INTERNATIONAL COMMISSION FOR   THE NORTHWEST ATLANTIC FISHERIES

REDBOOK   1971   PART III

SELECTED PAPERS FROM THE 1971 ANNUAL MEETING

(Serial Numbers 2515, 2615, 2585, 2567, 2485,
 2556, 2529, 2575, 2619, 2564, 2589, 2535,
 2552, 2476, 2509, 2559, 2605, 2522, 2528,
 2598, 2532, 2304 (Summary), and 2614)

Note

REDBOOK 1971 appears in 3 books. The first
book contains Part 1, Proceedings of the
Standing Committee on Research and Statistics.
The second book contains Part II, Reports on
Researches in the ICNAF Area in 1970. The
third book contains Part III, Selected Papers
from the 1971 Annual Meeting.

prepared by Mrs Vivian C. Kerr

Issued from the Headquarters of the Commission

Dartmouth, N.S., Canada

1971

PART III. SELECTED PAPERS FROM THE 1971 ANNUAL MEETING

1. <u>Temperatures and salinities in the eastern Newfoundland area in 1970</u>[1]

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Introduction

The 6 standard monitoring sections, taken each year at approximately the same dates in July-August across the Labrador Current east of Newfoundland, were occupied by the *Cape Freels*. Station 27, off Cape Spear, was occupied monthly or more often during the year. The section temperatures are compared with the lowest, average, and highest temperatures at each depth at each station in 1951-65 in July-August (unpublished) and also with temperatures in 1969 (Templeman, 1970) and for the St. John's-Flemish Cap section for 1966-69 (Templeman, 1967, 1968, 1969, 1970). Salinities are also compared with those in the above years.

Sections across the Labrador Current in July-August

Temperatures

In the Seal Islands, Labrador, section across Hamilton Inlet Bank (Fig.1), surface temperatures were similar to the long-term average. The lowest temperatures at mid-depths near the coast were similar to the lowest of the 1951-65 period and were slightly lower than in 1969. The volume of water with temperatures below -1°C was above average. Temperatures in the more off-shore portion of the cold central area of the Labrador Current were lower than the average of the 1951-65 period but higher than the lowest recorded and the 1969 temperatures. Temperatures of the bottom water in Hawke Channel were slightly higher than the long-term average and higher than in 1969. The temperature at the crest of Hamilton Inlet Bank was the highest recorded. Temperatures of the deep water seaward of Hamilton Inlet Bank at Stations 55A and 56 were similar to the highest recorded averages and considerably higher than in 1969, and at Station 57, the most seaward station, deep-water temperatures from 200 to 1,000 m were higher than any previously encountered, and between 200 and 600 m considerably higher than in 1969.

In the section off Cape Bonavista and southward to the northern Grand Bank (Fig. 2), surface temperatures of the Cape Bonavista portion were slightly below the long-term average and below those of 1969, except at the most coastal station, and mainly slightly below 1969 in the Grand Bank section. Temperatures in the inshore central core of the Labrador Current were slightly lower than the 1951-65 average and approximately similar to those of 1969, and the volumes of water with temperatures of below -1°C and 0°C were close to the average. The lowest temperature of the shoreward cold water and the lowest temperatures of the eastward-flowing branch of the Labrador Current near the Grand Bank were slightly below those of 1969. Except for the bottom temperatures at Stations 46 and 47, temperatures from 300 to 1,000 m were the highest recorded and considerably higher than in 1969.

In the St. John's-Flemish Cap section (Fig. 3), surface temperatures were slightly below average and approximately similar to those of 1969, except at

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[1] Submitted to the 1971 Annual Meeting of ICNAF as ICNAF Res.Doc. 71/22.

the inshore Station 27 where the surface temperature was high. The lowest temperatures of the shoreward central core of the Labrador Current were similar to the 1951-65 average and below those of 1969. The amount of water below 0°C was also close to the average but the temperature at the bottom at Station 27 in the Avalon Channel was the second highest recorded. Temperatures at the cold-water core of the eastern branch of the Labrador Current were close to the average and the extent of water with temperatures below 0°C a little greater than the average. Water temperatures in the upper layers above 150 m were average. Temperatures from 400 m downward in the Flemish Channel and those from 200 to 1,000 m seaward of Flemish Cap were among the highest and sometimes, including the 200-800-m levels at Station 42A, the highest recorded in the period 1951-70.

In the section from St. John's to the southeast slope of the Grand Bank (Fig. 4), the lowest temperatures in the coldest part of the Labrador Current, near shore, were similar to the lowest recorded. The temperature near bottom at Station 27 and temperatures over the surface of the Grand Bank were near but mainly slightly above the average. The distribution of the coldest water of the eastern branch of the Labrador Current, which usually hugs the eastern slope of the Grand Bank, was highly unusual, swinging away from the bank and with a warmer water border fringing the bank. Temperatures at the centre of this cold water were average. Temperatures at the most eastern station (33F) were above average but lower than those of 1969.

In the section extending along the southwestern edge of the Grand Bank at about 75 m (Fig. 5), surface temperatures were close to the 1951-65 average and higher than in 1969. Temperatures in the cold water near bottom in the Haddock Channel were close to the highest of the 1951-65 period but lower than in 1969. Bottom temperatures over the surface of the Grand Bank were close to the average for 1951-65 and somewhat similar to those of 1969. In the cold eastern branch of the Labrador Current at the eastern edge of the bank, temperatures were higher and the volume and depth of water with temperatures below 0°C and below 2°C much less than usual. The temperatures of the water fringing the Grand Bank on its eastern slope were by far the highest recorded and this warm water intrusion separated the low temperature and the median temperature water of the Labrador Current.

In the section at 275 m along the southwestern slope of the Grand Bank and extending to St. Pierre Bank (Fig. 6), surface temperatures were above the average for the 1951-65 period and considerably higher than in 1969. Temperatures of the intermediate cold Labrador Current water from the Haddock Channel were below average and, in the coldest water of the eastern branch of the Labrador Current, above average and almost as high as the highest recorded. Temperatures of the higher temperature deep slope water between these two branches of the Labrador Current were well above average. The bottom temperatures were mainly above average, all at Stations 10, 15, and 19 higher than any previously encountered in the 1951-65, 1969 period. As in the previous section (and at the same station, 26F) a branch of the Labrador Current with intermediate temperatures, which could be a return current passing northward, was apparent to the east of the slope separated from the main eastern branch by a warm water intrusion.

