, but was well represented in the Gulf of Maine. The mean lengths of the age-groups IV and V from the 1960 year-class were generally less than those from other year-classes; the slow growth and the apparent high abundance suggest that growth is density-dependent. Differences in the peak of spawning and spawning seasons among the areas were small.

Introduction

Until 1961 the traditional harvest of herring, *Clupea harengus harengus* L., in the Gulf of Maine was largely from the inshore fishery for immature fish (sardines); the only significant fishery for adult herring was in southern Nova Scotia. In 1961, the USSR established a fishery for adult herring on Georges Bank (offshore Gulf of Maine); the annual catch from that fishery has exceeded the inshore catch for the State of Maine in every year through 1965. The average catches for these 5 years by the USSR and the State of Maine were about 108,000 and 47,000 metric tons, respectively. To date the development of the offshore fishery has given no evidence of any effect on the sardine fishery. It is not known whether the offshore spawning contributes to the inshore populations of sardines, or if the adult populations are discrete. One way to determine the relationship of offshore and inshore populations of herring is to compare the biological characteristics of fish from known spawning sites. The data compared in this report include information on age, length, and gonadal stages of herring from the Gulf of Maine and Georges Bank where the spawning

has been documented (Moore, 1898; Huntsman, 1919; McNairn, 1933; Fish and Johnson, 1937; Sanders, 1952; Bigelow and Schroeder, 1953; Tibbo, 1957; Leim, 1958; Tibbo, Legare, Scattergood, and Temple, 1958; Colton and Temple, 1961).

Collection of Samples

Samples from the Gulf of Maine were divided into two groups — those from the United States coastal area between Cape Cod, Massachusetts, and Eastport, Maine, and those from the southern coast of Nova Scotia between St. Mary's Bay and Port Mouton (Fig. 1). The US areas are referred to collectively as the Coastal Gulf of Maine. Three sites provided the majority of the samples: Eastport and Boothbay Harbor, Maine, and Cape Cod, Massachusetts. Additional samples were taken from Isles of Shoals, Matinicus, and Monhegan Island. Herring from Isles of Shoals were available only during the spring and late autumn, and herring from Matinicus and Monhegan Islands were taken during the summer.

Samples from Nova Scotia were collected from Trinity Ledges eastward to Port Mouton in June–September. Samples of herring obtained during May, October, and December were from the St. Mary's Bay area on the western coast of Nova Scotia.

In April, Georges Bank herring occurred between the Southwest Part and Southeast Part of the Bank and west of Cultivator Shoals, but were absent from the Northern Part of the Bank. In June and July, herring were evenly dispersed throughout the Bank; approximately equal catches per unit of time were obtained from trawl drags on the Southwest Part, Southeast Part, Northeast Peak, Northern Edge, and the Northern Part as far west as Cultivator Shoals. Our findings of herring throughout the Bank during

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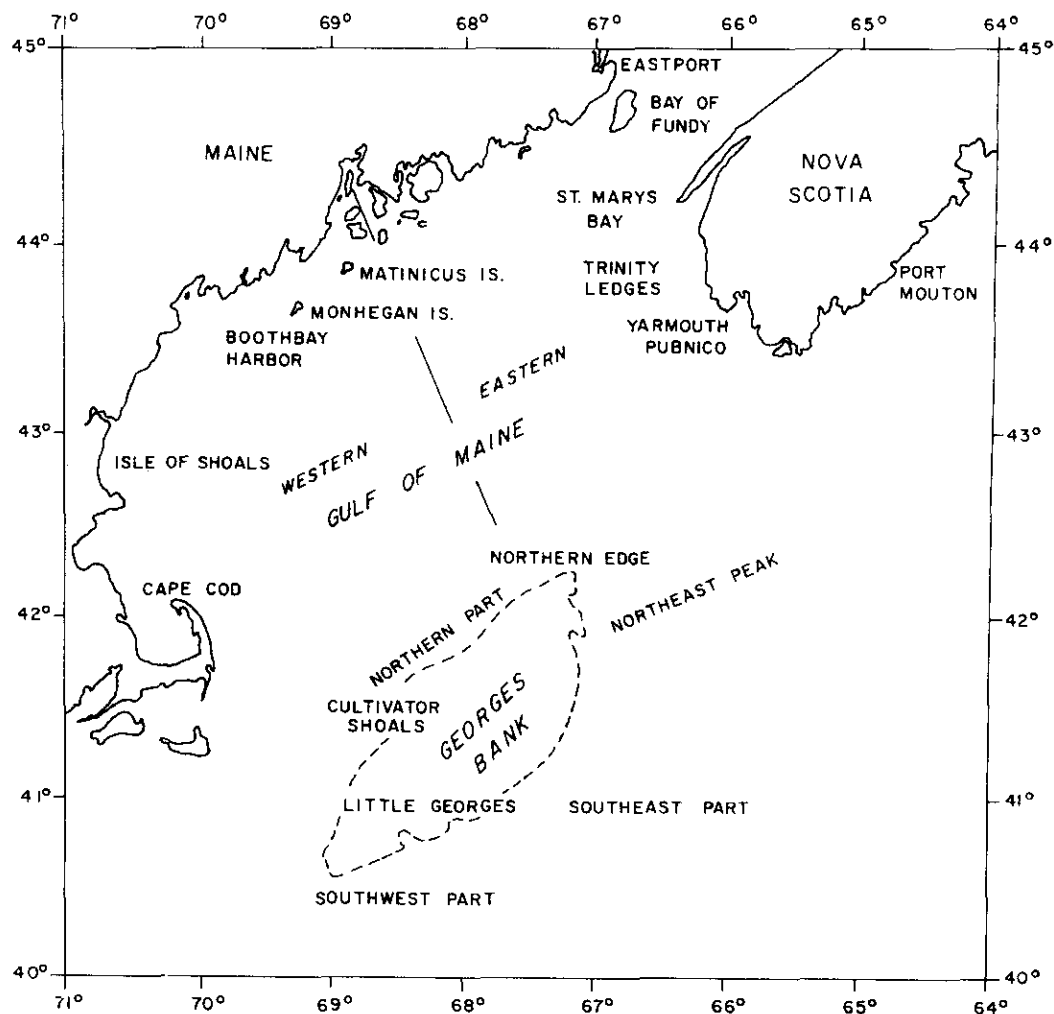
Fig. 1.　Areas of sampling for herring on Georges Bank, coastal Gulf of Maine, and Nova Scotia.

TABLE 1.　Length at age and percentage of age composition from samples of herring caught with gill nets, trawls, and purse seines from Georges Bank, Coastal Gulf of Maine, and Nova Scotia, June 1964.　Number of fish in parentheses.

Age-group	Georges Bank				Coastal Gulf of Maine				Nova Scotia	
	Gill net (310)		Dutch trawl (762)		Purse seine (200)		Commercial trawl (52)		Gill net (529)	
	%	Average length	%	Average length	%	Average length	%	Average length	%	Average length
		cm		cm		cm		cm		cm
III	1	22.8	—	—	5	23.4	5	21.8	—	—
IV	66	26.5	63	26.7	89	25.9	76	26.0	29	25.9
V	8	29.0	7	29.3	4	29.4	11	28.9	9	28.5
VI	20	30.2	21	30.2	2	31.2	8	30.4	22	30.3
VII	5	31.4	9	30.8	—	—	—	—	27	31.4
VIII	—	—	—	—	—	—	—	—	8	32.2
VIII+	—	—	—	—	—	—	—	—	5	33.7

June 1964 and 1965 differed from those of Bryant-sev (1966) who reported that herring did not move in a northerly direction beyond the South-east Slope in June–July 1962. From August through November, herring congregated on the Northern Part of the Bank (west of Cultivator Shoals to the Northern Edge).

Trawls were the principal gear for the col-lection of herring on Georges Bank. In waters where trawling was not possible, we used gill nets. In the Coastal Gulf of Maine, the majority of the herring were obtained with trawls; occasion-al samples were collected from gill nets and purse seines. Most of the fish were taken in waters beyond the limit of the stop seines and weirs which are fished in the inshore fishery. Herring from Nova Scotia were obtained primarily by gill nets, but some came from weirs.

The lengths of fish of the various age-groups and the age compositions for herring caught with the different gears used in each area were com-pared to determine whether there was any bias because of selection of gear (Table 1). Although a detailed analysis of the selective action of the gear is beyond the scope of this report, a limited comparison of the tabulated data reveals no major bias. Herring (exclusive of the immature fish) caught with the various types of gear were similar in size for a particular age-group, and the same age-group (IV) dominated all the samples (weakly in Nova Scotia) regardless of the gear used.

The commercial fishermen used nylon gill nets with a mesh of $2\frac{5}{8}$- to 3-inch (61- to 76-mm) stretched measure and generally caught adult fish. Aboard research vessels, gill nets ranged from 1 to $2\frac{3}{4}$ inches (25 to 70 mm) stretched mesh and caught both immature and adult fish. Fisher-men on commercial draggers caught herring with trawls that had a stretched mesh of 2 inches (51 mm) in the body, and 1-inch (25-mm) liner in the codend. Scientists aboard the research vessels caught herring with a Dutch herring trawl that was lined from belly to codend with a 1-inch (25-mm) stretched mesh. The trawls caught all sizes of herring. Samples from purse and stop seines, and weirs ($\frac{1}{4}$- to 1-inch stretched mesh - 6- to 25- mm) were not considered selective either and contained fish of all age groups present on the grounds. Fish of age-group II have been included in the Georges Bank data because they were taken in sufficient abundance to help describe that popu-lation. To obtain an index of population struc-

ture of the adult herring in Coastal Gulf of Maine, age-groups III and upward were used; very few fish of age-groups I and II (less than 150 fish) were taken. No fish of the age-groups I and II were obtained from Nova Scotia, and no fish of age-group I from Georges Bank.

In 1960–65, 112 samples (9,880 herring) from Georges Bank, 160 samples (11,435 herring) from Coastal Gulf of Maine, and 81 samples (7,436 herring) from Nova Scotia were obtained for study (Table 2). Whenever possible, monthly samples of at least 100 fish were collected.

TABLE 2. Number of samples and total number of herring collected in different years from Georges Bank, Coastal Gulf of Maine, and Nova Scotia, 1960–65.

	Georges Bank		Coastal Gulf of Maine		Nova Scotia	
	Number of		Number of		Number of	
Year	Samples	Fish	Samples	Fish	Samples	Fish
1960	5	571	1	106	5	384
1961	3	588	6	282	4	490
1962	13	1,080	1	251	7	850
1963	24	3,044	35	2,398	20	1,797
1964	35	2,549	46	3,565	20	1,787
1965	32	2,048	71	4,833	25	2,128
Total	112	9,880	160	11,435	81	7,436

Age and Length

Age determinations were made from otoliths. The age was recorded as the number of actual or virtual summer growth zones on the otolith. The year-class to which a fish belonged was also recorded and refers to the year of deposition and hatching of the majority of the eggs. It was assumed that all fish spawned in the autumn were hatched before 1 January; for fish spawned in the spring, hatching took place between April and June. Virtually all of the spawning, how-ever, occurred in the fall. In accordance with International Commission for the Northwest At-lantic Fisheries (ICNAF) procedures, all fish older than age-group VIII were combined into a VIII+ category. Since the I and II group fish were eliminated from the Coastal Gulf of Maine and Nova Scotia samples, the age scale is from II to VIII+ for herring of Georges Bank, and III to VIII+ for herring from Coastal Gulf of Maine and Nova Scotia (Fig. 2).
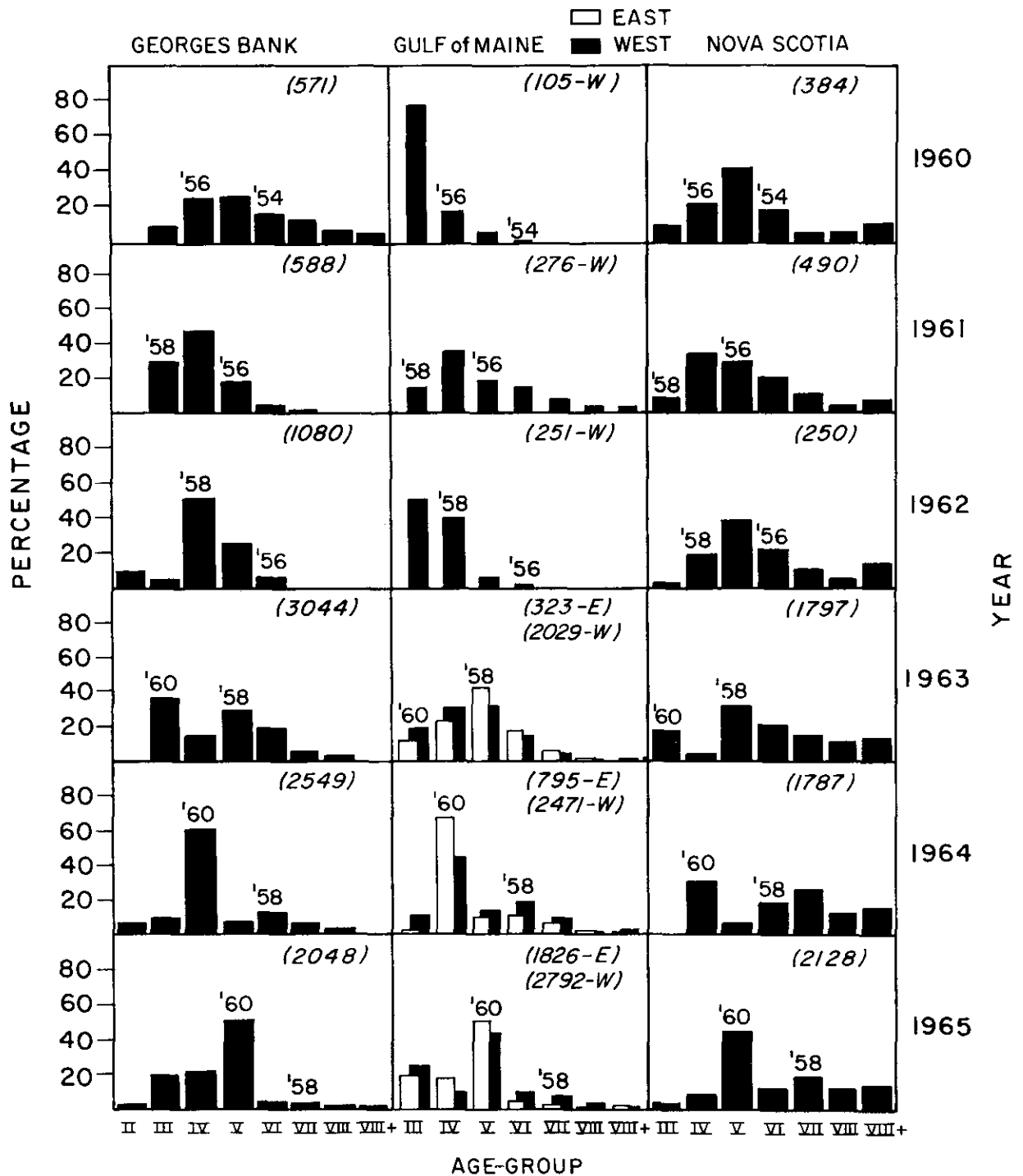
Fig. 2.   Age and year-class composition of herring from Georges Bank, coastal Gulf of Maine, and Nova Scotia, 1960–65.   Numbers of fish in parentheses.

Fish were measured from the tip of the lower jaw to the end of the longest lobe of the tail, with the fish lying in a natural position (natural total length). When the tail was damaged, fish were measured from the tip of the lower jaw to the silvery area on the caudal peduncle (standard length), and the length was converted to natural total length (TL = 2.80 + 1.157 SL where SL = standard length in millimeters). Length data, recorded to the nearest millimeter, have been grouped into 1-cm intervals.

Georges Bank

In 1960–65, age-group IV was dominant in the samples, followed in abundance by age-groups V, III, and VI. (Fig. 2). The highest frequency of occurrence of age-group IV was in 1964 (1960 year-class). The 1960 year-class entered the fishery in 1962 when it ranked third in percentage occurrence; in 1963–65 it ranked first. The 1960 year-class belonged to age-group II in 1962, age-group V in 1965. The 1960 year-class was not dominant or was absent from occasional samples taken in areas away from the Banks. In a sample from 40°46'N lat, 67°50'W long (June 1964), the 1958 and 1957 year-classes formed 61% of the sample, and the 1960 year-class, 24%. In a sample from 41°04'N lat, 66°12'W long (June 1965), the 1958 and 1957 year-classes formed 75% of the sample and the 1959 and older year-classes, 25%; the 1960 year-class was not represented. In a sample from the Northeast Peak in August 1964, the 1959 and 1958 year-classes accounted for 50% of the sample; the 1960 year-class, 25%. It seemed evident from the above samples, that the fish schooled according to age and to size.

The distribution of immature fish appeared to be restricted to the Banks proper, and the samples in which they dominated the catch were obtained from the vicinity of Cultivator and Georges Shoals and Northeast Little Georges. Immature herring were not caught farther east than Georges Shoals. Apparently these fish prefer the shallow areas (20 fathoms or less) of the Banks during the summer and early autumn, possibly because the bottom temperatures are higher than in the deeper areas as shown below.

Month and year	Range in temperature (°C)	
	Shallow water	Deeper water
June 1964	9.2–9.8	3.0–8.2
October 1964	13.1–15.1	4.8–13.1
September 1965	11.0	2.4–5.4

Comparable data are not available for Coastal Gulf of Maine and Nova Scotia.

The length of fish of each age-group increased from late spring through the summer, but during spawning season, the mean lengths of a particular age-group were frequently equal to or even less than the mean lengths before the spawning season. The apparent decrease of length in some samples can be explained on the assumption that the larger fish of an age-group spawn first, move off the spawning grounds, and are replaced by the smaller fish of the age-group. The dominance of the smaller fish of age-groups persists in the samples throughout the first few months of the following year. The last of the autumn spawning occurs at this time.

The mean length of a given age-group collected in August–September did not vary more than 1 cm, among the year-classes, except for the III-group fish (Table 3). The average increase in annual length from the III- to the IV-group fish was 2.8 cm; from the IV- to the V-group, 1.6 cm; and from the V- to the VI-group fish, 1.3 cm.

Coastal Gulf of Maine

Evidence supports a separation of eastern and western stocks of herring along the Gulf of Maine. Sindermann (1959) reported differences among parasites of herring in the eastern and western areas, and Sherman (1966) found differences in hydrographic conditions and abundance of zooplankton. On the basis of these differences, I have also divided herring samples from the Coastal Gulf of Maine into western and eastern groups. In 1960–65, herring of age-group V

TABLE 3.   Mean lengths (cm) of herring of various age-groups and year-classes from Georges Bank in August–September, 1960–65.

Year-class	Year of capture					
	1960	1961[a]	1962	1963	1964	1965
1956						
Age-group	IV	V	VI	VII	VIII	—
Length	27.6	29.3	30.6	31.4	33.0	—
1957						
Age-group	III	IV	V	VI	VII	VIII
Length	25.6	27.8	29.3	30.4	32.1	33.3
1958						
Age-group	—	III	IV	V	VI	VII
Length	—	24.9	27.8	29.4	30.6	32.0
1959						
Age-group	—	—	III	IV	V	VI
Length	—	—	25.5	27.9	29.4	30.8
1960						
Age-group	—	—	—	III	IV	V
Length	—	—	—	24.3	27.3	28.9
1961						
Age-group	—	—	—	—	III	IV
Length	—	—	—	—	23.7	27.1

[a]Only data available were for October.

dominated the samples in both sections (Fig. 2). The order for other major age-groups was IV, III, and VI in both sections. The dominant year-class was always more abundant in the eastern section than in the western section. In both sections the 1960 year-class was first evident in the samples in 1963 (age-group III) and was dominant in 1964 and 1965 (age-groups IV and V). The relative abundance of fish of the 1959 year-class was greater along western and eastern Coastal Gulf of Maine than on Georges Bank. In 1963 and 1965 fish of the dominant year-class were plentiful in all samples. A few 1964 samples from Provincetown, Massachusetts, and Boothbay Harbor, Maine, were dominated by fish of the 1958 and 1959 year-classes, and fish of the 1960 year-class made up less than 10% of the collections.

The length frequencies of fish from the western and eastern sections were similar in 1965 and 1963, but in 1964 differences between lengths of fish from these sections were highly significant. The mean length of fish of an age-group collected in August–September did not vary more than 1 cm among year-classes, except for IV-group fish from the eastern section (Table 4). In the western section, the average increase in annual length

from III- to the IV-group fish was 2.7 cm; from IV- to the V-group, 1.3 cm; and from V- to the VI-group, 1.4 cm. In the eastern section, the average increase in length from IV- to the V-group was 1.4 cm; and from V- to the VI-group, 1.5 cm.

Nova Scotia

Herring of age-group V were dominant in the samples in 1960–65 (Fig. 2) followed in percentage occurrence by age-groups VII, VI, and IV. Fish in age-groups V and VIII were more abundant in the samples than fish in age-group IV, except in 1961 and 1964. The 1960 year-class which ranked third in abundance in 1963 (age-group III) was dominant in 1964 and 1965. In general, the samples from Nova Scotia contained a higher percentage of older fish than the samples from either Georges Bank or the Gulf of Maine. The 1959 year-class, as on Georges Bank, was noticeably weak.

Although the 1960 year-class contributed 43% of all fish collected in 1965, some samples from St. Mary's Bay, Port Mouton, and Locke-port contained less than 10% of this year-class. Fish of the 1958 and 1957 year-classes were abundant in these collections. In 1964, the

TABLE 4. Mean lengths (cm) of herring from various age-groups and year-classes from Coastal Gulf of Maine in August-September, 1960–65 (W—Western Section, E—Eastern Section).

Year-class	1960		1961		1962[a]		1963		1964		1965	
	W	E	W	E	W	E	W	E	W	E	W	E
1956												
Age-group	IV	—	V	—	VI	—	VII	VII	VIII	VIII	—	—
Length	27.7	—	29.4	—	30.2	—	31.9	32.1	33.4	33.1	—	—
1957												
Age-group	III	—	IV	—	V	—	VI	VI	VII	VII	VIII	VIII
Length	25.0	—	28.2	—	29.2	—	30.8	30.5	32.0	32.1	33.2	33.0
1958												
Age-group	—	—	III	—	IV	—	V	V	VI	VI	VII	VII
Length	—	—	25.7	—	27.4	—	29.5	29.0	30.8	30.6	31.9	32.0
1959												
Age-group	—	—	—	—	III	—	IV	IV	V	V	VI	VI
Length	—	—	—	—	25.3	—	28.0	27.9	29.6	29.6	30.9	30.8
1960												
Age-group	—	—	—	—	—	—	III	III	IV	IV	V	V
Length	—	—	—	—	—	—	25.2	23.1	27.8	26.6	29.2	28.9
1961												
Age-group	—	—	—	—	—	—	—	—	III	—	IV	IV
Length	—	—	—	—	—	—	—	—	23.6	—	27.5	26.8

[a] Only data available were for October.

TABLE 5. Mean lengths (cm) of herring of various age-groups and year-classes from Nova Scotia in August–September, 1960–65.

Year-class	1960	1961	1962	1963	1964	1965
1956						
Age-group	IV	V	VI	VII	VIII	—
Length	27.7	29.5	30.9	32.1	33.0	—
1957						
Age-group	—	IV	V	VI	VII	VIII
Length	—	27.9	29.1	30.8	32.0	33.4
1958						
Age-group	—	—	IV	V	VI	VII
Length	—	—	27.2	29.2	30.7	32.1
1959						
Age-group	—	—	—	IV	V	VI
Length	—	—	—	27.2	29.6	30.9
1960						
Age-group	—	—	—	III	IV	V
Length	—	—	—	23.7	26.4	28.9
1961						
Age-group	—	—	—	—	—	IV
Length	—	—	—	—	—	27.2

1960 year-class was dominant, but some samples from Port Mouton. Lockeport, and Pubnico were dominated by the 1957 and 1958 year-classes. The 1958 year-class dominated the samples in 1963. but some samples from Trinity Ledges, Carleton Village, and Yarmouth were dominated by the 1960, 1957, or 1956 year-classes.

The range in lengths of herring of the various year-classes collected in August–September varied little from year to year. The mean length of fish for any age-group did not vary more than 1 cm, except for IV-group fish (Table 5). The average increase in length from age-group IV- to the V-group was 2.0 cm; from V- to the VI-group, 1.5 cm.

Stages of Maturity

Most herring from Georges Bank, Coastal Gulf of Maine, and Nova Scotia are mature at age-group IV, although in some years large percentages of fish may mature at age-group III (Table 6). The length of the fish at the time of its first spawning did not differ appreciably between the sexes. Scattergood (1952) reported the same for the herring he examined and stated, "there seems to be no reason to believe that the size at maturity is markedly different between males and females." Although the lengths of fish at the time of their first spawning varied slightly from year to year and from area to area, in general, fish of age-group III which had matured were approximately 26.0 cm long. Fish of age-group IV which had matured were approxi-

mately 27.5 cm long. The fish of age-group IV which had not matured and which would not spawn until the following year were usually less than 27.0 cm long.

TABLE 6.   Percentage of mature herring for age-groups III and IV collected during the spawning season from Georges Bank, Coastal Gulf of Maine, and Nova Scotia, 1960–65.

Year	Georges Bank		Coastal Gulf of Maine		Nova Scotia	
	Age-group		Age-group		Age-group	
	III	IV	III	IV	III	IV
1960	62	97	2	79		100
1961	6	87	0	92		95
1962	56	95	15	66	—	91
1963	33	97	27	96	7	100
1964	9	93	1	92	—	84
1965	10	79	7	70	0	94

Data on state of gonads pooled for 1960–65 were compared by month for each of the three areas. The maturity scale proposed by the International Council for the Exploration of the Sea in 1963 and adopted by ICNAF in 1964 was used in the classification of the various gonadal stages (Table 7). Eight stages of gonadal development were recorded, but to simplify the comparison, the stages were grouped into four categories: II and III — Maturing; IV and V — Full; VI and VII — Spawning and Recently Spent; and VIII — Recovering Spent. Fish of stage I were omitted from the comparisons.

TABLE 7.   Gonadal stages and the description of the gonads and eggs of herring in the various stages.[a]

Stage	Description
I	Virgin herring. Gonads very small, threadlike, 2–3 mm broad. Ovaries wine red. Testes whitish or grey brown.
II	Virgin herring with small sexual organs. The height of ovaries and testes about 3–8 mm. Eggs not visible to the naked eye but can be seen with magnifying glass. Ovaries a bright red colour; testes a reddish grey colour.
III	Gonads occupying about half of the ventral cavity. Breadth of sexual organs between 1–2 cm. Eggs small but can be distinguished with naked eye. Ovaries orange; testes reddish grey or greyish.
IV	Gonads almost as long as body cavity. Eggs larger, varying in size, opaque. Ovaries orange or pale yellow; testes whitish.
V	Gonads fill body cavity. Eggs large, round; some transparent. Ovaries yellowish; testes milkwhite. Eggs and sperm do not flow, but sperm can be extruded by pressure.
VI	Ripe gonads. Eggs transparent; testes white; eggs and sperm flow freely.
VII	Spent herring. Gonads baggy and bloodshot. Ovaries empty or containing only a few residual eggs. Testes may contain remains of sperm.
VIII	Recovering spents. Ovaries and testes firm and larger than in virgin herring in stage II. Eggs not visible to naked eye. Walls of gonads striated; blood vessels prominent. Gonads wine red colour. (This stage passes into stage III.)

[a]Descriptions are verbatim from the official ICNAF definition.
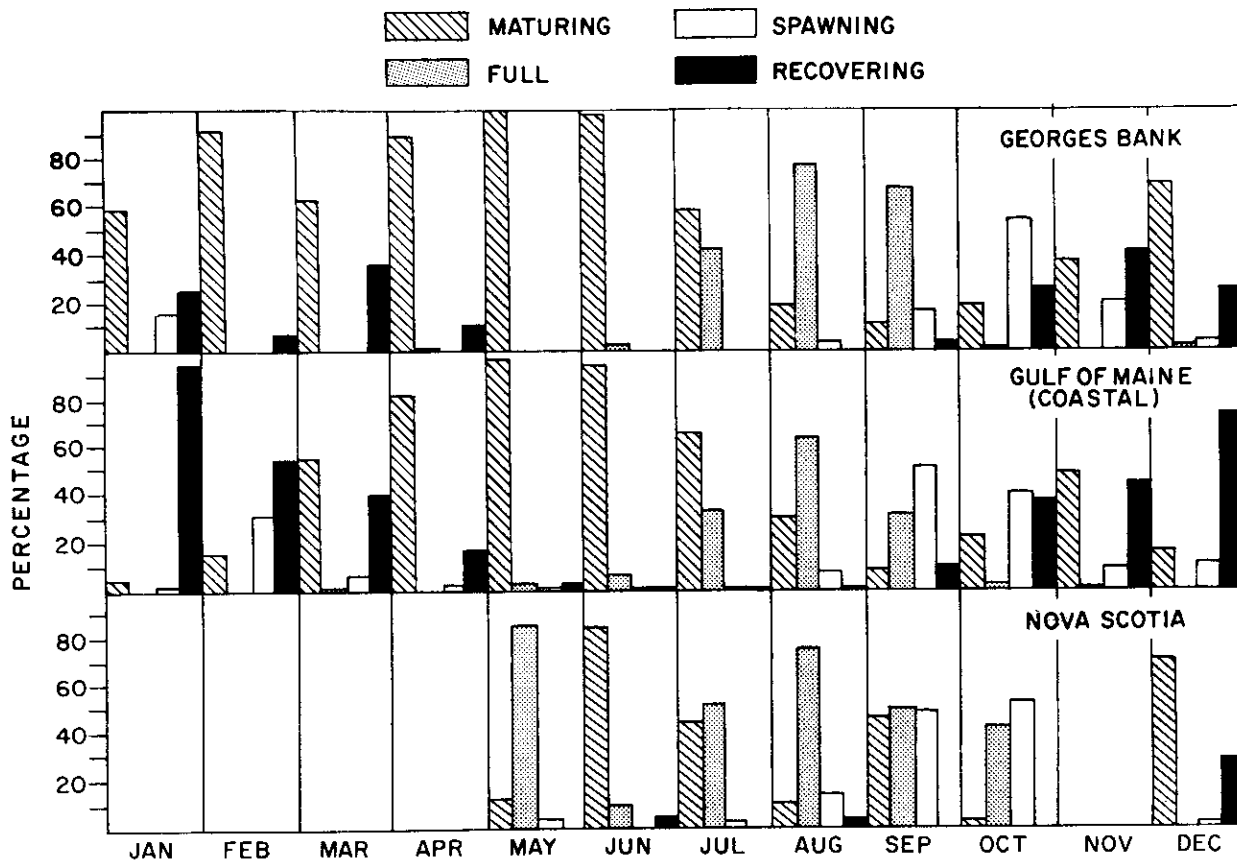
Fig. 3.   Annual trend in gonadal stages of herring from Georges Bank, coastal Gulf of Maine, and Nova Scotia, 1960-65 (pooled data).

Georges Bank

During the first 7 months of the year most herring were maturing (Fig. 3). The percentage of maturing fish decreased in August and reached a minimum in September. The number of maturing fish increased gradually from late October through December due to an influx of virgin herring. The first full fish were taken in April; they reached their peak by August, and decreased during September and October. Spawning began in the latter part of August and yolk-sac larvae were first collected in September. The percentage occurrence of spawning fish increased through September. Spawning and recently spent fish were usually in the majority during October and were still present in January. Recovering spent fish were first collected in September and numbers increased during the late autumn. Recovering spent fish also were collected from January to April.

Coastal Gulf of Maine

As on Georges Bank, most herring were maturing during the first 7 months of the year (Fig. 3). Full fish, first taken in March, increased through July, and reached their maximum frequency by August. The number declined sharply in September and only a few full fish were caught in October and November. The capture of a few spawning fish (less than 2% of those sampled) from Eastport, Maine, and Cape Cod, Massachusetts, during the spring and early summer indicates some spring spawning. The percentage of spawning fish in the monthly samples was highest in September in 1964 and 1965 and in October in 1963. The onset of spawning was during August in 1964 and 1965, and in September in 1963. The percentage of spawning fish decreased from November through March. The collection of recovering spent fish during most months provided additional evidence of limited spring spawning in the coastal waters.
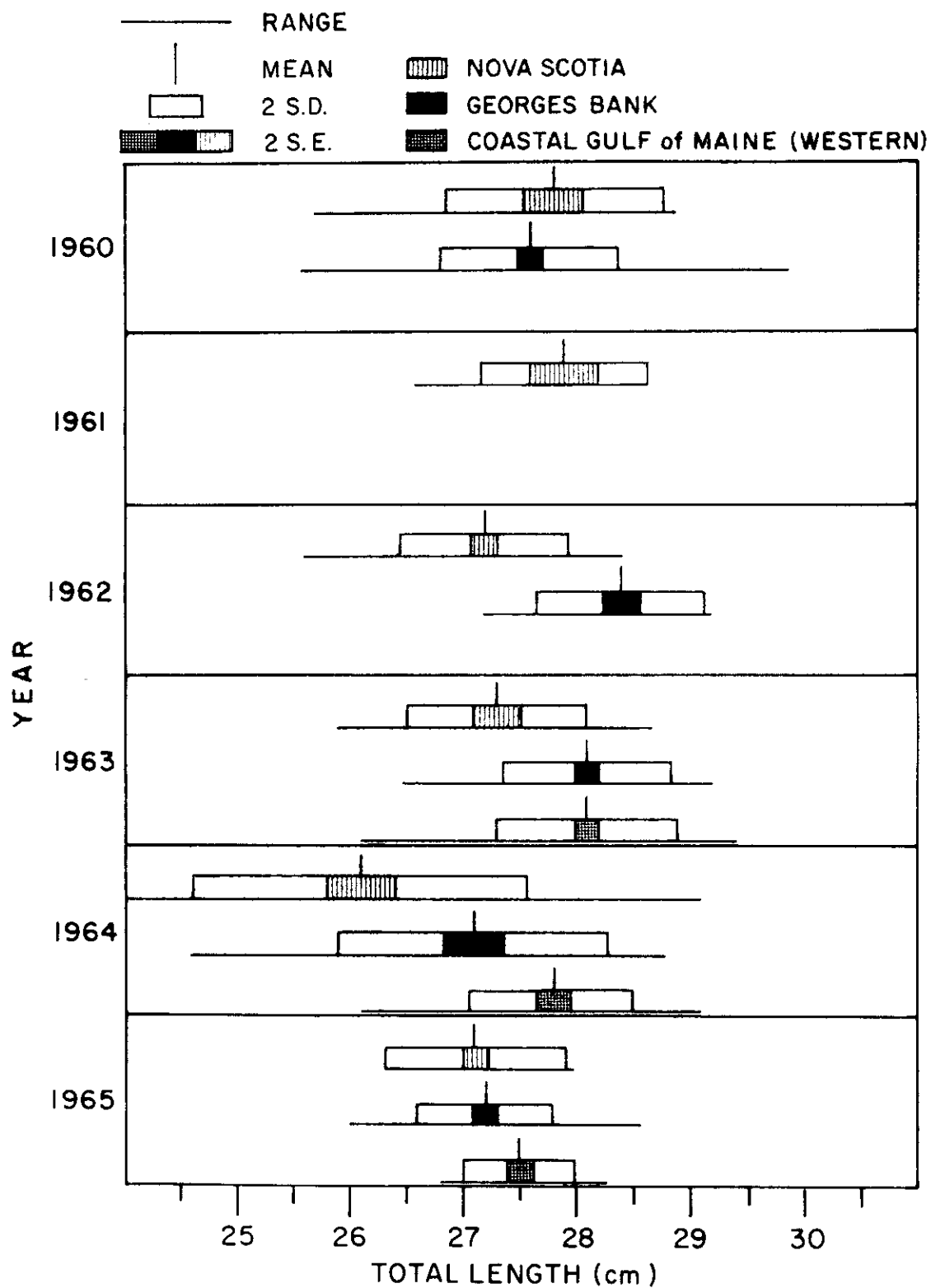
Fig. 4.   Lengths of herring of age-group IV from Georges Bank, coastal Gulf of Maine and Nova Scotia in August, 1960–65.
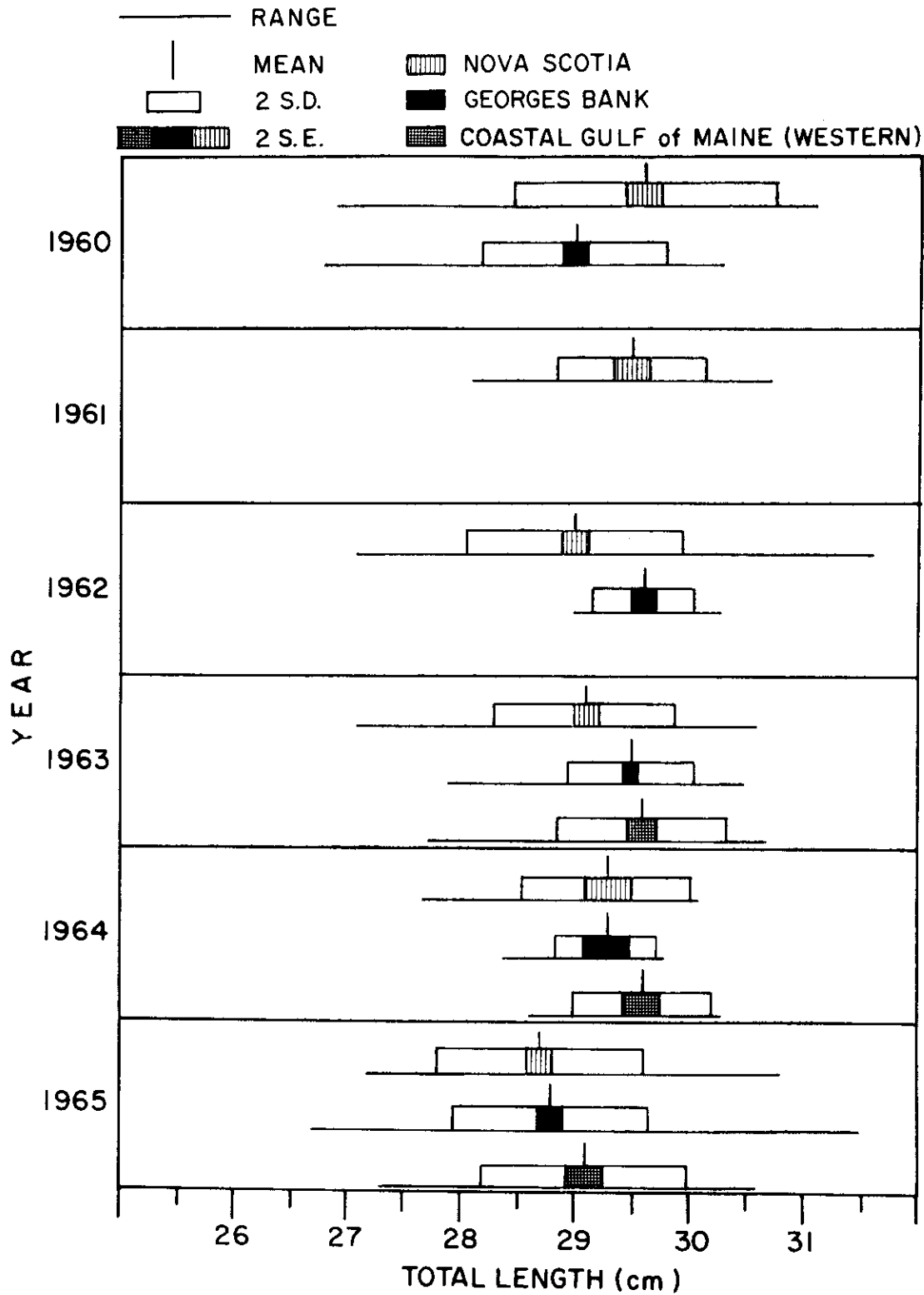
Fig. 5.   Lengths of herring of age-group V from Georges Bank, coastal Gulf of Maine, and Nova Scotia in August, 1960–65.

Nova Scotia

Most samples from Nova Scotia were collected from May to October (Fig. 3). Most fish were maturing in June, and by August the percentage of mature fish had decreased considerably. Full fish were first collected in May, and predominated in July and August. The capture of a few spawning fish in late spring and early summer suggests some spring-summer spawning. Autumn spawning began in August, and as indicated by the percentage of full fish in September, reached its peak during October. A few recovering spent fish taken in September provide additional evidence that the peak of spawning came later than September. The high incidence (over 80%) of full fish (stage V) in the sample of May 1962 suggests that these fish would have spawned in the spring. These fish were taken from St. Mary's Bay. The presence of several fish in stage VIII in July samples indicates that they had spawned sometime in the spring.