Salinities

In these comparisons, salinities from 20 m to the surface are omitted

because they are too much influenced by local and temporary precipitation and runoff to be very useful in year to year comparisons.

In the Seal Island section off southern Labrador (Fig. 1), at all stations except 55A, where there was some upwelling, salinities in the upper 100 m, at Station 53 the upper 150 m, and at Station 57 the upper 200 m were either the lowest or generally among the lowest 2 to 5 out of 16 or 17 years of records. Salinities were also in the lower half of records for the period at Station 55 for 150-250 m, at Station 55A for 50 m to 300 m, at Station 56 for 200 m, and at Station 57 for 250-500 m. The salinities at 200-250 m at Station 53 were close to the average. Seaward from this station, salinities were above average and usually in the upper quarter for the period at Station 54, 100 m and deeper; Station 55, 300 m and deeper; Station 55A, 400 m and deeper; at Stations 56 and 57 at 250 m and deeper. Salinities at Station 55A (500 m), at Station 56 (300-500 m) and at Station 57 (600-1,000 m) were the highest in the records for 6-17 years.

In the section off Cape Bonavista and southward to the northern Grand Bank (Fig. 2), at all depths from 30 m and greater at Stations 43 and 44, depths down to 150 m at Stations 45 and 49, to 250 m at Stations 46 and 47, to 100 m at Station 48, and to 200 m at Station 50 were either the lowest encountered in the period under comparison (18 of 40) or were in the lowest quarter. Salinities in the deep water: bottom at Station 45 and 47, 250 m to bottom at Stations 48 and 49, and 400 to 1,000 m at Station 50, were either the highest or equal to the highest on record (9 of 12) or in the highest quarter. Similarly high deep-water salinities and low upper-water salinities prevailed in the northern Grand Bank portion of the section for which long-term comparisons are not available.

In the section from St. John's to Flemish Cap (Fig. 3), salinities at Station 27 (30-125 m), Station 28 (30-100 m), Stations 29, 36 and 37 (30-50 m), Station 35 (30 m to bottom), Station 37A (30 m), Stations 38 and 40 (30-150 m), Stations 39 and 42A (30-100 m), and Stations 41 and 42 (30-75 m) were all below average; 9 (8 at 30 m) of 44 the lowest encountered for the period 1951-70, and 33 of 44 in the lowest quarter. Deep-water salinities at Station 27 (150 m to bottom), Station 28 (bottom), Stations 34, 36 and 37 (75 m to bottom), Station 37A (50 m to bottom), Station 38 (200-800 m), Station 39 (150-750 m), Station 40 (200 m to bottom), Stations 41 and 42 (100 m to bottom), and Station 42A (150 m to bottom) were above average, 33 of 53 the highest or equal to the highest encountered for the period 1951-70 and 46 of 53 in the highest quarter. The deep-water salinities above 35 °/oo at Stations 38-42A, in Flemish Channel and on the eastern slope of Flemish Cap, were the highest in our records.

In the section from St. John's to the southeast slope of the Grand Bank (Fig. 4), salinities at Stations 27-32A (all depths from 30 m downward), Stations 33 (30-75 m), 33A (30-250 m), 33B (30-400 m), 33D (30-250 m) and 33F (30-150 m) were below average, 34 of 55 the lowest encountered for the period and 49 of 55 in the lowest quarter. Salinities in the deeper water of the eastern slope: Station 33 (100 m to bottom), Stations 33A and 33D (300 m to bottom), Station 33B (bottom), and Station 33F (200 m to bottom) were mostly above average, 6 of 20 the highest or equal to the highest encountered for the period and 10 of 20 in the highest quarter.

In the section at about 75 m extending along the southwestern slope of

- 8 -

the Grand Bank (Fig. 5), salinities at all depths from 30 m downward at Stations 20B-26A and at depths of 30-200 m at Station 26F were the lowest (12 of 38) or among the lowest (1/8 to 1/4) of the salinities encountered in the period under comparison. At depths of from 30 m to bottom at Station 26B, 50 m to bottom at Station 26D, and from 300 to 600 m at Station 26F, salinities were equal to the highest or were the highest recorded (13 of 20) or were in the highest quarter recorded.

In the section at 275 m along the southwestern slope of the Grand Bank and extending to St. Pierre Bank (Fig. 6), salinities down to 100 m at Station 10, to 150 m at Station 13, to 75 m at Station 18 and at 30 m at Stations 16, 17 and 19 were usually either the lowest (7 of 15) or in the lowest quarter of salinities in the period under comparison. Salinities from 150 m to bottom at Stations 10, 15 and 17, 200 m to bottom at Stations 13 and 16, and from 50 m to bottom at Station 19 were either the highest or equal to the highest on record for the period under comparison (11 of 24) or usually among the highest quarter of the records for the period. Data for Stations 26D and 26F of this section are the same as in Fig. 5.

The most noteworthy features of the 1970 sections were the warmer water and especially the unusually high salinities in the deeper water at the eastern slope of the continental shelf and banks. Judging from the location of occurrence of high salinities in the sections (Figs. 1-6), and from Dietrich (1965, fig. 11) there was an unusual degree of intrusion of Atlantic water into the eastern and deeper parts of the Labrador Current on the northeastern and eastern slopes of the Grand Bank. Also noteworthy were the unusually low salinities of the upper water layers and the separation of the cold core of the Labrador Current from the Grand Bank to the east of the Southeast Shoal. The latter must be highly unusual as it is the first time that it has occurred in 17 years of records since 1951.

Station 27, 1970

In Station 27 off Cape Spear (Fig. 7), except for January, surface temperatures throughout the year were above the 1950-62 average (Templeman, 1965). Also, the highest surface temperatures in July-August were well above those in 1969 (Templeman, 1970). Bottom temperatures except for February and December were above the 1950-62 average and were mostly similar to those of 1969. At intermediate levels, the lowest water temperatures, below -1°C, were below the 1950-62 average and below those of 1969 and were evidently not produced locally but were brought in by the Labrador Current. The coldest water came through Station 27 in August and there was a much greater than usual persistence of a large volume of water with very low temperatures up to the beginning of December.

Upper layer salinities in late summer and in autumn were well below and surface salinities throughout the year usually below those of 1969. Otherwise, they were generally similar to those of 1969, except that water with a salinity below 33 °/₀₀ sometimes extended to the bottom in 1970 but not in 1969.