Comparison of Maturity, Age, and Length Frequency Distributions

Even before the start of the extensive offshore fishery on Georges Bank, biologists in the Northwest Atlantic were interested in the relationships among the populations of herring from Georges Bank and the Gulf of Maine (Tibbo et al., 1958; Sindermann, 1959; Colton and Temple, 1961). Basic information on the biology of adult herring from Nova Scotia had been documented (Tibbo, 1957), but knowledge about adult herring from Georges Bank and the Coastal Gulf of Maine, until recent years, had been almost negligible. The present report, based on herring collected in 1960–65, provides additional information on the biology of adult herring from these areas.

The IV- and V-group fish dominated the samples in the three areas for every year except 1963, when age-group III was dominant on Georges Bank and in 1960 and 1962 when age-group III was dominant in the Coastal Gulf of Maine. The 1960 year-class dominated the samples in the three areas in 1965 and 1964. The 1960 year-class was dominant on Georges Bank in 1963 and the 1958 year-class was dominant in the Coastal Gulf of Maine and Nova Scotia. In 1962, the 1958 year-class dominated on Georges Bank, the 1957 year-class in Nova Scotia, and the 1959 year-class in the Coastal Gulf of Maine. The 1957 year-class dominated the samples from all three areas in 1961. In 1960, the 1955 year-class was dominant on Georges Bank and off Nova Scotia, but the 1957 year-class dominated the samples from Coastal Gulf of Maine.

The mean lengths of fish from the 1960 year-class in August 1964 and 1965 were less than the mean lengths of age-groups IV and V collected in the other years, except for age-group IV from the Coastal Gulf of Maine in 1965 (Fig. 4 and 5). The mean lengths of age-groups IV and V from the Coastal Gulf of Maine were consistently greater than those of fish of the same age from Georges Bank; the Georges Bank fish, except in 1960, were longer than fish from Nova Scotia.

The mean lengths of fish of the 1960 year-class were generally smaller than those of fish of the same age from other year-classes. Because the 1960 year-class was dominant in many samples, the growth may be density-dependent. The 1959 year-class which dominated the samples in Coastal Gulf of Maine during 1962 and ranked second in occurrence in 1963 was extremely weak in the other two areas. In no year did it rank higher than fourth in either Georges Bank or Nova Scotia.

Differences in spawning time of herring were slight. From 1960 through 1965, herring from Georges Bank and Nova Scotia began to spawn in August; in Coastal Gulf of Maine, the spawning began either in August or September. The peak of spawning on Georges Bank and Nova Scotia always came in October. The peak of spawning in Coastal Gulf of Maine was in October in some years, and September in others. Evidence is lacking for any spring spawning on Georges Bank, but a few spring spawners were collected in Coastal Gulf of Maine and in Nova Scotia.

The differences in age composition and length of fish of a given year-class and the slight differences in spawning time, along with the obvious geographic separation of the three spawning stocks studied, suggest that the stocks may be independent subpopulations. Before conclusions can be reached as to the discreteness of each spawning stock, data from meristic characters and other racial information must be analyzed.

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Distribution and Characteristics of Atlantic Salmon Over Oceanic Depths and on the Bank and Shelf Slope Areas off Newfoundland, March–May, 1966

BY WILFRED TEMPLEMAN [1]

Abstract

Between 21 March and 1 May 1966, 45 Atlantic salmon were caught in eight surface drift-net night sets east and southeast of the Newfoundland area over depths greater than 1,800 m.

Some salmon were caught in all sets with surface temperatures between 3.7° and 6.1°C but none in a set on the eastern border of the area with a surface temperature of 9.2°C. The salmon were all captured in the upper 1.5 m of the nets.

Eighty-four per cent of the salmon were 2-sea-year fish and 4% had spawned previously. River life was mainly 2–4 years. Gutted weights were 89.7% of round weights.

In a comparison with salmon taken by the author in the Labrador Sea–West Greenland in July–August 1965 no distinct differences were noted in body proportions, and of the meristic characters only gill rakers and pectoral fin-ray numbers were significantly different. There were also some differences in parasitic infestations.

Food was 95% fish, the main diet being the paralepid, *Paralepis coregonoides* and lantern fish, especially *Notoscopelus*. There was less food in the stomachs than in the Labrador Sea–West Greenland salmon during July–August 1965 and much less than in salmon from the West Greenland banks in August 1965.
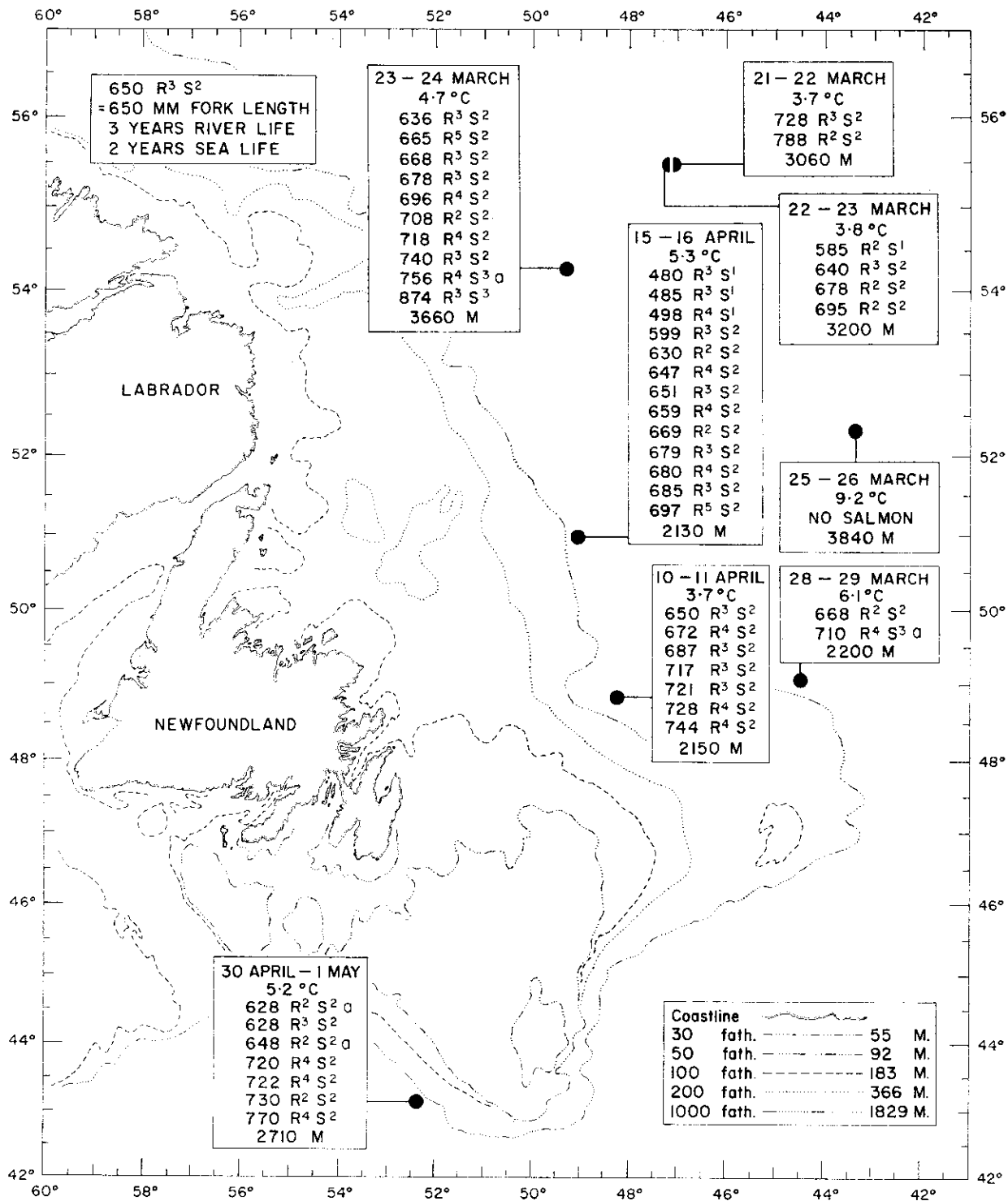
Fig. 1.   Numbers, fork lengths (cm), river and sea life of Atlantic salmon caught in surface drift nets in night sets by the *A. T. Cameron*, 21 March–1 May 1966 at the positions, dates and surface temperatures indicated.

(a = spawned at 1+ sea years.)

Introduction

In July–August 1965 (Templeman, 1967) salmon were caught from the *A. T. Cameron* by drift net over oceanic depths in the Labrador Sea.

Between 21 March and 1 May 1966, seven surface drift-net night sets, each with 21-22 synthetic (mainly Ulstron) nets ranging from 83 to 89 mm mesh (1 to 2 nets only and not in all sets) and from 114 to 152 mm stretched mesh, were made in the Labrador Sea east of southern Labrador, east of the Northeast Newfoundland Shelf, and north of the Grand Bank and Flemish Cap, all over water deeper than 1,000 fathoms (1,800 m). A similar set was also made off the southwestern Grand Bank beyond the 1,000 fathom (1,800 m) isobath (Fig. 1). A preliminary brief account of this work was presented in Templeman (MS, 1966).

Materials and Methods

The twine used, the methods of handling the nets and of examination were generally similar to those described in Templeman (1967), but in 1966 the fish were frozen at sea, thawed in flaked ice at the Biological Station (St. John's) several days to 2 weeks later and the final measurements, weights, and detailed examinations were then carried out at the Station. Sea measurements and round weights were also taken. The numbers and the locations of attachment of the copepod, *Lepeophthirus salmonis* were observed at sea.

Standard lengths were taken on a measuring board from the anterior tip of the snout, with the mouth closed, to the posterior end of the hypurals as judged from the crease formed in the tail when the caudal fin was bent sharply upward.

Unless otherwise stated the lengths of salmon mentioned in this paper are fork lengths measured on a measuring board from the most anterior point, the snout with the mouth closed, to the posterior end of the mid-fork of the caudal fin.

Gutted weights were taken as in 1965 with all the viscera removed but with the gills remaining. The Toledo balance used was checked at intervals and was accurate to the nearest ounce or half-ounce.

Results

Fishing localities and catches

Forty-five salmon were caught (Fig. 1, Tables 1, 2). Some salmon were caught in all sets with surface temperatures between 3.7° and 6.1°C but none in a set on the eastern border of the area with a surface temperature of 9.2°C. The most northerly stations at the mid-mouth of the Labrador Sea were in the same general location where salmon were caught by the *A. T. Cameron* in July 1965 (Templeman, 1967). The greatest numbers of salmon were found closer to rather than more seaward from the 1,000 fathom (1,800 m) isobath. The salmon caught east of the Labrador Shelf in March were on the average larger than those caught off the northeastern Newfoundland Shelf in April.

Location of salmon in net

The salmon were all captured in the upper 5 ft (1.5 m) of the nets of which three were 2.4–3.2 m and the remainder (18–19) were 4.4–5.0 m deep. Even in this upper 1.5 m most salmon were near the surface, the distribution of capture in each foot of the first 5 ft (1.5 m) from the surface being 16, 15, 5, 3, 3 respectively.

There was little evidence from the captures that the salmon were moving in close schools. The individuals of one pair were 3.7 m apart and the individuals of two pairs 5.5 m apart. The remaining spaces between pairs of individuals were approximately : 28 m (1), 31 m (2), 50 m (5), 80 m (3), 140 m (10), 240 m (5), 380 m (2), 530 m (4), and 690 m (2).

Comparative salmon catches in nets of different mesh sizes

No salmon were caught in the $3\frac{1}{2}$-inch-(89-mm) mesh-trout net nor in the $3\frac{1}{4}$-inch-(83-mm) mesh-mackerel net. The 5–6-inch (127–152-mm) mesh nets caught more salmon, larger salmon and a greater weight of salmon per net set than the $4\frac{1}{2}$-inch- (114-mm-) mesh nets (Table 3). The same number of $4\frac{1}{2}$-inch nets (12) was used at each set and approximately the same number (8–10) of 5–6-inch nets. The $3\frac{1}{4}$–$3\frac{1}{2}$-inch nets were 4.3 m deep. Ten of the $4\frac{1}{2}$-inch nets were 4.4 m deep and two were 3.2 m deep. Eight of the 5–$5\frac{1}{2}$-inch nets were 5.0 m deep, one $5\frac{1}{2}$-inch net was 4.6 m deep and the 6-inch net was 2.4 m deep. Since no salmon were caught in any net below 1.53 m it is unlikely that the comparative catches of the $4\frac{1}{2}$ inch and the larger mesh nets were greatly affected by differences in the depth of the nets.

TABLE 1.   Position of salmon surface drift-net sets, gear used, and time of sets by the *A. T. Cameron*, 21 March–1 May 1966.

Date 1966	Position Lat N	Position Long W	No. of linear m of gill nets used 3¼–3½ inches (83–89 mm)	No. of sq m of gill nets used 3¼–3½ inches (83–89 mm)	No. of linear m of gill nets used 4½–6 inches (114–152 mm)	No. of sq m of gill nets used 4½–6 inches (114–152 mm)	No. of linear m of gill nets used 3¼–6 inches (83–152 mm)	No. of sq m of gill nets used 3¼–6 inches (83–152 mm)	Newfoundland standard time Beginning of set	Beginning of haul	End of haul	No. minutes between setting and beginning of haul	Distance from nearest Newfoundland or Labrador coast in nautical miles
21–22 March	55°29'00"	47°07'30"	181	773	1,720	7,802	1,901	8,575	1700	0530	0720	750	325
22–23 March	55°30'00"	47°08'00"	181	773	1,720	7,802	1,901	8,575	2045	0530	0650	525	324
23–24 March	54°14'30"	49°20'00"	181	773	1,720	7,802	1,901	8,575	1730	0820	1000	890	230
25–26 March	52°16'50"	43°22'20"	181	773	1,720	7,802	1,901	8,575	1715	0530	0645	735	405
28–29 March	49°04'00"	44°30'00"	181	773	1,720	7,802	1,901	8,575	1725	0500	0645	695	345
10–11 April	48°50'00"	48°14'00"	84	359	1,808	7,982	1,893	8,341	1710	0600	0715	770	185
15–16 April	50°58'00"	49°00'00"	0	0	1,895	8,377	1,895	8,377	1830	0500	0600	630	205
30 April–1 May	43°15'00"	52°45'00"	0	0	1,895	8,377	1,895	8,377	1845	0530	0645	645	205

TABLE 2.   Numbers and weights of Atlantic salmon caught in surface drift-net sets at and above various temperatures by the *A. T. Cameron*, 21 March–1 May 1966.   (See Fig. 1 and Table 1 for positions, and Table 1 for number and mesh sizes of nets used and details of time of set.)

Date 1966	Locality	Depth at position (m)	Temperature °C Surface	5 m	25 m	50 m	100 m	Salmon caught (No.)	Total weight of salmon caught (kg)
21–22 March	Labrador Sea	3,060	3.7	3.7	3.7	3.7	3.7	2	9.0
22–23 March	Labrador Sea	3,200	3.8	3.8	3.8	3.8	3.8	4	11.5
23–24 March	Labrador Sea	3,660	4.7	4.7	4.7	4.7	4.6	10	36.3
25–26 March	N of Flemish Cap	3,840	9.2	9.2	9.1	9.0	8.6	0	0.0
28–29 March	N slope of Flemish Cap	2,200	6.1	6.1	5.5	5.1	5.0	2	6.9
10–11 April	N of Grand Bank	2,150	3.7	3.7	4.1	4.4	3.9	7	25.2
15–16 April	E of NE Nfld. Shelf	2,130	5.3	5.3	5.4	5.4	5.1	13	33.8
30 April–1 May	Off Southwest Grand Bank	2,710	5.2	5.2	4.9	4.8	5.7	7	24.7
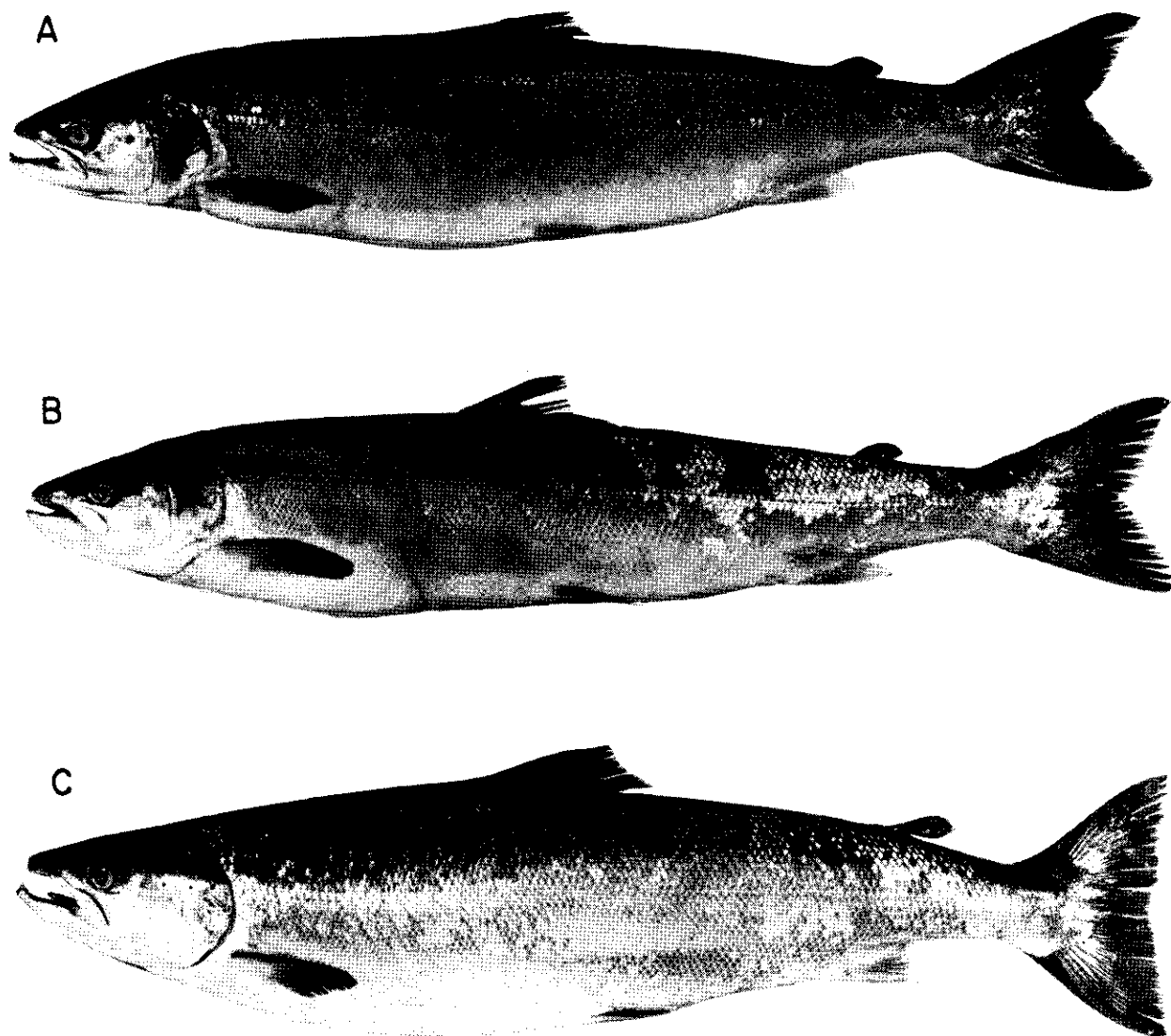
Fig. 2.   Atlantic salmon taken by the *A. T. Cameron* in surface drift nets in the Labrador Sea, 18–19 July, 1965 (A and B) and (C) west of Cape Farewell 21–22 August, 1965: (A) 600 mm fork length, female immature, 2.0 kg round weight, sea age 1+ years; (B) 540 mm fork length, male immature, 1.4 kg round weight, sea age 1+ years; (C) 707 mm fork length, female immature, 4.1 kg round weight, sea age 1+ years.

Condition of salmon as taken from the net

Salmon taken by drift net were often in poor condition when taken on board the *A. T. Cameron*. The salmon of Fig. 2A and 2B were taken on board in a strong wind of about 55 km per hour and were dead and in poor condition with most of the scales absent by the time they came on board. They show severe net scars. Other fish were in better condition with regard to scale covering when captured (Fig. 2C, 3). In all cases the photographs were taken at the Biological Station after freezing and thawing the specimens and in addition the fish of Fig. 2A and 2B were gutted at sea and thus were in gutted condition when the photographs were taken. The larger fish were meshed more anteriorly and this often appeared to produce less serious net effects than when there was greater mesh penetration. Fish caught as far back as around the operculum, however, often had serious injuries dorsally through cutting by the meshes during struggles by the fish and retrieval of the net.

TABLE 3. Catch of Atlantic salmon east and southeast of the Newfoundland area 21 March–1 May 1966 by nets of various mesh sizes. (No. of nets and No. of salmon in parentheses. Weights are whole sea weights in kilograms. The set where no salmon were caught is not included. One net for 1 set = 1 net set.)

Weight and number of salmon caught	3¼–3½ inches (83–89 mm)	4½ inches (114 mm)	5 inches (127 mm)	5¼ inches (133 mm)	5½ inches (140 mm)	6 inches (152 mm)
Total salmon, kg (No. salmon)	0	66.0(23)	32.1(8)	7.6(2)	29.0(9)	3.4(1)
Weight of one salmon, kg	...	2.9(23)	4.1(8)	3.8(2)	3.2(9)	3.4(1)
Weight of one salmon, kg (combining 5–6 inch nets)	...	2.9(23)	...	3.6(20)	...	...
No. of salmon per net set (No. net sets)	...	0.27(84)	...	0.33(61)	...	...
Salmon per net set, kg (No. net sets)	0(9)	0.79(84)	1.28(25)	1.07(7)	1.12(26)	1.13(3)
Salmon per net set, kg (combining 5–6 inch nets)	0(9)	0.79(84)	...	1.18(61)	...	...

TABLE 4. Numbers, river and sea ages, and lengths of Atlantic salmon caught by the A. T. Cameron east and southeast of Newfoundland, 21 March–1 May 1966. (M = male, F = female, * = spawned at 1+ sea years.)

Date 1966	Locality	No. of salmon at river ages (years)				No. of salmon at sea ages (years)										No. of salmon at total lengths to end of mid-fork of caudal (cm)									
						Maiden fish						Fish with one spawning mark				1 sea year			2 sea years			3 sea years			Total
		2	3	4	5	1+ M	1+ F	2+ M	2+ F	3+ M	3+ F	2+ M	2+ F	3+ M	3+ F	45 to 49	50 to 54	55 to 59	60 to 64	65 to 69	70 to 74	75 to 79	80 to 84	85 to 89	
21–24 March	Labrador Sea E of Hamilton Inlet Bank	5	7	3	1	1	....	5	8	....	1	....	....	....	....	....	....	....	2	4	6	1*	....	1	16
28–29 March	N slope Flemish Cap	1	....	1	....	....	....	1	....	....	....	....	....	1	....	....	....	....	....	....	1*	1*	....	....	2
10–16 April	E of NE Nfld. Shelf and N of Grand Bank	2	10	7	1	2	1	5	12	....	....	....	....	....	....	2	1	....	2	10	5	....	....	....	20
30 April–1 May	SW slope Grand Bank	3	1	3	....	....	....	....	5	....	....	....	2	1(1)*	1*	....	....	....	1(1)*	3	1	....	1*	....	7
Total		11	18	14	2	3	1	10	26	....	1	....	2	1*	1*	2	1	....	5(1)*	15(1)*	14	2	1*	1*	45

Fig. 3.   Atlantic salmon taken by the *A. T. Cameron* in surface drift nets in the Labrador Sea, 23 March 1966:   (A) 668 mm fork length, male immature, 2.8 kg round weight, sea age 2+ years; (B) 718 mm fork length, male immature, 3.8 kg round weight, sea age 2+ years; (C) 756 mm fork length, male spawned at 1+ sea years and now in immature condition, 3.7 kg round weight, sea age 3+ years.

The March–May 1966 fish were generally in better condition on capture with better retention of scales than those of July–August 1965.   It is possible that the fish caught in March–April 1966, being closer to entering the rivers for spawning, had a thicker epidermis, and that providing suitable methods of capture had been employed, tagging would have been more successful at this time than from the July–August 1965 captures,

(in the Labrador Sea-West Greenland area) which were not so close to spawning.   It is also possible that by 1966 the fishermen on the *A. T. Cameron* had learnt how to handle the drift nets better on recovery.

Male salmon for both periods (Fig. 2, 3) showed no apparent difference in anterior lower jaw development beyond that in the females.

Age and length

Most of the salmon (84%) were 2-sea-year fish (Fig. 1, Table 4). There were 9% 1-sea-year and 7% 3-sea-year fish. Two of the 2-sea-year and two of the 3-sea-year fish had spawned in their 1+ year as grilse. Fork lengths of the 1-sea-year fish ranged from 480 to 585 mm, of the 2-sea-year fish from 599 to 788 mm but mainly between 645 and 744 mm. The two 2-sea-year salmon which had spawned previously as grilse were toward the lower part of the length range of the 2-sea-year fish. Fork lengths of the 3-sea-year fish ranged from 710 to 874 mm, the single fish which had not spawned previously being considerably larger than the two which had spawned as grilse.

River life was 24%, 2; 40%, 3; 31%, 4; and 4%, 5 years.

There is a possibility that the growth of each sea-year group of salmon is affected adversely by the presence of tapeworms and by the quantity of tapeworms present (Table 5). Only the 2-sea-year group was numerous enough to be worthy of this comparison.

Length-weight

Whole weight (measured at the Station) increased from about 1.3 kg at 500 mm fork length to about 4.1 kg at 750 mm. The largest salmon, at 874 mm, weighed 7.7 kg (Fig. 4).

Three 1-sea-year fish ranged in round weight from 1.2 to 2.1 kg, 38 2-sea-year fish from 2.4 to 4.5 kg and three 3-sea-year fish (the two smaller spawning as grilse) from 3.5 to 7.7 kg. The average round weight of 44 salmon at sea immediately after capture, 3.31 kg, was only slightly higher than the weight at the Station, 3.27 kg.

In view of the small numbers and the considerable individual variation in weight, there are no great differences in weight in the places and times sampled but there is a weak tendency for most individuals caught in the Labrador Sea in March to be lower in weight. In the small numbers examined there are no obvious sex differences in weight. Three of 1-, 2-, and 3-sea-year fish which spawned as grilse are close to or slightly above the average weight curve and the largest is below but not more so than some of the maiden fish.

Average gutted weights as percentages of whole weights for salmon of lengths to mid-fork in mm of 485–648, 650–679, 680–720, 721–788, and 721–874 were (number of fish in parentheses): 89.0(11), 88.8(11), 89.6(11), 91.2(10), 91.4(11), overall 89.7(44).

The weight curves are not greatly different from those for the 1965 Labrador Sea-West Greenland salmon (taken from Templeman, 1967, and superimposed in Fig. 4) but weights are higher at the smaller sizes for the 1966 salmon.

The presence of tapeworms in the pyloric caeca and intestine, and quantities of tapeworms as high as 38–49 cc per salmon did not have any noticeable effect on the salmon round or gutted weight relative to salmon of similar lengths with no tapeworms or with only small infestations.

Body proportions

Greatest length. The greatest length to the tip of the upper or the lower lobe of the caudal fin, extending directly backwards, declined from about 107.5% of the fork length at the smaller to about 106.5% at the larger sizes (Fig. 5A).

In 9 males and 19 females (total 28) the greatest length was to the tip of the upper caudal

TABLE 5. Relation of length of Atlantic salmon with 2 sea-years, caught by the *A. T. Cameron* east and southeast of the Newfoundland area 21 March–1 May 1966, to volumes of tapeworms in pyloric caeca and intestine.
(* = spawned at 1 + years.)

Fork length of salmon	Quantities of tapeworms present (in order of increasing length of salmon with 2 sea years)	Total salmon with tapeworms	Total salmon	Average volume tapeworms per salmon	Average volume tapeworms per kg salmon gutted weight
mm	*cc*	*No.*	*No.*	*cc*	*cc*
599–650	14, 33*, 9.5, 26, 22, 7, 30, 23*, 24	9	9	20.9	8.6
651–679	26, 6.5, 20.5, 41, 25, 39, 9, 0, 2, 49	9	10	21.8	8.1
680–720	5.5, 7, 0, 0, 10, 10, 32.5, 9, 22, 25	8	10	12.1	4.1
721–788	22, 38, 0, 0, 0, 0, 34, 0, 0	3	9	10.4	3.1
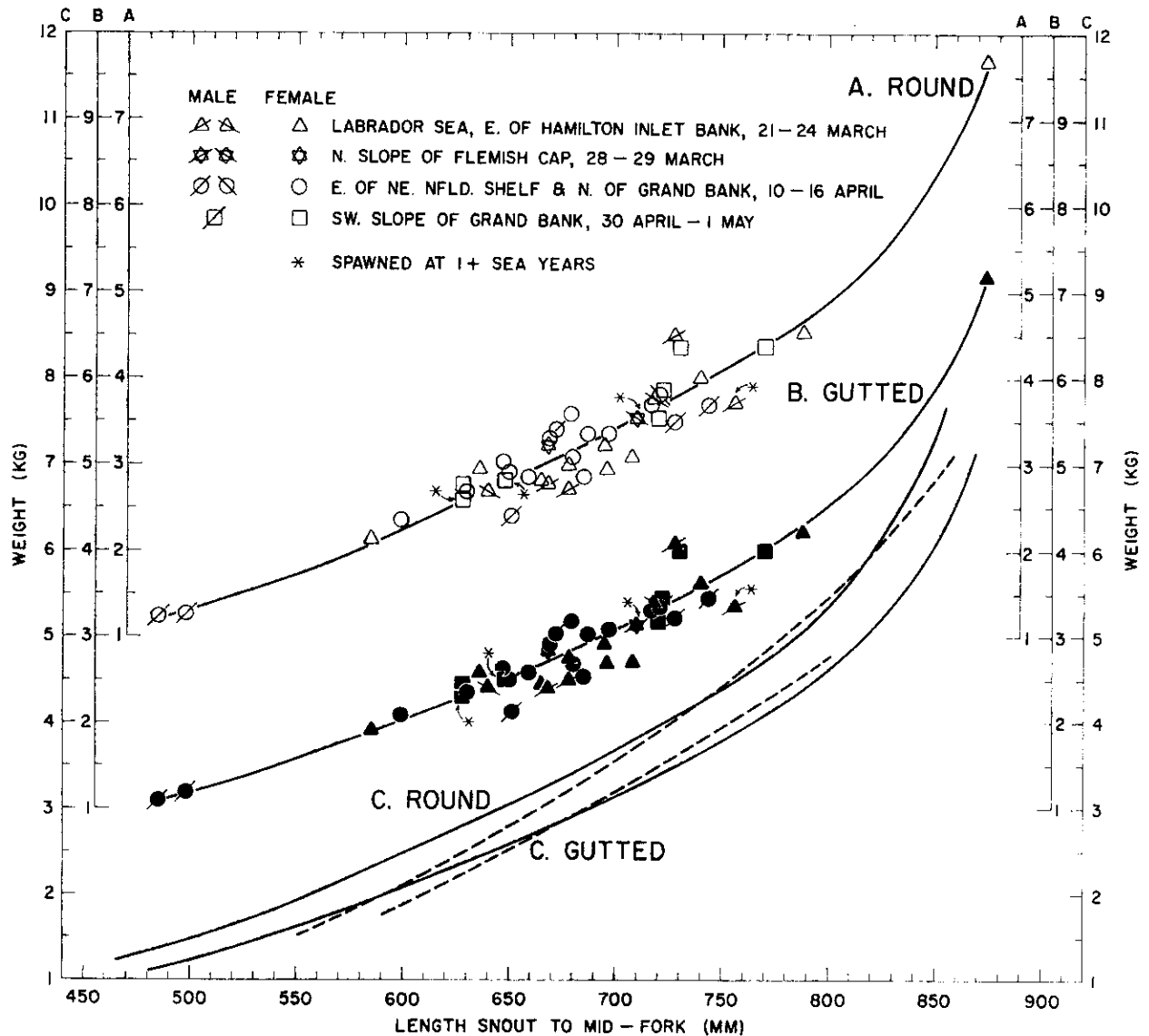
Fig. 4.   Length-weight relationships of Atlantic salmon from east and southeast of Newfoundland, 21 March 1 May 1966.   (The dashed lines show the round and gutted weights of the Labrador Sea-West Greenland salmon. July–August 1965, Templeman, 1967).

lobe; in 3 males and 3 females (total 6) the greatest lengths to the tips of the upper and of the lower caudal lobes were equal; and in 1 male and 6 females (total 7) the greatest length was to the tip of the lower caudal lobe.   On the average the greatest length to the tip of the upper lobe in 41 fish was 0.27% greater in terms of total length to the mid-fork than that to the tip of the lower lobe.

Standard length.   Standard length for 14 salmon 485-659 mm fork length was 91.0% of

fork length, for 14 salmon 665-695 mm fork length it was 91.3% of fork length, and for 15 salmon 722-874 mm fork length it was 91.0% of the fork length.   Overall for 43 fish the standard length was 91.1% of the total length to the mid-fork of the caudal fin.   There was thus in these fish no change of relative standard length with increase in fork length, and plotting body proportions relative to fork length should on the average be approximately as suitable as plotting them against standard length.   The policy of
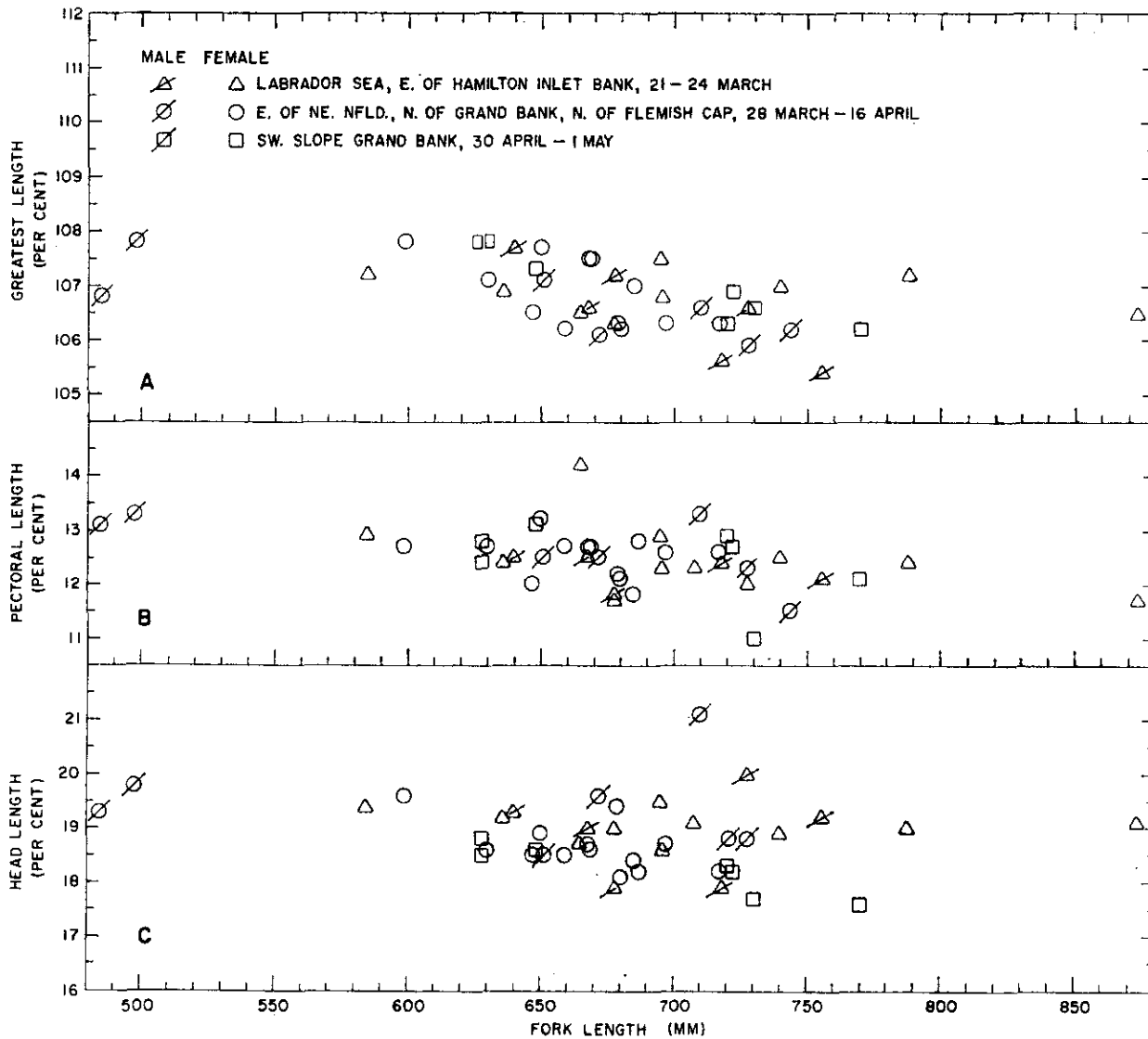
Fig. 5.   Head, pectoral fin and greatest lengths relative to the total length to the end of the mid-fork of the caudal fin for Atlantic salmon taken east and southeast of Newfoundland, 21 March–1 May 1966.

plotting them against fork length has been followed so that they may be compared with the data for 1965 (Templeman, 1967) for which no standard lengths are available.

Sea lengths and Station lengths. The fork length was measured on a measuring board to the nearest millimetre fresh at sea. The fish were frozen on board ship and measured on shore a few days to 2 weeks later after thawing in flaked ice. For 44 salmon, fork lengths measured at sea averaged 689.8 mm and on shore 681.5 mm.

Pectoral length. The pectoral length relative to the fork length (Fig. 5B) declines from about 13% at the smaller to about 12% at the larger fish lengths. In these small numbers there is no apparent difference between areas or sexes.

Head length. The trend in relative head length (Fig. 5C) with increasing fish length is uncertain. It may hold level at about 19% and on the average from these data head length is 18.8% fork length. The small number of fish

Fig. 6. Length-girth relationships for Atlantic salmon taken east and southeast of Newfoundland, 21 March–1 May 1966.

from the southwestern slope of the Grand Bank are toward the lower part of the distribution of head length compared with the fish from the more northern areas.

Girth. There is no indication that greatest girth changes in relation to the fork length with increase in fish length (Fig. 6C). The opercular girths of the smaller fish are above the average (Fig. 6D) but this was not the case 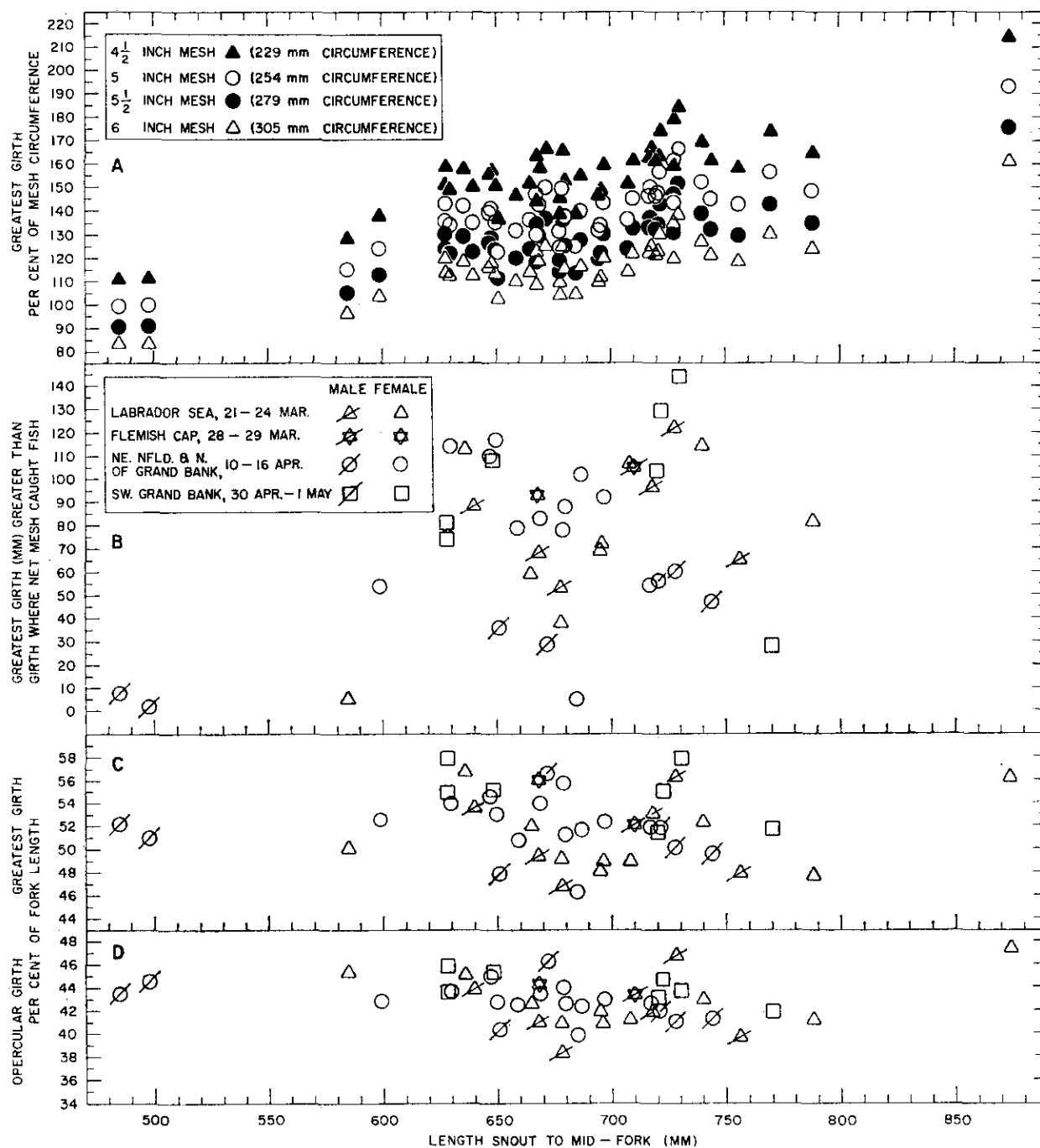in the Labrador Sea and West Greenland fish (Templeman, 1967, fig. 6D). Hence with the small numbers available here it cannot be assumed that relative girth changes with fish length. The largest specimen of these data (Fig. 6C and D) as well as the two large specimens of 800 mm and over in the 1965 data (Templeman, 1967, fig. 6C and D) were well above the average in relative girth. Many other fishes increase in relative girth with length but the numbers of large fish here are too few to reach a conclusion.

The lowest girths were for salmon from the Labrador Sea 21–24 March, the next lowest from east of the Northeast Newfoundland Shelf and north of the Grand Bank 10–16 April, and the highest from southwest of the Grand Bank, 30

April–1 May. The girths of females were slightly higher than those of males. Overall the opercular girth for 43 fish was 42.9% and the maximum girth 52.1% of the fork length (Table 6). With the small numbers of fish, all of these comparisons are presented to be compared with data of other investigators rather than to prove the statements regarding them. The small numbers in any length class and the possibility of changes in relative girths with increase in length do not make statistical comparisons worthwhile.

Average girths for salmon from the Labrador Sea-West Greenland for July–August 1965 (Table 6) were generally similar to those of March–May 1966 but again there was considerable difference between areas and times as shown in Table 6 and described and discussed by Templeman (1967).

A few fish (Fig. 6B) were caught close to their greatest girth and the greatest girth of several of the smaller fish was below the mesh circumference of the 5½-inch (140-mm), and the 6-inch (152-mm) nets and thus could have passed through the meshes of these nets. The two smallest fish could probably have passed through the 5-inch (127-mm) meshes also (Fig. 6A).

TABLE 6. Atlantic salmon 1965–66—opercular girth and greatest girth as percentages of total length to end of mid-fork of the caudal fin (No. of fish in parentheses).

	Average of per cent opercular girth of fork length			Average of per cent greatest girth of fork length		
	Male	Female	Total	Male	Female	Total
Labrador Sea, 21–24 March 1966	41.9(6)	42.4(9)	42.2(15)	51.2(6)	50.4(9)	50.7(15)
Flemish Cap, 28–29 March 1966	43.4(1)	44.3(1)	43.9(2)	52.1(1)	56.0(1)	54.1(2)
E of NE Nfld. Shelf and N of the Grand Bank, 10–16 April 1966	42.7(7)	42.9(12)	42.9(19)	51.3(7)	52.4(12)	52.0(19)
SW Grand Bank, 30 April 1 May 1966	...	44.1(7)	44.1(7)	...	54.9(7)	54.9(7)
Labrador Sea, 19–20 July 1965	41.1(3)	43.0(2)	41.8(5)	47.8(3)	52.7(2)	49.7(5)
W Greenland banks, 5–16 Aug. 1965	44.0(5)	43.5(8)	43.7(13)	53.9(5)	54.9(8)	54.5(13)
W of C. Farewell and C. Desolation, 21–22 Aug. 1965	41.3(4)	41.5(11)	41.5(15)	50.2(4)	50.9(11)	50.7(15)
Labrador Sea, 22–23 Aug. 1965	44.3(1)	43.4(2)	43.7(3)	56.3(1)	54.4(2)	55.0(3)
Total: 21 March–1 May 1966	42.4(14)	43.1(29)	42.9(43)	51.3(14)	52.5(29)	52.1(43)
Total: 19 July–23 Aug. 1965	42.5(13)	42.5(23)	42.5(36)	51.5(13)	52.8(23)	52.3(36)

TABLE 7. Meristic characters of Atlantic salmon east and southeast of Newfoundland. 21 March–1 May 1966.

Years of river life:

Vertebral numbers:

	2				3				4–5				Total 2–5			
	58	59	60	61	58	59	60	61	58	59	60	61	58	59	60	61
1. Labrador Sea E of Hamilton Inlet Bank	...	3	2	...	...	4	2	1	...	2	...	2	...	9	4	3
2. N slope of Flemish Cap	...	1	...	...	...	...	...	...	...	1	...	...	...	2	...	...
3. E of NE Nfld. Shelf and N of Grand Bank	...	...	1	1	1	2	6	...	1	3	2	2	2	5	9	3
4. SW slope Grand Bank	1	1	1	...	...	...	1	...	...	3	...	...	1	4	2	...
Total	1	5	4	1	1	6	9	1	1	9	2	4	3	20	15	6

Dorsal fin rays:

	2				3				4–5				Total 2–5			
	14	15	16	17	14	15	16	17	14	15	16	17	14	15	16	17
1. Labrador Sea E of Hamilton Inlet Bank	2	3	...	...	1	3	2	1	1	3	...	...	4	9	2	1
2. N slope of Flemish Cap	1	...	...	...	...	...	...	...	...	1	...	...	1	1	...	...
3. E of NE Nfld. Shelf and N of Grand Bank	1	...	1	...	1	6	3	...	2	4	2	...	4	10	6	...
4. SW slope Grand Bank	2	1	...	...	...	1	...	...	1	2	...	...	3	4	...	...
Total	6	4	1	...	2	10	5	1	4	10	2	...	12	24	8	1

Anal fin rays:

	2			3			4–5			Total 2–5		
	11	12	13	11	12	13	11	12	13	11	12	13
1. Labrador Sea E of Hamilton Inlet Bank	...	3	2	1	4	2	...	3	1	1	10	5
2. N slope of Flemish Cap	...	...	1	...	...	...	...	...	1	...	...	2
3. E of NE Nfld. Shelf and N of Grand Bank	1	1	...	1	6	3	...	6	2	2	13	5
4. SW slope Grand Bank	...	2	1	1	...	...	...	2	1	1	4	2
Total	1	6	4	3	10	5	...	11	5	4	27	14

TABLE 7. (continued)

Pectoral fin rays:

Years of river life:	2			3			4–5			Total 2–5		
	13	14	15	13	14	15	13	14	15	13	14	15
1. Labrador Sea E of Hamilton Inlet Bank	2	2	1	…	6	1	…	4	…	2	12	2
2. N slope of Flemish Cap	…	1	…	…	…	…	…	1	…	…	2	…
3. E of NE Nfld. Shelf and N of Grand Bank	1	1	…	1	7	2	…	7	1	2	15	3
4. SW slope Grand Bank	…	2	1	…	…	1	…	…	2	…	3	4
Total	3	6	2	1	13	4	…	13	3	4	32	9

Gill rakers first arch:

Years of river life:	2						3						4–5						Total 2–5					
	17	18	19	20	21	22	17	18	19	20	21	22	17	18	19	20	21	22	17	18	19	20	21	22
1. Labrador Sea E of Hamilton Inlet Bank	…	…	…	2	2	1	…	…	3	3	…	1	…	1	…	2	1	…	…	1	3	7	3	2
2. N slope of Flemish Cap	…	…	1	…	…	…	…	…	…	…	…	…	…	…	1	…	…	…	…	…	2	…	…	…
3. E of NE Nfld. Shelf N of Grand Bank	…	2	…	…	…	…	1	2	6	1	…	…	2	1	2	3	…	…	3	5	8	4	…	…
4. SW slope Grand Bank	…	…	3	…	…	…	…	…	…	1	…	…	…	…	…	1	2	…	…	…	3	2	2	…
Total	…	2	4	2	2	1	1	2	9	5	…	1	2	2	3	6	3	…	3	6	16	13	5	2

Gill rakers lower limb, first arch:

Years of river life:	2				3				4–5				Total 2–5			
	10	11	12	13	10	11	12	13	10	11	12	13	10	11	12	13
1. Labrador Sea E of Hamilton Inlet Bank	…	…	2	3	…	1	5	1	…	1	2	1	…	2	9	5
2. N slope of Flemish Cap	…	1	…	…	…	…	…	…	…	…	1	…	…	1	1	…
3. E of NE Nfld. Shelf and N of Grand Bank	1	1	…	…	…	2	7	1	1	1	6	…	2	4	13	1
4. SW slope Grand Bank	…	2	1	…	…	1	…	…	…	1	1	1	…	4	2	1
Total	1	4	3	3	…	4	12	2	1	3	10	2	2	11	25	7

Meristic characters

The numbers of salmon from the various areas are too small to make definite statements of differences in meristic characters. However, it is indicated (Table 7) that vertebral numbers, dorsal fin-ray and gill-raker counts may be lower in the fish from the southwestern slope of the Grand Bank than in those from the northern areas – off Labrador, east of the Northeast Newfoundland Shelf and north of the Grand Bank.

Sex ratio and stage of sexual maturity

Of the maiden fish, 68% of the total and 73% older than 1-sea-year were females.

All males were immature or (for the previously spent fish) in immature condition. Testes were pink or reddish pink, the volume of both testes ranging from 1 cc for the smallest fish to 3.7–4.5 cc for the largest.
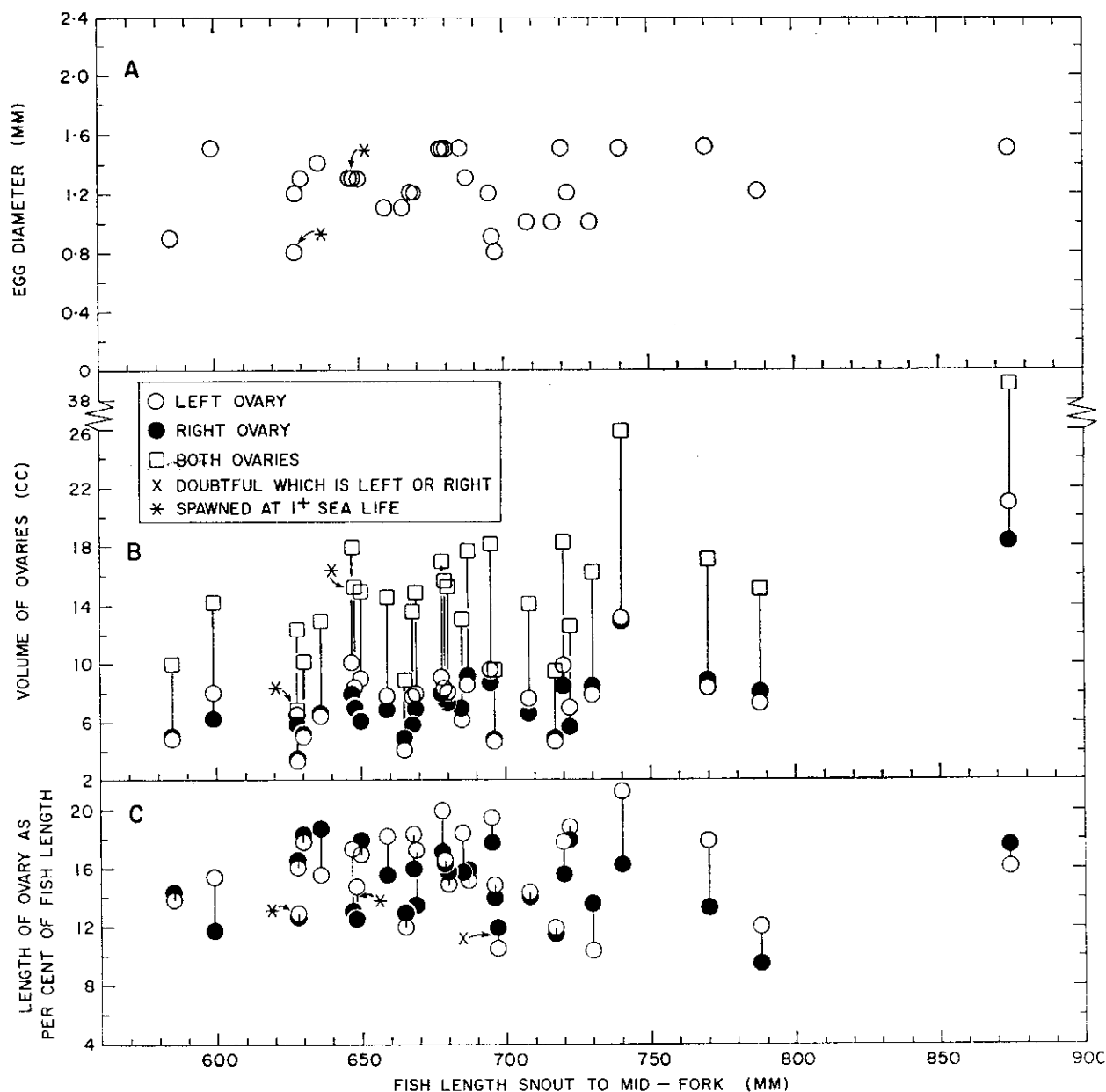

Fig. 7.   Egg diameters, and lengths and volumes of ovaries of Atlantic salmon of various fork lengths taken east and southeast of Newfoundland, 21 March–1 May 1966.

All females were immature or (for the previously spent female) in immature condition, with egg diameters ranging from 0.8 to 1.5 mm (Fig. 7) and ovarian volumes from 7 to 39 cc (all except two, 7–18 cc). In most individuals, however, both eggs and ovaries were beginning to enlarge slightly.

The left ovary was the longer in 19 of 30 fish. In 11 fish the right ovary was the longer. In volume the left was greater in 16, in 7 the right was greater and in 7 both ovaries were approximately equal. The average ovarian length relative to fish length to the mid-fork, in 29 females, was 16.0% for the left and 15.0% for the right ovary. The average ovarian volume in 29 females was 7.9 cc for the left and 7.3 cc for the right ovary.

Food

Food in the stomachs was mainly (95%) fish, the most important being the paralepid, *Paralepis coregonoides*, and lantern fishes, especially *Notoscopelus* sp. and *Lampanyctus* sp. Noteworthy among the invertebrate food were small amounts of arctic squid, *Gonatus fabricii*; pelagic shrimp, *Pasiphaea multidentata*; pelagic amphipods, *Parathemisto*; and euphausiids (Table 8).

No very large fish or invertebrates were present in the stomachs, but there was a considerable range in food size. The largest fish were *Paralepis coregonoides*, usually 250–300 mm long, and secondly the lantern fishes, *Lampanyctus*, up to 136 mm in length, and *Notoscopelus*. Invertebrates as small as pelagic amphipods, *Parathemisto*, down to about 1 cm in length and 0.1 cc in volume were eaten in small numbers.

The intestines all contained mainly remains of small fish and were usually filled chiefly with bones of these fish of the same size found in the stomachs.

Parasites

Sea lice, *Lepeophtheirus salmonis*. These external copepods were present on 75% of 16 salmon from east of Hamilton Inlet Bank 21–24 March, on 77% of 22 salmon from east of the Northeast Newfoundland Shelf to Flemish Cap 28 March–16 April, and on 71% of 7 salmon from the southwest slope of the Grand Bank 30 April–1 May. In the overall total they were present on 76% of 45 salmon and were mainly females with

large egg sacs, but some males were present. The number of parasites ranged from 3.3 per salmon and 4.6 per infested salmon off the southwest Grand Bank to 5.8 per salmon and 7.7 per infested salmon in the Labrador Sea east of Hamilton Inlet Bank (Table 9).

Both in 1965 and 1966 these *Lepeophtheirus* copepods were most numerous on the body near the base of and immediately posterior to the anal fin (Fig. 8, 9). The remainder were mostly situated dorsally and mainly posterior to the greatest girth of the body which is near the anterior border of the dorsal fin.

Numbers of parasites and of fish parasitised, and distribution of the copepods are certainly minimal since some copepods would have been lost in the gill nets, especially from the part of the body anterior to the first dorsal.

Salmon gill-maggot, *Salmincola salmonea*. Gills of all salmon were examined for this parasite and only one was found, a normal sized female without egg sacs (length excluding maxillary arms 4.6 mm) on a male salmon 480 mm fork length with 1 year at sea and no indication of spawning marks. The parasite was attached to a gill filament on the anterior face of the lower limb of the first left branchial arch and at least 9 gill filaments in the vicinity of attachment had the distal two-thirds eaten away.

Eubothrium crassum. Seventy-one per cent of the 45 salmon possessed tapeworms, *Eubothrium crassum* in the pyloric caeca and intestines (Table 10). In the northern area east of Hamilton Inlet Bank, 56% of 16 salmon carried tapeworms. In the area somewhat farther south, from east of the Northeast Newfoundland Shelf to Flemish Cap, 83% of 22 salmon possessed tapeworms and southwest of the Grand Bank 71% of 7 salmon carried tapeworms. These numbers of salmon especially southwest of the Grand Bank are too small to provide more than an indication of the true percentage of infestation. The quantity of tapeworms present in a single fish ranged from 1 to 49 cc.

There is an indication also that more fish of the higher river ages carry tapeworms — 62% of 29 fish at 2–3 years river life and 88% of 16 fish at 4–5 years river life. There is, however, no indication that the amounts of tapeworms present (Table 10) increase with a longer period of river life.

TABLE 8.   Stomach and intestinal contents of Atlantic salmon from surface drift-net sets east and southeast of Newfoundland, 21 March 1 May 1966.   (Numbers of food individuals in parentheses.   Portions only were sometimes present but were counted when they represented individual organisms.)

	Labrador Sea, E of Hamilton Inlet Bank	North slope of Flemish Cap	E of NE Nfld. Shelf and N of Grand Bank	SW slope of Grand Bank	Total
Date 1966:	21-24 March	28-29 March	10-16 April	30 April 1 May	21 March 1 May
Depth to bottom (m):	3,060–3,660	2,200	2,130-2,150	2,710	2,130 3,660
No. salmon stomachs with contents					
Empty	2	. . .	3	1	6
Arctic squid (*Gonatus fabricii*)	3	. . .	1	. . .	4
Part of arm of squid (*Histioteuthidae*)	. . .	. . .	. . .	1	1
Piece of squid pen	. . .	. . .	1	. . .	1
Amphipod (*Eurythenes* sp.)	1	. . .	. . .	. . .	1
Pelagic amphipod (*Parathemisto abyssorum*)	. .	. . .	1	. . .	1
Pelagic amphipod (*Parathemisto gaudichaudi*)	1	. . .	1	. . .	2
Pelagic amphipod (*Parathemisto libellula*)	. . .	. . .	2	. . .	2
Pelagic amphipod (*Parathemisto* sp.)	2	. . .	4	. . .	6
Euphausiid (*Meganyctiphanes norvegica*)	. . .	. . .	1	. . .	1
Euphausiid	1	. . .	2	. . .	3
Pelagic shrimp (*Pasiphaea multidentata*)	1	. . .	1	. . .	2
Shrimp	1	. . .	. . .	. . .	1
Paralepis coregonoides	1	1	7	2	11
Lantern fish (*Benthosema glaciale*)	2	. . .	. . .	. . .	2
Lantern fish (*Hierops arctica*)	. . .	. . .	1	. . .	1
Lantern fish (*Lampanyctus* sp.)	. . .	. . .	2	. . .	2
Lantern fish (*Notoscopelus* sp.)	4	1	1	. . .	6
Lantern fish	. . .	1	2	1	4
Launce (*Ammodytes* sp.)	. . .	. . .	. . .	1	1
Pelagic fish (*Bathylagus* sp.?)	. . .	. . .	1	. . .	1
Pelagic fish	3	. . .	. . .	. . .	3
Fish fragments	3	1	6	2	12
No. salmon intestines with contents					
Intestine containing bones of small fish, mainly vertebrae with some otoliths and jaw bones, scales, etc.	16	2	20	7	45

TABLE 8. (continued)

	Labrador Sea, E of Hamilton Inlet Bank	North slope of Flemish Cap	E of NE Nfld. Shelf and N of Grand Bank	SW slope of Grand Bank	Total
Date 1966:	21–24 March	28–29 March	10–16 April	30 April–1 May	21 March–1 May
Depth to bottom (m):	3,060–3,660	2,200	2,130–2,150	2,710	2,130–3,660

Total quantity (cc) in stomachs (No. of individuals)

Arctic squid (*Gonatus fabricii*)	16.3 (4)	. . .	1.5 (2)	. . .	17.8 (6)
Part of arm of squid (*Histioteuthidae*)	. . .	. . .	. . .	2.0 (1)	2.0 (1)
Piece of squid pen	. . .	. . .	0.1 (1)	. . .	0.1 (1)
Amphipod (*Eurythenes* sp.)	0.1 (1)	. . .	. . .	. . .	0.1 (1)
Pelagic amphipod (*Parathemisto abyssorum*)	. . .	. . .	0.1 (1)	. . .	0.1 (1)
Pelagic amphipod (*Parathemisto gaudichaudi*)	0.1 (1)	. . .	0.1 (2)	. . .	0.2 (3)
Pelagic amphipod (*Parathemisto libellula*)	. . .	. . .	0.1 (2)	. . .	0.1 (2)
Pelagic amphipod (*Parathemisto* sp.)	0.8 (8)	. . .	0.8 (8)	. . .	1.6 (16)
Euphausiid (*Meganyctiphanes norvegica*)	. . .	. . .	0.3 (1)	. . .	0.3 (1)
Euphausiid	0.7 (2)	. . .	0.4 (2)	. . .	1.1 (4)
Pelagic shrimp (*Pasiphaea multidentata*)	5.0 (1)	. . .	2.0 (1)	. . .	7.0 (2)
Shrimp	1.0 (1)	. . .	. . .	. . .	1.0 (1)
Paralepis coregonoides	42.0 (1)	30.0 (1)	251.2 (10)	53.0 (2)	376.2 (14)
Lantern fish (*Benthosema glaciale*)	7.5 (3)	. . .	. . .	. . .	7.5 (3)
Lantern fish (*Hierops arctica*)	. . .	. . .	1.5 (1)	. . .	1.5 (1)
Lantern fish (*Lampanyctus* sp.)	. . .	. . .	46.0 (3)	. . .	46.0 (3)
Lantern fish (*Notoscopelus* sp.)	62.8 (9)	25.0 (6)	24.0 (4)	. . .	111.8 (19)
Lantern fish	. . .	2.0 (1)	16.0	15.0 (1)	33.0
Launce (*Ammodytes* sp.)	. . .	. . .	. . .	11.0 (1)	11.0 (1)
Pelagic fish (*Bathylagus* sp.?)	. . .	. . .	11.0 (1)	. . .	11.0 (1)
Pelagic fish	27.8 (3)	. . .	. . .	. . .	27.8 (3)
Fish fragments	4.5	0.2	16.6	10.0	31.3

Total salmon stomachs examined (No.):	16	2	20	7	45

Total round weight of salmon whose stomachs were examined (kg):	56.5	6.8	57.5	24.3	145.1

Total fish in stomachs (cc):	144.6	57.2	366.3	89.0	657.1

Total invertebrates in stomachs (cc):	24.0	.0	5.4	2.0	31.4

Total food in stomachs (cc):	168.6	57.2	371.7	91.0	688.5

Total food (cc) per kg of salmon round weight:	3.0	8.4	6.5	3.7	4.7

TABLE 9.   Number of external copepods, *Lepeophtheirus salmonis*, on Atlantic salmon from east and southeast of the Newfoundland area, 21 March–1 May 1966.

Locality and date of capture, 1966	Total salmon	Salmon containing *L. salmonis*	*L. salmonis*	(a) *L. salmonis* per salmon with these parasites	(b) *L. salmonis* per salmon
	No.	*No.*	*No.*	*No.*	*No.*
Labrador Sea, E of Hamilton Inlet Bank (21–24 March)	16	12	92	7.7	5.8
E of NE Nfld. Shelf, N of Grand Bank and N of Flemish Cap (28 March–16 April)	22	17	102	6.0	4.6
SW slope of Grand Bank (30 April–1 May)	7	5	23	4.6	3.3
Total all areas	45	34	217	6.4	4.8
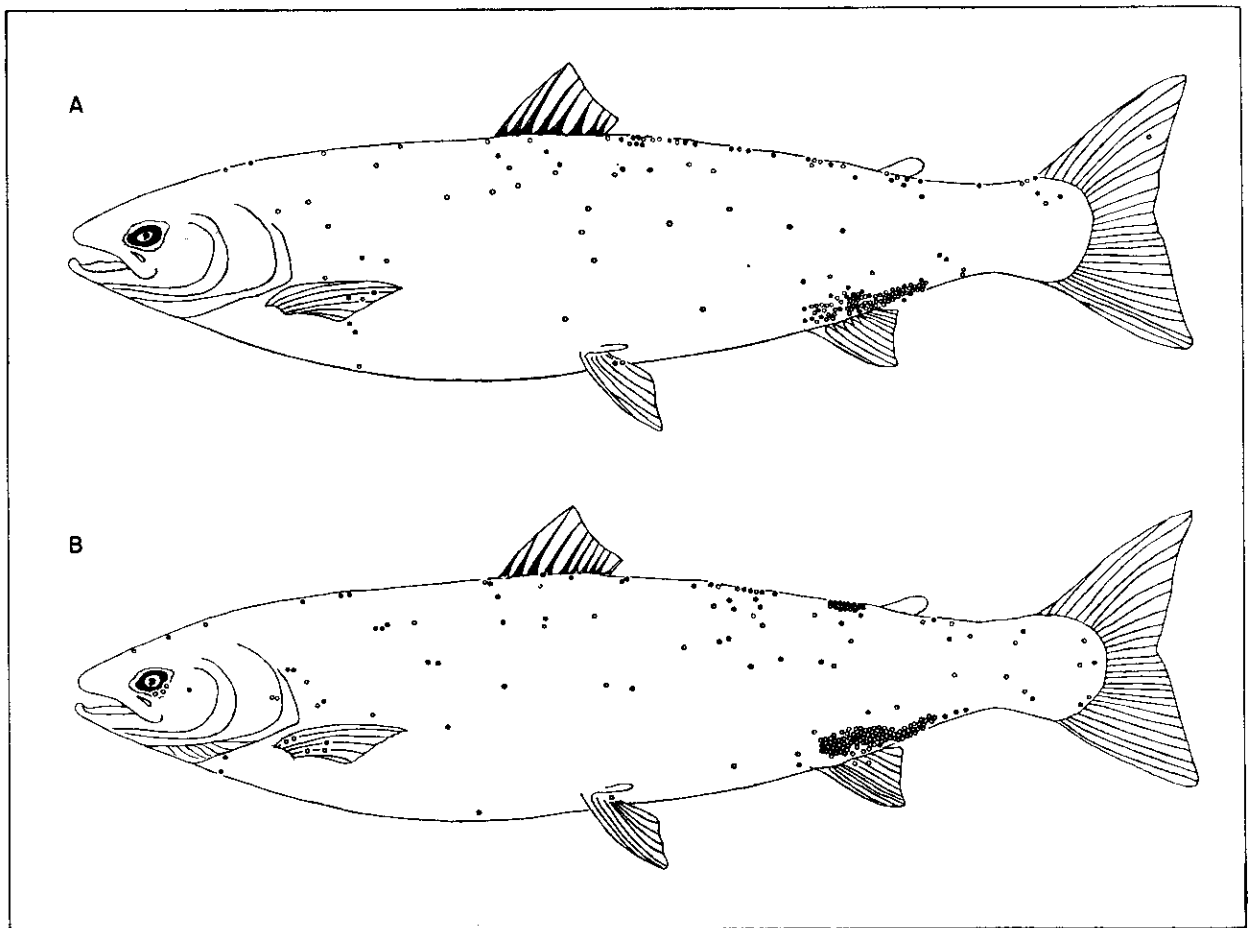
Fig. 8.   Distribution of the copepod, *Lepeophtheirus salmonis* on Atlantic salmon caught by the *A. T. Cameron*   (A) July–August 1965, Labrador Sea-West Greenland and (B) March–May 1966, Labrador Sea-Southwest Grand Bank.

Fig. 9. Four *Lepeophtheirus salmonis*, two with egg-sacs, situated near the posterior end of the anal fin of a female Atlantic salmon, 861 mm fork length, taken by the *A. T. Cameron* at the midmouth of the Labrador Sea, 19-20 July 1965.

Anisakis sp. Larval nematodes, *Anisakis* sp., encysted in flat circular coils on the liver, nearly always on its ventral surface, occurred in 33% of the salmon. The two northern areas had 31 and 32% of the 16 and 22 fish parasitised with *Anisakis* on the surface of the liver (range 0-1 and 0-2 and average 0.3 and 0.5 parasites per fish), and the southwestern Grand Bank area 43% of 7 fish parasitised (range 0-4 and average 1.0 *Anisakis* per fish). Because of the small numbers of fish these small differences between areas are unlikely to be important.

Discussion and Conclusions

Distribution

The expanding salmon fishery in West Greenland, based on Canadian and European salmon (Hansen, 1965, 1967), shows that large numbers of salmon journey to West Greenland from these areas. Templeman (1967) showed the presence of salmon in the surface layers in July–August at the mid-mouth of the Labrador Sea, and west of Cape Farewell. The new investigations reported in this paper show that numerous salmon are present in March–April over oceanic depths east of the continental shelf and together with the July–August captures indicate that salmon live year round over the waters deeper than 1,800 m in the Labrador Sea. The moderately high surface temperatures (3.7° to 6.1°C) found in this March–April period, and presumably throughout the winter, enable the salmon to live close to the surface even in winter. Whereas in July–August 1965, salmon were present and sometimes relatively abundant at the mouth of the Labrador Sea and off Cape Farewell at temperatures of 8.5° to 8.6°C and fairly abundant at 9.6°C, in March–April 1966 they were most abundant at lower temperatures between 4.7° and 5.4°C. There is in this area, therefore, only a narrow annual range of surface temperatures, allowing the salmon as is apparent from the scales, to have a slower but still significant amount of growth during the winter-early spring period.

The legal salmon fishing season on the east coast of Newfoundland begins on 15 May and some salmon strike the coast before this time. On the average the larger salmon approach the coast first and the grilse later. The catch of 7 salmon off the southwestern Grand Bank indicates that the slope water in the vicinity of 3° to 6°C between the warm Gulf Stream water and the colder bank water along the Newfoundland and Nova Scotian banks may be the winter abode of certain numbers and groups of salmon and may also form a winter-spring migration track of salmon from the northern eddy systems. It is also possible that many salmon may follow the intermediate temperature slope water into the Gulf of St. Lawrence or the

TABLE 10. Presence or absence of tapeworms, *Eubothrium crassum*, in Atlantic salmon from east and southeast of Newfoundland, 21 March–1 May 1966 (No. of salmon in parentheses).

Years river life	Labrador Sea, E of Hamilton Inlet Bank 21–24 March		E of NE Shelf, N of Grand Bank & N of Flemish Cap 28 March–16 April		SW Slope Grand Bank 30 April–1 May		Total		
	Average amount of tapeworms		Average amount of tapeworms		Average amount of tapeworms		Average amount of tapeworms		Per cent with tapeworms
	Per salmon with tapeworms	Per salmon	Per salmon with tapeworms	Per salmon	Per salmon with tapeworms	Per salmon	Per salmon with tapeworms	Per salmon	
	cc	cc	cc	cc	cc	cc	cc	cc	%
2	17.3(2)	6.9(5)	30.0(3)	30.0(3)	28.0(2)	18.7(3)	25.8(7)	16.4(11)	64
3	23.3(3)	10.0(7)	21.6(7)	15.1(10)	9.5(1)	9.5(1)	21.0(11)	12.8(18)	61
4	11.5(3)	11.5(3)	13.4(7)	11.7(8)	31.5(2)	21.0(3)	15.9(12)	13.6(14)	86
5	20.5(1)	20.5(1)	10.0(1)	10.0(1)	...(0)	...(0)	15.3(2)	15.3(2)	100
4 + 5	13.8(4)	13.8(4)	12.9(8)	11.5(9)	31.5(2)	21.0(3)	15.8(14)	13.8(16)	88
Total 2 5	17.7(9)	10.0(16)	19.1(18)	15.7(22)	25.7(5)	18.4(7)	19.8(32)	14.1(45)	71

Bay of Fundy without first approaching the nearest coast. It may be some of these salmon from the southwestern slope of the Grand Bank which begin to pass near the Port-aux-Basques and neighbouring areas of the western part of the south coast of Newfoundland and into the Gulf of St. Lawrence early in May.

As in the 1965 results (Templeman, 1967) the salmon at night were very close to the surface.

Sea age and spawning

Most of the West Greenland catch consists of 1+ sea-year salmon and the remainder 2+ or greater sea-year salmon. Thus most of the 2-sea-year salmon (84% of the total), and of the 3-sea-year (7%), and some of the 1-sea-year (9%) caught in the oceanic areas on 21 March–1 May 1966 were presumably those returning to the Canadian rivers for spawning.

Length-weight

The weak tendency in Fig. 4 for the Labrador Sea, 21–24 March individuals to be lower in weight is also reflected in the girths of these fish being lowest (Table 6). The amount of food in the stomach per kilogram of body weight was also lowest in these Labrador Sea salmon (Table

8) and temperatures in the upper 100 m are generally lower in the north (Table 2, Fig. 1). The small numbers of fish examined here, therefore, reflect the same tendency reported by Lindsay and Thompson (1932) that the yearly growth during the first and second years at sea of coastal salmon taken toward the north off St. Anthony, Newfoundland and Battle Harbour, Labrador was less than that of salmon taken farther southward off Bonavista and the Avalon Peninsula.

The gutted weights were 89.7% of the whole weight, very similar to the 88.7% for the Labrador Sea-West Greenland salmon (Templeman, 1967). This relationship is affected by the relative amounts of food present in the stomach and intestine and the amounts of fat on the viscera and will vary somewhat between areas and times even if the fish flesh is in equally as good condition.

There is an apparent contradiction in the small amount of data presented in that while no apparent relationship could be detected at neighbouring lengths between the presence or numbers of tapeworms and the fish weights, there is some evidence (Table 5) that the amount of growth in a sea year-group may be affected by the amounts of tapeworms present. The effects

TABLE 11. Comparison of meristic characters of Atlantic Salmon from the Labrador and West Greenland area, July–August 1965, and from the areas closer to Newfoundland included in the present paper, March–May 1966. (The 1965 data are calculated from Templeman (1967, table 6) and the 1966 data from the present paper (Table 7).

Meristic character	No. of individuals		Mean		Standard deviation		Values of t	Probability
	1965	1966	1965	1966	1965	1966		
Vertebrae	37	44	59.62	59.55	0.59	0.82	0.43	0.7
Dorsal fin rays	38	45	15.03	14.96	0.63	0.73	0.46	0.7
Anal fin rays	38	45	11.97	12.22	0.63	0.60	1.84	> 0.05
Pectoral fin rays	38	45	13.82	14.11	0.66	0.53	2.24	< 0.05
Gill rakers on first branchial arch	37	45	21.00	19.44	1.51	1.14	5.33	< 0.001
Gill rakers on lower limb of first branchial arch	37	45	12.54	11.82	0.90	0.75	3.96	< 0.001
Vertebrae[a]	27	44	59.48	59.55	0.34	0.82	0.43	0.7
Pectoral fin rays[a]	28	45	13.79	14.11	0.74	0.53	2.15	< 0.05

[a]1965 values from West Greenland banks and off Cape Farewell and Cape Desolation only.

of the quantities of tapeworms present, on the growth and weight, are worth investigating further with larger numbers of salmon and, if possible, from fresh arrivals to the same river run.

Body proportions

In both the 1965 (Templeman, 1967) and the 1966 samples of salmon, with increase in total length to the mid-fork there is a small decrease in relative greatest length and in relative pectoral length. The relative proportions of these measurements and of the head length to the fork length appear to be approximately similar in the samples for both years.

Meristic characters

The salmon caught in March–May 1966 were relatively close to the Canadian area and almost all were 2-year fish and greater which make up only a very small proportion of the West Greenland landings. It can therefore be assumed that they were mainly Canadian fish. The samples obtained in July–August 1965 presumably contained mainly Canadian fish from the mid-mouth of the Labrador Sea and both European and Canadian fish in the larger part of the sample taken off West Greenland.

The probability values of a number of meristic characters for these 1965 and 1966 samples are compared in Table 11. The differences in vertebral averages and dorsal fin rays are not significant. The differences in the pectoral fin-ray averages are significant at less than the 5% level. The differences in averages both of total gill rakers on the first branchial arch and of those on the lower limb of the first branchial arch are highly significant. It would appear therefore that meristic characters are worth studying further as a means of showing differences between North American and European salmon. Actual differences may be greater than those shown here since the 1965 samples were almost certain to be of mixed North American and European origin.

The gill-raker numbers show the greatest difference, and our 1966 sample average for gill rakers on the first branchial arch (19.44) is between that of McCrimmon (1949) for presumably Canadian Atlantic salmon but of unidentified origin (average 19.8 for 41 specimens) and that of Wilder (1947) from Canadian rivers of the Maritimes and Quebec (average 18.8 for 28 adult salmon).

If the Labrador Sea data are removed from the 1965 samples leaving only the West Green-land related data the probability of the differences in the 1965 and 1966 pectoral fin-ray averages being significant is not improved (Table 11). The 1965 vertebral average is now below that of 1966 but the differences between vertebral averages still do not approach significance. For other meristic data, inspection of the original 1965 frequencies in Templeman (1967) and of the 1966 frequencies in Table 6 indicates that removal of the 1965 Labrador Sea data would have little influence on the t and probability values.

Food

Total stomach contents per kilogram of salmon round weight (4.7 cc) in the March–May salmon (Table 8) were only half those in Labrador Sea-West Greenland July–August 1965 fish (9.6 cc) and still less than the amounts per kilogram of salmon weight on the West Greenland banks in August 1966 (15.9 cc) (Templeman, 1967).

In both the 1965 and the 1966 salmon the main diet was fish but lantern fish were not noted in the summer diet, and squid, *Gonatus fabricii*, were more important to the oceanic salmon in July–August 1965 than in March–April 1966. By the latter period most of the young *Gonatus* hatched early in the previous year had grown large enough to lie deeper as do the adults, and the new larvae of the year were not large enough to be attractive as food except on a minor scale. In plankton tows in the upper 50 m in March 1966 at the mouth of the Labrador Sea, these *Gonatus* larvae were fairly numerous and were about 1 cm and less in mantle length.

Parasites

Lepeophtheirus salmonis. The infestation rate of 76% on the salmon taken in April–May 1966 is similar to the 70% infestation on 10 salmon from the Labrador Sea and considerably lower than the 93% infestation on 28 salmon from the West Greenland banks and off Cape Farewell and Cape Desolation in July–August 1965 (Templeman, 1967). This may mean that more European than Canadian salmon are infested with these parasites, but under the conditions of capture the possibilities of loss of these parasites and of variations in this loss were great.

Salmincola salmonea. Friend (1941) from observations on salmon in Scottish rivers says that fresh-run maiden salmon are never seen with obvious maggots on their gills. Six previously spawned salmon taken in nets near the Scottish

Coast all had female gill-maggots without egg sacs, 4–75 mature-sized gill-maggots per fish. Estuarine previously spawned fish returning from the sea also carry mature-sized female gill-maggots but none of them have egg sacs. Immature river fish, up to and including the smolt stage, have not been found to possess gill-maggots. Infection of returning maiden fish and reinfection of returning previously spawned fish occurs in the river or estuary.

In our investigations none of these salmon maggots were found on the gills of 4 salmon which had spawned previously. The presence of an adult female parasite of this species on a male salmon with only 1 sea year which showed no evidence of spawning unless it spawned as a parr, appears to be unusual.

Eubothrium crassum. The 71% of the 45 March–May 1966 salmon infested with this tapeworm is similar to the 60% with tapeworms of 10 salmon from the Labrador Sea in July–August 1965 and different from the 21% with tapeworms of 28 salmon from the West Greenland banks and west of Cape Farewell and Cape Desolation in August 1965 (Templeman, 1967). This suggests that less European salmon in the West Greenland area may have tapeworms.

As in the 1965 data there is an indication that the percentage of salmon infested with tapeworms may increase with length of river life. The differences in this regard for the 1966 data, however, are less than in those of 1965 where the salmon closer to the European area dominated at the lower ages and also had fewer tapeworms. Because the quantities of tapeworms present in the 1966 samples (Table 10) did not increase with length of river life too much confidence should not be placed on the relationships with river age in the number infested with these parasites.