Acknowledgements

I am grateful to Mr A.G. Kelland, hydrographic technician at the St. John's Station and to Mr L.N. Cluett for their interest in gathering data for

this paper, also to the scientists and technicians of the St. John's Station
who have taken hydrographic observations on Station 27 and on the various
sections.

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    Flemish Cap section in 1968. *Ibid.*, 1969, Part III, p. 39-41.

    1970. Temperatures and salinities in the eastern Newfoundland area in
    1969. *Ibid.*, 1970, Part III, p. 11-21.

51 52   53   53A   54   55 55A 56   57
7·9 8·4   7·5   6·4   6·9   5·8 4·9 5·9   7·1

5·2   3·29   5   6·10
−1·63   −1·50   −0·92   −1   0   −1·23   3
−1·68   −1·49   −1·33   −0·96   3·77
−1·66   −1·5   −1·13   −1   0   2·43
−1·24   −1·13   −1   −1·08   2·80
−1·46
−0·70   0   −0·38   4·41   3·72
2·38   2
0·36   2·06   3   4·12   4·25   4·22
A   HAMILTON INLET BANK   2·14   4   4·39   4·51
1·00   4·42   4·37   4·52
4·24

METRES   FATHOMS
0, 50, 100, 150, 200, 250, 300, 350, 400, 600, 800, 1000

4·66   4·52   4·53
4·54   4·43   4·33 / 4·24
3·97
3·74

(Inset map: 58° 56° 54° 52° 50° 56°; 100 fath.; Hamilton Inlet Bank; 56 57; 55 55A; 54; 53A; 53; 51 52; Seal Is.; Labrador; 54°; 52°; 1000 fath.; 200 fath.; NAUTICAL MILES 0 10 20 30)

51 52   53   53A   54   55 55A 56   57
27·94 27·41   29·45   29·14   30·39 31·42 32·83   33·49

28·0 28·5 29·0   29·5   30·0   31·0
32·18   32·5   32·0   31·5   30·5
32·38   33·0   34·45
32·75   33·5   34·58
34·0   34·5
34·40   34·81   34·70
33·93   34·67 34·83   34·79
B   34·31
34·04   HAMILTON INLET BANK   34·70 34·92   34·90
34·11   34·74 34·76 34·94   34·92
HAWKE CHANNEL   34·81

NAUTICAL MILES 0 10 20 30

34·90 34·94   34·92
34·99 34·94   34·92
34·96
34·96

METRES   FATHOMS
0, 50, 100, 150, 200, 250, 300, 350, 400, 600, 800, 1000

Fig. 1. Temperature (°C) above and salinity (°/₀₀) below, Seal Island-
Hamilton Inlet Bank section, 2-3 August 1970.
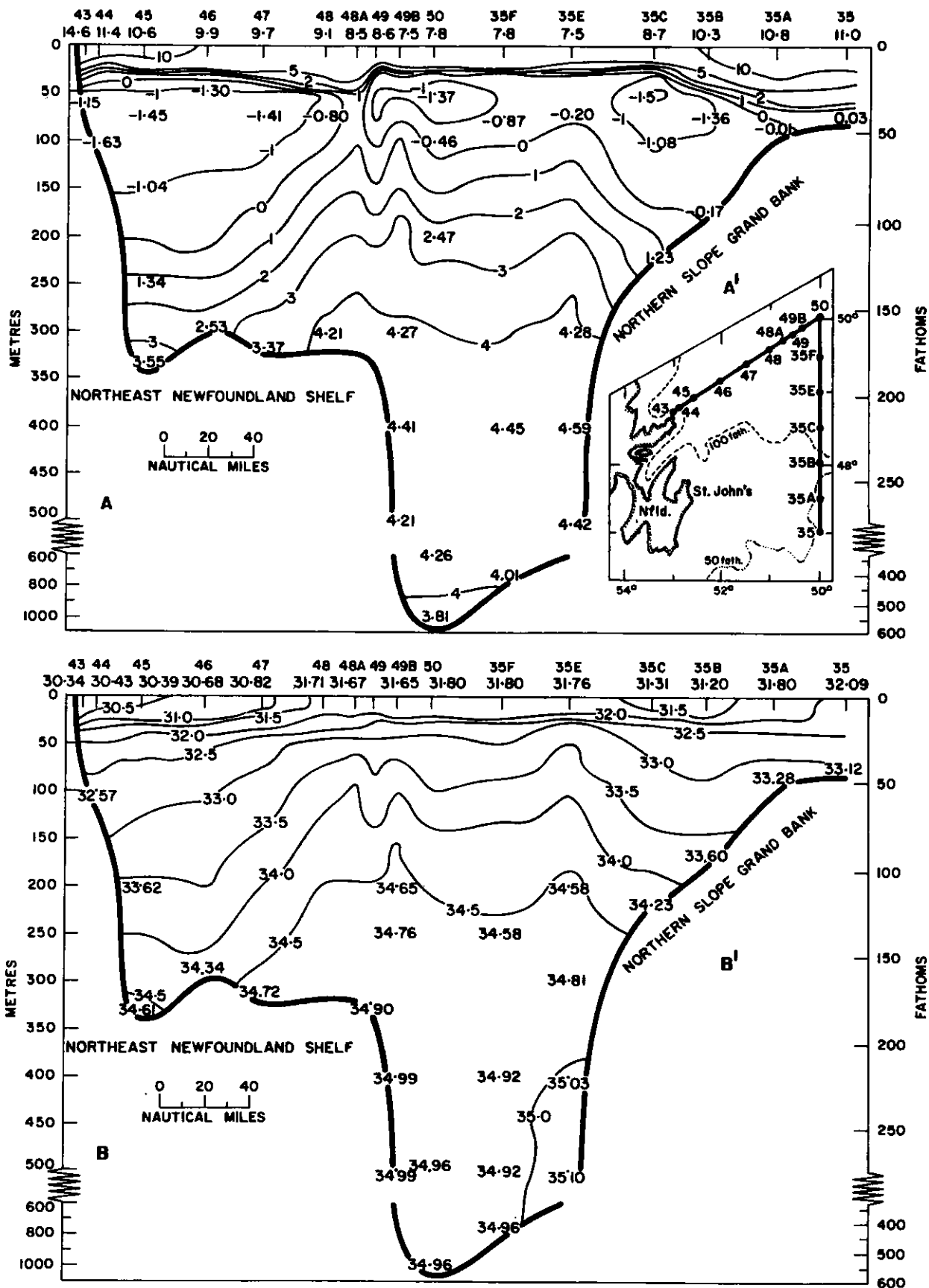
Fig. 2. Temperature (°C) above and salinity (°/oo) below, for