Anisakis sp. The percentage of salmon caught in March–May 1966 carrying this nematode on the ventral surface of the liver (33%) was considerably less and the average number of nematodes per fish (0.5) was less than in salmon from any area in July–August 1965 — 56% of 9 salmon (average 0.8 nematodes) from the Labrador Sea, 54% of 13 salmon (average 1.2 nematodes) from the West Greenland banks, and 73% of 15 salmon (average 2.2 nematodes) from west of Cape Farewell and Cape Desolation (Templeman, 1967). It is possible that the numbers may be too small for adequate comparison or that European salmon in the West Greenland area

have higher numbers of this parasite. The 1966 salmon were frozen and then thawed before examination whereas the 1965 ones were examined fresh and it is possible, although unlikely, that the freezing and thawing loosened and displaced some of these small parasites so that they were not noted.

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A Study of Blood Serum Protein Composition by Agar-gel Electrophoresis in Types of Redfish (genus *Sebastes*)

BY JU. P. ALTUKHOV [1,2] AND G. N. NEFYODOV [1]

Abstract

The protein pattern of blood serum was studied by the agar-gel electrophoresis method in 49 specimens of the *marinus*, 53 of the *mentella* and in 43 of the "giant"-types of redfish from the Iceland-Greenland area of the North-west Atlantic Ocean. It was found that the types of redfish studied differ significantly from each other in α_1 — globulins and A and B albumins, being probably, under the genetic control of a pair of autosomal allels. A general evaluation of the biochemical position of the "giants" suggests their hybrid origin.

Introduction

The *marinus*- and *mentella*- types of redfish from the Northwest Atlantic Ocean differ in thermostability of isolated muscle tissue (Altukhov *et al.*, 1967). Inasmuch as this feature has been established as the species-specific criterion for poikilothermal animals (Ushakov, 1959*a*, 1959*b*, 1964), it was believed that there was an intra-specific level of divergence in the forms of redfish studied.

On the other hand, it was discovered that the West Greenland population of *marinus* appeared to be characterized by a level of thermostability which placed it in an intermediate position be-tween the *marinus*- and *mentella*- types from the Iceland area. This discovery as well as an exa-mination of a number of biological peculiarities of the West Greenland *marinus*-type and of a rela-tively large number of the so-called "giant"-type in this region, suggested that the West Greenland *marinus*-type was identified as such only by its external characteristics and was, in fact, an F_1 hybrid of the *marinus*- and *mentella*-types which were interbreeding to some extent in Icelandic waters. Apparently, both for a solution and for a fuller understanding of the taxonomic relationship of the redfishes, it is advisable to analyze their differences not only for a single diagnostic charac-teristic but for a complex of features. From the point of view of molecular taxonomy, work has been done on this problem by O'Rourke (1961) and Schaeffer (1961). This report presents the results of our investigations on the blood serum proteins of the *marinus*-, the *mentella*- and the "giant"-types of redfish by the agar-gel electrophoresis method.

Materials and Methods

The work was carried out on board the RV *Sevastopol* of the Polar Research Institute of Marine Fisheries and Oceanography (PINRO) and in the laboratory of Moscow University in the autumn of 1965 and the winter of 1966. A total of 142 samples of blood serum from the *marinus*-, *mentella*-, and "giant"-types were subjected to electrophoresis in agar-gel. Specimens more than 60 cm in length were referred to as "giants". Location of the trawled samples is shown in Fig. 1.

Blood sampling and preparation of serum. Blood was taken with a sterile Pasteur's pipette by cardiac puncture and put into test-tubes. It is well known that the blood of many species of fishes, and especially those from fresh-water, co-agulates in a very short time, which is measured in dozens of seconds or even in seconds (Puchkov, 1954). But in redfish, for reasons yet unknown, the clotting time is very long. Fresh-sampled blood was therefore centrifuged for 10–15 min at 6,000–7,000 rpm without waiting for coagulation. The serum was put in glass ampoules, preserved with merthiolate (concentration of 1 in 10,000) and frozen. On thawing, colourless clots appeared in some samples, while in others, clots were absent probably having been removed after centrifugation with the blood cells.

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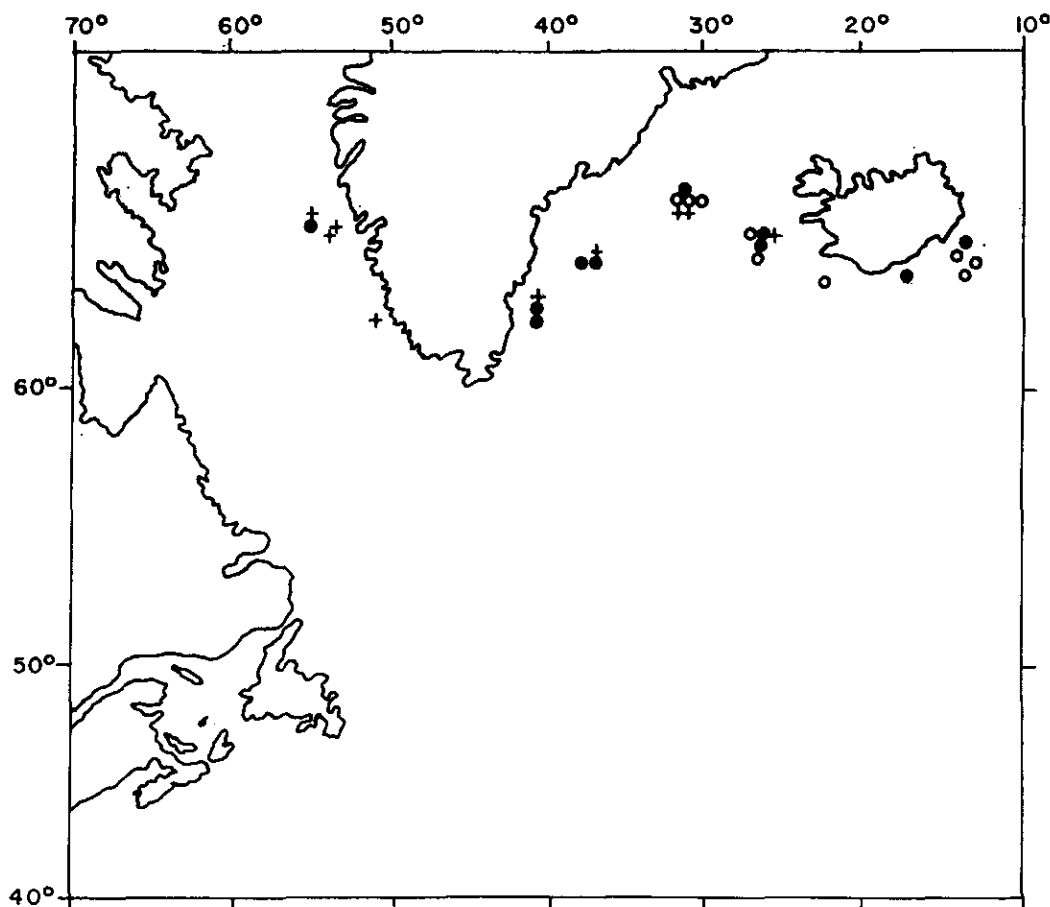
Fig. 1.   Sampling locations for redfish blood (○ = *mentella*; ● = *marinus*; + = "giants").

Electrophoresis was conducted in a handmade plastiglass apparatus (Zilber and Abelev, 1962) in 1% "Difco" agar-gel spread over a 9 × 12 cm photographic glass plate with the emulsion washed off.

Agar was prepared in medinal-veronal buffer at pH 8.6 (range 8.4–8.8).   This buffer was also in the vessel sections of the camera.   Samples diluted with the same buffer in a proportion of 1:2 were placed in standard trenches and were subjected to electrophoresis for $1\frac{1}{2}$ hr at 60 v and 12–15 mA. The plates were put in 5% acetic acid for fixation, then dried and stained in Amidoblack 10B for an hour.

The results were read visually and with the help of a microphotometer, taking into account only the qualitative characteristics of the protein spectrum, i.e., the absence or presence of distinct components differing in mobility.

Results

The results are presented in photographs of phoregrams (Fig. 2a) and by three densitometric curves (Fig. 2b).   Photographs 1–7 (Fig. 2a) show the phoregrams of blood serum from individual specimens of redfish.   Number 8 is the phoregram of normal human serum taken from Grabar and Burtin (1960) and is presented here for comparison.

Examination of the results obtained showed the following differences between the redfish and human blood serum proteins to be the most conspicuous: (1) contrary to the redfish albumin, human albumin shows much less mobility; (2) two distinct fractions are visible in the cathode half of the human serum phoregram (β- and γ- globulins), whereas, in the redfish protein spectrum, separation of the proteins is weak and their small concentration suggests they are identical with γ-globulins.

Hence, from this point of view, β- and α- globulins and albumins—the most mobile fractions are situated in the anode part of the redfish blood phoregram (Fig. 2a).

The results also establish the wide individual variability of the samples expressed by the presence or absence of certain proteins, differing from each other by their electrophoretic mobility. Such a pattern is characteristic both for the albumin and to a great extent for the globulin parts of the phoregram. As mentioned above, the differentiation of proteins is not clear enough in the γ-globulin zone only and this zone of the spectrum is not discussed now. On the other hand, in the zone of α- and β-globulins it is possible to see four fractions (photographs of phoregrams number 1 and 4), and in some cases a division of α_2-globulins into two subfractions may be seen.

The variability of albumins is also typical. Thus, sera from redfish Numbers 1–3 possess slow albumin (B type), the sera from redfish Number 6 and 7 have a more rapid albumin (A type), and the sera from redfish Number 4 and 5 have both types (AB). The mobility of albumins varies from test to test depending on a number of circumstances (Grabar and Burtin, 1960), but if, in the samples studied, there is even a single serum containing both albumins it is relatively simple to understand to which type, A or B, these variations refer.

The individual variability of blood protein composition in redfishes is independent of their taxonomical relations, viz. when examining the samples of *mentella*, *marinus* or "giants", it is possible to find fish of any of the types discovered. At the same time, there is a difference in frequency of these proteins among the types of redfish
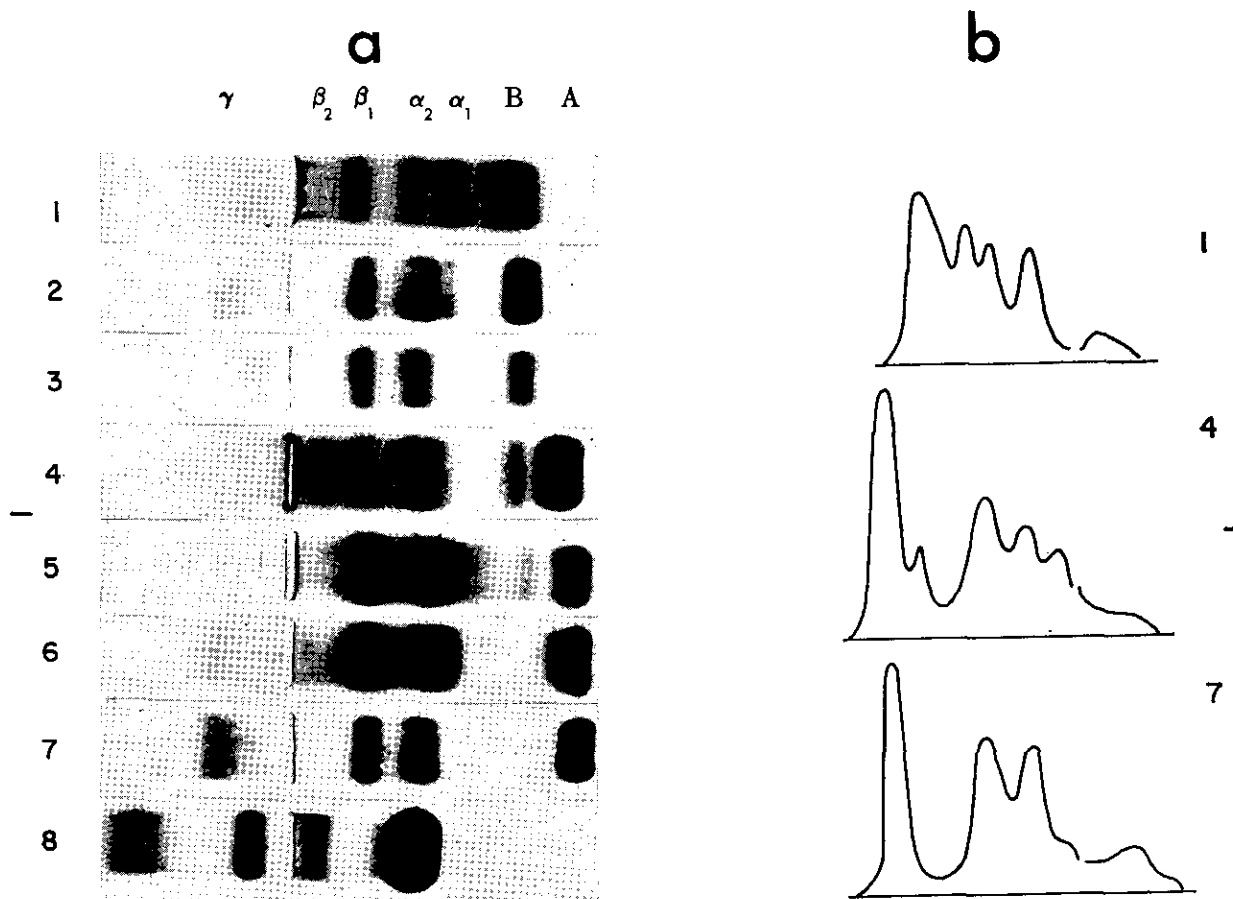

Fig. 2.   (a)   Phoregrams of the redfish (Numbers 1-7) and human (Number 8) blood sera: Numbers 1, 4–6 = *mentella*: Number 3 = *marinus*: Numbers 2 and 7 = "giants"; Number 8 = human serum.
(b)   Densitometric curves of redfish blood phoregrams.   Numeration as in (a).

TABLE 1. Frequency of the protein fractions in redfish blood sera.

Types of redfish	Number of fish tested	Albumins			Globulins				
		A	AB	B	α_1	α_2	β_1	β_2	γ
marinus	46*	8.7	8.7	82.6	42.5	100	100	2.5	100
giants	43	18.6	16.4	65.0	16.3	100	100	7.0	100
mentella	53	22.6	37.8	39.6	17.0	100	100	9.4	100

*Since in six cases the protein pattern in this part of the spectrum appeared to be unsatisfactory, the globulins were studied only in 40 specimens.

(Table 1). The most significant is the difference between the *marinus*- and *mentella*-redfish which differ substantially from each other in the frequency of specimens with albumin B, AB, and α_1-globulins (P < 0.05). For albumin A and β_2-globulins, the difference is not statistically significant. However, the lack of difference is probably determined not by a real absence of difference, but rather by insufficient data.

The protein compositions of the "giant" sera do not show biochemical identity with that from *marinus*, in spite of their striking external likeness, although the differences are not statistically significant for all variable protein fractions, except albumin B and α_1-globulin (P ≤ 0.05). On the other hand, the "giants" are very close, if not identical, to *marinus* in frequency of albumin A and α_1- and β_2- globulins, but differ significantly in the frequency of albumin B and A B (P ≤ 0.05).

It is known, that the individual variability of serum proteins connected with their presence or absence in some specimens, is often genetically controlled. It is usually especially noticeable in albumins, where two types of protein show three distinct phenogroups, viz., A, AB, and B. Such interdependence suggests genetic control by a pair of autosomal codominant allels. This hypothesis is verified below by the Hardy-Weinberg distribution on an example of gene frequencies in a sample of *mentella* (0.41 pA and 0.59 qB).

Table 2 shows that there is no significant difference between the observed and expected numbers of the phenotypes both in each of the three phenotypical classes and their totals. This means that the system of genetic control of the albumins is really two-allelic, and the *mentella*

TABLE 2. Verification of genetic equilibrium and control by a two-allelic gene of *mentella* albumins.

Pheno-type	Geno-type	Number of phenotypes		χ^2 $\left(\dfrac{(f\text{-}F)^2}{F} \right)$
		observed (f)	expected (F)	
A	AA	12	8.90	1.08
AB	AB	20	25.60	1.22
B	BB	21	18.50	0.33
		53	53.00	2.63

population from which the given sample is taken is in genetic equilibrium. When the same calculations are made for *marinus* and "giants", a good fit to the Hardy-Weinberg law is not obtained and χ^2-homogeneity tests give values of 17.33 and 14.64 respectively.

Discussion

Examination of the experimental data shows significant differences in the protein composition of blood among the forms of redfish investigated. Especially interesting is the biochemical position of the "giants". In albumin A they approach the *marinus*-type and in α_1-globulin, the *mentella*-, and they occupy an intermediate position in albumin B frequency, clearly indicating the hybrid origin of the "giant"-type. This explains why, in

applying a mathematical analysis to the *marinus* and the "giant" samples, a good fit to the Hardy-Weinberg law is not obtained—the violation of panmixian is the result of a sterilization of the majority of specimens. Of course, it is possible to mention other circumstances preventing the establishment of a genetic equilibrium (e.g., Neel and Schull, 1954; Li, 1955; Stern, 1960), but in this situation we actually pay attention to sterilization. This line of research has been discussed in our previous report (Altukhov *et al.*, 1967).

This study reveals the differentiation of the *marinus*- and *mentella*-types of redfish by means of one more inherited feature—the protein composition of the blood serum. The fact agrees with the results obtained by Schaeffer and O'Rourke who demonstrate the possibility of distinguishing both redfish types by means of the antigen composition of blood and the aminoacid composition of gill mucus and muscles. These results together with our results on electrophoresis again raises the question of the taxonomical range of divergency of the *marinus*- and *mentella*-redfish from the North Atlantic.

Conclusions

By the method of agar-gel electrophoresis statistically significant differences were found in the protein composition of the blood serum of *marinus*- and *mentella*-types of redfish from the Northwest Atlantic. These differences refer both to α_1-globulins and to albumin phenotypes B and AB, evidently being under direct genetic control.

The "giant"-type of redfish, in spite of its striking external likeness to the *marinus*-type, shows no biochemical identity with it, differing significantly from the latter in frequency of albumin B and α_1-globulins. The "giant"-type also differs significantly from the *mentella*-type in

frequency of albumin phenotypes B and AB. A general evaluation of the biochemical position of the "giant"-type suggests it is a hybrid.

Evidence from the data presented here and by other investigators enable us to raise a question about the taxonomical range of divergence between the *marinus*- and *mentella*-redfish.

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Comparison of Meristic Characters of Adult Atlantic Herring from the Gulf of Maine and Adjacent Waters

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Abstract

Counts of vertebrae and of rays of the right pectoral, dorsal, and anal fins were examined from 5,829 Atlantic herring of the 1958 and 1960 year-classes collected in 1962–65 from areas of Cape Cod, Western Maine, Eastern Maine, Southern Nova Scotia, and Georges Bank. Meristic counts were not significantly different between sexes. Differences in meristic counts among years of sampling were significant, indicating a change in the distribution of herring for a particular year for a given area. Counts of vertebrae and rays of the right pectoral fin suggested that two complexes of herring existed: a Georges Bank-Cape Cod complex which was significantly different from a Maine-Nova Scotia complex. The magnitude of differences among areas in the mean meristic counts for herring of the 1958 year-class was greater than for fish of the 1960 year-class.

Introduction

The racial differences of stocks of Atlantic herring, *Clupea harengus harengus* L., in the Gulf of Maine are being studied by the U. S. Bureau of Commercial Fisheries at the Boothbay Harbor Biological Laboratory. Serological methods; age, length, and maturity data; parameters of growth; and meristic characters are being investigated as indicators of racial differences. This paper gives the results of the investigation of meristic characters of adult herring in the Gulf of Maine and adjacent waters.

Rounsefell and Dahlgren, 1932; Tester, 1937; McHugh, 1942; Bückmann, 1950; and others have found that counts of vertebrae and fin rays of herring increase with a latitudinal decrease in temperature. If this increase holds for herring in the Gulf of Maine and adjacent waters and if herring remain in or return to their respective areas of birth, they should exhibit meristic counts typical of that environment; in particular, counts should be higher in colder waters.

The time in the ontogeny of Atlantic herring when the counts of vertebrae and fin rays are fixed is not known. Tåning's (1952) work with brown trout, *Salmo trutta trutta* L., indicates that the number of vertebrae is determined before hatching, and that the period of fixation for the anal fin begins in the egg stage but continues after hatching. The dorsal and then the pectoral fins are formed next. Gabriel (1944) showed for *Fundulus heteroclitus* (L.) and Dannevig (1950) for *Pleuronectes platessa* (L.) that the number of vertebrae is determined during incubation of the egg. Hempel and Blaxter (1961) reported that the myotome count of Atlantic herring is determined before hatching, although Bückmann (1950) and Tester (1938) gave evidence that the number of vertebrae is at least partially determined after the eggs have hatched. Bigelow and Schroeder (1953) gave 15–17 mm and Blaxter (1962) gave 13–14 mm as the lengths at which the dorsal fin is formed.

Atlantic herring spawn in the Gulf of Maine from late August through October. The eggs are demersal and incubate 10–15 days before hatching, after which the larvae rise to the surface waters. If the meristic characters are fixed while the herring are in this larval stage, the temperature of the surface water would influence development.

Collection and examination of samples

Adult herring were sampled in the Gulf of Maine and adjacent waters in 1962–65. Coastal samples (mostly from spawning schools) were obtained from Stonington, Connecticut, to Grand Manan, New Brunswick, and from St. Mary's Bay to Port Mouton, Nova Scotia; offshore samples were from Georges Bank. Counts of fin rays (right pectoral, dorsal and anal) and vertebrae were made for 100 fish from each collection with the aid of a low power (10X to 30X) dissecting microscope. Vertebral counts excluded the hypural plate. The 1958 and 1960 year-classes of herring—the two dominant year-classes from 1962 to 1967—were chosen for analysis (Table 1). Since

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TABLE 1. Mean counts of vertebrae and of fin rays in the right pectoral, dorsal, and anal fins of the 1958 and 1960 year-classes of Atlantic herring, by years and areas of sampling, and probabilities that the mean counts are not different among years.

| Area and Year	Year-class:	Number of fish		Vertebrae		Right pectoral fin		Dorsal fin		Anal fin	
		1958	1960	1958	1960	1958	1960	1958	1960	1958	1960
Nova Scotia											
1962		53	—	55.5283	—	18.4717	—	19.3774	—	17.9434	—
1963		283	133	55.5830	55.4060	18.4806	18.2632	19.3145	19.4587	17.9152	18.1579
1964		129	291	55.4729	55.4914	18.5039	18.3849	19.3876	19.4399	18.1240	18.1615
1965		185	540	55.5730	55.5519	18.4108	18.4963	19.5514	19.4944	18.1405	18.1815
1962–65		650	964	55.5538	55.5135	18.4646	18.4305	19.4015	19.4730	18.0231	18.1722
Probabilities				P > .25	P < .10	P > .25	P < .01	P < .01	P > .25	.01 < P < .05	P > .25
Eastern Maine											
1963		97	—	55.6495	—	18.5361	—	19.5567	—	18.2062	—
1964		38	185	55.3421	55.4973	18.2895	18.4000	19.5000	19.4324	18.2105	18.2324
1965		31	641	55.3871	55.4774	18.6775	18.4571	19.4194	19.4415	18.2258	18.1061
1963–65		166	826	55.5301	55.4818	18.5060	18.4443	19.5181	19.4395	18.2108	18.1998
Probabilities				.01 < P < .05	P > .25	P < .25	P > .25	P > .25	P > .25	P > .25	P > .25
Western Maine											
1963		211	233	55.5924	55.4764	18.4265	18.2146	19.5356	19.4741	18.0237	17.9399
1964		82	315	55.3781	55.4064	18.3537	18.3302	19.3293	19.2857	18.0976	18.1016
1965		111	401	55.5496	55.4763	18.3784	18.3990	19.5676	19.5162	18.1712	18.1671
1963–65		404	949	55.5371	55.4531	18.3985	18.3309	19.5025	19.4215	18.0792	18.0896
Probabilities				.01 < P < .05	P > .25	P > .25	.01 < P < .05	.01 < P < .05	P < .01	P > .25	P < .01
Georges Bank											
1962		261	—	55.4061	—	18.1648	—	19.1916	—	18.0575	—
1963		265	389	55.2793	55.3342	18.0340	18.0257	19.3849	19.4396	18.0906	18.0540
1964		157	834	55.3440	55.4089	18.1783	18.2062	19.2994	19.4353	18.0892	18.1391
1965		51	632	55.1765	55.3354	18.1765	18.1013	19.4118	19.4035	18.2157	18.1155
1962–65		734	1855	55.3311	55.3682	18.1213	18.1326	19.2998	19.4253	18.0872	18.1132
Probabilities				P < .25	P < .10	P < .25	P < .01	P < .01	P > .25	P > .25	P > .25
Cape Cod											
1963		169	—	55.3550	—	18.1420	—	19.3195	—	17.9882	—
1964		152	296	55.2303	55.3311	18.0395	18.1892	19.2895	19.4493	18.1184	18.1926
1965		—	361	—	55.3490	—	18.2133	—	19.3989	—	18.1607
1963–65		321	657	55.2960	55.3409	18.0935	18.2024	19.3053	19.4216	18.0498	18.1750
Probabilities				P < .25	P > .25	P < .25	P > .25	P > .25	P > .25	P < .25	P > .25
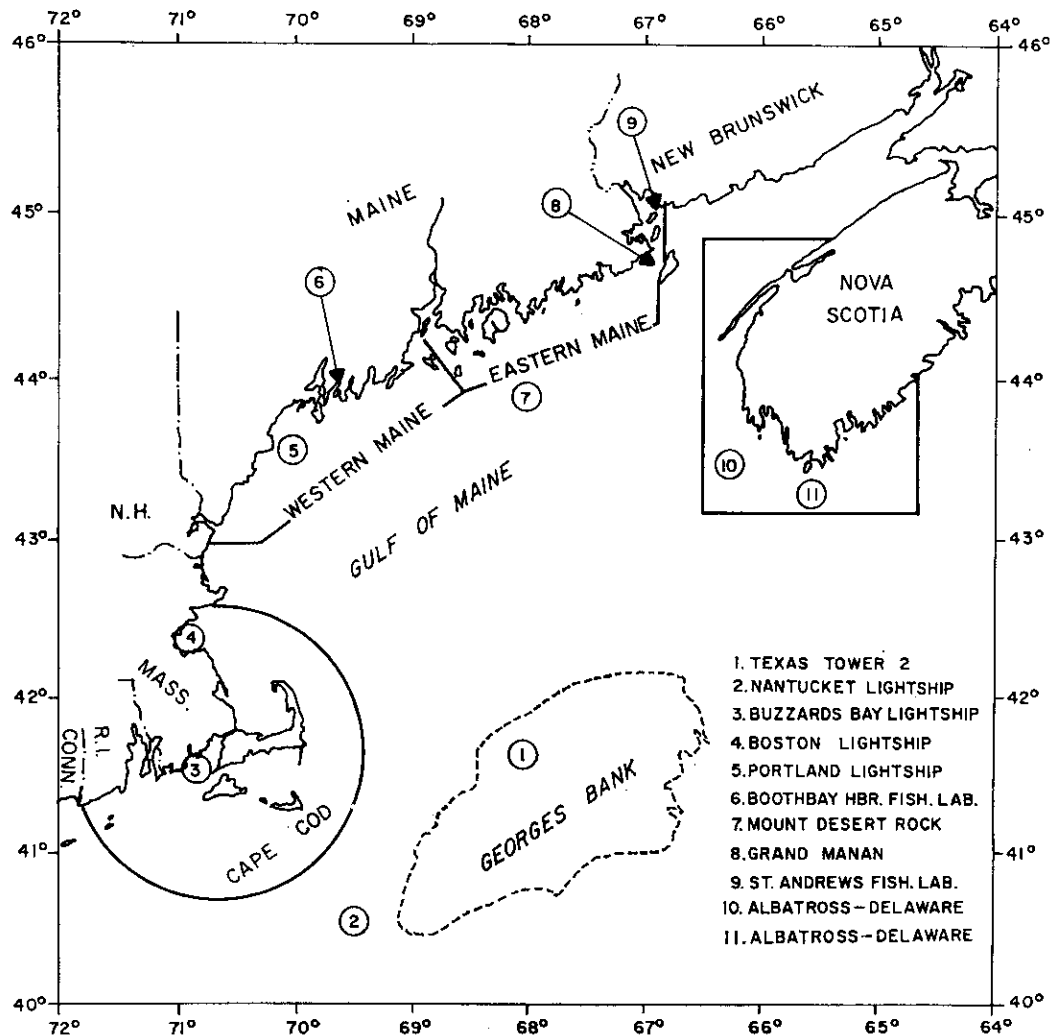
Fig. 1.   Gulf of Maine, showing areas of investigation and locations (encircled numbers) where temperature data were collected.

little was known about the identity and boundaries of stocks within the Gulf of Maine, five arbitrary areas were selected: Western and Eastern Maine, Nova Scotia, Georges Bank, and Cape Cod (Fig. 1).

Since the time of fixation of meristic characters is not precisely known, and since bottom temperatures at the spawning sites are unavailable, the mean temperatures of surface water for September–October were used for comparisons among areas (Table 2 and Fig. 1).   The differences in surface temperature were pronounced; temperatures were lowest in the Nova Scotia and Eastern Maine areas, and were lower in 1958 than 1960 in all areas.

Methods of analysis

We examined the differences of the meristic characters between years of sampling and between sexes for each of the two year-classes to see if the data for different years of sampling and for both sexes could be combined.   Because sample size varied among years and areas, unequal variances would invalidate analysis of variance procedures and comparisons based on the t-distribution.   The Bartlett test (Brownlee, 1960) was therefore used to test for homogeneity of variance for meristic data sampled among years, for each sex, area, and meristic character.   Six of eighty comparisons were significantly different ($P \leq 0.05$) instead of the expected four at the 5% level which indicates

TABLE 2.   Mean temperature (°C) of surface waters in September–October, 1958 and 1960, at selected sites in the Gulf of Maine and adjacent waters.

	Year	
Area, station number, and site[a]	1958	1960
Georges Bank:		
1. Texas Tower 2	14.8	15.5
Nantucket Shoals:		
2. Texas Tower 3	—	15.5
Cape Cod:		
3. Buzzards Bay Lightship	15.9	16.6
4. Boston Lightship	12.8	14.3
Western Maine:		
5. Portland Lightship	11.8	12.6
6. Biological Laboratory, Boothbay Harbor	11.9	12.3
Eastern Maine:		
7. Mount Desert Rock	—	10.8
8. Grand Manan Island	11.4	—
9. Biological Station, St. Andrews, N. B.	11.5	11.7
Nova Scotia:		
Albatross-Delaware cruise	10.2	—
Albatross-Delaware cruise	12.5	—

[a]See Fig. 1 for locations of stations.

that, generally, the variances are not different among years. Bartlett's test, however, is sensitive to nonnormality and may falsely reject the hypothesis of equality of variance when the frequency distribution is heavily concentrated about the mean (Scheffé, 1959), (as it is for vertebral counts of herring). Because three of the six significant values were with vertebral data and may have been partially due to nonnormality, the assumption of homogeneity of variances is strengthened. The inferences associated with the t- and the F-distributions also are not seriously affected by nonnormality.

Two-way analysis of variance tests were conducted between years of sampling and sexes. The probabilities that the mean counts are not different among years are entered in Table 1. There were no significant differences in meristic counts between sexes. Some mean meristic counts, however, were significantly different from year to year for a given year-class within an area. Each area may have contained several stocks of herring, but more likely the herring in the Gulf of

Maine and adjacent waters were not distributed similarly in successive years. For example, on Georges Bank in June, 1964, the herring of the 1960 year-class had a significantly higher ($P \leq 0.05$) meristic count than all other herring obtained from Georges Bank; in the fall, this difference no longer existed. If the generalization is true that higher meristic counts exist in herring from colder water, then herring of this type apparently moved onto Georges Bank in June, and were replaced with a different group in the fall.

In 1965 samples of both the 1958 and 1960 year-classes of herring from southern Nova Scotia also had unusually high meristic counts (Table 1). The counts of the rays of the right pectoral fin for the 1960 year-class and the counts of the rays of the dorsal fin for the 1958 year-class were significantly higher ($P \leq 0.01$) in 1965 than samples collected in other years. The t-test, adjusted for planned comparisons, was used to determine the year or years responsible for the significant differences. This test consists of allocating beforehand the chosen total error probability α (in our
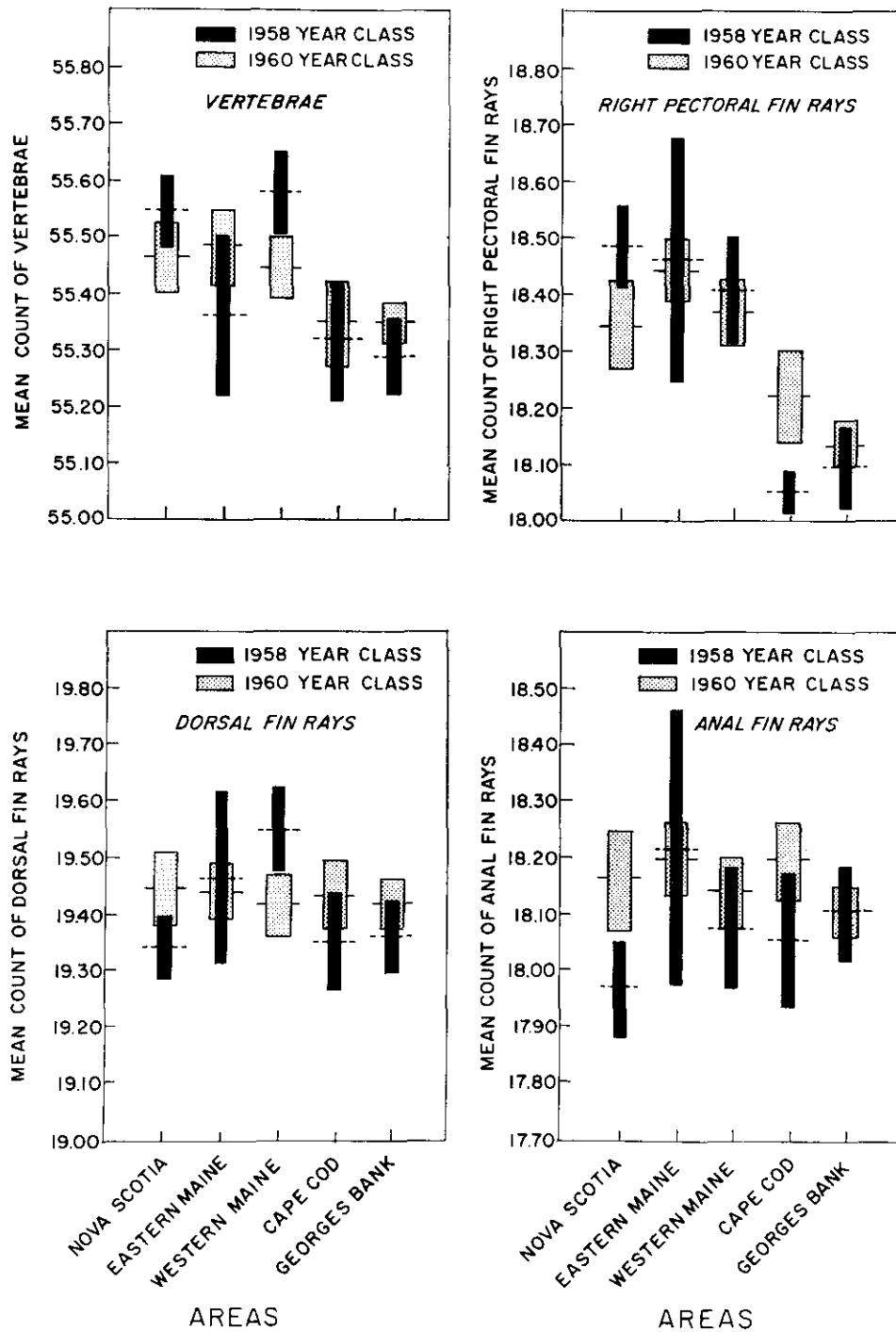
Fig. 2.   Mean counts of four meristic characters by area and year class (horizontal lines indicate means; vertical bars indicate two standard errors on each side of the mean).

case $= 0.05$) into components $\{\alpha_1^*, \ldots, \alpha_m^*\}$ for the m comparisons of means to be covered by the t confidence intervals so that $\sum\limits_{i=1}^{m} \alpha_i^* = \alpha.$

The confidence interval about the difference between means is

$$\bar{x}_i - \bar{x}_j \pm t_\alpha* \sqrt{S^2\left(\frac{1}{n_i} + \frac{1}{n_j}\right)}$$

where S^2 is the error mean square from the one-way analysis of variance. The probability that all of these intervals simultaneously cover the true values is then $\geq 1 - \sum\limits_{i=1}^{m} \alpha_i^*$ (Scheffe, 1959) and the adjusted t-test is then

$$t_\alpha* = \frac{x_i - \bar{x}_j}{\sqrt{S^2\left(\frac{1}{n_i} + \frac{1}{n_j}\right)}}$$

This is a planned comparison technique and avoids the wide intervals encountered with unplanned comparison techniques. When used to test for differences between means, the null hypothesis tends to be rejected more easily than with an unplanned comparison technique.

In Western Maine, meristic counts were significantly different between years for five of eight combinations of meristic characters and year-classes. For the 1958 year-class, vertebral and dorsal ray counts were significantly lower in 1965 than in other years; for the 1960 year-class, right pectoral and anal ray counts were significantly lower in 1963 and dorsal fin ray counts in 1964.

Samples of herring were discarded from further analysis when they were significantly different ($P \leq 0.05$) from all other samples collected within the same area and when the differences were present in several meristic characters, because we assumed that the discarded herring belonged to groups or stocks not normally found in that area.

Fish excluded from the samples of Nova Scotia and Eastern Maine had unusually high meristic counts and those discarded from Georges Bank (other than the samples of the 1960 year-class collected in June, 1964) and Western Maine, had unusually low meristic counts. Such dis-

carding of data does not create significant differences between areas but reduces the probability of herring from two areas having significantly different meristic counts, because the counts of fish from Nova Scotia and Eastern Maine are generally much higher than those from Georges Bank and Cape Cod and about the same as those from Western Maine. The single possible exception is Western-Eastern Maine; the counts of the right pectoral rays for the 1960 year-class might have indicated that herring from Eastern Maine were significantly different from herring of Western Maine if all available data from Western Maine had been used. The remaining data were combined for different years of sampling and for both sexes. The area means and their reliability are shown in Fig. 2.

The combined data for each year-class and meristic character were tested for differences among areas by a one-way analysis of variance test and by adjusted t-tests to determine the significance of each area comparison (Table 3). The assumptions of normality and equality of variance required for variance analysis were satisfied.

The probabilities (P_i) that two areas do not differ were combined for the four meristic characters for each year-class according to Fisher (1963) where $-2 \sum \log_e P_i$ is distributed as chi-square with twice as many degrees of freedom as there are P_i to be combined. Disadvantages of combining in this fashion are that all four meristic counts are treated equally and each P_i is treated as being independent. No conclusions are possible from the dorsal and anal fin ray data by themselves, but the counts of vertebrae and right pectoral fin rays show similar and distinct differences.

Comparison of Areas

Adult herring from Georges Bank and Cape Cod have similar meristic counts, as, in general, do herring from Eastern Maine, Western Maine and Nova Scotia. Some differences in meristic counts between Nova Scotia and Western Maine, however, are not clearly explainable. The counts of the right pectoral fin rays of the 1958 year-class were significantly lower in Western Maine than in Nova Scotia, and the counts of the dorsal fin rays of the 1958 year-class were significantly higher (Fig. 2). On the basis of an adjusted t-test, the general significance level between Nova Scotia and Western Maine is $0.05 > P > 0.02$. A one-way test between these two areas would not indicate

TABLE 3. Probabilities based on four meristic characters that herring from two areas
do not differ.