section off Cape Bonavista, and southward to northern Grand Bank, 28 July–1 August 1970.
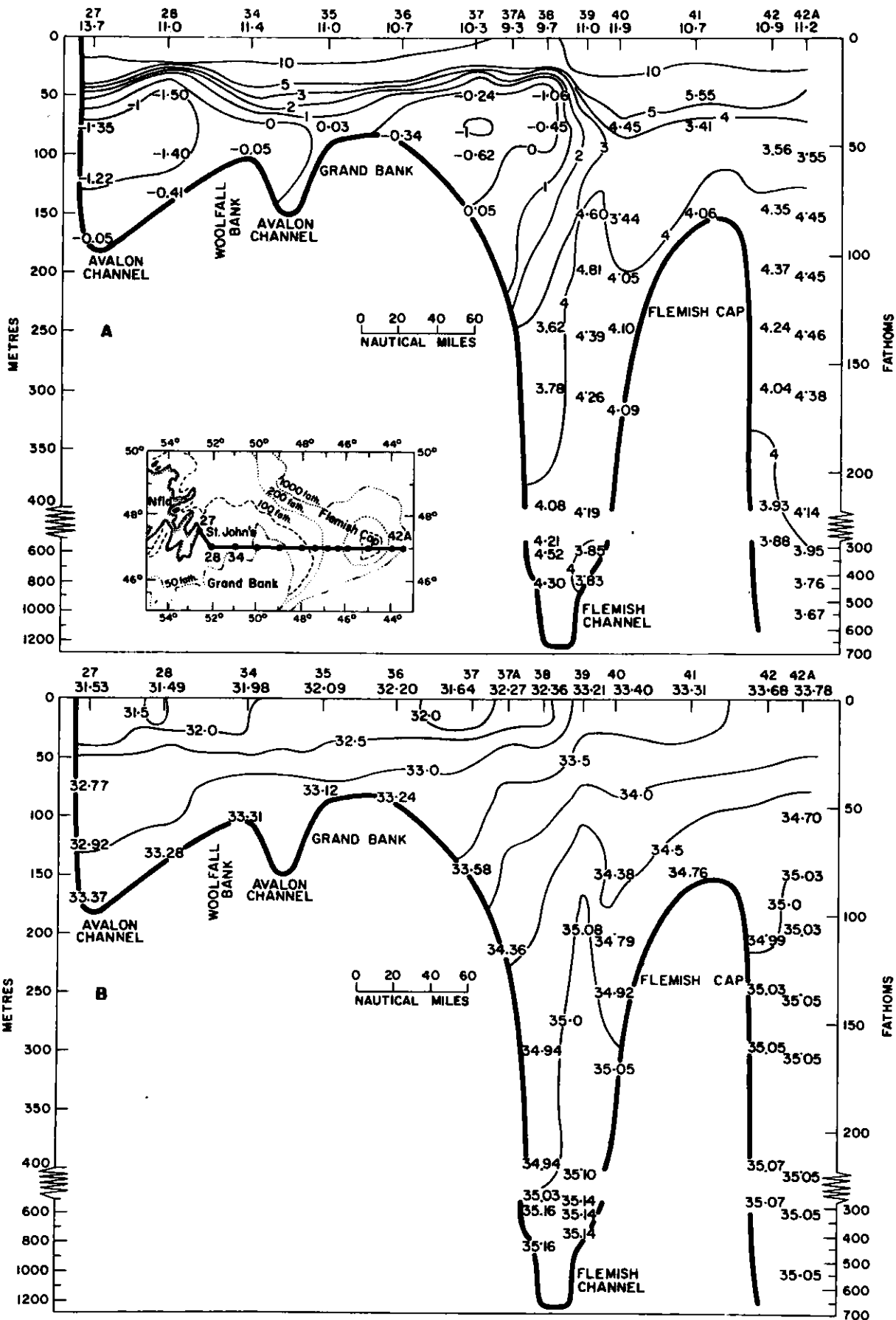
Fig. 3.   Temperature (°C) above and salinity (°/₀₀) below, St. John's-Flemish Cap section, 27-29 July 1970.
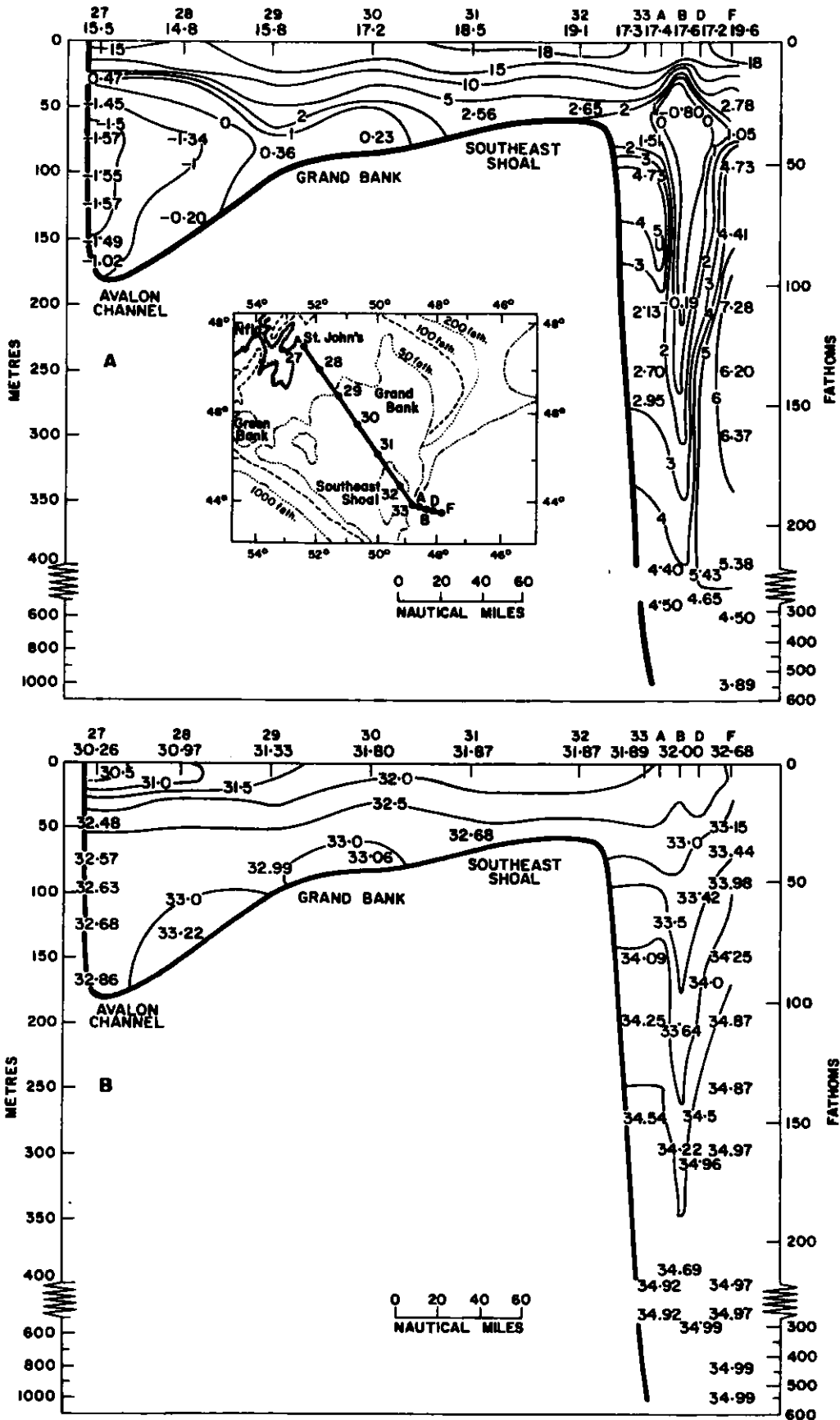
Fig. 4.   Temperature (°C) above and salinity (°/₀₀) below, St. John's-SE