Area comparisons by year-class	Vertebrae	Right pectoral fin	Dorsal fin	Anal fin	Total for each year-class
Nova Scotia vs. Georges Bank:					
1958	< .005	< .005	> .900	.230	< .005
1960	.030	< .005	> .900	> .900	< .005
Western Maine vs. Georges Bank:					
1958	< .005	< .005	< .005	> .900	< .005
1960	.030	< .005	> .900	> .900	< .005
Western Maine vs. Cape Cod:					
1958	< .005	< .005	< .005	> .900	< .005
1960	> .900	< .005	> .900	> .900	< .250
Nova Scotia vs. Cape Cod:					
1958	< .005	< .005	> .900	> .900	< .005
1960	.040	.030	> .900	> .900	> .500
Eastern Maine vs. Georges Bank:					
1958	> .900	< .005	> .900	> .900	< .005
1960	< .005	< .005	> .900	.100	< .005
Eastern Maine vs. Cape Cod:					
1958	> .900	< .005	.697	> .900	< .005
1960	< .005	< .005	> .900	< .900	< .005
Nova Scotia vs. Western Maine:					
1958	> .900	< .005	< .005	> .900	< .005
1960	> .900	> .900	> .900	> .900	> .900
Cape Cod vs. Georges Bank:					
1958	> .900	> .900	> .900	> .900	> .900
1960	> .900	< .005	> .900	.700	< .025
Eastern Maine vs. Western Maine:					
1958	.180	.300	> .900	> .900	> .900
1960	> .900	.290	> .900	> .900	> .900
Nova Scotia vs. Eastern Maine:					
1958	.350	> .900	> .900	.343	> .900
1960	> .900	.370	> .900	> .900	> .900

that the fish from Nova Scotia had overall significantly higher counts. A one-way test, however, assumes that meristic counts increase with a decrease in water temperature, which we are investigating here and cannot assume at this point. This variability of meristic data in Western Maine suggests that stocks frequently intermingle there.

The mean counts of vertebrae and right pectoral rays for the 1958 and 1960 year-classes were significantly different (P ≤ 0.05) between Nova Scotia and both Georges Bank and Cape Cod, and between Western Maine and Georges Bank. Evidence that herring from Western Maine and Cape Cod are different is given by the mean counts of the rays of the right pectoral fin for both year-classes and the vertebral counts for the 1958 year-class (P ≤ 0.005). The vertebral counts for the 1960 year-class and the counts of the right pectoral fin rays for both year-classes indicate that Eastern Maine is also significantly different (P ≤ 0.005) from both Georges Bank and Cape Cod. These differences combined with the similarities between both sections of Maine

and Nova Scotia and between Cape Cod and Georges Bank, suggest that herring from Coastal Maine and Nova Scotia form one complex of herring which are significantly different from a Georges Bank-Cape Cod complex.

Comparison of year-classes

Although both year-classes generally indicated the same areal differences, the meristic counts were not similar between the two year-classes in their magnitude or in relation to temperature. The magnitude of differences in the mean meristic counts among areas for fish of the 1960 year-class was less than for fish of the 1958 year-class. Herring of the 1960 year-class from Nova Scotia and Maine, for example, were very similar in all meristic characters, indicating that fish may have mixed between the two areas.

The mean counts of the 1958 year-class for the areas of Maine and Nova Scotia were greater than those of the 1960 year-class, as we had expected from the water temperatures (Fig. 1). The mean counts of the 1958 year-class for the areas of Georges Bank and Cape Cod, however, were consistently less than those of the 1960 year-class, even though the water temperatures were lower in 1958 than in 1960, which may have been due to a variation in spawning time from year to year irrespective of temperature.

Conclusion

Despite the year-class differences, the two year-classes independently indicate consistent areal differences for a given meristic character and provide evidence of the existence of two general groups of herring within the Gulf of Maine. The composition of each complex is not yet known and more than one stock may, in fact, exist within a complex. Indeed, the herring discarded because of high or low meristic counts were assumed to come from other groups within or on the periphery of the Gulf of Maine. The herring discarded from northern waters were those with high counts indicating that they belonged to more northern, colder waters, and those discarded from the southern waters were those with low counts indicating that they belonged to more southern, warmer waters. The present data, however,

show clearly that two complexes of herring exist within the Gulf of Maine and that if sub-groups are present within each complex, they are much more nearly alike than are the two complexes.

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Size, Age, and Recruitment Comparisons for Haddock of the Central Scotian Shelf

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Abstract

Haddock, *Melanogrammus aeglefinus*, landings from the central Scotian Shelf (ICNAF Div. 4W) ranging from 13,000 to 51,000 metric tons in the period 1948-65 have been mainly of fish from 45 to 55 cm in length and 4 to 10 years of age. No discernible trend to smaller fish is apparent from Canadian landings which made up over 70% of the total during this period.

Year-class strength fluctuating from about 7 to 34 million fish in landings has had a marked effect on sizes landed and development of the fishery. A period of high Canadian landings from 1956 through 1962 apparently resulted from the extremely good 1952 year-class and above average recruitment from year-classes 1956 through 1958. A subsequent decline in Canadian landings is attributed to poor year-classes in 1958 and 1960.

Total mortality coefficient estimates for year-classes 1944-55 were Z = 0.60 from Canadian landings in Quarter 1 of each year, and Z = 0.73 from landings in the remainder of the year. Estimates suggest that annual mortality was increasing from about 40 to 50% for year-classes from 1945-49 to about 50 to 60% for year-classes 1950-55.

Introduction

Haddock, *Melanogrammus aeglefinus*, is one of the most important species of groundfish taken from the Scotian Shelf off central Nova Scotia (ICNAF Div. 4W). Landings between 1948 and 1965, the period considered in this paper, have ranged from about 13,000 to 51,000 metric tons (Fig. 1). In the early portion of the period, 1948-53, Canadian landings averaged about 10,000 tons annually and made up about 60% of the total. Between 1954 and 1962 Canadian landings averaged about 17,000 tons annually and were about 85% of the total. Since 1963 Canadian landings from Div. 4W have declined as effort was shifted elsewhere. At about 10,000 tons annually they were about 50% of the total in 1963-64, and less than 15% in 1965 when the USSR landed over 45,000 tons from Div. 4W.

From 1948 to 1965 Canadian landings of haddock have been sampled systematically for size and age. Measurements of fish have provided information about sizes landed. Otolith collection and subsequent age interpretations have provided information about age composition of haddock taken by the Canadian fishery. In addition, calculations based on landings, sizes, and catch per unit effort have provided information about recruitment and strength of various year-classes in the fishery. Relatively little has been published about these results. This paper provides various comparisons of sizes, ages, and year-class strengths of haddock in the stock fished from 1948 to 1965.

Material and Methods

Haddock from which samples were taken are landed usually graded into two categories, large and scrod. Fish lengths have been measured and otoliths taken from each category, and the final length and age composition derived by proportioning samples to the quantities of each category landed in the manner described by Kohler (1958). When other landing categories have occurred, such as when smaller fish have been landed round, these have also been sampled and their contribution to the total landings determined. Throughout this period haddock were measured to the nearest centimetre from tip of the snout to the fork of the tail.

For presentation in this paper various calculations from the basic data have been made. During most of the period large (151–500 ton) trawlers have taken the largest proportion of the Canadian landings. These vessels also provided the best records of effort in terms of days and hours fished. Where quantities of sizes and ages landed have been calculated in terms of catch per effort these data have been used. Where age
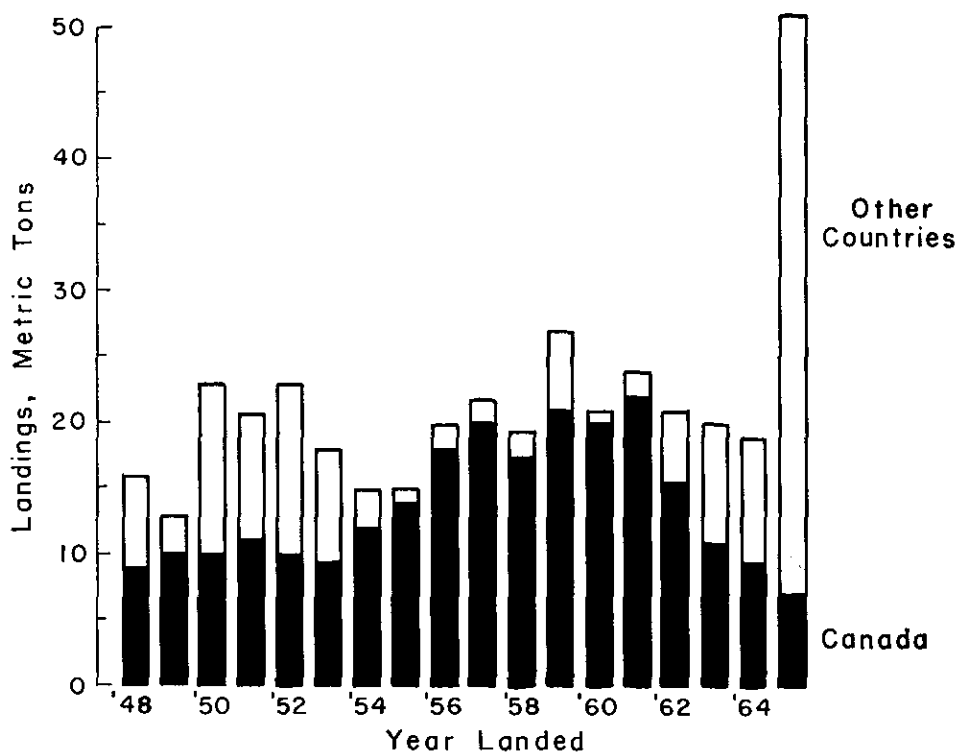
Fig. 1.   Landings of haddock from central Scotian Shelf (Div. 4W), all gears, all countries,
1948–55.   (Div. 4W portion of Div. 4V-W estimated for 1948–52.)

composition has been related to total Canadian landings, total numbers were derived from the total weight landed divided by the mean weight of haddock landed as calculated from our samples.

For one series of calculations, landings by all countries were used in determining total numbers of each year-class landed.   It was assumed that size and age of haddock in landings by other countries were similar to those taken by Canadians.   For the period considered in these calculations (1951–63) this is believed to be substantially correct.

Ages were determined by reading hyaline and opaque rings on haddock otoliths using a binocular microscope and reflected light in the manner described by Kohler (1958).   Hyaline (winter) zones, separated by opaque (summer) zones, were counted to give the age of the fish.

Results

Size-composition comparisons

Throughout the period considered (1948–65) haddock landed during February–April

(Quarter I) have ranged from about 38 to 65 cm, most being between 45 and 55 cm (Fig. 2).   A comparison of sizes landed by averaging number caught per hour trawled for 3-year periods beginning in 1948 and continuing through 1965 shows no great changes.   During the early part of this period (1948–53) there were somewhat greater numbers of haddock over 60 cm landed.   More recently there has been a greater proportion of haddock landed between 40 and 45 cm.

Between 1948 and 1956 about half the fish landed were   over 50 cm.   Between 1957 and 1962 considerably more than half the fish landed were under 50 cm.   However, in the most recent period (1963–65) the size composition was again more like the earlier years when about half the fish were above and half below 50 cm in length.

Comparisons between landings in the remainder of each year have been for data grouped for the period May through January (Quarters II, III, and IV) since landings have been less regular and varied considerably by seasons in different years.   These landings show more variation in size composition than those landed in
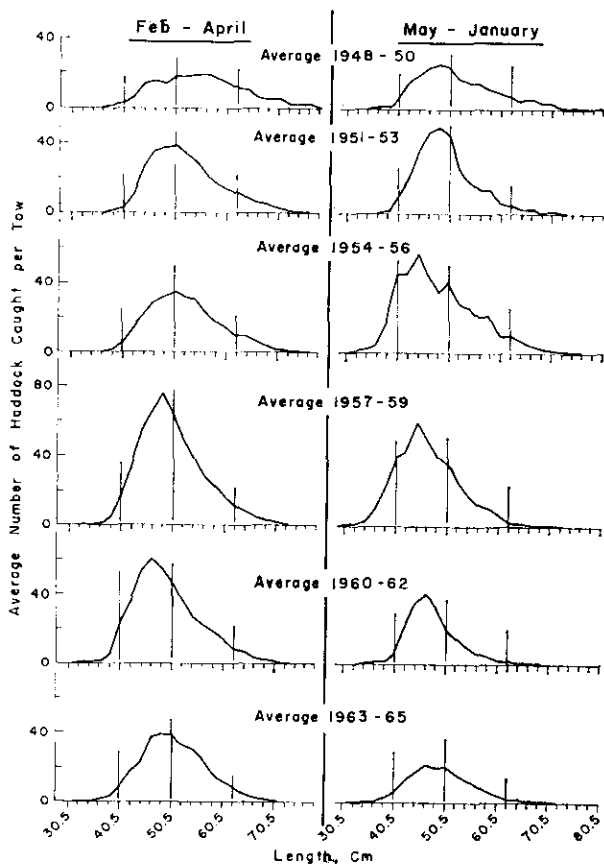
Fig. 2. Length composition of haddock landed from Div. 4W (Div. 4V-W for 1948–52) by Canadian otter trawlers of 151–500 gross tons, 1948–65; averages by 3-year periods.

Quarter I (Fig. 1). Sizes landed have ranged between 35 and 60 cm and, in general, there has been a tendency to land fewer large fish than in Quarter I. Haddock landed in Quarters II–IV were mainly between 42 and 52 cm. However, in the middle part of the series of years being considered (1954–59) most fish were between 40 and 50 cm. Size compositions in terms of numbers of fish caught per hour trawled for the two seasons are presented on an annual basis in Appendix Table I.

Age-composition comparisons

Haddock landed in the February–April period (Quarter I) from 1948 to 1965 have ranged between 3–14 years of age but were mainly from 5 to 9 years old (Fig. 3). There has also been considerable variation between periods. From 1948 to

1956 most haddock were landed as 6- to 8-year-old fish. From 1957 to 1962 a preponderance of the fish landed were from 4 to 6 years of age. In the most recent 3-year period (1963–65) there were fewer younger fish, and landings were again dominated by fish from 6 to 8 years old.

In the remainder of the year, May through January (Quarters II, III, and IV), the haddock landed were generally younger than those of Quarter I. Haddock of 3–7 years of age predominated (Fig. 3), with considerable variation between periods. From 1954 to 1962 most haddock landed were between 3 and 5 years of age. Prior to 1954 and in the most recent 3-year period (1963–65) a larger proportion of 5- to 7-year-old fish were being landed.

Data plotted in Fig. 3 show marked changes in numbers of haddock landed by Canada. Most haddock were landed in 1957–59 and 1960–62. Smallest numbers of haddock were landed in the 3-year period 1948–50 and in the most recent period 1963–65. Age compositions by seasons on an annual basis are presented in Appendix Table II.

Recruitment variations

Estimates of haddock recruitment show wide fluctuations in year-class strength (Fig. 4). Mean number caught and landed per hour fished by large (151–500 gross ton) Canadian otter trawlers for year-classes 1942–59 as 5 and 6 year olds was 95.5. Maximum deviation above the mean was 189.5 for the 1952 year-class, and maximum deviation below the mean was 77.5 for the 1942 year-class. Based on average catch/hour fished, the 1952 year-class was about 16 times that of the 1942 year-class in numbers. (Less reliable estimates of abundance for the 1941, 1960, and 1961 year-classes are provided. These estimates rely on catch/effort figures for 1 year only. However, they do appear to be correct in the general order of year-class strength shown.)

A series of poor year-classes from 1941 to 1945 was followed by above average year-classes in 1946 and 1947. Below average year-classes in 1948–51 were followed by the most successful year-class of 1952 which dominated the fishery in the late 1950's. Better than average recruitment in 1955–57 was followed by below average year-classes in 1958, 1960, and 1961, with a better than average year-class in 1959.
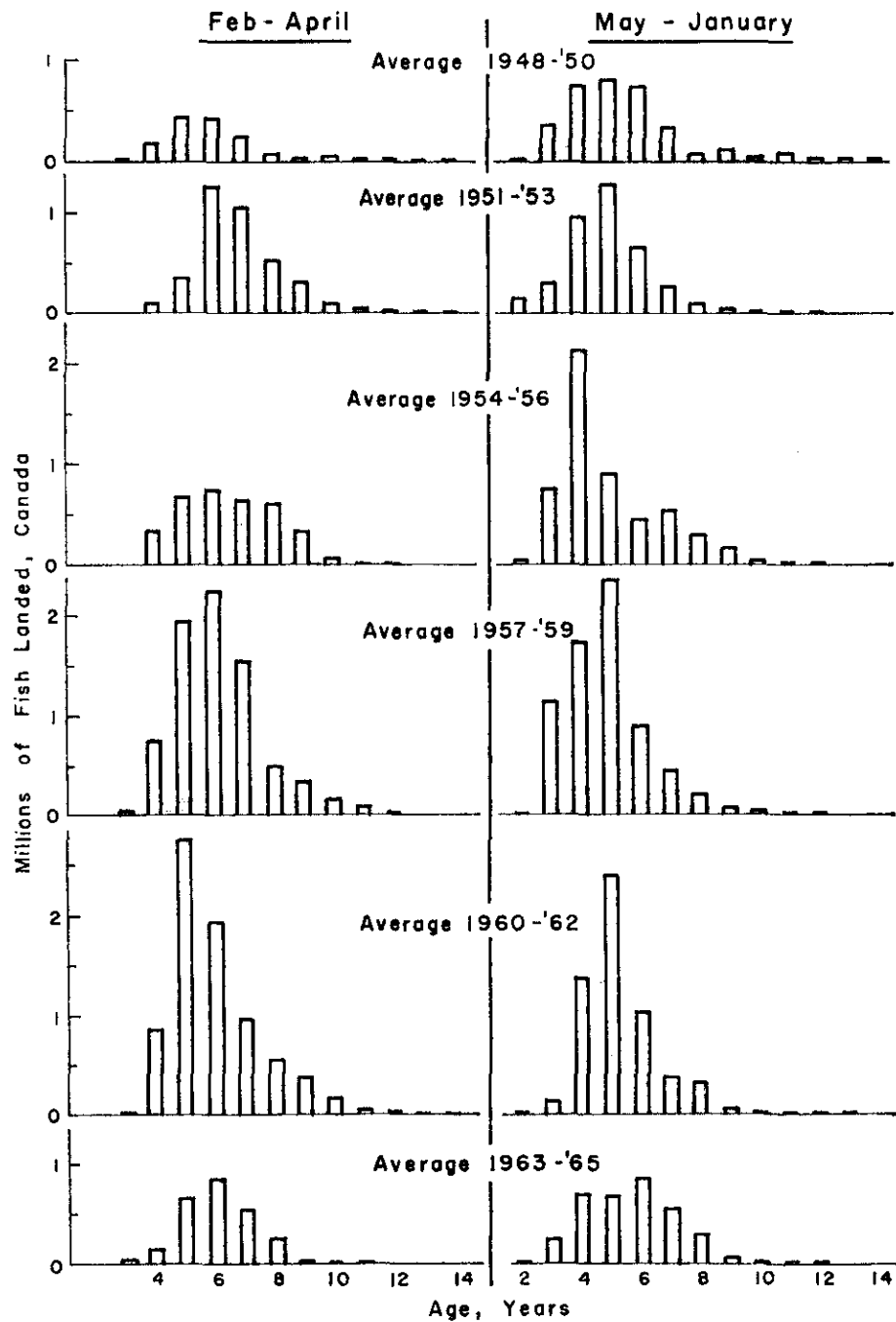
Fig. 3.   Age composition of haddock landed from Div. 4W (Div. 4V-W for 1948–52)
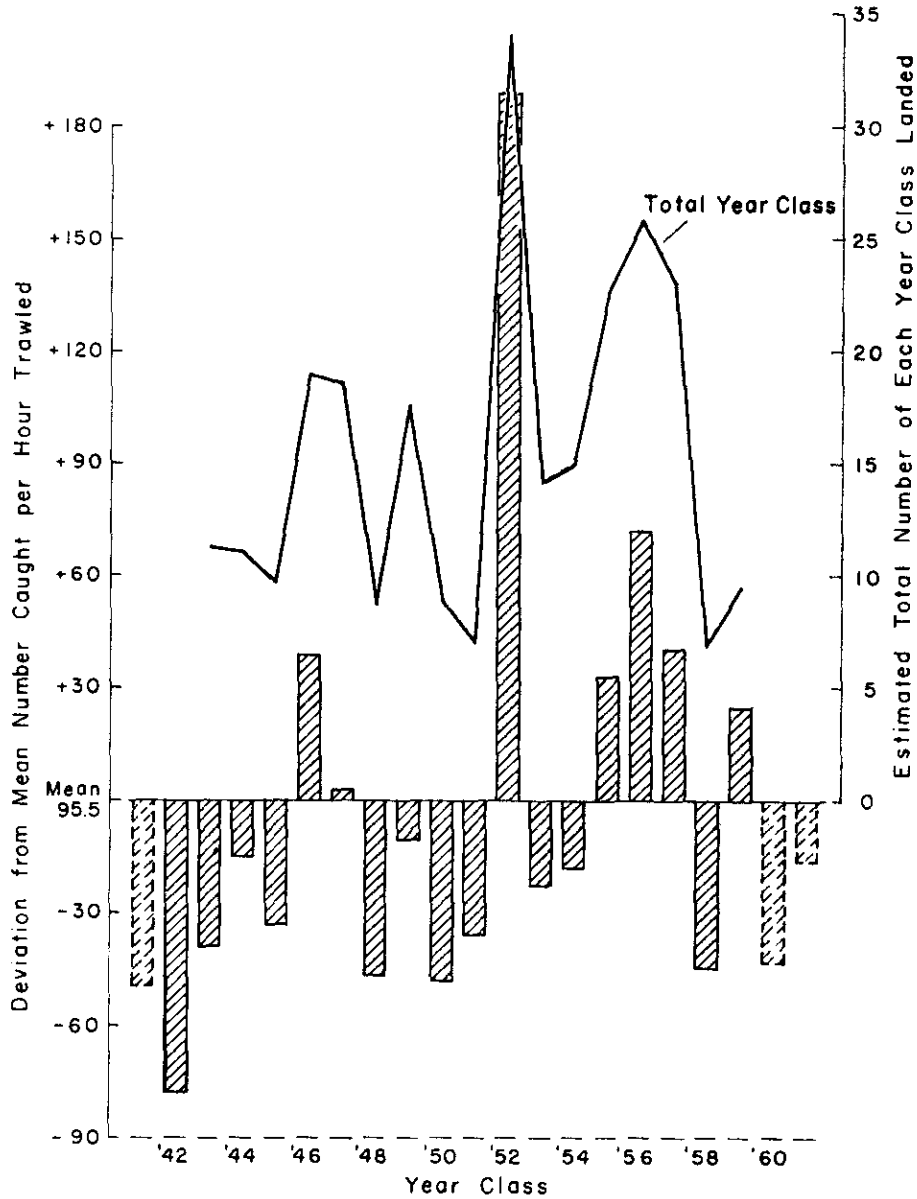by all Canadian vessels; averages by 3-year periods.

Fig. 4. Estimates of haddock year-class strength 1941–60 and contributions to total
landings, all countries, by year-classes, 1943–58; year-class strengths 1942–59
estimates based on Canadian catch /effort figures.

Estimates of total numbers of each year-class caught by all gears and all countries follow closely the pattern shown by the Canadian catch/effort data (Fig. 4 and Table 1). Average year-class strength, as landed, from 1943 to 1957 was about 16 million fish (Table 1). The maximum difference between year-classes was 27 million fish (Table 1).

TABLE 1. Estimates of contributions of haddock year-classes to total landings, all countries, ICNAF Div. 4W.

Year-class	Total numbers landed
1959	9,673,172+
1958	6,768,619+
1957	23,174,479
1956	26,386,197
1955	22,788,547
1954	15,187,280
1953	14,317,131
1952	34,142,968
1951	6,943,783
1950	8,176,934
1949	17,762,024
1948	7,687,442
1947	18,458,393
1946	18,918,638
1945	9,916,319
1944	11,324,203
1943	11,332,329

Average year-class strength 1943–57 = 16,400,000 fish.
Maximum difference between successive year-classes = 27,000,000 fish.
Average difference between successive year-classes = 7,500,000 fish.
Maximum divergence single year-class from long-term mean = 17,700,000 fish.
Average divergence of year-classes from long-term mean = 6,200,000 fish.

Calculations of year-class contributions from total landings show poor recruitment in the mid 1940's, better than average year-classes in 1946–47, poor recruitment in the early 1950's, an outstanding 1952 year-class, and good recruitment from 1955 to 1957 (Fig. 4).

Mortality rates

Along with estimates on changes in recruitment the data on catch/effort by age of haddock (Appendix Table II) provide material for estimates

of total mortalities. Plotting logarithms of numbers per hour fished for year-classes 1944–55 against age for Quarter I (February–April) for ages 3–12 (Fig. 5) shows that haddock were probably fully recruited from age 6 on. Using the median values of catch/hour at each age from 6 to 11 years and fitting a line by eye through the straight part of this curve provided an estimate of survival of 55% per year or a coefficient of mortality, Z, equal to 0.60. A similar procedure using material from Quarters II, III, and IV of each year (May–January) for year-classes 1945–55 and ages 5–9 gives an estimated annual survival of 48% and a value of Z=0.73 (Fig. 6). The data available are not adequate to allow separation of total mortality estimates into fishing and natural mortality components.

To enable some comparison of changes in total mortality with time and in relation to the various year-classes entering the fishery, a line was fitted by the least squares method to the logarithm of catch/hour as a function of age for individual year-classes from 1945 to 1955. Quarter I, and Quarters II, III, and IV were treated separately. Quarter I, ages 6–12, were used in the calculations. For Quarters II, III, and IV, ages 5–10 were used. The occasional zero catch/hour entry which occurred was replaced by 0.5 in order to prevent the logarithm of zero from completely dominating the calculation. The complement of the resulting slope for each series of ages is taken as

TABLE 2. Mortality of haddock by year-classes from 1945 to 1955 in the central Scotian Shelf region (ICNAF Div. 4W). Estimates from catch curves using ages 6–12 for Quarter I and ages 5–10 for Quarters II, III, and IV.

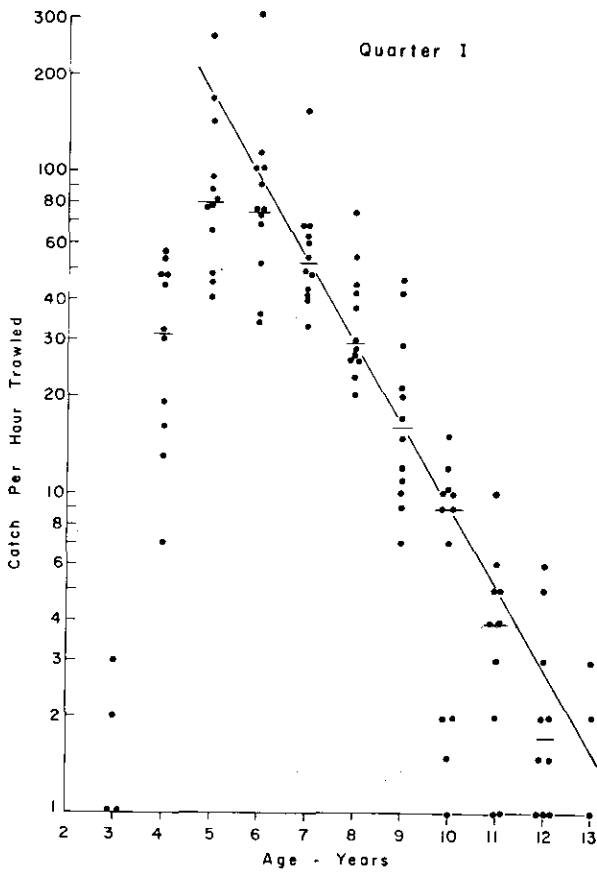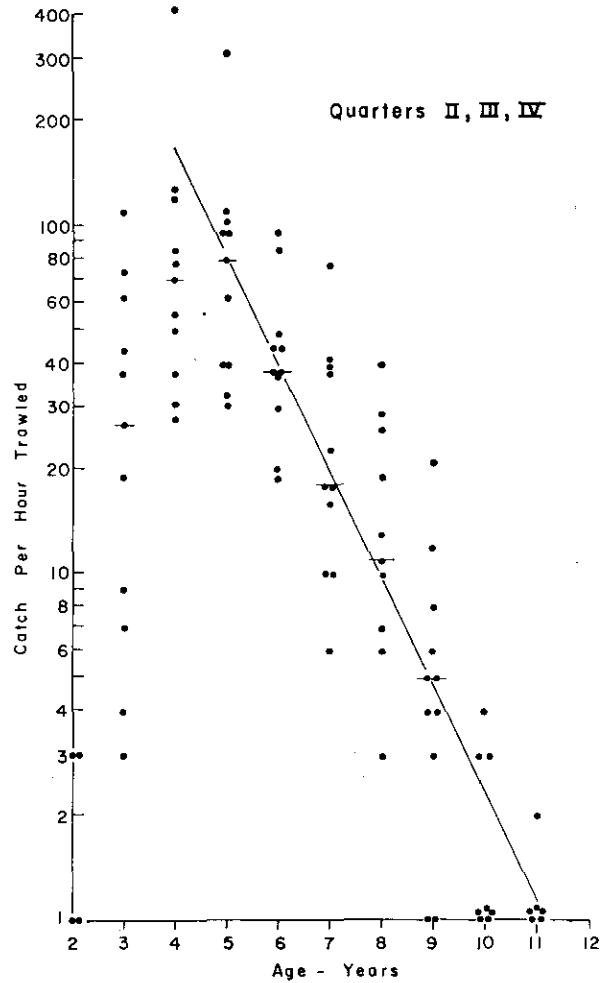| Year-class	Total mortality (% year)	
	Quarter I	Quarters II, III, IV
1945	45	32
1946	46	50
1947	45	47
1948	29	53
1949	41	56
1950	46	50
1951	56	61
1952	64	81
1953	56	59
1954	60	53
1955	63	58

Fig. 5. Estimate of total mortality (Z) for haddock from the central Scotian Shelf (ICNAF Div. 4W) derived from age compositions and catch/effort of Canadian otter trawlers in Quarter I, for year-classes 1944–55.

Fig. 6. Estimate of total mortality (Z) for haddock from the central Scotian Shelf (ICNAF Div. 4W) derived from age compositions and catch/effort of Canadian otter trawlers in Quarters II, III, and IV, for year-classes 1945–55.

the estimate of total mortality and presented in Fig. 7. Percentage annual mortalities calculated on this basis range from 29 to 64 for Quarter I and from 32 to 80 for the remainder of the year. In general, mortality estimates for the two portions of the year follow the same pattern although anomalies do occur (1948 year-class). The results also show a generally increasing trend in total mortality, with estimates for earlier year-classes generally between 40–50, while those for later year-classes are between 55–65%.

Discussion

Variation in recruitment (year-class strength) has been the dominant feature of the stock of haddock from the central Scotian Shelf in the period considered. While these fluctuations have not been as pronounced as those reported in haddock stocks of St. Pierre and Grand Banks (Templeman, 1966; Hodder, 1966), it appears that relative success of the fishery has been a direct result of year-class strengths. Thus poor year-classes in the mid 1940's resulted in poor landings in the late 1940's (Fig. 1). The dominant 1952 year-class and better-than-average year-classes in the late 1950's led to a build-up of Canadian otter-trawl effort in the 4V-W region. Similarly the poor year-classes of 1958, 1960, and 1961 probably contributed to decreased Canadian effort in the region from 1962 to date (Fig. 1).
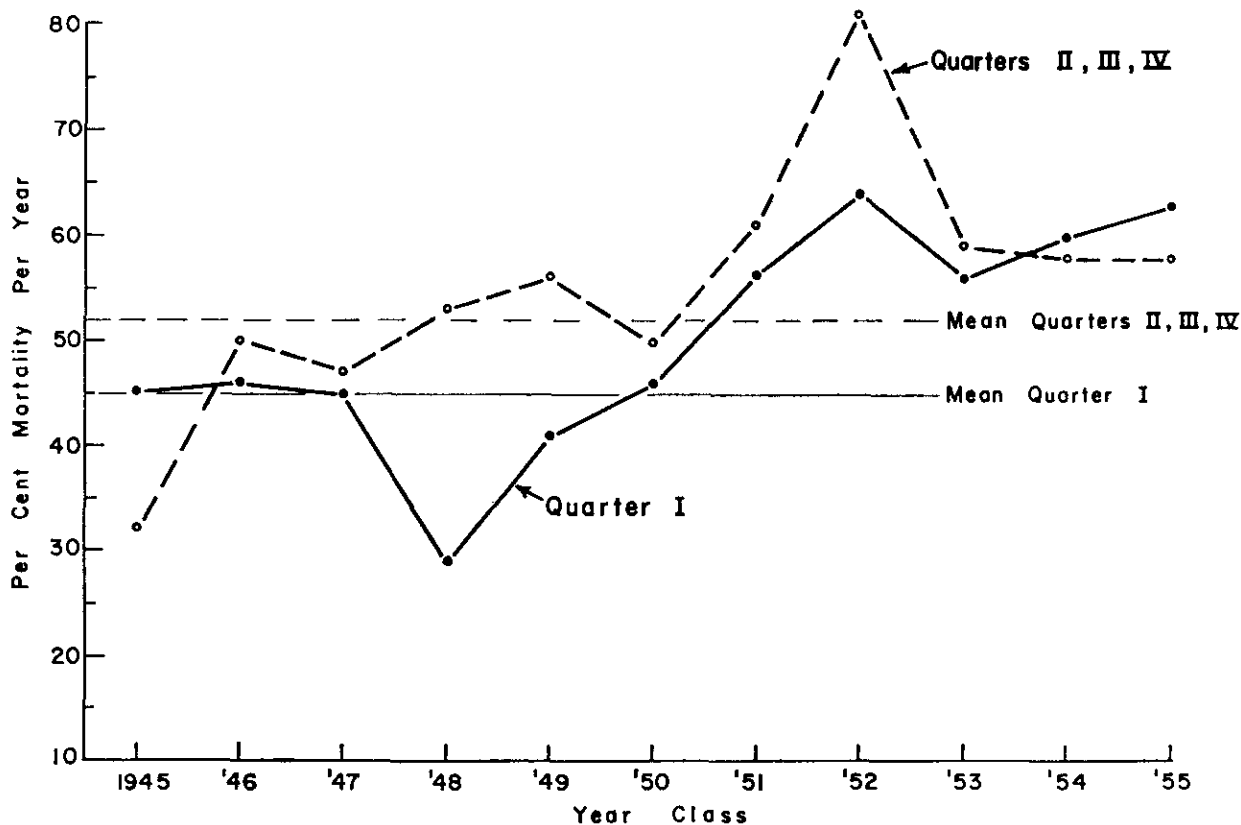
Fig. 7. Estimates of total mortality (% annual) by year-classes from 1945 to 1955 for haddock from the central Scotian Shelf (ICNAF Div. 4W).

No very consistent relationship between the occurrence of good year-classes of haddock on the central Scotian Shelf and those of other sections of the Northwest Atlantic can be recognized. The extremely large 1949 year-class of haddock from St. Pierre and Grand Bank (Templeman, 1966; Hodder, 1966) corresponded with a moderately good survival of the 1949 year-class on the central Scotian Shelf. However, this year-class was not particularly large in the Browns-LaHave region (Hennemuth, Grosslein, McCracken, 1964) or in the Georges Bank region (Taylor, 1958). The 1952 year-class which was strong in all areas of the Scotian Shelf (Martin and Kohler, 1965) and Georges Bank (Graham, 1954) had only moderate survival in the Grand Bank region (Hodder, 1966).

As pointed out by Templeman (1966) and Hodder (1966), the 1955 year-class of haddock was outstanding on Grand Banks. However, this year-class appears not to have been particularly large on any of the banks to the westward (Hennemuth *et al.*, 1964; Graham, 1959).

That there has been relatively little change in size and age composition of haddock landed in the Canadian fishery between 1948 and 1965 is an interesting situation. It seems likely that the relative mobility of the fleet and the fact that haddock is a prime target of the fishery are both involved. Thus examination of landing statistics in the various ICNAF Statistical Bulletins shows a reduction in USA effort and landings in the area as the poor year-classes of the early 1950's began to contribute and United States effort was confined to more western regions. This gap was filled only slowly by the Canadian effort. As previously mentioned, the Canadian effort has also been shifted recently to the more western regions (4X and 5Z) as poor recruitment of the 1958, 1960, and 1961 year-classes apparently affected yield to the fishery.

For most of the period considered haddock were not being taken incidentally to other species and fishing mortality was not being imposed from such efforts. Only recently, about 1963–64, has

mortality from other fisheries been important, as the USSR began to exploit silver hake in the same region. The most noticeable changes in size and age of haddock landed in the Canadian fishery have resulted from changes in recruitment, with lowering of sizes and ages landed as large year-classes entered the fishery and increasing of sizes and ages landed when poorer year-classes yielded fewer recruits. Reduction in acceptable size of fish appears to have played a minor part.

Such stability in sizes landed is in contrast to the change for cod in the Gulf of St. Lawrence (4T) where increased effort by less mobile Canadian fleet and additional fishing mortality produced by European vessels have resulted in much reduced landings of large cod (Kohler, 1965). Vessels of the Canadian and USA fleets, fishing haddock in Div. 4W, have been larger and more mobile and have tended to change area or to fish for other species either seasonally or for longer periods when catch/effort of haddock on the central Scotian Shelf decreased to undesirable levels. For haddock the total mortality coefficient $Z = 0.60$ (Quarter I) and 0.73 (Quarters II, III, and IV) from Div. 4V-W is similar to previous assessments at about 0.70 (ICNAF, 1962). However, our recent calculations show an increasing trend in total annual mortality while previous estimates suggested that total mortalities were decreasing significantly (ICNAF, 1962), and in the period 1955–58 were about $Z = 0.50$. The lack of change in haddock sizes and ages landed for the period 1948–64 indicates that fishing effort and mortality have not changed sufficiently to change the population structure despite the apparent trends shown by mortality calculations. However, the very large catch by the USSR in 1965, taken mainly during July and August when smaller fish are known to be present, may have changed markedly the current situation.

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APPENDIX TABLE I. Length frequency haddock landings (average number caught/hour trawled, Canadian otter trawlers 151–500 gross tons) from ICNAF Div. 4W, February–April (Quarter I) and May–January (Quarters II, III, and IV), by years, 1948–65.

Quarter 1

Length (cm)	1948[a]	1949[a]	1950[a]	1951[a]	1952[a]	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965
36.5	—	—	—	—	—	—	—	—	0.2	1.9	—	0.7	1.5	1.4	0.8		1.6	—
38.5	0.4	—	0.3	0.4	1.2	—	0.3	0.4	1.5	7.7	0.9	5.1	4.2	6.6	5.4	2.4	4.6	0.2
40.5	2.3	2.1	3.3	5.5	1.6	0.2	2.7	2.1	9.7	16.5	13.5	18.2	21.9	27.0	19.0	6.1	17.5	1.1
42.5	3.1	4.3	11.9	21.7	6.2	3.8	10.9	4.9	23.3	45.0	28.0	25.7	40.2	34.3	33.3	18.6	30.0	1.8
44.5	8.1	13.2	20.5	46.5	19.0	10.2	26.7	11.6	23.7	85.5	51.0	28.9	52.2	55.0	51.0	27.8	37.6	2.4
46.5	8.3	23.3	15.5	45.4	38.4	23.2	39.2	16.3	28.5	83.1	78.9	33.9	52.2	80.0	49.1	54.2	51.7	6.0
48.5	8.4	17.1	17.5	41.6	38.7	30.1	50.1	21.7	24.0	69.6	106.1	52.2	46.7	77.4	43.4	54.7	50.2	14.5
50.5	12.0	23.3	16.5	33.8	36.2	44.0	37.1	29.8	34.7	53.0	96.2	49.2	37.8	66.7	36.9	51.2	42.3	21.2
52.5	8.9	21.6	22.4	24.0	36.0	42.4	35.5	29.8	30.6	32.5	72.4	42.2	37.7	51.3	23.0	41.0	36.6	21.2
54.5	11.9	19.6	25.0	19.6	28.4	38.8	25.4	33.7	33.3	28.3	53.5	35.6	33.4	31.9	17.7	36.0	34.0	24.4
56.5	10.5	20.2	25.5	19.6	20.3	30.4	15.2	27.6	25.1	24.4	32.7	30.8	27.9	29.1	13.6	25.1	29.0	23.0
58.5	11.3	17.8	19.7	15.4	15.7	20.2	10.5	22.0	19.2	17.5	26.2	26.8	23.9	22.2	11.3	17.0	18.0	16.9
60.0	7.0	17.5	19.1	10.7	12.6	14.3	7.9	17.5	16.7	17.1	16.4	17.9	17.1	15.7	10.9	11.1	10.7	14.9
62.5	8.4	13.2	13.8	13.6	11.5	9.7	5.6	11.8	11.1	10.7	11.1	12.0	8.9	9.7	8.0	7.4	7.2	10.6
64.5	10.2	9.9	12.0	10.1	8.1	6.1	3.7	9.7	12.2	7.1	7.8	9.3	6.8	11.4	4.7	4.3	3.8	6.5
66.5	8.8	5.2	3.8	7.7	6.8	4.1	2.1	9.8	6.4	3.8	3.9	6.0	5.1	6.8	3.4	2.0	2.5	4.7
68.5	6.0	4.8	4.7	6.2	5.5	1.0	1.7	4.4	3.2	2.8	3.0	4.0	2.5	3.9	2.7	1.1	1.2	1.8
70.5	4.1	9.6	3.2	5.0	1.5	0.8	0.6	1.6	0.8	1.6	1.6	3.4	0.8	3.3	2.0	0.3	0.4	1.1
72.5	1.7	1.9	2.1	3.0	0.9	0.2	—	1.0	0.5	0.8	0.3	0.6	0.5	1.9	1.0	—	—	0.5
74.5	1.7	1.5	1.5	—	0.9	—	—	0.2	0.2	0.2	0.3	0.8	0.1	2.2	0.3	0.1	—	0.2
76.5	0.8	4.2	1.8	0.6	0.4	—	—	0.2	—	0.2	0.2	0.4	—	1.0	0.1	0.1		—
78.5	0.5	0.3	0.6	—	—	—	—	—	—	—	0.2	—	0.2		1.0	—		—
80.5	0.4	0.1	0.3	0.6	0.2	—	—	—	—	—	—	0.1	—	—	0.1	—	—	—

Quarters II, III, and IV

Length (cm)	1948[a]	1949[a]	1950[a]	1951[a]	1952[a]	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965
32.5	—	—	—	—	—	—	—	0.9	2.5	—	0.7	3.3	—	—		0.2		
34.5	—	—	—	—	—	—	—	1.9	8.1	1.0	2.0	4.6	—		0.1	0.1	0.1	—
36.5	—	0.4	—	—	—	—	—	3.2	12.9	2.1	6.5	21.7	0.3	—	0.4	0.1	1.3	0.2
38.5	—	1.6	0.6	—	—	3.7	—	14.1	43.8	10.5	14.3	44.9	1.6	0.3	1.8	1.3	4.8	2.2
40.5	0.4	12.3	4.7	5.6	1.5	18.4	—	28.4	104.5	35.4	25.8	58.3	4.9	5.4	6.1	4.4	7.7	8.1
42.5	1.3	23.5	21.8	22.2	6.7	31.0	5.9	20.6	114.2	42.1	35.8	52.2	35.8	14.8	11.9	12.0	13.7	10.8
44.5	5.2	27.8	24.6	44.7	22.5	37.4	13.4	23.2	134.1	86.2	36.2	57.2	60.3	25.4	22.3	26.0	17.2	7.0
46.5	12.2	24.8	34.5	53.9	46.5	40.4	24.3	31.6	80.9	91.7	35.2	26.4	59.8	31.2	29.9	29.8	20.3	9.8
48.5	15.2	24.5	32.7	50.3	48.6	45.4	24.9	36.3	46.3	67.4	37.0	17.6	39.2	29.2	29.8	31.2	19.5	10.8
50.5	12.5	27.8	31.4	27.2	51.1	55.9	38.2	36.5	46.3	54.9	36.8	17.2	16.8	17.3	26.1	26.0	20.3	16.2
52.5	12.9	23.2	16.1	16.4	29.2	30.5	29.6	29.5	25.2	43.5	27.0	11.8	13.4	15.6	17.9	17.4	17.1	14.0
54.5	11.2	20.3	12.5	11.2	17.3	26.3	36.9	20.5	21.4	26.1	19.8	12.1	7.5	8.4	13.3	13.8	13.3	12.1
56.5	9.6	17.2	15.8	8.0	9.0	24.2	26.9	15.7	18.6	23.0	12.0	5.6	6.4	6.8	7.2	7.1	12.3	10.0
58.5	8.1	13.7	12.9	7.6	5.3	26.8	37.6	14.1	12.4	19.7	7.2	4.8	5.1	3.8	4.3	6.8	8.1	7.9
60.5	6.5	9.7	10.9	5.5	3.0	8.4	16.3	6.1	7.0	10.8	4.8	3.8	1.7	2.5	2.8	4.5	3.9	5.9
62.5	4.6	9.7	7.5	5.3	2.7	4.6	22.0	6.3	2.0	4.5	2.9	1.2	3.2	2.1	1.5	3.0	3.1	3.5
64.5	4.1	6.4	4.0	3.7	2.0	3.1	16.3	2.8	1.4	1.2	1.7	1.3	0.8	0.7	0.7	1.3	2.9	2.3
66.5	7.8	6.1	1.9	2.8	1.0	3.1	7.8	2.9	1.5	1.3	1.5	0.5	0.7	0.7	0.5	0.8	1.6	1.2
68.5	5.7	4.6	1.4	1.2	0.5	0.7	5.7	1.0	0.7	0.4	1.1	—	0.4	0.2	0.2	0.2	0.7	0.3
70.5	4.4	3.8	—	1.1	—	2.3	3.5	1.0	0.3	—	0.5	—	—	0.3	0.1	0.3	0.1	—
72.5	1.5	1.3	—	0.2	—	0.8	0.7			—	0.1	—			0.2	0.2	0.2	—
74.5	1.4	0.9	—	—	—	—	2.1	0.2	—	—	0.2	—	—	0.1	0.1	—	—	—
76.5	0.4	0.7	0.7	—	—	—	—	—	—	0.2		—	—	—	—	0.1	—	—
78.5	0.4	0.4	—	0.2	—	—	—	—	—	—	—	0.1	—	—	—	0.1	—	—
80.5	0.5	0.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

[a] Includes 4V since landings not separated until 1953.

APPENDIX TABLE II. Age composition haddock landings in terms of catch/hour as landed by Canadian otter trawlers, 151–500 gross tons, from ICNAF Div. 4W, February–April (Quarter I) and May–January (Quarters II, III, and IV), by years, 1948–65.

Age (yr)	Year																	
	1948[a]	1949[a]	1950[a]	1951[a]	1952[a]	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965
Quarter I																		
2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3	—	—	3	—	1	1	—	—	—	2	—	3	—	—	—	—	1	—
4	19	17	32	55	7	30	13	16	54	48	45	48	41	89	6	25	22	15
5	40	87	48	168	95	65	80	45	41	263	78	79	142	211	100	41	162	28
6	21	74	76	36	101	103	34	90	51	73	305	68	76	115	124	170	60	62
7	21	14	55	41	43	40	54	33	68	60	62	153	68	49	48	88	81	25
8	13	11	6	25	20	27	74	44	26	38	42	23	54	26	30	28	36	34
9	5	9	7	—	11	11	20	21	46	10	42	12	17	29	15	7	9	6
10	6	7	2	2	4	2	—	7	12	10	15	10	9	9	10	1	2	2
11	2	3	6	2	2	1	—	—	4	4	10	5	6	3	2	1	5	1
12	3	6	3	1	4	—	—	—	1	1	3	2	6	5	2	—	1	—
13	1	1	1	1	1	1	—	—	1	—	—	—	2	3	1	—	—	—
14	2	1	1	—	1	1	—	—	1	—	2	1	1	1	—	—	—	—
15	1	—	1	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—
16	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
17	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Quarters II, III, and IV																		
2	1	1	—	—	3	—	—	10	3	—	1	—	—	2	—	—	—	1
3	7	38	19	3	44	27	4	110	74	9	63	121	6	2	5	1	7	27
4	48	31	56	71	50	120	28	38	420	86	79	127	92	28	11	67	9	20
5	36	91	31	110	96	63	104	40	80	315	40	33	97	73	82	31	61	17
6	8	68	64	45	37	86	30	45	38	49	97	19	20	38	57	62	21	30
7	9	9	40	23	10	38	77	18	41	23	10	40	18	6	16	27	37	11
8	7	5	3	8	5	13	40	26	11	29	7	—	19	10	6	3	25	13
9	5	6	10	4	2	5	21	5	12	5	8	3	4	4	1	1	6	3
10	2	4	3	2	—	—	—	3	3	4	1	1	—	1	—	—	1	1
11	3	2	6	1	—	4	8	1	1	1	2	—	1	—	—	—	1	1
12	1	2	1	—	—	—	—	—	1	1	—	—	—	—	—	—	—	—
13	—	2	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—
14	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
15	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
16	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—
17	—	—	—	—	—	4	—	—	—	—	—	—	—	—	—	—	—	—

[a]Includes 4V since landings not separated prior to 1953.

A Comparison of Current and Long-Term Temperatures of Continental Shelf Waters, Nova Scotia to Long Island

BY JOHN B. COLTON, JR.

Abstract

Offshore temperature conditions during December 1964 and 1965, March 1953, 1965, and 1966, and May–June and September 1965 and 1966 are compared with 1940–59 mean values for these months. Charts showing the distribution of temperature at the surface, 20 m, 50 m, and 100 m, and of temperature anomalies at the surface, 20 m, and 50 m are presented. At most locations and depths the 1964-66 temperatures were appreciably colder than the 1940–59 mean values. The magnitude of the negative anomalies tended to be greatest in areas off the edge of the Continental Shelf. Temperatures in March 1953 were warmer than the 1940-59 mean values. These trends paralleled trends at coastal stations as exemplified by Boothbay Harbor, Maine temperatures. The reliability of the use of coastal temperatures for indexing offshore conditions, the possible biological effects of warming and cooling trends, and the causes of these trends are discussed.

Introduction

This paper provides a summary of current and long-term temperature conditions during March, May–June, September, and December in the Continental Shelf area bounded by longitudes 64°W and 72°W. The long-term temperature data are for 1940–59, and are from the file of bathythermograph and oceanographic station observations at the Woods Hole Oceanographic Institution. The current temperature data were collected on a series of eight quarterly environmental surveys made by the U.S. Bureau of Commercial Fisheries from December 1964 to September 1966. These surveys, conducted during a period of severe drought in the New England area, afford an opportunity to compare recent inshore and offshore temperatures with long-term means.

Analysis of the Data

The initial monthly tabulation of the 1940 - 59 temperature data was made on a basis of 10-min quadrangles at depths of 1, 10, 20, 30, 40, 50, 75, 100, 150, 200, and 250 m. In this report these data have been grouped in terms of 30-min quadrangles.

Observations for any month within a given year were weighted in favor of certain days (dates). To offset possible bias in determining monthly means all data for a given day were averaged and monthly means based on the daily means rather than on the total number of observations. Some of the inshore quadrangles included daily observations made at lightships. To eliminate the bias of the data in these quadrangles due to the preponderance of lightship observations, 10-day mean values of lightship observations were determined for each month and these values treated as three observations.

Because observations were so few in certain months, the 1940–59 monthly mean values at specific depths were plotted and smooth curves showing the seasonal cycle of temperature were drawn as described by Fuglister (1947). In drawing these curves the greatest weight was given to mean values for months having the most years represented. The resultant curves for specific depths in adjacent quadrangles were so closely similar that occasional inconsistencies in the data were obvious. A sample of seasonal temperature curves and the corrections applied at the surface, 50 m, and 100 m is shown in Fig. 1. The correction applied to monthly mean values based on a small number of observations was often considerable; where only a few years were represented the corrected value was sometimes outside the range of the observed temperatures.

All 1940–59 mean temperature values were read from these seasonal curves and isotherms were drawn on a basis of corrected values entered at the center of each 30-min quadrangle. The May–June mean temperature values for 1940–59 are based on an average of the corrected values for these 2 months. Temperature distributions based

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	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
SURFACE												
NO. OF OBSERVATIONS	37	11	22	20	54	105	114	97	127	48	37	16
NO. OF DAYS	11	9	7	12	14	25	28	26	35	20	9	4
NO. OF YEARS	7	5	5	6	9	11	11	13	14	11	6	3
AVERAGE TEMP.	6.9	6.8	5.5	6.8	10.7	14.7	18.5	22.3	20.0	16.7	13.7	12.4
CORRECTED TEMP.		5.2	5.0				19.2			16.8		10.4
50 METERS												
NO. OF OBSERVATIONS	35	10	22	18	53	95	107	97	125	40	36	14
NO. OF DAYS	9	8	7	11	14	24	25	26	34	17	9	4
NO. OF YEARS	6	5	5	7	9	11	9	13	13	9	6	3
AVERAGE TEMP.	8.8	8.2	7.0	7.5	8.4	8.2	8.9	9.7	11.8	14.7	14.3	13.5
CORRECTED TEMP.		7.6		7.0	7.4	8.0		10.4	12.0	13.9		11.8
100 METERS												
NO. OF OBSERVATIONS	24	4	19	10	43	60	69	57	68	25	18	7
NO. OF DAYS	7	4	7	5	12	18	19	17	24	14	6	2
NO. OF YEARS	6	4	5	5	9	9	7	8	12	9	4	1
AVERAGE TEMP.	12.3	11.7	11.0	10.5	11.0	10.1	11.0	11.8	12.3	12.2	13.9	16.4
CORRECTED TEMP.		11.6			10.5	10.6		11.7		13.3	14.0	13.6

Fig. 1.   Seasonal temperature curves and temperature corrections applied for 30-min quadrangle, 40°00'N to 40°29'N, 70°30'W to 70°59'W.

on the quarterly environmental survey data were determined from *in situ* bathythermograph observations.

Accuracy of the Data

The greatest single source of error in the 1940–59 mean temperature data was faulty navigation. Position errors were not always easy to detect, but in relatively shoal water (<250 m) a comparison of the bathythermograph echo sounder depth with chart soundings usually would reveal the error. Errors due to defective instruments were relatively few and these were usually detected easily. A considerable amount of personal judgment was involved in deciding what observations were in error; generally this decision was withheld until a comparison could be made with supplementary observations.

Validity of the Data

Iselin (1955) has discussed the complications of obtaining a synoptic picture of the distribution of physical and chemical properties in coastal waters characterized by strong tidal and nontidal currents and short-period internal waves. Obviously when observations are averaged for an area as large as a 30-min quadrangle for a period as long as a month, only the most general approximation of reality is obtained. This fact is evidenced by the appreciable ranges in monthly temperature values observed in most quadrangles and at most depths and by the greater sharpness of horizontal and vertical gradients based on quarterly environmental survey data compared with those based on 1940–59 mean data. The validity of the temperature estimates based on monthly mean values varies with the season. These estimates are nearest actual conditions in the winter, when temperature gradients are weak over most of the area. Summer on the other hand, is a period of strong horizontal and vertical stratification.

Examples of short-term temperature fluctuations at anchor and parachute drogue stations and at "repeat" sections in the Gulf of Maine-Georges Bank area during the summer are shown in Fig. 2. The variations in temperature observed in a specific water mass and at specific locations were considerable; it is apparent that internal waves as well as advection were a contributing factor. Although the methods used impose serious limitations, whereby temperature

values based on long-term averages are employed to interpret conditions in a region characterized by large temporal and spatial fluctuations, the method does appear to provide a general picture of the major temperature features to which specific cruise data may be compared.

Distribution of Temperature

The distribution of temperature during March, May–June, September, and December at the surface, 20 m, 50 m, and 100 m, based on 1940–59 mean values and 1964, 1965, and 1966 quarterly environmental survey data is shown in Fig. 3–10.

In general, the 20-year mean and specific year seasonal and areal temperature trends at all depths were similar; minimum temperatures occurred in March and inshore and maximum temperatures occurred in September and offshore. As would be expected, the temperature gradients based on survey cruise data were much sharper than those based on 1940–59 mean values. The contrast in the complexity of the distribution patterns based on 1940–59 mean and survey cruise data was greatest in September. The most striking feature of the data is that with but few exceptions the survey cruise temperatures were lower than the 1940–59 mean temperatures during all months and at all depths and locations.

Temperature Anomalies

To assess current temperature trends more effectively, temperature anomalies were computed as the difference between the monthly mean for a specific year and the monthly mean for the base period 1940–59. In determining 1940–59 means, 30-min quadrangle values within 1- or 1/2-degree quadrangles were averaged. Monthly means for specific years were determined by averaging all station data within 1- or 1/2-degree quadrangles. Values from survey cruise stations located on whole degree latitude or longitude lines were entered in the quadrangle immediately to the south or west. Monthly temperature anomalies at the surface, 20 m and 50 m for specific years are shown in Fig. 11–14.

With the exception of surface values along the New England coast during May–June 1965 and 1966, 20-m values in the Wilkinson Basin area in September 1965, and surface and 20-m values in the central and western Gulf of Maine and off the southwest coast of Nova Scotia in

September 1966, all temperature anomaly values were negative. Although not illustrated, all 100-m anomalies were negative with the exception of positive values at the extreme southeasterly quadrangle during May–June 1965 and 1966. Considering that at most locations and seasons the temperature data from survey cruises were characterized by marked short-term fluctuations and that the temperature data for any quadrangle represent a sampling period of less than 12 hr, the temperature anomalies are remarkably consistent.
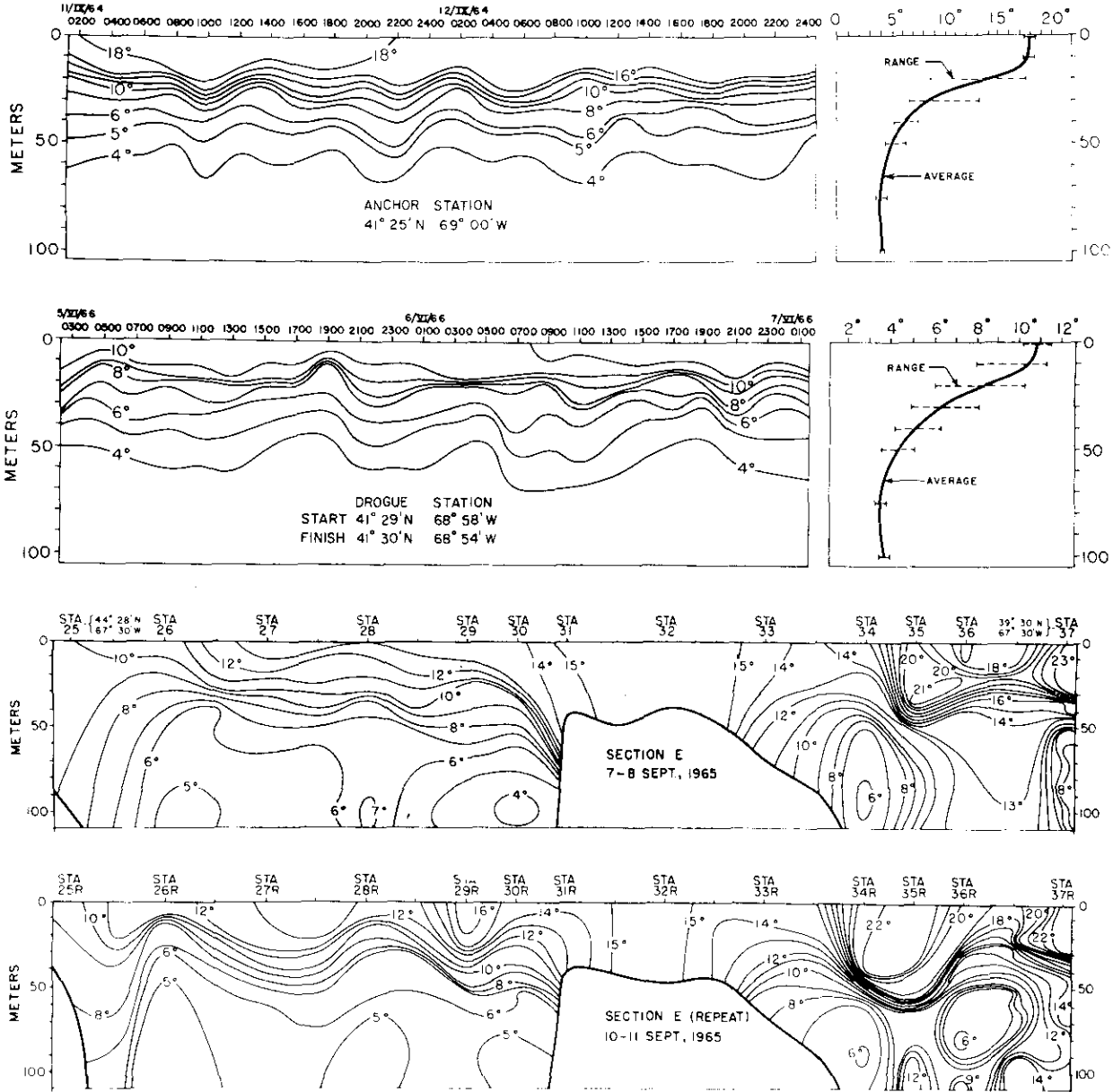

Fig. 2.   Temporal variations in the distribution of temperature at anchor and drogue stations and at repeat sections.

SURFACE   20 METERS
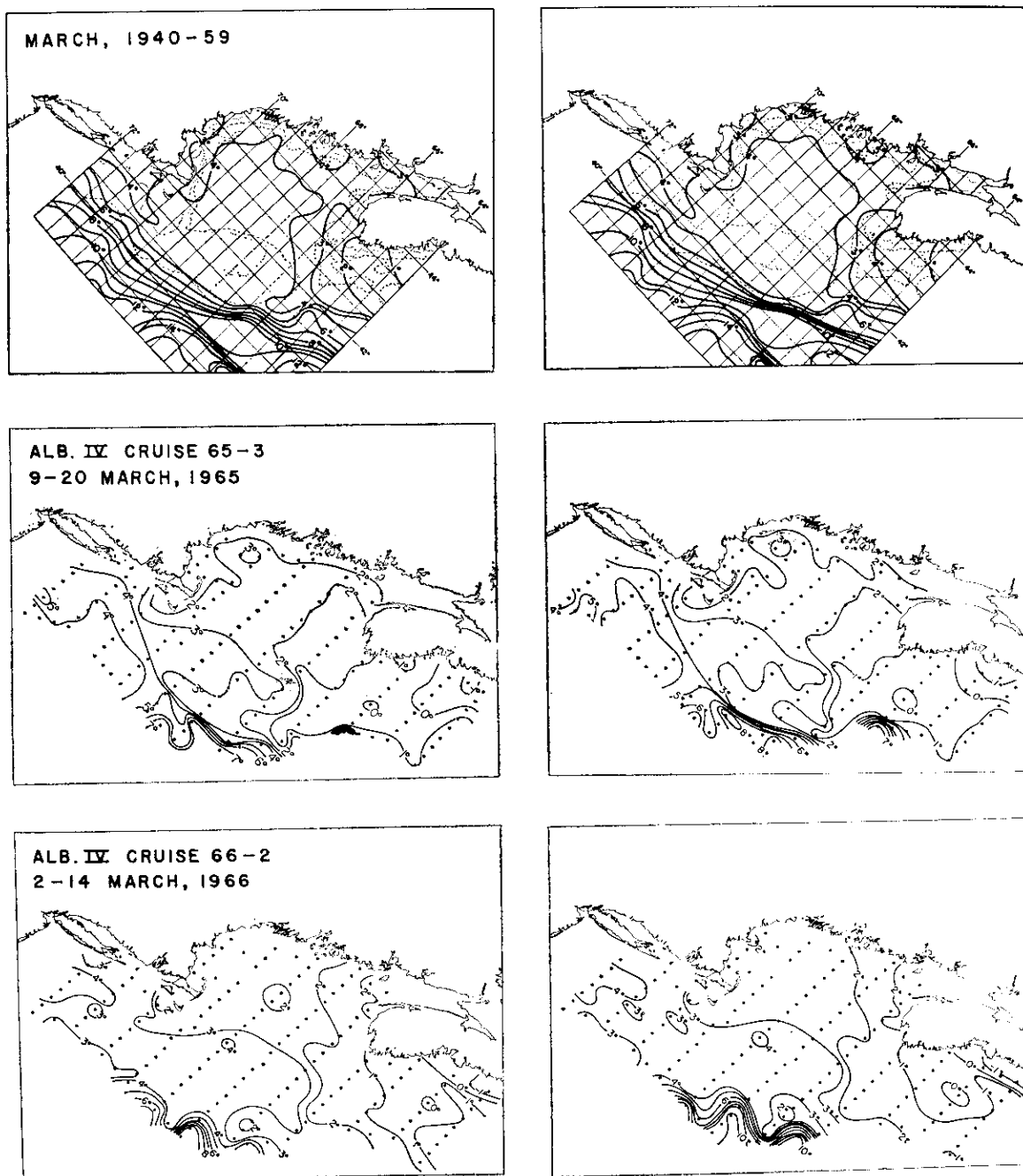
Fig. 3.   Temperature distribution at the surface and 20 m, March 1940–59, 1965, and 1966.

50 METERS

100 METERS

MARCH, 1940 – 59

ALB. IV CRUISE 65 – 3
9 – 20 MARCH, 1965

ALB. IV CRUISE 66 – 2
2 – 14 MARCH, 1966
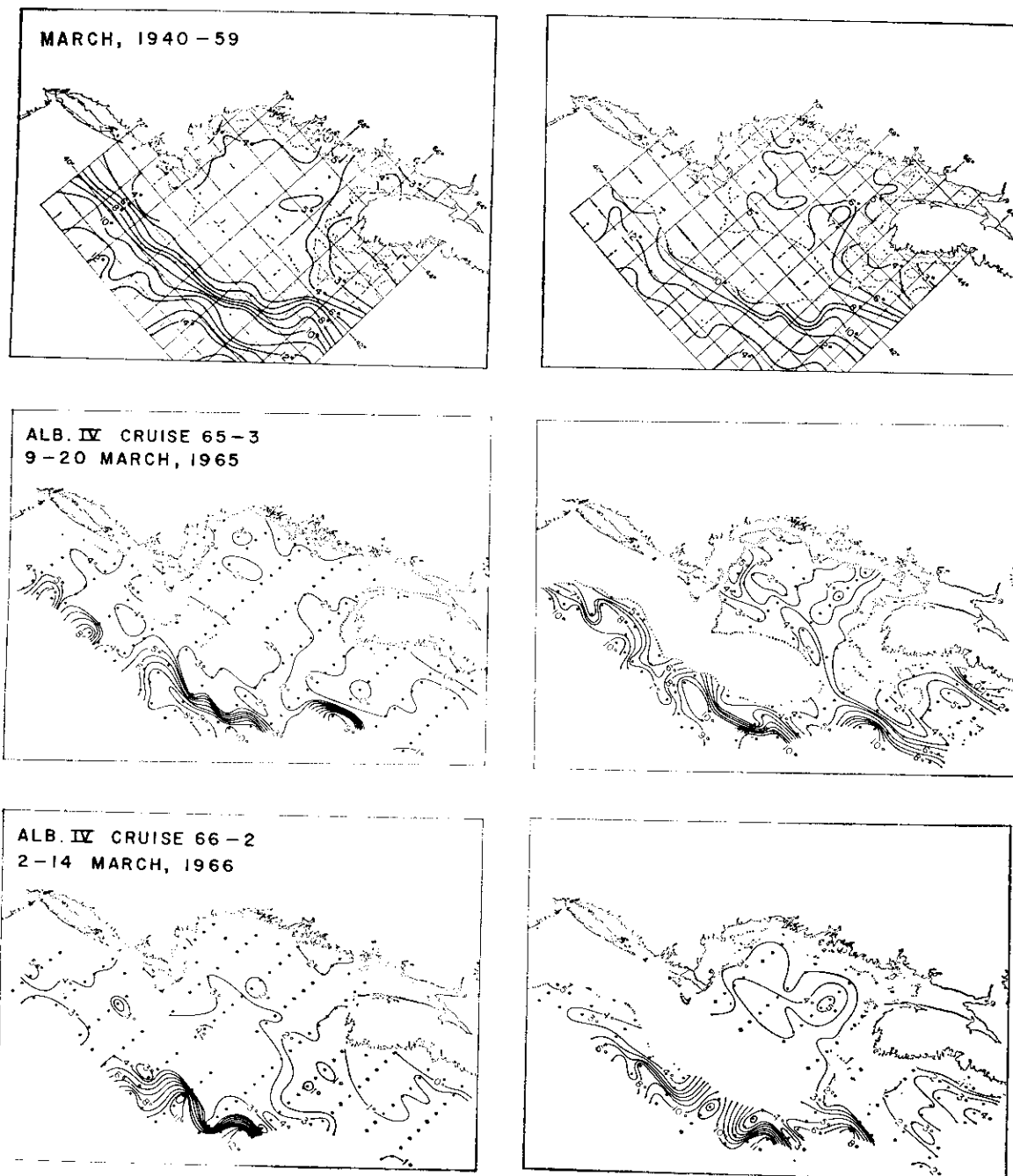
Fig. 4.   Temperature distribution at 50 and 100 m, March 1940–59, 1965, and 1966.
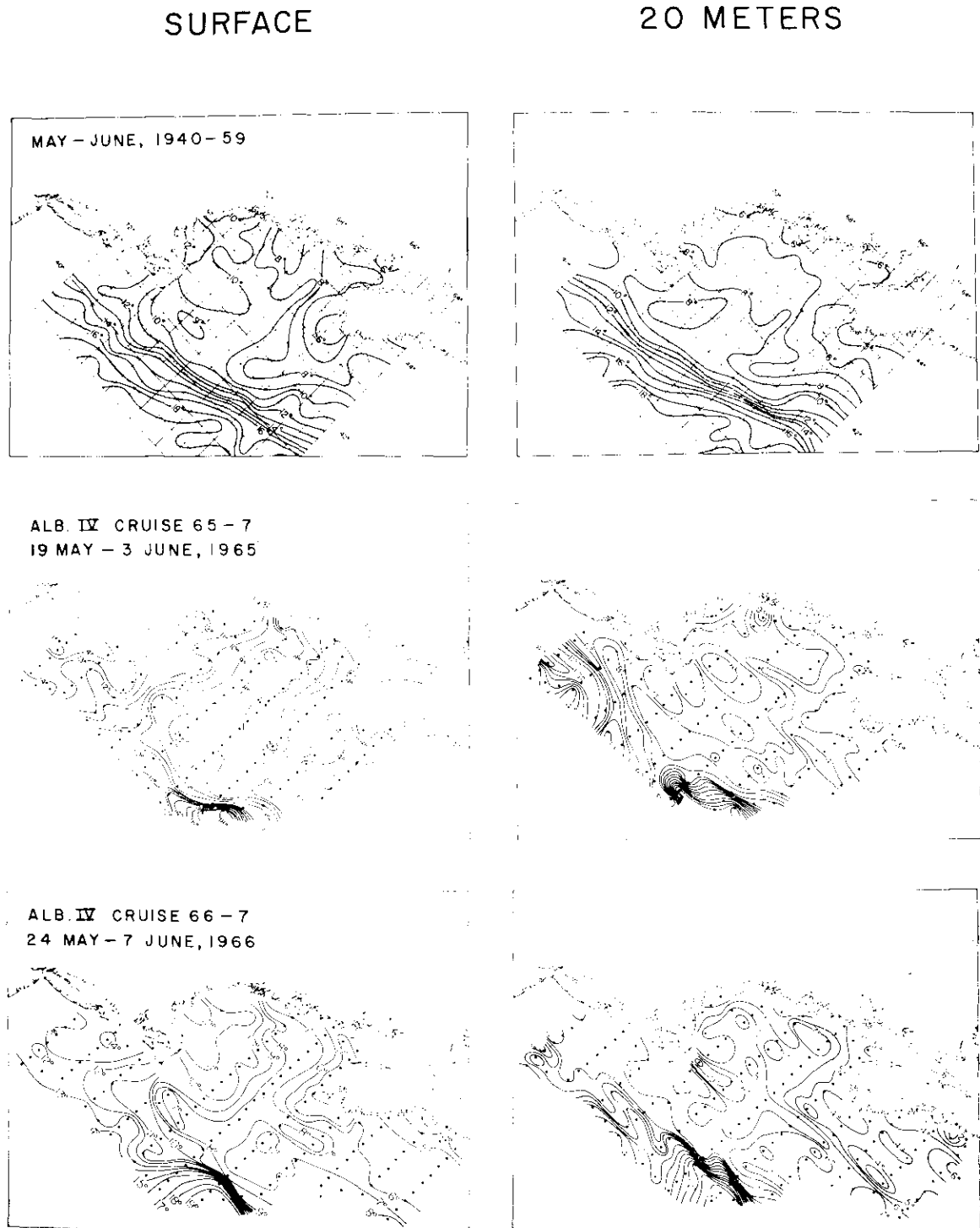
SURFACE   20 METERS

Fig. 5.   Temperature distribution at the surface and 20 m, May–June 1940–59, 1965, and 1966.

50 METERS   100 METERS

MAY – JUNE, 1940 – 59

ALB. IV CRUISE 65 – 7
19 MAY – 3 JUNE, 1965

ALB. IV CRUISE 66 – 7
24 MAY – 7 JUNE, 1966
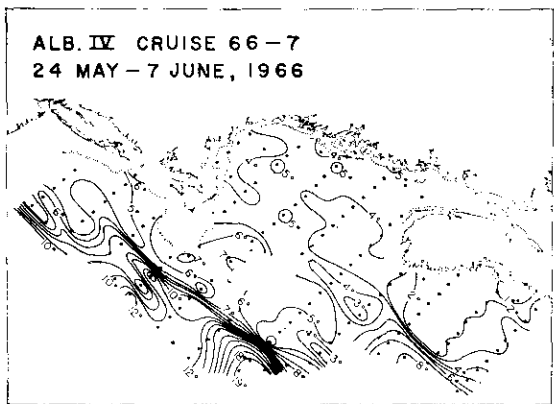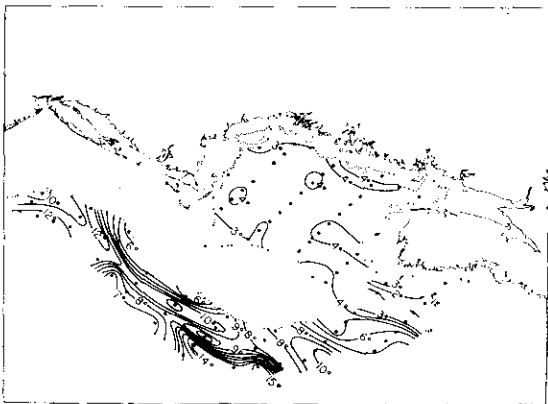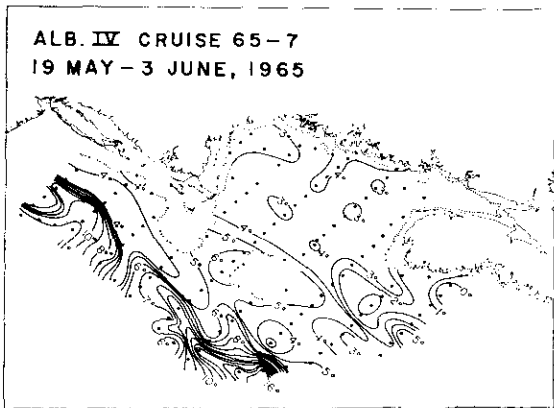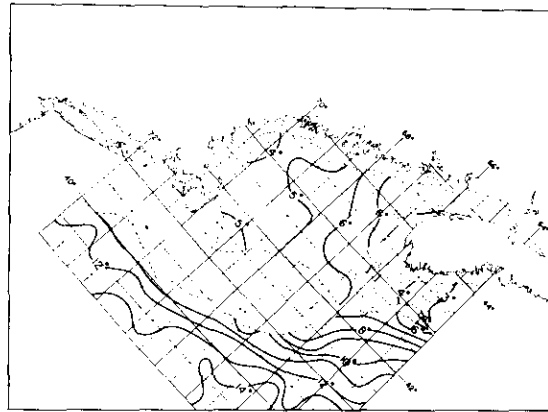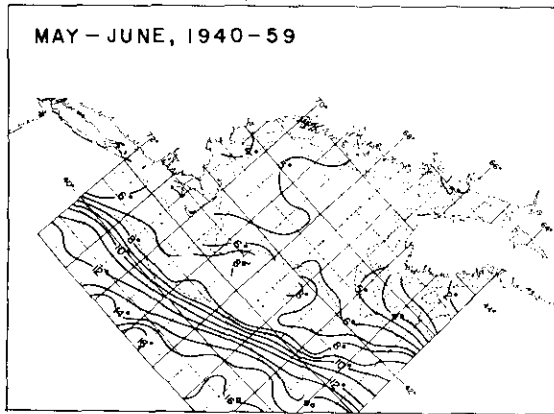
Fig. 6.   Temperature distribution at 50 and 100 m, May–June 1940-59, 1965, and 1966.
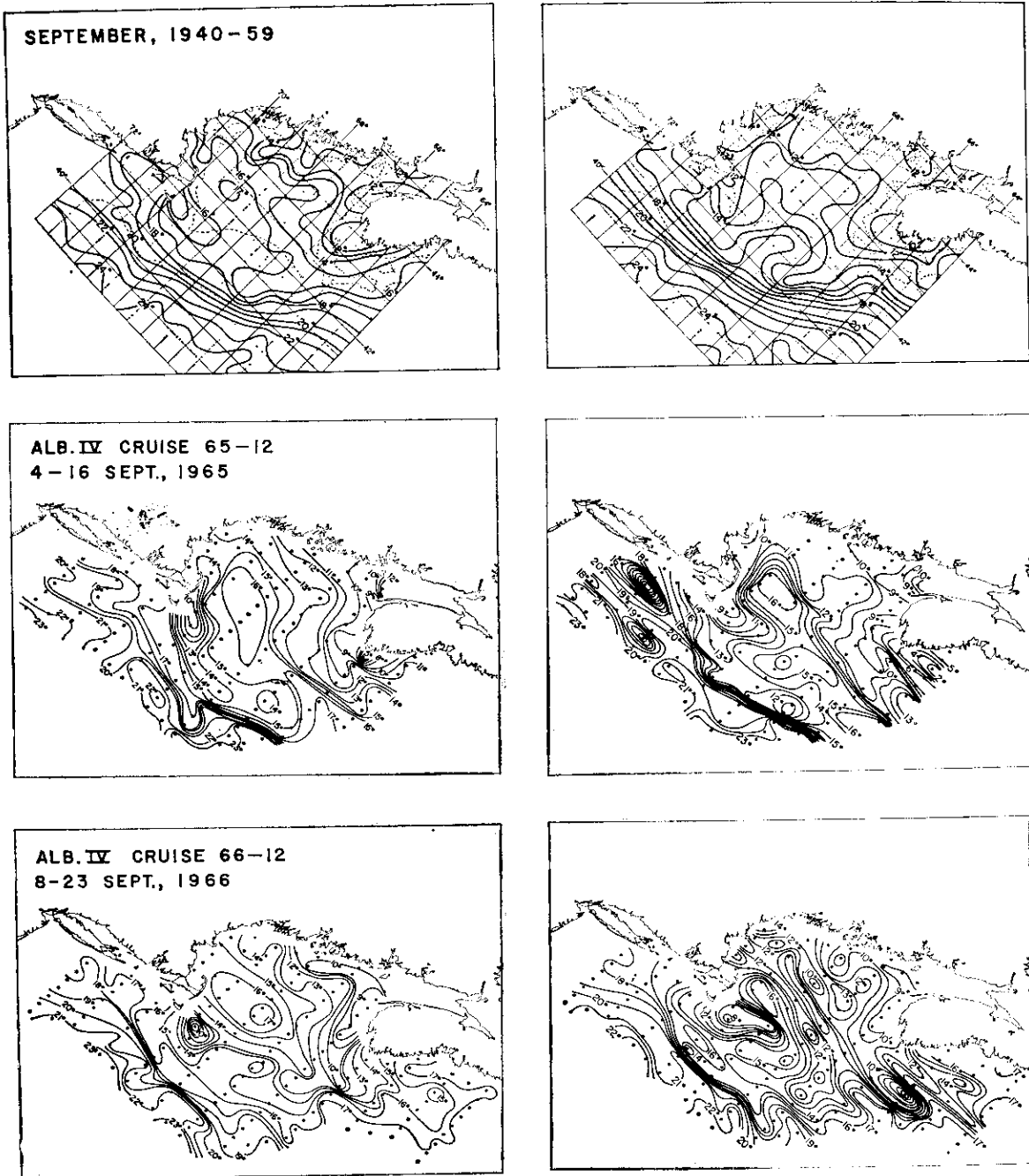
SURFACE   20 METERS

Fig. 7.   Temperature distribution at the surface and 20 m, September 1940–59, 1965, and 1966.