slope Grand Bank, 17-19 August 1970.
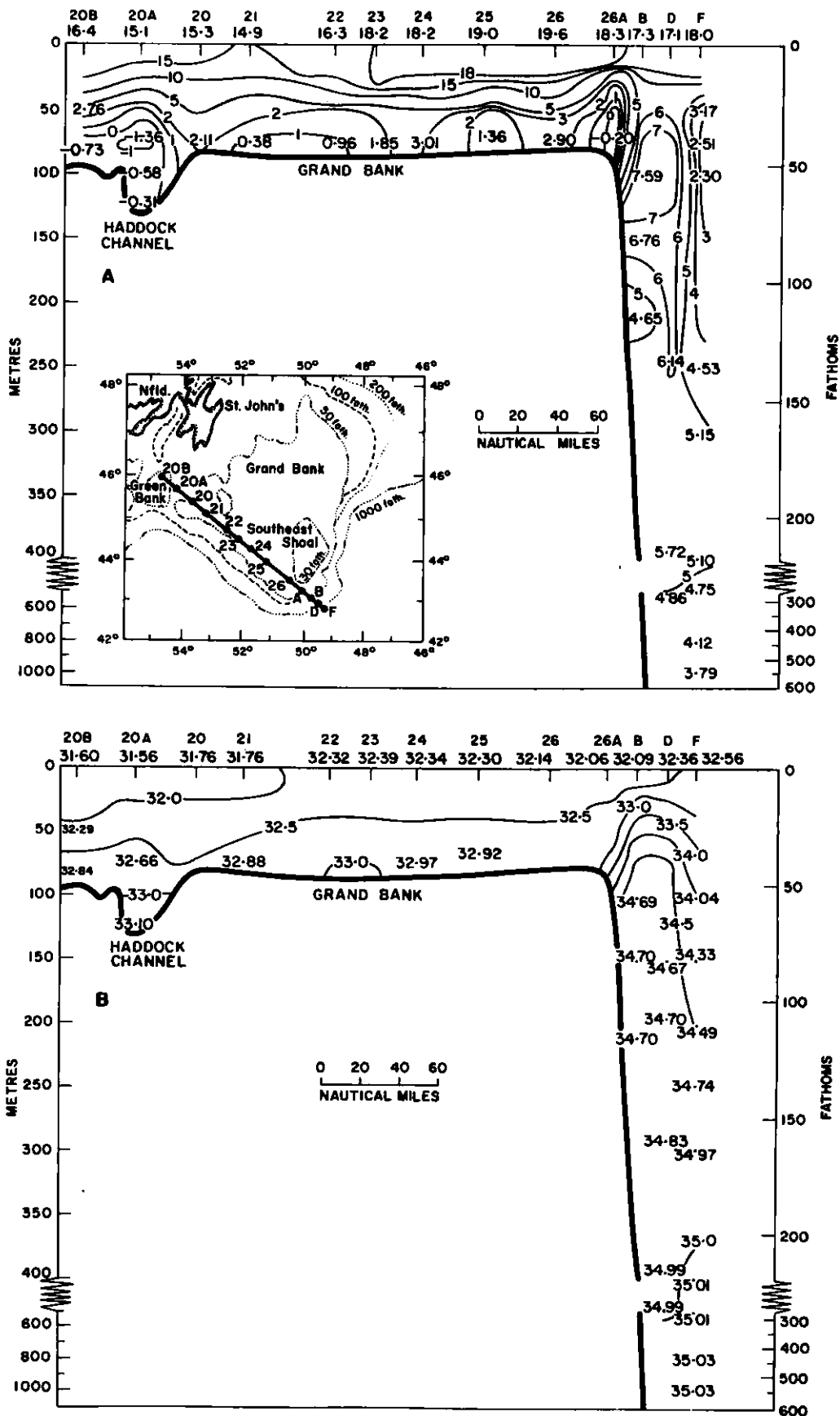
Fig. 5. Temperature (°C) above and salinity (°/oo) below, Green Bank-SE
Grand Bank, 20-23 August 1970.
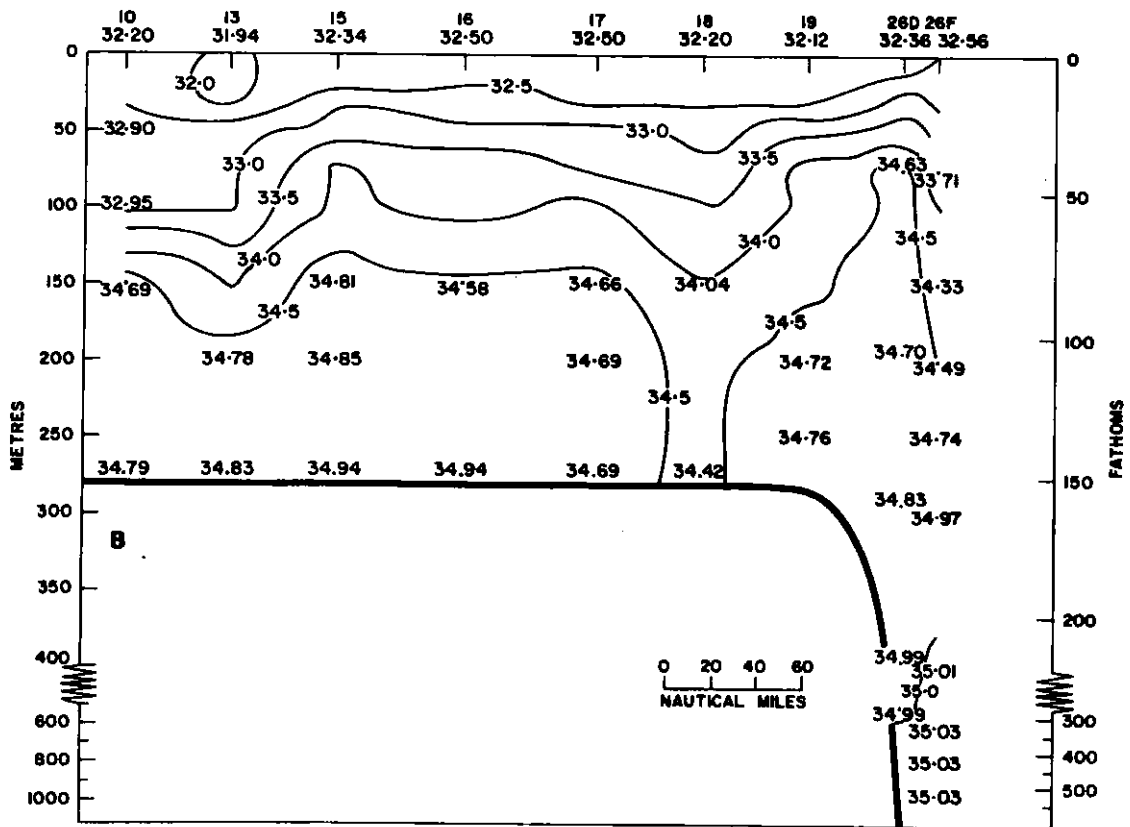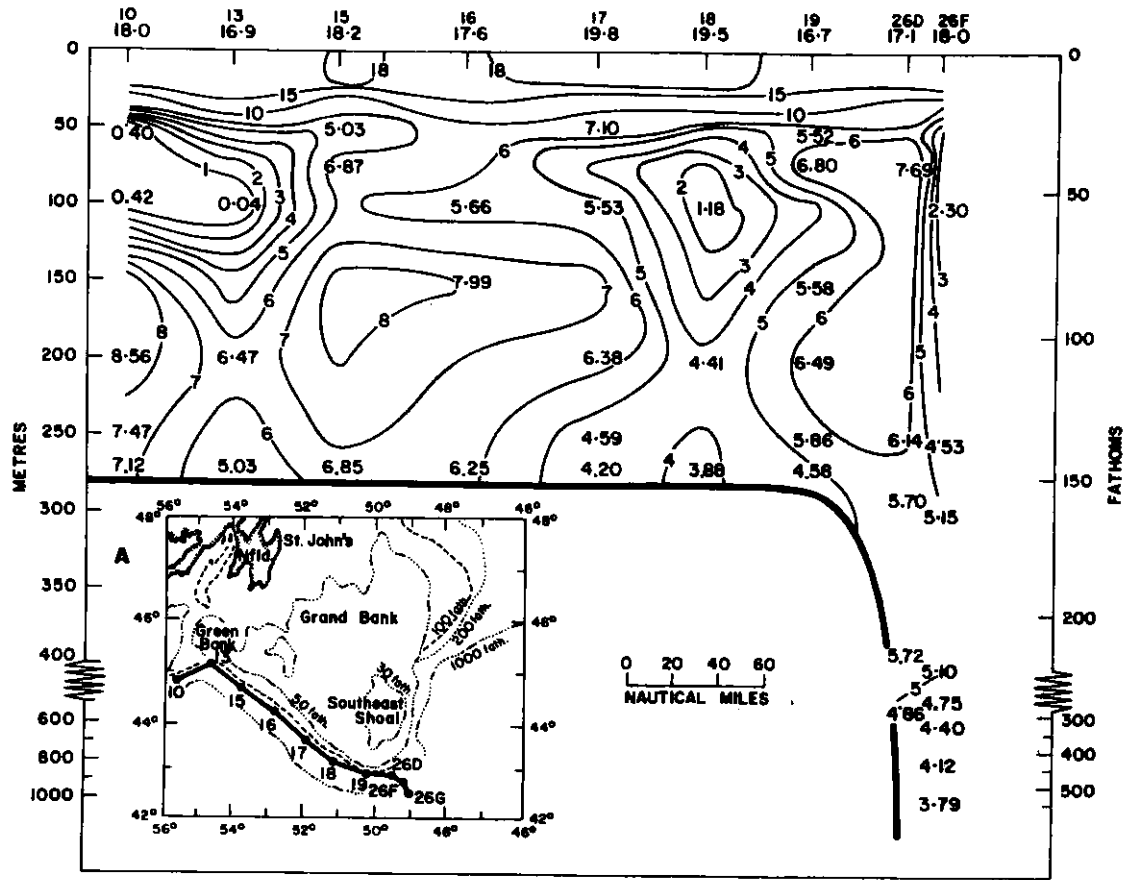
Fig. 6.   Temperature (°C) above and salinity (°/oo) below, SW slope Grand Bank-St. Pierre Bank, 20-23 August 1970.