50 METERS

100 METERS

SEPTEMBER, 1940-59

ALB. IV CRUISE 65-12
4-16 SEPT., 1965

ALB. IV CRUISE 66-12
8-23 SEPT., 1966
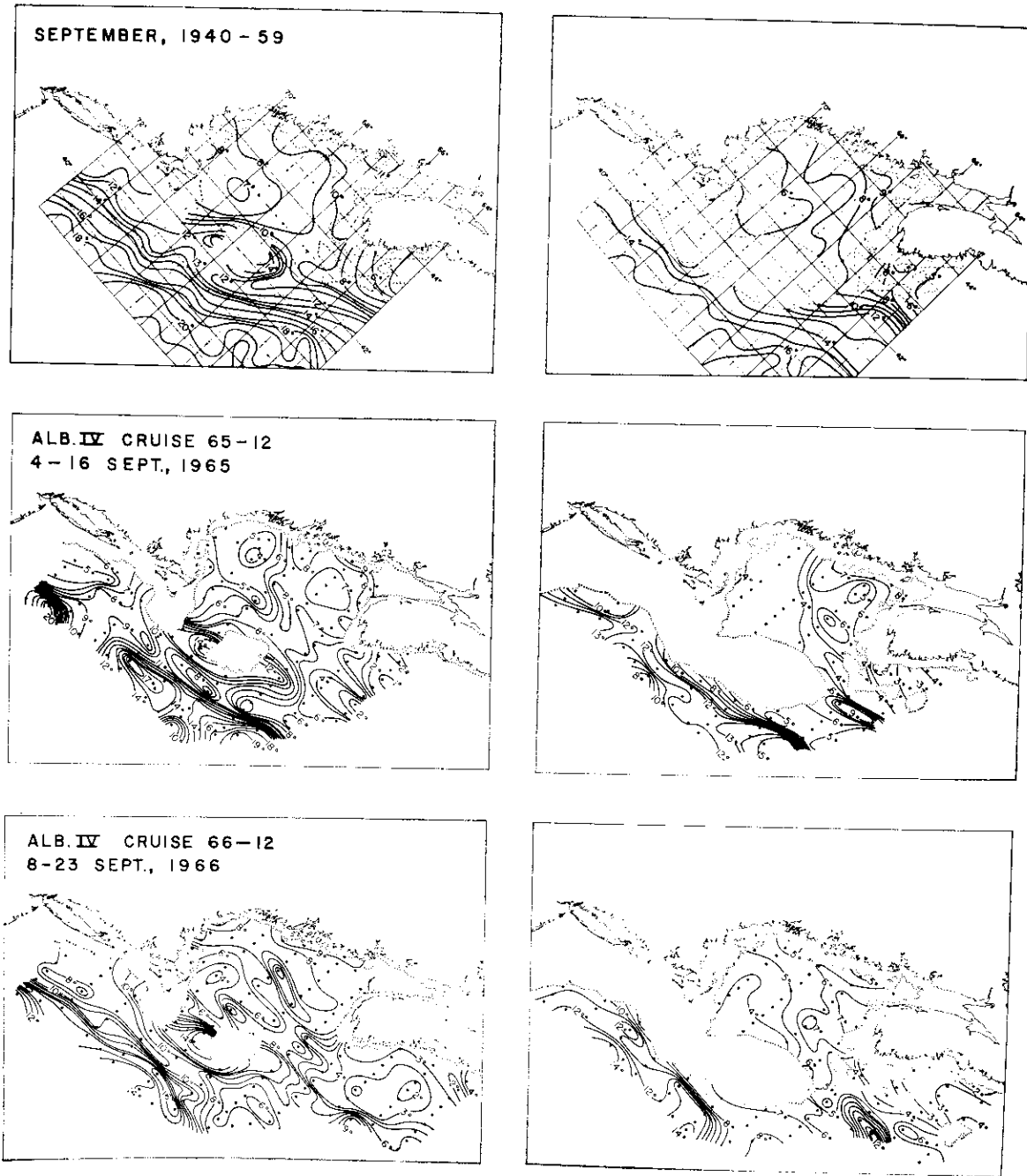
Fig. 8.   Temperature distribution at 50 and 100 m, September 1940–59, 1965, and 1966.

SURFACE

20 METERS

DECEMBER, 1940 – 59

ALB. IV CRUISE 64 – 14
3 – 18 DEC., 1964

ALB. IV CRUISE 65 – 15
8 – 22 DEC., 1965
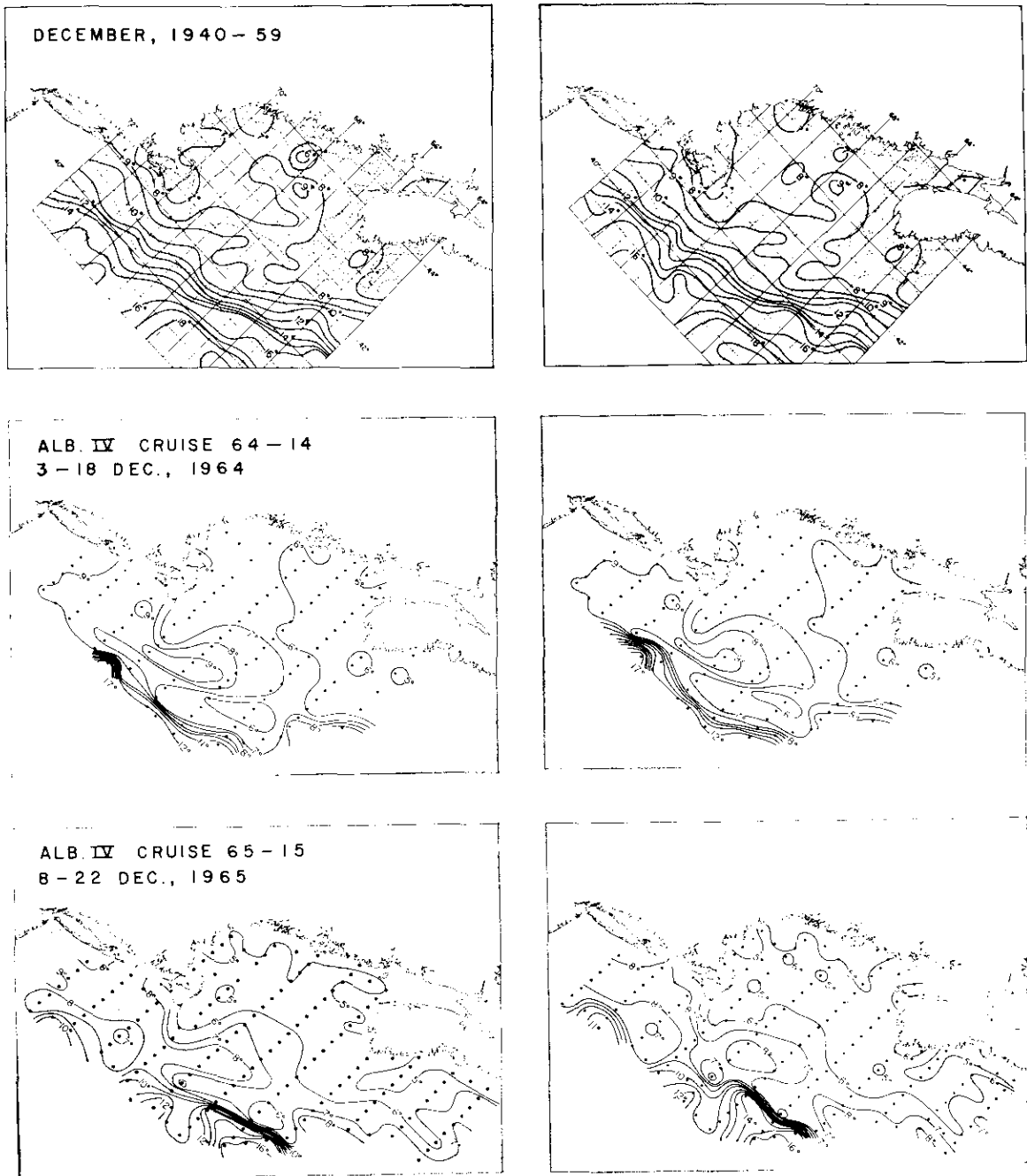
Fig. 9.   Temperature distribution at the surface and 20 m, December 1940–59, 1964, and 1965.

50 METERS

100 METERS

DECEMBER, 1940 — 59

ALB. IV CRUISE 64 — 14
3 — 18 DEC., 1964

ALB. IV CRUISE 65 — 15
8 — 22 DEC., 1965
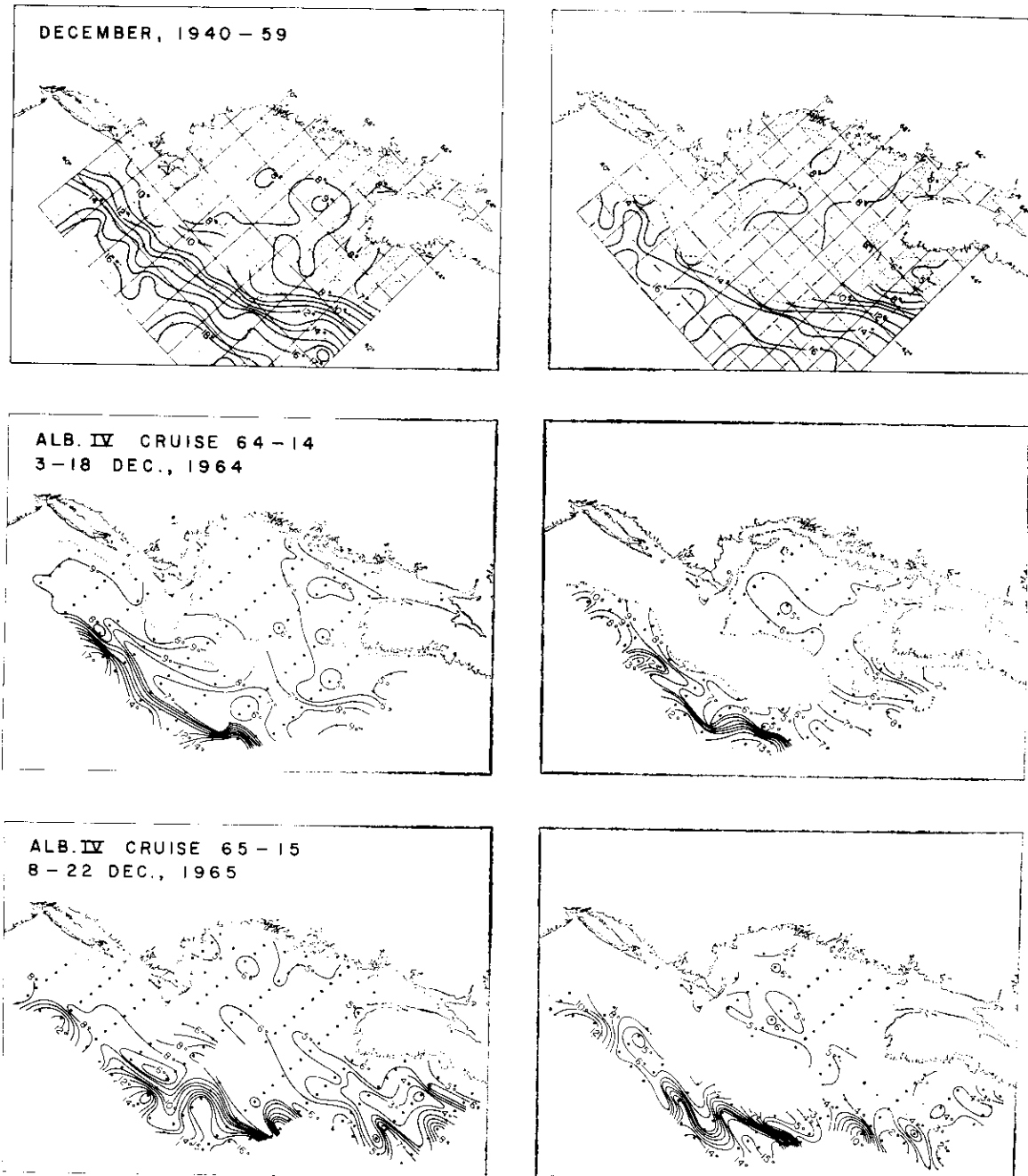
Fig. 10.   Temperature distribution at 50 and 100 m, December 1940–59, 1964, and 1965.

MARCH

1965

—— NEGATIVE
--- POSITIVE
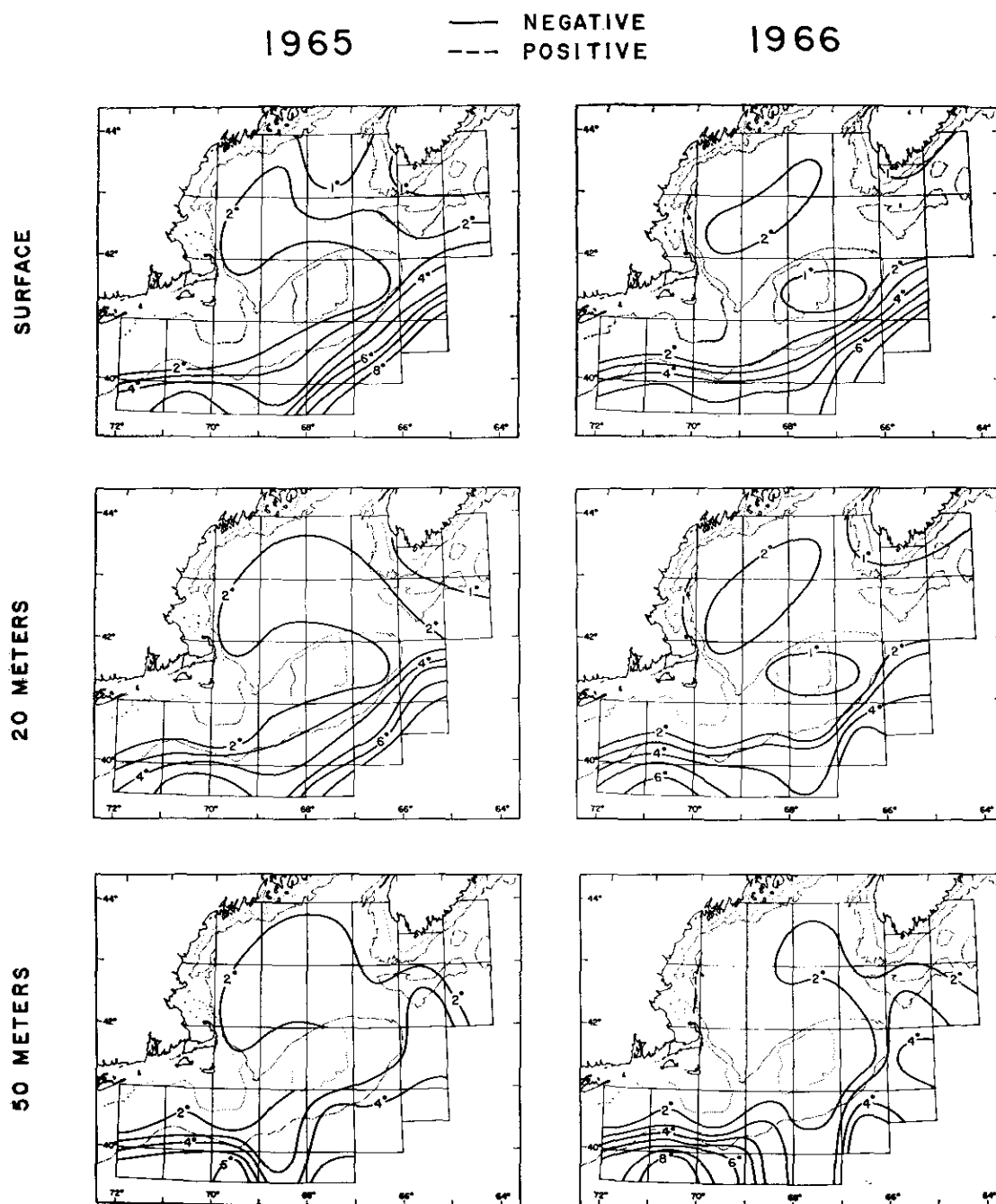
1966

Fig. 11. Temperature anomalies at the surface, 20 m, and 50 m, March 1965 and 1966.

MAY - JUNE

1965   —— NEGATIVE   1966
              --- POSITIVE
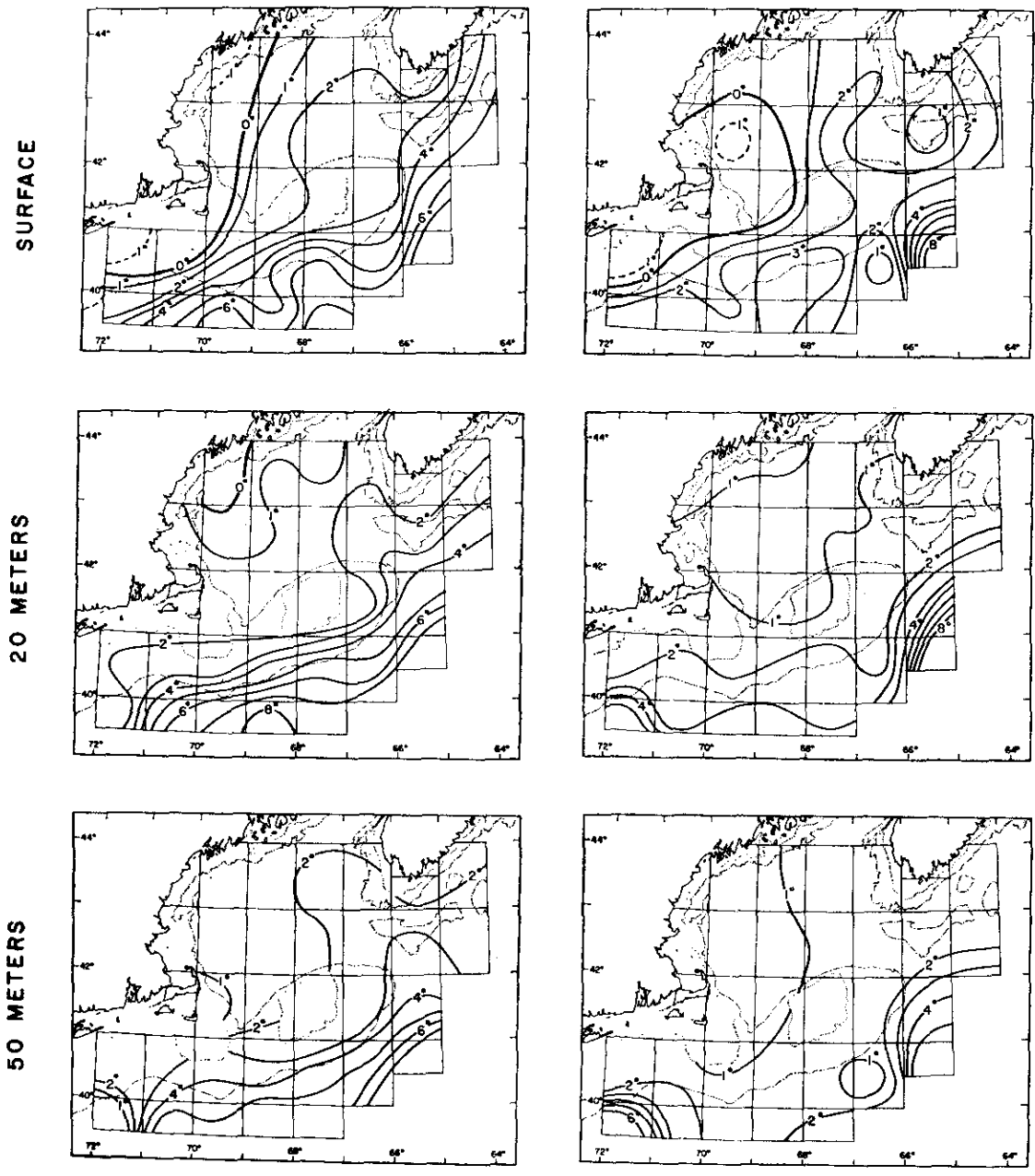
Fig. 12.   Temperature anomalies at the surface, 20 m, and 50 m, May–June 1965 and 1966.

SEPTEMBER

1965   ⎯⎯ NEGATIVE   **1966**
‑ ‑ ‑ POSITIVE

SURFACE
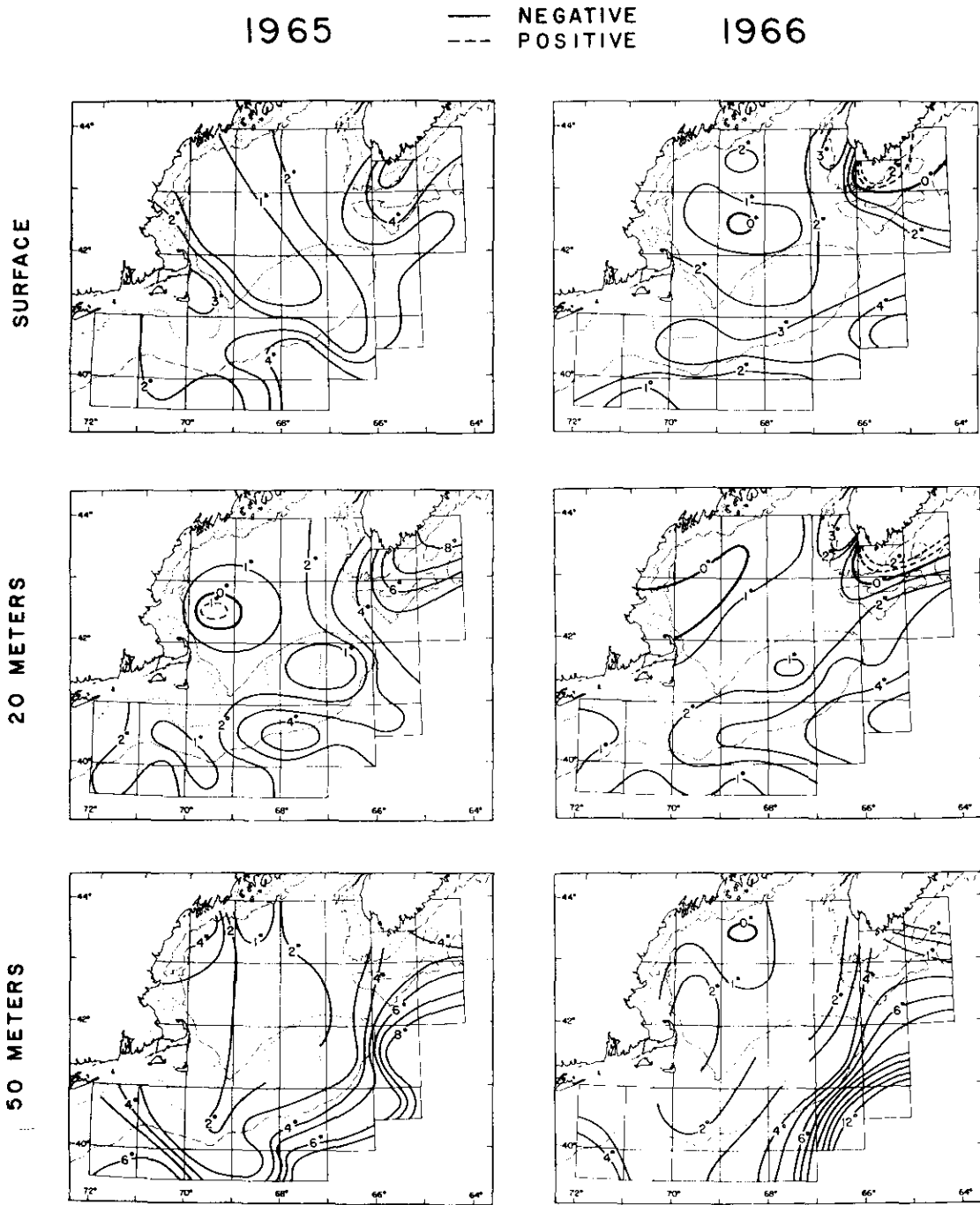
20 METERS

50 METERS

Fig. 13.   Temperature anomalies at the surface, 20 m, and 50 m, September 1965 and 1966.

DECEMBER

1964   —— NEGATIVE   **1965**
                  --- POSITIVE
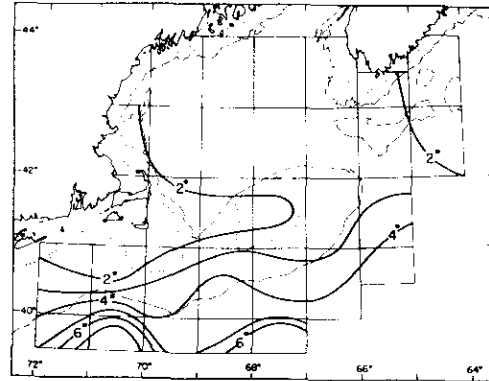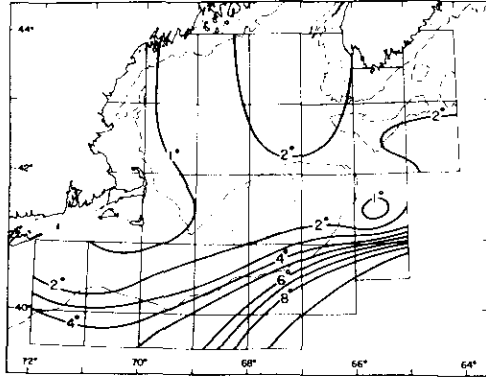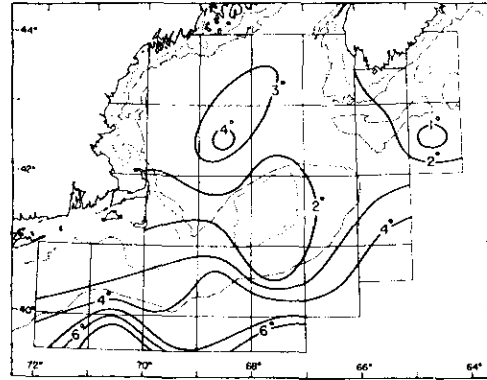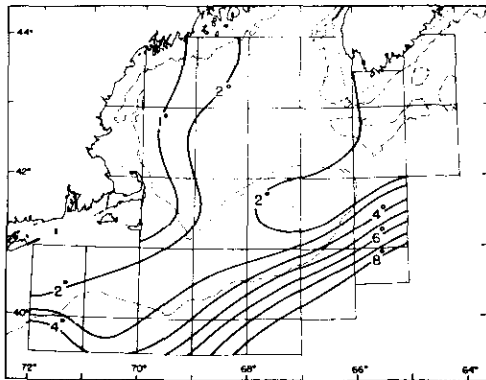
SURFACE

20 METERS

50 METERS
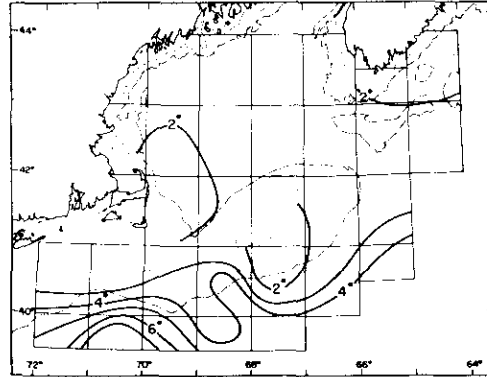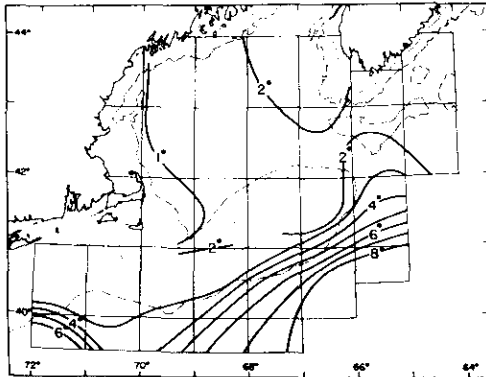
Fig. 14.   Temperature anomalies at the surface, 20 m, and 50 m, December 1964 and 1965.

In general, the greatest negative anomalies occurred south of Georges and Browns Banks. The boundary between high and low negative values roughly paralleled the 100-m isobath. The most marked exception to this situation was the occurrence of an area of relatively high negative anomalies at the 20-m level southwest of Nova Scotia in September 1965. The highest positive anomalies (>2°C) occurred in this same general area at the surface and 20-m in September 1966.

A surface-water cooling trend commencing in the middle 1950's has been observed at Atlantic coast stations from Halifax, Nova Scotia to Cape Hatteras (Lauzier 1965; Stearns 1965). This cooling trend has been most pronounced along the coast between Cape Sable and Long Island. One of the longest series of inshore temperature records are the observations made at Boothbay Harbor, Maine. These daily records, maintained since 1905, show that preceding the current cooling period, a significant warming period began about 1945 and reached a maximum during 1952–53. This warming trend was discernible in offshore data as well (Taylor, Bigelow, and Graham 1957).

In Fig. 15 are plotted temperature anomalies at the surface, 20-m, and 50-m during March 1953 (*Albatross III* Cruise 46, 19 March–2 April) relative to the March 1940–59 mean. The anomalies in all areas and at all depths were positive, but tended to be highest over shoal water areas.

SURFACE   20 METERS   50 METERS
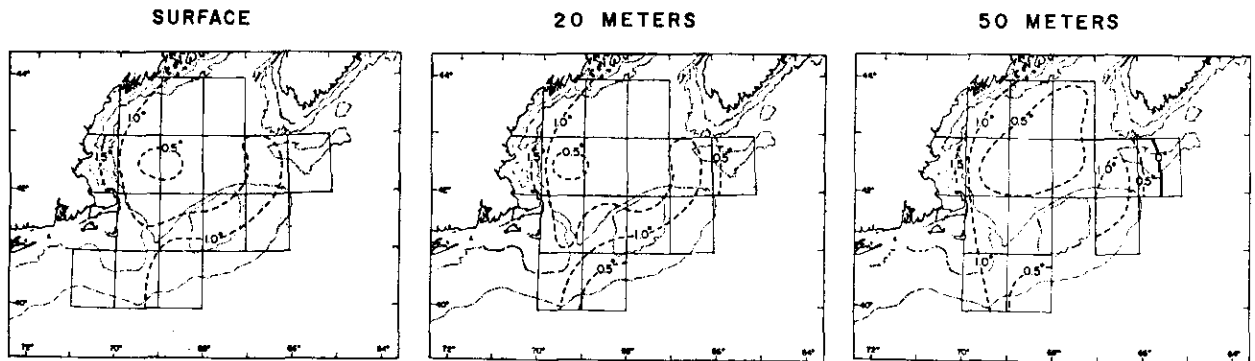
Fig. 15.   Temperature anomalies at the surface, 20 m, and 50 m, March 1953.

Seasonal surface-temperature curves based on monthly mean temperatures at Boothbay Harbor, Maine, for the period 1940–59, 1953, 1964–66 are shown in Fig. 16. Temperature data for the period 1940–55 are from Bumpus (1957). Subsequent data were obtained from the files at the Woods Hole Oceanographic Institution. With the exception of January and February 1964 and May 1965, all monthly mean temperatures in the 1960's were lower than the 1940–59 means. The seasonal magnitude of the negative anomalies at Boothbay Harbor and of the anomalies observed in the immediate offshore region during the 1960 survey cruises were similar. For example, the May–June survey data showed a slight positive anomaly for the quadrangle immediately adjacent to Boothbay Harbor in 1965 and May was the only month in 1965 in which the Boothbay monthly mean temperature was not lower than the 1940–59 mean. During most months in the 1960's the negative anomalies in deep-water offshore areas were greater than the negative anomalies at Boothbay Harbor.

The 1953 monthly mean temperatures at Boothbay Harbor were appreciably higher than the 1940–59 means. In March 1953 the positive anomaly at Boothbay Harbor was greater than that in any offshore area. A comparison of monthly mean temperatures at Boothbay Harbor from 1906 to 1927 and 1928 to 1949 by Taylor *et al* (1957) showed significant increases in winter temperatures (November–February) but slight decreases in summer temperatures (July–September) during the latter period. In 1953, although the anomalies were greater in the winter, the anomalies were positive for all months. The similarity of the temperature trends at Boothbay Harbor and offshore areas in the 1960's indicate that at least during the peak of the warming period temperatures were higher during all months in the majority of offshore areas as well.
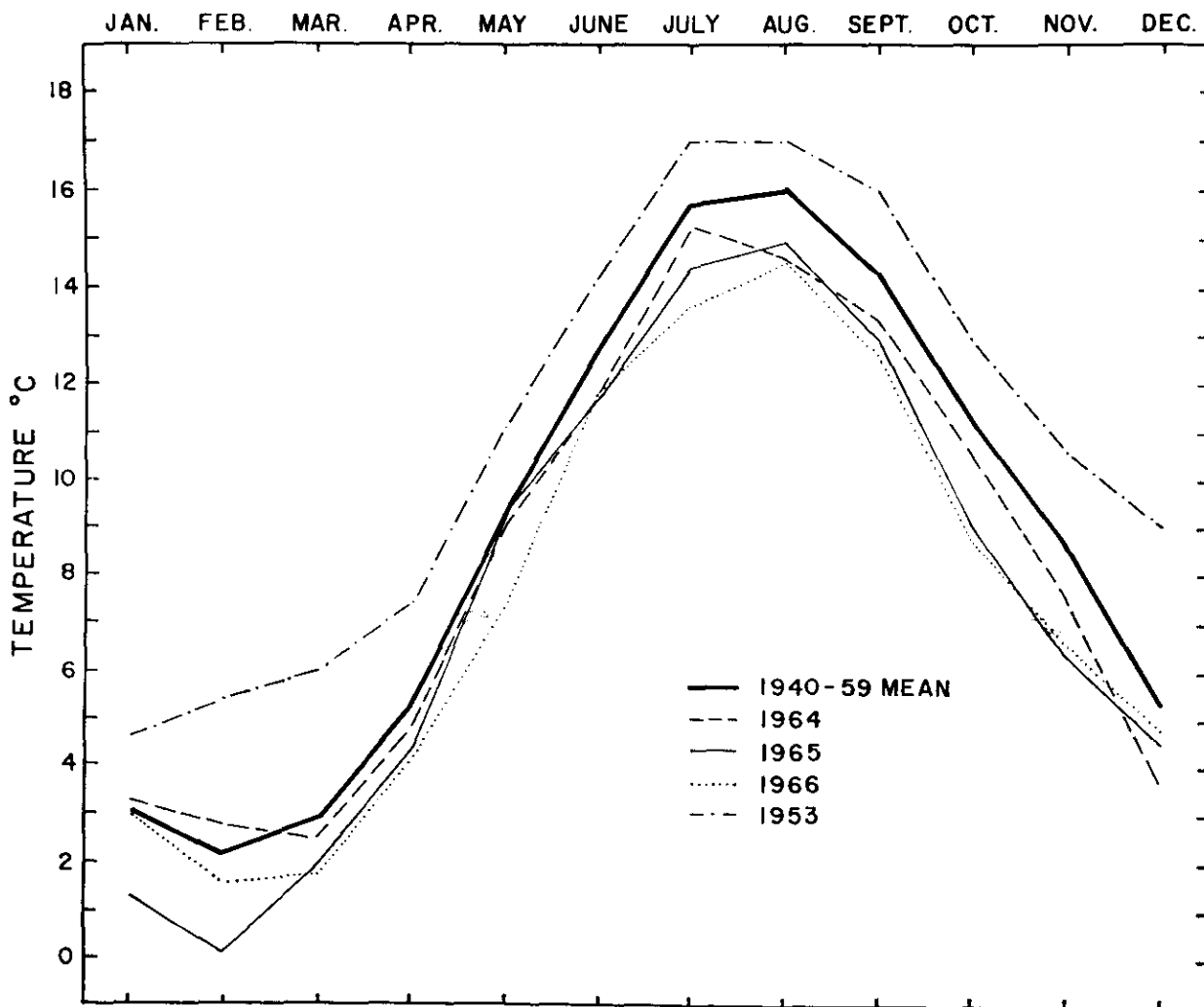
Fig. 16.   Seasonal temperature curves, Boothbay Harbor, Maine, 1940–59, 1953, 1964, 1965, and 1966.

Discussion

Earlier publications give clear evidence of cyclic change in ocean temperatures off New England and the Maritime Provinces. A comparison of offshore temperatures for 1953–54 and 1912–26 made by Taylor et al (1957) indicated an increase of from 0.5° to 2.0°C throughout the water column since 1912–26 in most parts of the Gulf of Maine. Lauzier (1965) showed that trends in bottom temperature on the Scotian Shelf and in the Bay of Fundy were similar to the surface temperature trends at St. Andrews, New Brunswick and Boothbay Harbor, Maine, although the rate of cooling during the late 1950's and early 1960's was more pronounced within the bottom water.

The data from the 1964–66 survey cruise further document the fact that similar temperature fluctuations occurred offshore and within water masses as well as at the surface. Although temperature anomalies tended to be greater in the deeper water along the edge of the Continental Shelf, the trends in inshore temperature resembled those in most offshore areas. Clearly we may now place more reliance on the use of inshore temperature observations as an index to offshore conditions.

Taylor et al (1957) concluded that the composition of the fish and invertebrate fauna in the Gulf of Maine had undergone no obvious general change as a consequence of the warming trend during the early 1950's. To my knowledge,

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there is also no evidence of a conspicuous change in faunal composition during the current cooling period. These temperature fluctuations do, nevertheless have significant effects.

For example, the timing of haddock spawning appears to be regulated in part by temperature. Fish egg and larval surveys conducted during 1953, 1955, and 1956 showed that the main spawning on Georges Bank was in March and April at prevailing water temperatures of 4° to 7°C (Colton and Temple, 1961). Spawning began at about the time of the start of vernal warming. In Table I are tabulated the March and April mean temperatures at Boothbay Harbor during 1953, 1955, and 1956 and the March/April ratio of egg abundance on Georges Bank during these same years. As March and April mean temperatures decreased during succeeding years the time of maximum spawning on Georges Bank was delayed correspondingly as indicated by the decrease in the March/April egg abundance ratio.

TABLE 1. March and April mean temperatures at Boothbay Harbor and the March/April ratio of haddock egg abundance on Georges Bank, 1953, 1955, and 1956.

Year	Temperature, °C		March/April egg abundance ratio
	March	April	
1953	6.1	7.5	7.3
1955	4.2	6.9	2.7
1956	3.2	5.3	1.3

An unpublished analysis of the distribution and abundance of *Calanus finmarchicus* based on collections made during the 1953 and 1955 egg and larval surveys revealed a difference also in the timing of the vernal augmentation of the stock of *Calanus* during these 2 years. The developmental stages collected in the cruises of 1953 indicate that the main spawning of the overwintering stock occurred in February and that the progeny of that spawning reached maturity in late May. In 1955 the overwintering stock did not spawn until March and the second generation did not reach maturity until late June. It is highly probable that spawning time and availability of food organisms of suitable size influence the survival rate of larval and juvenile fish.

Lauzier (1965) suggested that variations in the degree of upwelling due to fluctuations in the intensity of westerly winds could effect short-term changes in annual temperatures along the Canadian Atlantic coast. The nature of the distribution of temperature and negative anomalies observed during the survey cruises of 1964–66 however, give evidence that temperature trends recorded at most Atlantic coast stations are not caused by variations in local conditions such as upwelling and river runoff, but are due in large measure to changes in the relative position and degree of mixing of coastal and oceanic water masses. An example is the fact that the gradient of negative anomalies which occurred off the edge of the Continental Shelf was least during September, a period in which indications of intrusions of Slope and Gulf Stream water onto the southern edge of Georges Bank have been most frequent (Colton, 1961). It would appear also that the change in sign of the anomalies off the southwest coast of Nova Scotia in September 1965 (negative) and 1966 (positive) resulted from a variation in the degree of influx of Nova Scotian current water into this area during these years.

It has been postulated by Iselin (1940) and Stommel (1958) that the degree of mixing of coastal and oceanic water and the resulting warming or cooling of North Atlantic coastal water are related to fluctuations in the strength of the North Atlantic gyre. Bjerknes (1963) and Rodewald (1963) have related these changes in oceanic circulation to variations in atmospheric circulation due to changes in the relative strengths of the Bermuda-Azores High and the Icelandic Low. The cooling trends have been linked to a constriction and warming trends to an expansion of the warm oceanic water mass.

Summary

Although long-term mean temperatures were used to interpret conditions in a region characterized by short-term temperature fluctuations, the method appears to provide a measure of major temperature conditions to which specific cruise data may be compared.

The 20-year mean and specific-year seasonal and areal temperature trends were similar; minimum temperatures occurred in March and inshore and maximum temperatures in September and offshore.

During all seasons and at most locations and depths the 1964–66 temperatures were appreciably lower than the 1940–59 mean values. The magnitude of the negative anomalies was greatest in areas off the edge of the Continental Shelf. Temperatures in March 1953 were higher than the 1940–59 mean values.

The trends in offshore temperatures at the surface and within water masses paralleled trends in surface temperatures at Boothbay Harbor, Maine. These correlations justify the use of inshore temperature observations for indexing offshore conditions.

A delay in the timing of maximum haddock spawning on Georges Bank in 1955 and 1956 as compared with 1953, and of the vernal augmentation of the stock of *Calanus finmarchicus* in the Gulf of Maine during 1955 as compared with 1953 was attributed to decreasing temperatures.

The nature of the distribution of temperature and of negative anomalies observed in 1964–66 suggest that temperature trends recorded at most Atlantic coast stations depend in large measure on the relative position and degree of mixing of coastal and oceanic water masses.

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Thermostability of Isolated Muscle in Determining the Taxonomic Relationship of the *marinus-* and *mentella-*Types of the Redfish (*Sebastes*)

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Abstract

The thermostability of isolated muscles was studied in more than 1,000 specimens of the *marinus-* and *mentella-*types of redfish from the Northwest Atlantic Ocean. The two types were found to differ with the *mentella-*type having the higher level of thermostability.

Since the thermostability of isolated muscles has been established as a species specific criterion for poikilothermal animals, it has been possible to determine the taxonomic range of the differences between the *marinus-* and *mentella-*types of redfish.

Introduction

The problem of the taxonomic relationship of the *marinus-* and *mentella-* types of redfish from the North Atlantic Ocean has remained unresolved to the present time. For example, Travin (1951), using morphological characteristics, described *mentella* as an independent species, *Sebastes mentella* Travin, whereas Andriyashev (1954) described it as a subspecies, *Sebastes marinus* infsp. *mentella* Travin. Other researchers prefer to speak of different subspecies and even "types" of redfish (e.g. Kotthaus, 1961).

The essential differences between the *marinus-* and *mentella-*types of redfish can be established not only from their morphological characteristics, but also from biochemical and immunological studies (Schaeffer, 1961; O'Rourke, 1961). Hence, it seems expedient to look for divergences in North Atlantic redfish in a number of other features which are of diagnostic value in the systematics of species. This report deals with the results of an analysis of the differentiation of the *marinus-* and *mentella-*types in accordance with the degree of thermostability of isolated muscle tissue, which has been established as a species specific criterion for the poikilothermal animals (Ushakov, 1959, 1964).

Material and Methods

This study was made on R/V *Sevastopol* in September–October 1964 and repeated in August 1965, in the Northwest Atlantic Ocean. Figure 1 shows the sampling locations. The experiments consisted of determining and comparing, according to Ushakov's (1959) method, the thermostability of isolated muscles (m. geniohyoideus) of the redfish caught in trawls.

The muscle specimens were attached to thin glass rods and inserted into Dewar vessels, which were one-third filled with Ringer's solution heated within ± 0.2°C precision. From time to time the muscle specimens were removed for several seconds and tested for the excitability of tissues to inducted electric current from a transistorized stimulator with a maximum voltage of 130 v (Arzumanov and Kusakina, 1960). The length of time which the tissue retained excitability, from the moment it was immersed in the heated solution to the complete absence of contraction even in the filaments which were the most resistant to the action of the heat, served as the measure of thermostability. Research was carried out at experimental temperatures of 24°, 26°, 28°, and 30°C and at one experimental temperature of 28°C which provided an opportunity to analyze the inter- and intra-population variability of the feature. A total of 1,023 experiments to determine the thermostability of isolated muscles of redfish were completed.

Results

Results of determination of thermostability of muscles of redfish from the Iceland area at several experimental temperatures are shown in Table 1 and Fig. 2. Figure 2 shows that muscle tissue of the *mentella-*type redfish is approximately 2°C more stable thermally than muscle tissue of the
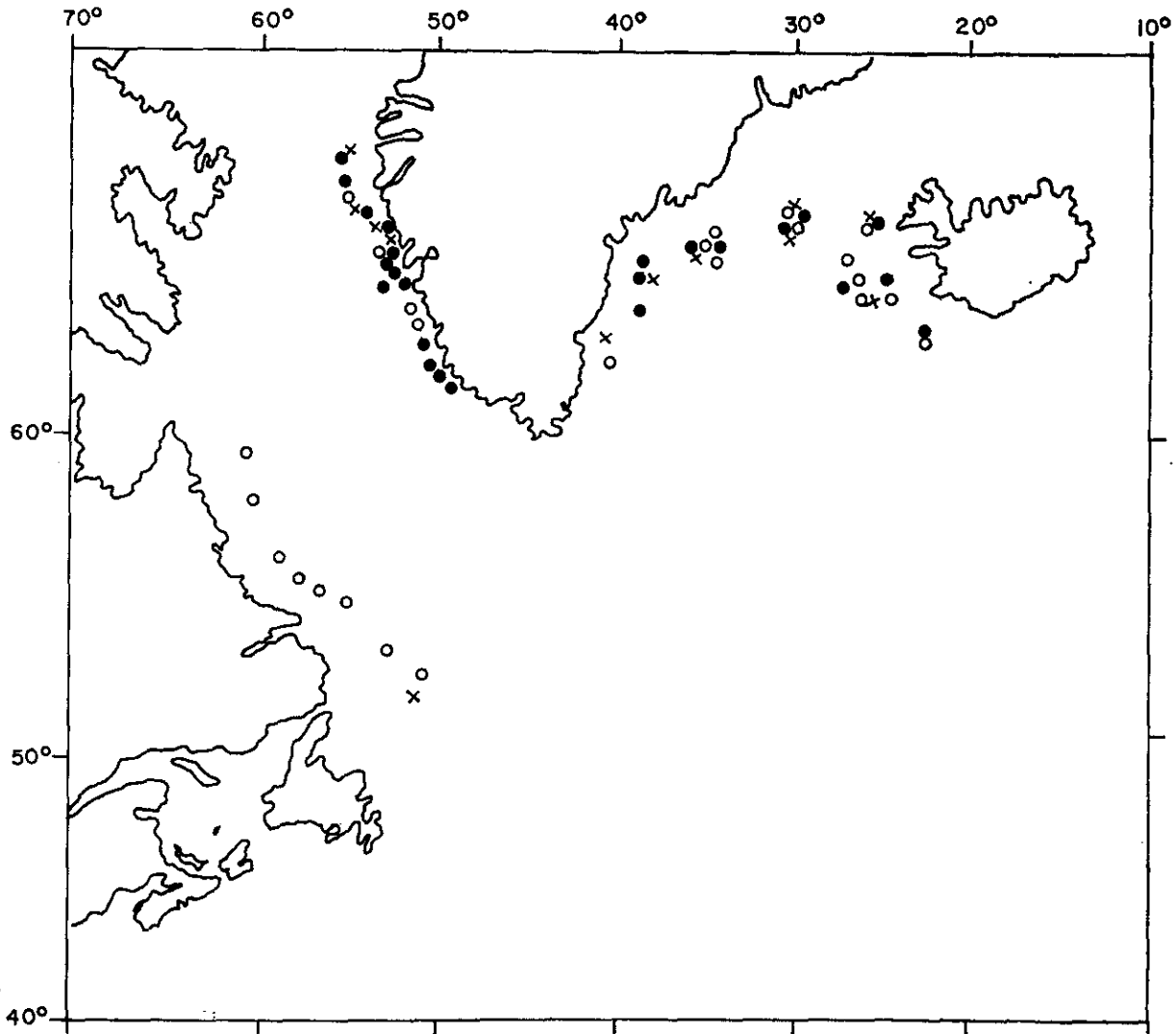

Fig. 1.   Location of catches of redfish for cytophysiological experiments.   O = *mentella*-type;   ● = *marinus*-type;
X = "intermediary" redfish.

TABLE 1.   Retention time of excitability (in minutes) of isolated muscle tissue of redfishes from the Northwest Atlantic at various temperatures (n = number of tests; M $\pm$ m = the arithmetic mean and its error in the second power; P = probability of difference unreliability).

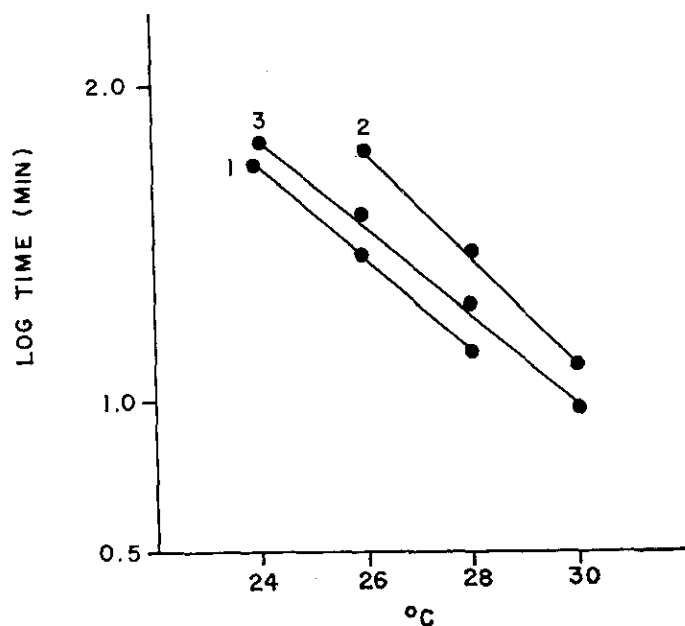| Type of redfish	24°C				26°C				28°C				30°C			
	n	M $\pm$ m		P	n	M $\pm$ m		P	n	M $\pm$ m		P	n	M $\pm$ m		P
mentella	—	—			17	59.9 $\pm$ 3.4			20	28.3 $\pm$ 2.1			7	11.9 $\pm$ 1.6		
				—				0.001				0.01				0.42
intermediary	18	61.1 $\pm$ 3.8			10	39.2 $\pm$ 1.4			17	21.6 $\pm$ 0.9			13	9.5 $\pm$ 1.6		
				0.60				0.01				0.001				
marinus	9	55.4 $\pm$ 7.6			15	28.8 $\pm$ 2.7			25	15.4 $\pm$ 0.9			—	—		—

Fig. 2. Thermostability of isolated muscles of redfish from the North-
west Atlantic. 1 = *marinus*-type; 2 = *mentella*-type;
3 = "intermediary" redfish.

TABLE 2. Thermostability (in minutes) of the isolated muscles of redfishes at various locations and times in the North-
west Atlantic, and tested at 28°C (n = number of tests; M $\pm$ m = the arithmetic mean and its error in the
second power; P = probability of difference unreliability).

Type of redfish	Sampling location and date	n	M $\pm$ m	P
marinus	Iceland, August, 1965	109	13.6 $\pm$ 0.69	
	East Greenland, October, 1964	71	14.25 $\pm$ 0.78	—
	West Greenland, September, 1964; August, 1965	166	20.05 $\pm$ 0.58	0.001
				0.001
mentella	Iceland, October, 1964; August, 1965	95	27.8 $\pm$ 1.07	—
	East Greenland, September, 1964; August, 1965	82	27.9 $\pm$ 1.13	—
	West Greenland, September, 1964; August, 1965	80	28.4 $\pm$ 1.09	—
	Labrador, August, 1965	142	28.5 $\pm$ 0.78	
				0.001
intermediary	Labrador, Greenland, Iceland; September–October, 1964; August, 1965	189	22.7 $\pm$ 0.75	

marinus-type. The difference is statistically significant (Table 1) and is in agreement with the differentiation which can usually be observed when the thermostability of cells of species of fish and other poikilothermal animals which are closely related taxonomically is compared (Kusakina, 1959; Altukhov, 1962a, b, 1967: Altukhov and Glushankova, 1966; Ushakov, 1964; Kaufman, 1965).

However, in nearly all the areas inhabited by redfish in the Northwest Atlantic, considerable quantities of fish are caught which have morphological characteristics of both the *marinus*- and *mentella*-types and are probably their hybrids (Kotthaus, 1961b; Travin and Pechenik, 1962). In confirmity with these data, the results of comparison of the thermostability of muscle tissue, both in the initial types and in redfish with mixed characteristics, i.e., the "intermediary" level of thermostability (Fig. 2). Comparison does not show any statistical difference between the "intermediary" type and the *marinus*-type at 24°C or between the "intermediary" type and *mentella*-type at 30°C (Table 1).

The results of determinations of the thermostability of the isolated muscle tissue of redfish at an experimental temperature of 28°C are given in Table 2, and show that all samples of the *mentella*-type are characterized by a pattern which coincides with the average. The amplitude of variability was also the same. This indicates the lack of *inter-population* variability of the given feature and, hence, the homogeneity of the population of the *mentella*-type redfish in the areas studied. A similar picture is obtained for Icelandic and East Greenland populations of the *marinus*-type which, being cytophysiologically identical, differ tangibly from the *mentella*-type in muscle thermostability. At the same time, the *marinus*-type redfish from West Greenland is characterized by a specific level of muscle thermostability which differs both from the Icelandic-East Greenland *marinus*-type and from the *mentella*-type and occupies an intermediary position.

Figure 3 shows the distribution of the thermostability of muscles in the *marinus*, *mentella*, and "intermediary" redfish. (The problem of the right-hand assymetry of curves of this kind is considered by Ushakov and Chernokozheva (1963).) The figure shows that each of the forms of redfish studied has its own peculiar distribution. The *marinus*- and *mentella*-types are characterized by unimodal curves No. 1 and 2 respectively in

Fig. 3, whereas the "intermediary" redfish has a bimodal curve. This means that, in the waters of Iceland, Greenland, and Labrador, where natural hybridization takes place among redfish, there is either a splitting of the feature studied into F_2, or the "intermediary" fish appear as a result of reverse crossings between the partially fertile F_1 hybrids and the initial forms.

The curve of the distribution of the thermostability of muscles of the *marinus*- type from West Greenland waters (Fig. 3) is of special interest. It is unimodal and occupies an intermediary position between the corresponding curves for the *mentella*- and *marinus*-types from Iceland and East Greenland. Table 2 shows that the average lifetime of the muscles of the West Greenland *marinus*-type redfish (20.05 ± 0.58 min) differs from that obtained for the *marinus*-type from Iceland (13.6 ± 0.69 min) and from East Greenland (14.25 ± 0.78 min), and is much closer to the level of thermostability of the muscles of the "intermediary" redfish (22.7 ± 0.75 min).

Thus, the experimental material reveals the existence in the sampled area of Northwest Atlantic of four cytophysiologically different populations of redfish: *mentella*, "intermediary", and *marinus*, represented, on the one hand, by the West Greenland, and, on the other—by Icelandic and East Greenland redfish. The hybrid nature of the "intermediary" type is not doubted. As for the West Greenland *marinus*-type, the results of cytophysiological analysis suggest that it is a hybrid. Apparently, this type of redfish is a *marinus*-type in appearance only, but, genotypically, it is a first generation hybrid of homozygous fishes of the *marinus*- and *mentella*-types.

Biological data obtained by Zakharov (1962) which show the juvenile nature of a considerable part of the population of the *marinus*-type in the waters of West Greenland, also support such an assumption. The author, in the course of the last 6–7 years, has analyzed about 5,000 adult females and concluded that from the condition of their gonads, they were no different from the immature *marinus*-type from the Barents Sea.

According to the cytophysiological evidence presented above, the *marinus*-and *mentella*-types are quite different. Hence, the possibility cannot be excluded that the juvenile nature of the population of females of the West Greenland *marinus*-type is the consequence of their hybrid origin from initial types, between which there exists a certain
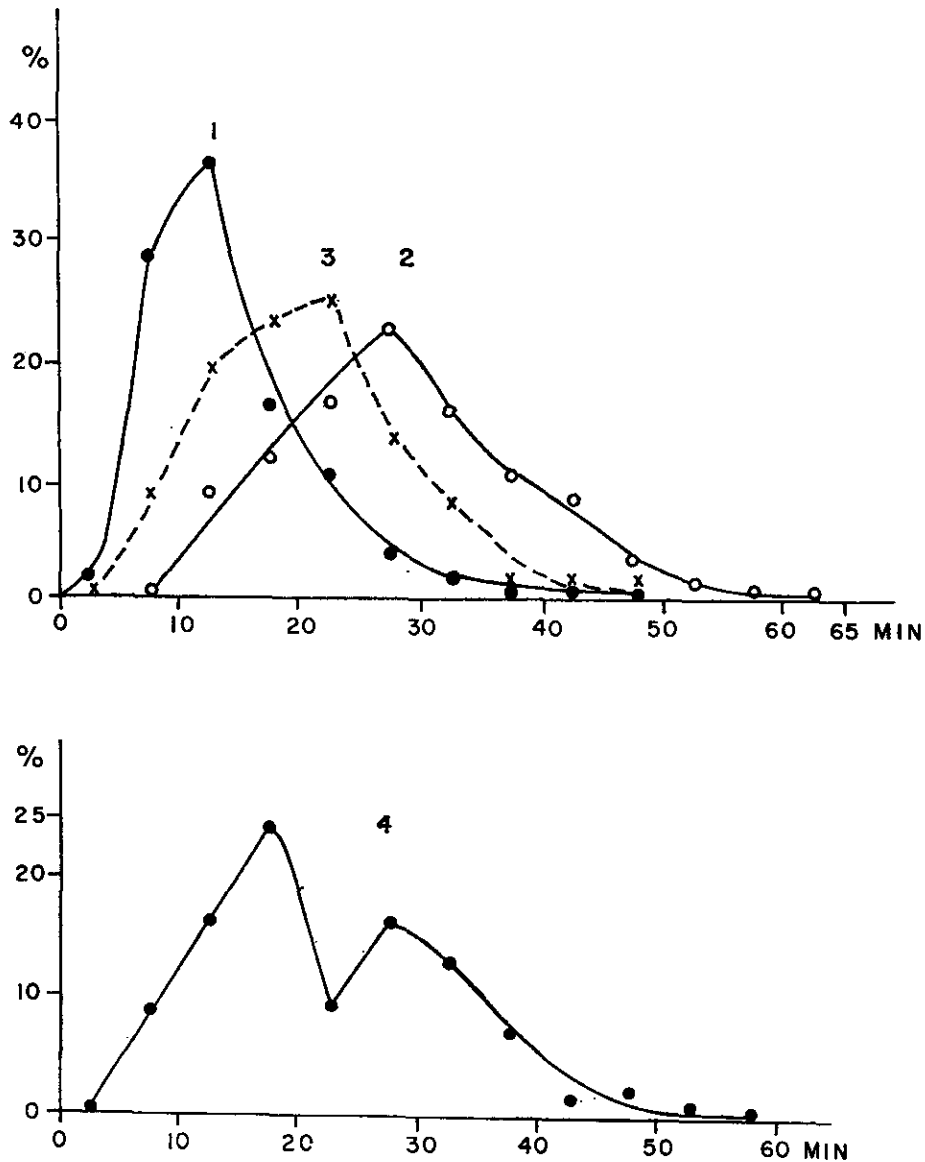
Fig. 3.   Curves giving the distribution of thermostability of isolated muscle tissue
          of the types of redfish studied.   1 = *marinus*-type from Iceland and East
          Greenland;   2 = *mentella*-type;   3 = *marinus*-type from West Greenland;
                        4 = "intermediary" redfish.

degree of physiological isolation. This leads to the underdevelopment of the reproductive system of a considerable proportion of the F_1 hybrids which cannot be identified externally as different from the *marinus*-type. This violation probably occurs mainly in the females and, to a lesser degree, in the males, if we assume that they are homogamous.

These data suggest that the so-called intermediary redfish appear as the result of initial types of redfish mating with the sexually mature males and, partly, with the hybrid females, of the F_1 generation. The pairing and spawning take place in the area of Iceland, and redfish is concentrated in the West Greenland through transport of the fry by the Irminger, East Greenland, and West

Greenland currents (Tåning, 1949; Templeman, 1959; Zakharov, 1962). It seems highly probable that the F_1 hybrids, because of their hybrid vigor are especially abundant in West Greenland waters. It is not difficult to imagine the effect of natural selection (Templeman, 1959) tells of the discovery of dead fry and even adult redfish in the cold waters in West Greenland), when the temperature conditions for the drift of fry in the warm Irminger Current (4° to 6°C) are compared with that in the fjords where the fry settle. In the latter case the water temperature goes down to 2°C and sometimes to 0°C and even lower (Kulerich, 1943; Tåning, 1949; Dunbar, 1951; Templeman, 1959; Herman, 1963), and is clearly outside the tolerance limits for redfish.

The above may be summarized as follows. Based on the results of cytophysiological analysis and on available data on the biological characteristics of the population of *marinus* redfish from West Greenland, it is suggested that this population is, to a considerable degree, represented by sterile hybrids of the F_1 generation, and that it is formed as the result of the elimination of the fry of the initial types of redfish which are carried from the spawning grounds at Iceland and Denmark Strait and which encounter unfavourably low temperatures during their drift and in the fjords. Needless to say, the assumptions laid down here are only in the nature of a hypothesis which needs further experimental research. Biochemical evidence in favour of such an assumption is given in another paper (Altukhov *et al.*, 1968).

Discussion

In conclusion let us consider the problem of the taxonomic status of the differentiation between the *marinus*- and *mentella*-types of redfish. In addition to the conclusions of Travin (1951) on the species type and Andriyashev (1954) on the subspecies type, those of O'Rourke (1961) and Kotthaus (1961) based on biochemico-immunological and morphological data, respectively, must also be considered.

O'Rourke's proposal that the analyzed types are sibling-species, is questionable, since these fishes appear quite different from one another in most parts of their areal distribution.

Kotthaus (1961) puts forward three possible explanations for the taxonomic and phylogenetic relationship among the redfish: (1) the *marinus*- and *mentella*-types are independent species con- nected by intermediary fish of hybrid origin; (2) the *marinus*-type is a phylogenetically more ancient type from which the *mentella*-type has detached itself. Here the process of the speciation has not been terminated yet, hence, the emergence of intermediary forms; (3) the intermediary type is the initial one and the *marinus*- and *mentella*-types are formed depending on the depth to which the fry settle. Of the three assumptions, the authors consider the first two to be the most probable.

Our research has established that there is yet another method of differentiating the two redfish types. This method is by the thermostability of their isolated muscle tissues, which is substantiated as a cytophysiological criterion for the species. The discovery of a difference in the thermostability of the cells of any forms of poikilothermic animals which are taxonomically close can be considered as an important proof of their being independent species, or as an indication that speciation is still going on (Ushakov, 1964). Thus, the first two suggestions of Kotthaus (1961) have been confirmed experimentally.

Since evolution is an adaptive process it is interesting to compare the differences established in the thermal stability of the muscles of redfish forms with water temperature. According to Travin (1951), in the Barents Sea, the *marinus*-type prefers warmer water than the *mentella*-type. At the same time, the data discussed at the 1959 ICNAF/ICES Redfish Symposium in Copenhagen gave evidence to the contrary. Workers studying the biology of the Barents Sea redfish at the Polar Institute (PINRO) also believe that the *mentella*-type redfish prefer warmer water (Berger, Zakharov, Sorokin, personal communications) because the temperature at the greater depths where it lives mainly, is as a rule 1.5° to 2° C higher than at the comparatively shallow depths where the *marinus*-type redfish lives. Templeman (1959) also cites similar evidence.

Thus, we believe that the cytophysiological differences between the *marinus*- and *mentella*-types result from their adaption to temperature, which can be found also at the cellular level. These differences seem to be significant and, combined with the data of other authors, who have demonstrated essential differences in the *marinus*- and *mentella*-type redfish in a number of other features, can, in our opinion, be regarded as an argument in favour of the concept of the taxonomic range of divergence of these types.

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Haddock Length Conversion Factors for St. Pierre Bank

Standard, extreme total and fork lengths, as outlined in May and McCracken (1966) were measured to the nearest centimeter for a sample of 152 haddock taken on St. Pierre Bank in April 1967. Least squares regression equations are shown in Fig. 1–3.
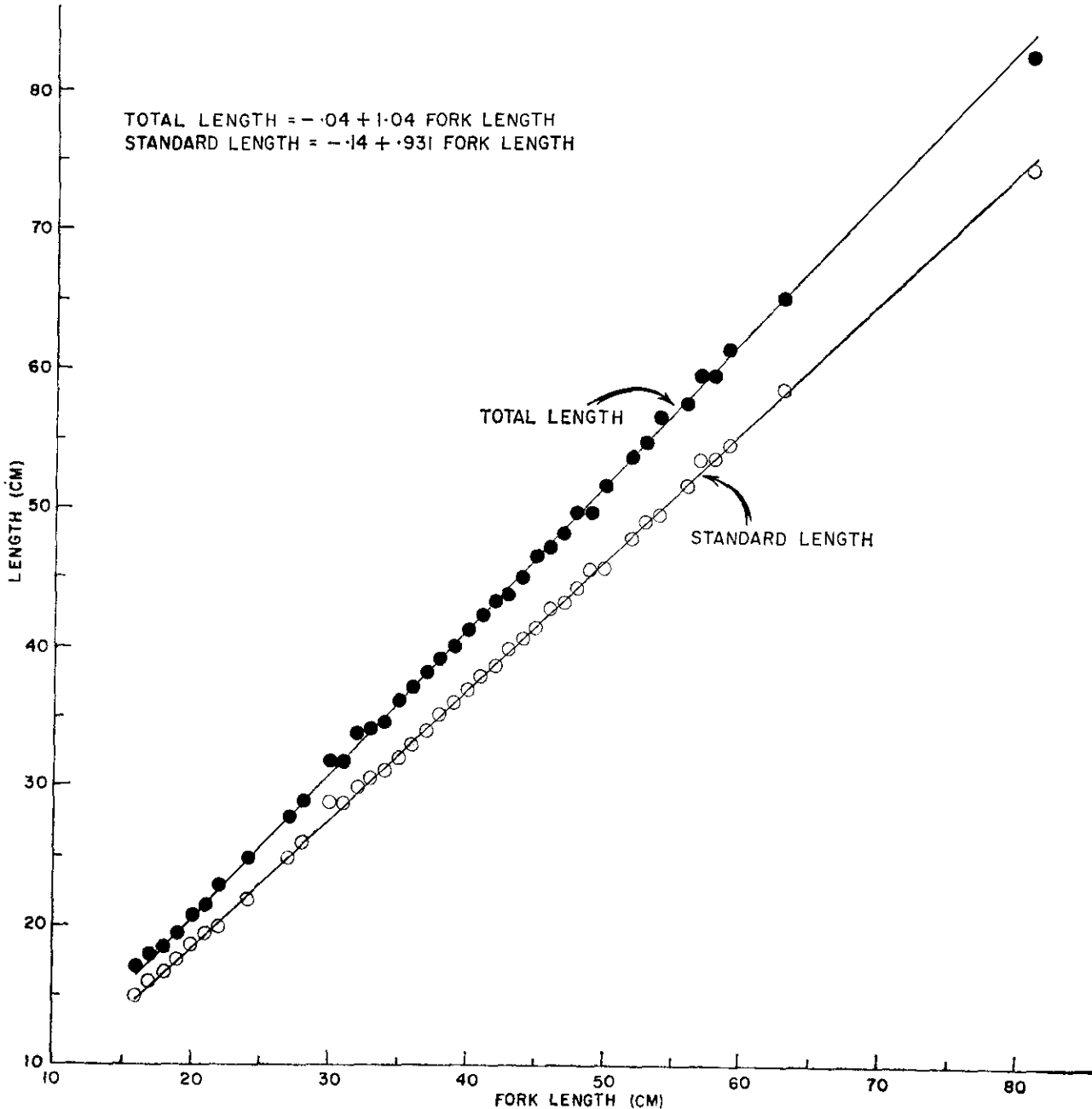

Fig. 1. Regressions of total and standard lengths on fork length of haddock from Division 3P.
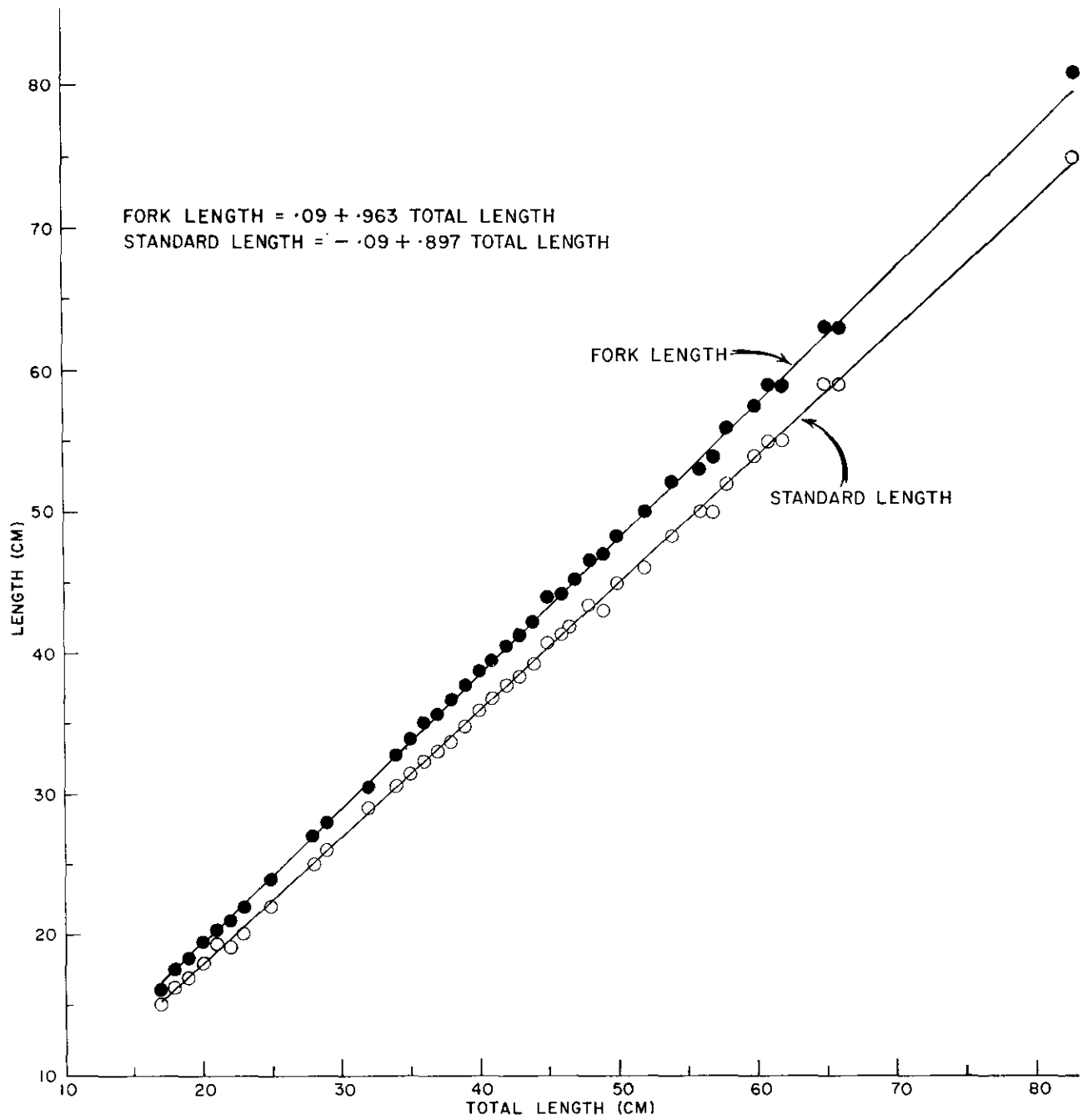
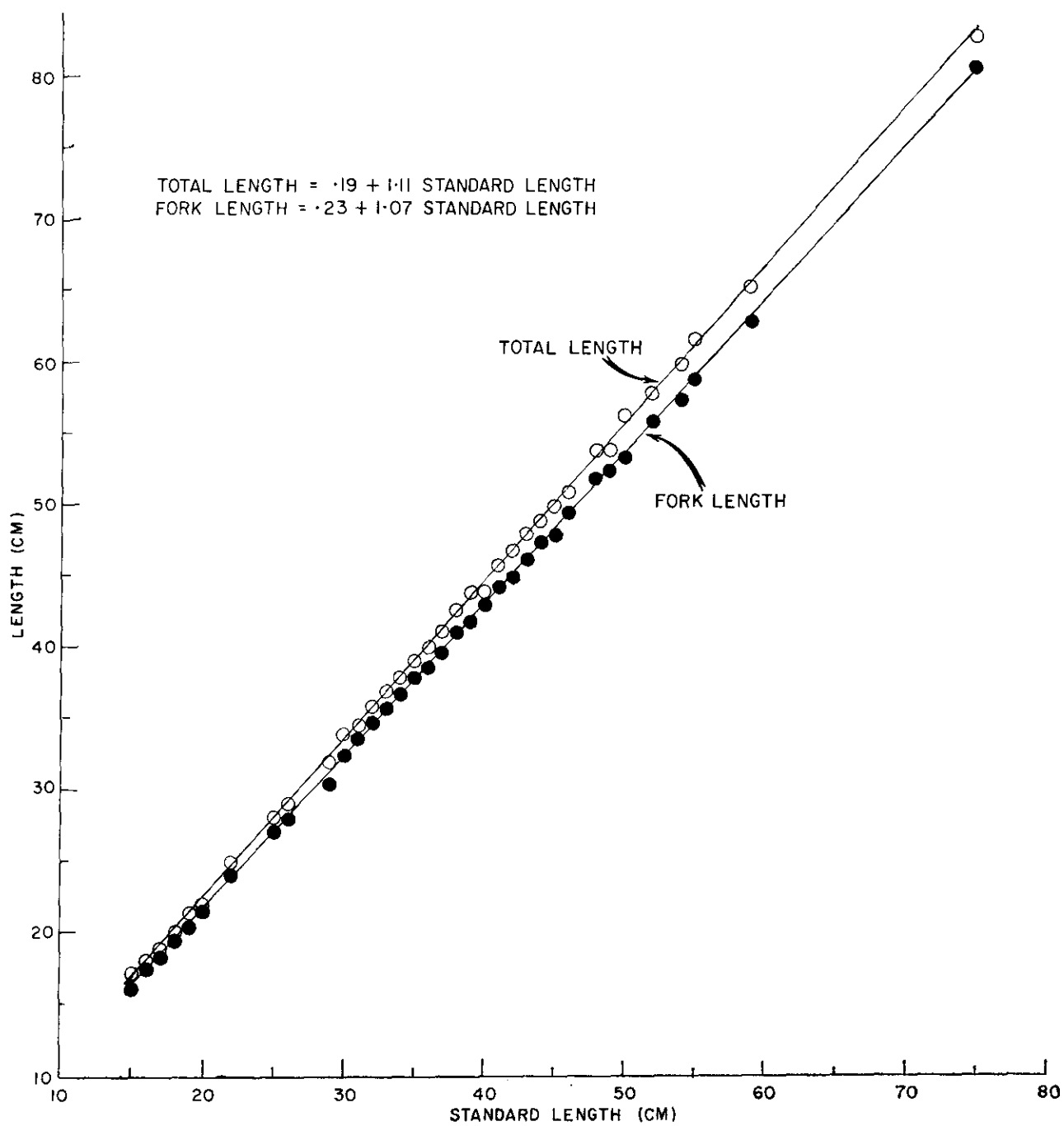Fig. 2.   Regressions of standard and fork lengths on total length of haddock from Division 3P.

TOTAL LENGTH = ·19 + 1·11 STANDARD LENGTH
FORK LENGTH = ·23 + 1·07 STANDARD LENGTH

Fig. 3.   Regressions of total and fork lengths on standard length of haddock from Division 3P.

Equations relating total length, l_t, and fork length, l_f, for other areas of the Northwest Atlantic are shown below.

ICNAF Division	Source	Equation
3N	Rojo (1957)	$l_t = 1.04 l_f - 0.18$
4X	May and McCracken (1966)	$l_t = 1.04 l_f - 0.21$
5Z	Livingstone (1957)	$l_f = 0.944 l_t + 0.58$

Fisheries Research Board of Canada,
Biological Station,
St. John's, Newfoundland.

Personal communications with the above authors have indicated:

1) for the 3N sample, extreme total length was measured and to the centimeter below;

2) for the 4X sample, natural total length was measured and to the nearest centimeter;

3) for the 5Z sample, measurements were taken in 1930 and total length, recorded to the nearest centimeter, was described then as "tip of snout to the end of the upper (dorsal) caudal rays".

R. Wells.

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International Commission for the Northwest Atlantic Fisheries

The Commission in Brief

Under the terms of a Convention signed in 1949, the International Commission for the Northwest Atlantic Fisheries (ICNAF) is responsible for promoting and co-ordinating scientific studies on the stocks of the species of fish which support international fisheries in the Northwest Atlantic. Based on these researches, the Commission recommends measures to keep these stocks at a level permitting the maximum sustained catch.

The governments sharing these conservation interests are Canada, Denmark, France, Federal Republic of Germany, Iceland, Italy, Norway, Poland, Portugal, Romania, Spain, Union of Soviet Socialist Republics, United Kingdom, and United States of America.

Research Bulletin of ICNAF

The International Commission for the Northwest Atlantic Fisheries invites contributions to its new serial publication, "The Research Bulletin of ICNAF".

There will be one or more issues each year depending on the number of papers received and accepted for publication.

Purpose. The main purpose of the Research Bulletin is to publish the results of research carried out in the ICNAF area. It is expected that most papers published in the Research Bulletin will be selected from papers presented at Annual Meetings of the Commission, but other papers, either concerning the ICNAF area or outside it, will be accepted if their contents are of importance to the work of the Commission.

Submission of Manuscripts. Manuscripts for publication should be submitted to the Commission's Secretariat on or before 1 October each year. This provides authors with sufficient time to revise or extend papers submitted or solicited at the previous Annual Meeting of the Commission which is held in early June each year. The arrangement also provides the possibility that the Bulletin can be issued before the next Annual Meeting of the Commission.

Editing. The Editor of the Research Bulletin will be the Executive Secretary of the Commission. He will be assisted on matters of editorial policy by the Chairman of the Commission's Standing Committee on Research and Statistics and the members of the Steering and Publications Subcommittee.

Refereeing. To maintain a high standard of publication each contribution will be submitted by the Editor to one or more referees from a panel of experts appointed for that purpose. On the advice of the referee(s), the Editor will request the author to make such amendments to his manuscript as will help to avoid error or misunderstanding and add strength to his presentation or will reject the manuscript. Referees will remain anonymous and will treat all manuscripts as confidential.

Preparation of Manuscripts. To achieve maximum conformity of presentation by authors and to minimize typing and other editorial work, the Commission's Secretariat has prepared the following aid.

Instructions to Authors for the Preparation of Manuscripts Intended for Publication in the Research Bulletin of ICNAF

Text

(a) Manuscript should be type-written, *double-spaced*, and on one side only of good quality white bond quarto paper, size $8\frac{1}{2} \times 11$ inches (220×280 mm).

(b) Leave all margins 1 inch (25 mm) to $1\frac{1}{2}$ inches (38 mm) for editorial marks and queries.

(c) Prepare and submit the original and two carbon copies of the text and at least two sets of illustrations.

(d) Number all pages of the manuscript consecutively with Arabic numerals in the centre of the top margin space.

(e) Start a new page for each of the following sections with appropriate headings and sub-headings: (1) title, name and address of author, list of contents (if applicable); (2) abstract of the paper; (3) text; (4) references to literature; (5) tables; (6) legends for figures and (7) figures.

(f) Please *double-space everything*—Text, quotations, footnotes, tables and table headings, legends, references to literature, and use even greater spacing where helpful (particularly around equations and formulae).

(g) Wherever practical the text should be subheaded into Introduction, Materials and Methods, Results, and Discussion. Authors must provide a Summary which lists one by one the principal facts and conclusions of the paper. Acknowledgements should be placed immediately after the Summary.

(h) All measurements, linear, weight, and time, should be given in numerals (not words) in the metric system. The Celsius scale should be used as a standard. When other units of measure are preferred, authors should include equivalents in metric units.

(i) Footnotes should be avoided as far as possible, but if necessary they must be numbered consecutively in the text and typed under a horizontal line at the foot of the page concerned.

(j) Only those words to be printed in italics should be underlined.

Abstract

Each manuscript should have an abstract not to exceed 3% of the length of the text or 200 words whichever is the smaller. For position of the abstract in the manuscript see (e) above. The abstract should summarize the contents and conclusions of the paper, point to new information in the paper and indicate the relevance of the work.

Tables

(a) Tables should be carefully constructed so that the data presented may be easily understood.

(b) Tables should be set out on separate sheets following the references.

(c) Position of the tables in the text should be indicated clearly.

(d) Each table should be provided with a descriptive heading which, together with the column headings, makes the table intelligible without reference to the text.

(e) Tables should be numbered consecutively with Arabic numerals, e.g. Table 1, 2, 3, etc.

Figures

(a) All illustrations, whether black-and-white drawings, graphs, photographs, or tone drawings, are to be considered as figures.

(b) Each figure should be mentioned and described in the text.

(c) A legend should be provided for each figure; the legends should all be typed together on a separate sheet or sheets attached to the manuscript following the tables.

(d) Figures should be numbered consecutively with Arabic numerals, as Fig. 1, 2, 3, etc.

(e) Figures should be set out on sheets preferably the same size as the text pages and in any case should not require a printer's reduction to less than one-third. Small figures can be arranged in groups on sheets the same size as the text pages.

(f) For guidance in preparing figures, the size of the printed area of the *Research Bulletin* page is 21 × 17 cm. The *Bulletin* will have a two-column format, each column 8 cm wide.

(g) Photographs presented as figures should be high contrast, glossy prints, about 5 × 7 inches (125 × 175 mm) in size and should be shipped flat protected by stout cardboard.

(h) Each illustration should be identified by marking on the back lightly in soft pencil on the margin the figure number and the author's name.

Bibliographic Style

(a) References to literature in the text should be by the author-date system, for example

It was reported that (Collins, 1960) the. . .;
In examining the situation, Rossini (1959) felt that. . .

Where more than one paper by the same author(s) have appeared in one year, reference should be given as follows:

Osborne and Mendel (1914*a*); Osborne and Mendel (1914*b*)
or Osborne and Mendel (1914*a* and *b*); (Barnet and Robinson, 1942;
King and Pierce 1943*a*, 1954)

Reference to material not yet submitted for publication should be written into the text e.g. "Harvey, in an unpublished manuscript,. . ." or "Harvey, in a letter,. . ."

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