JAN. | FEB. | MARCH | APRIL | MAY | JUNE | JULY | AUG. | SEPT. | OCT. | NOV. | DEC. | JAN.
-0.30 0.10 0.00 0.10 0.20 0.01 0.50 2.80 4.20 7.40 9.20 13.70 15.50 10.80 9.90 8.90 7.20 6.70 5.70 1.60 -1.10

-0.17   0   14.69   10   8   7
                                      9.79
-0.36   -0.46   0   4   6   7   8   10   6
                           3
                         2 1
-0.37   -0.81   0.06   0   5
                                                             4
                                                             3
-0.37   -0.64   -7   -1.57   2
                                                    0
-0.23   -0.83 1.18   -1.38   -1.12   -1.42   -1.31   1.06
                                -1.5
-0.15 -0.46 -0.78 -1.38   -1.32 -1.09   -1.22 -1.56   -1.43 -1.5 0.32   -1.01
                          -1
-0.21 -0.71 -0.53 -0.81 -0.74 -0.18 -0.77   -0.32 -1.31   -1.20 -1.43 -0.36   -0.70
-0.32 -0.63 -0.44 -0.56 -0.40 -0.28 -0.16 -0.70 -0.30 -0.05 -0.80   -0.96   -1.18   -0.69

JAN. | FEB. | MARCH | APRIL | MAY | JUNE | JULY | AUG. | SEPT. | OCT. | NOV. | DEC. | JAN.
31.94 31.80 31.76 31.85 31.96 31.78 31.65 31.40   31.53 30.26 30.66 30.52 30.77 30.55 31.29   32.07

31.94   32.10   30.5   30.55
32.27   32.0   30.66   30.72   31.0
32.12   31.83   31.0   30.90 30.59   32.12
32.0   31.65 31.69   31.60
32.0   32.0   31.5
32.10   32.27 32.34 32.38   31.5
32.21 32.45 32.32 32.41 32.41   32.56   32.77 32.57   31.73 31.64   32.47
                         32.5   32.0
32.5   32.66 32.63 32.66 32.65   32.5   32.84   32.39 32.45 31.73   32.48
32.95 32.79   32.56 32.77   32.72   32.92 32.68   32.84 32.65   32.03   32.5
32.66   32.83 32.65   32.81 33.28 32.75   32.92 32.77 32.86 32.27   32.88
                         33.0   33.0
33.40 33.33 33.13   32.95 33.08 33.15   33.37 33.10   33.21   33.21   32.90

Fig. 7.   Temperature (°C) above and salinity (°/oo) below, January 1970 to January 1971, from surface to bottom at Station 27 (see Figs. 3, 4 inset), 2 nautical miles off Cape Spear near St. John's.

2. Hydrographic conditions off West Greenland during 1970[1]

by Frede Hermann
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A number of standard sections off West Greenland (Fig. 1) were worked from the R/V *Adolf Jensen* from May to December 1970. Section I off Frederik-shaab was worked in May and October. Section II across Fyllas Bank was worked in May, June, twice in July and in September, October, November and December. Sections III and IV over Lille Hellefiske Bank and Store Hellefiske Bank were worked in May and July.

Ice conditions were rather severe in 1970. In both April and in July/August, the "storis" reached from Cape Farewell to a position north of Godthaab during its maximum extension. In April, the "storis" was relatively scattered and in a period with northerly wind in May, it disappeared from the bank area off the middle part of West Greenland.

Temperature sections are shown in Figs. 2-8. As in the two preceding years, temperatures were unusually low in the upper 100 m. In the Fyllas Bank section, negative temperatures were measured as late as September off the western slope of the Bank.
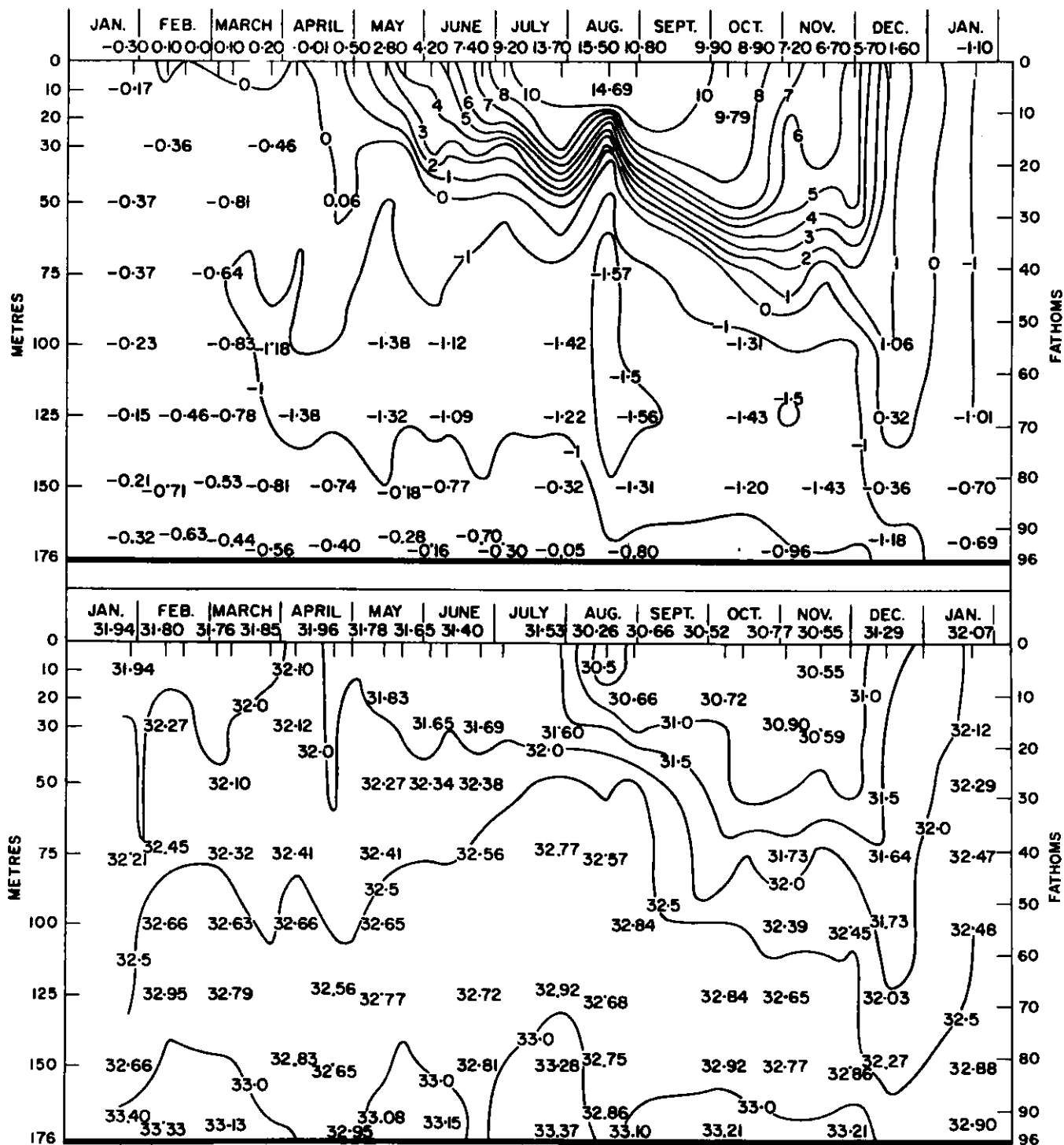
The temperature deviation from the mean value for the period 1950 to 1966 (Hermann, 1967) for the station at 63°53'N-53°22'W west of the slope of Fyllas Bank in July is given in Table 1 and the corresponding salinity anomaly is given in Table 2.

Table 1. Temperature anomalies west of Fyllas Bank in July.

Depth Interval (m)	Mean Temperature (1950-66)	Δ T (July 1970)
0- 50	2.07	-1.31
50-100	1.33	-1.12
100-200	1.85	-1.73
200-300	2.88	-2.06
300-400	3.79	-1.19
400-500	4.22	-0.08
0-500	2.89	-1.2

[1] Submitted to the 1971 Annual Meeting of ICNAF as ICNAF Res.Doc. 71/49, Part II.

Table 2. Salinity anomalies west of Fyllas Bank in July.

Depth Interval (m)	Mean Salinity (1950-66)	Δ S (July 1970)
0- 50	33.29	-0.46
50-100	33.65	-0.50
100-200	34.00	-0.56
200-300	34.39	-0.60
300-400	34.67	-0.30
400-500	34.81	+0.03
0-500	34.27	-0.38

In the upper 400 m the temperature was between 1° and 2° lower than the mean value and the salinity was between 0.30°/oo and 0.6°/oo lower than the mean value. The low temperature and salinity indicate a strong inflow of polar water to the West Greenland area.

Figure 9 shows the 5-year running averages of the surface temperatures in the West Greenland area (A_1) and South Greenland area (B) based on the surface anomalies by Jens Smed for the years up to 1969 (Smed, up to 1968).

The strong decrease in temperature in the last half of the sixties is rather alarming.

The low temperature in the surface layers will probably affect the survival of the cod larvae. The 1970 cod year-class will probably be very small in the northwest Greenland area.

The author is grateful to Jens Smed for placing the unpublished temperature anomalies for 1969 at his disposal.

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Smed, Jens. up to 1968. Monthly anomalies of the surface temperature of areas of the northern North Atlantic. *Ann. biol.*, Copenhague.
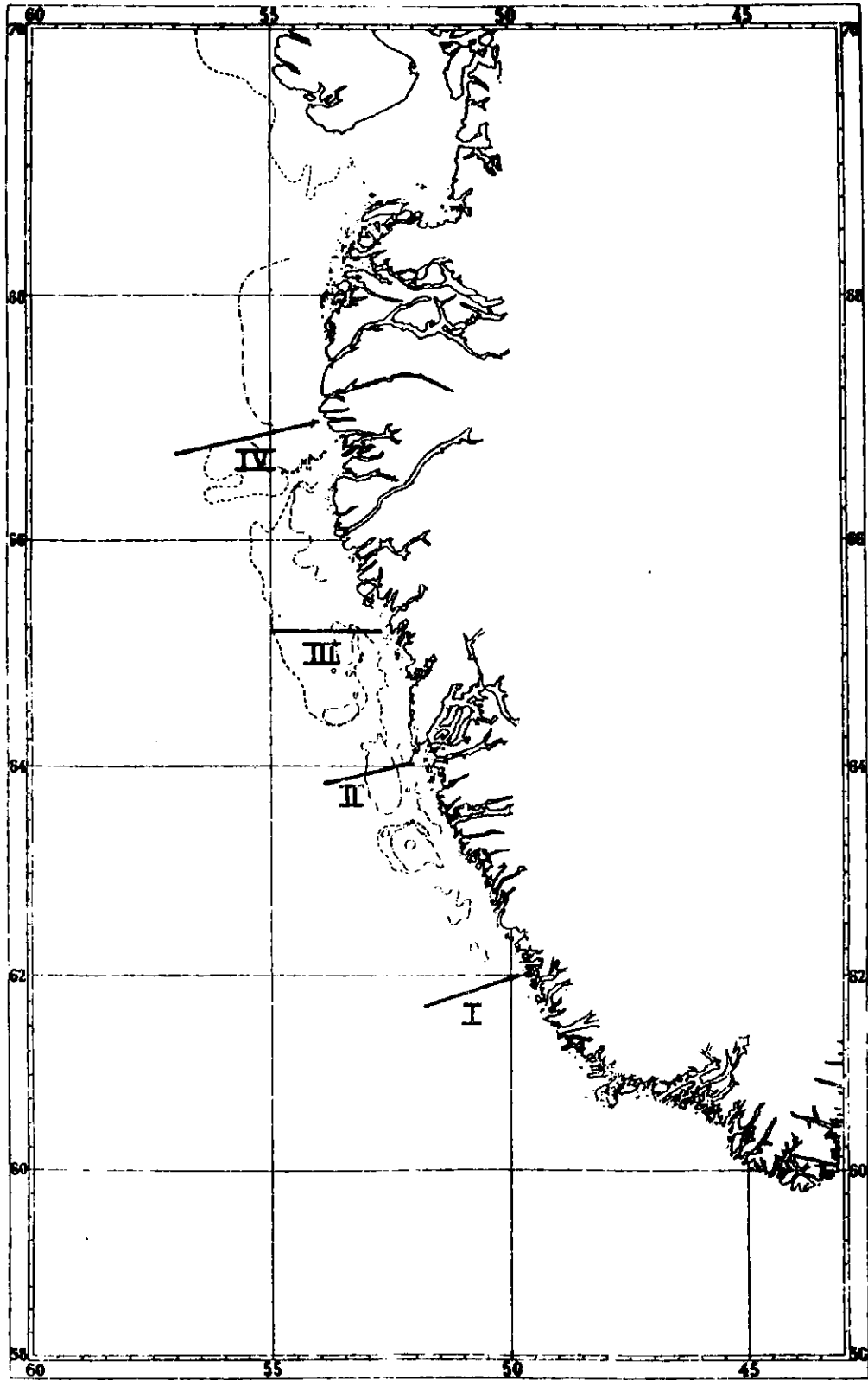
Fig. 1. Location of sections.
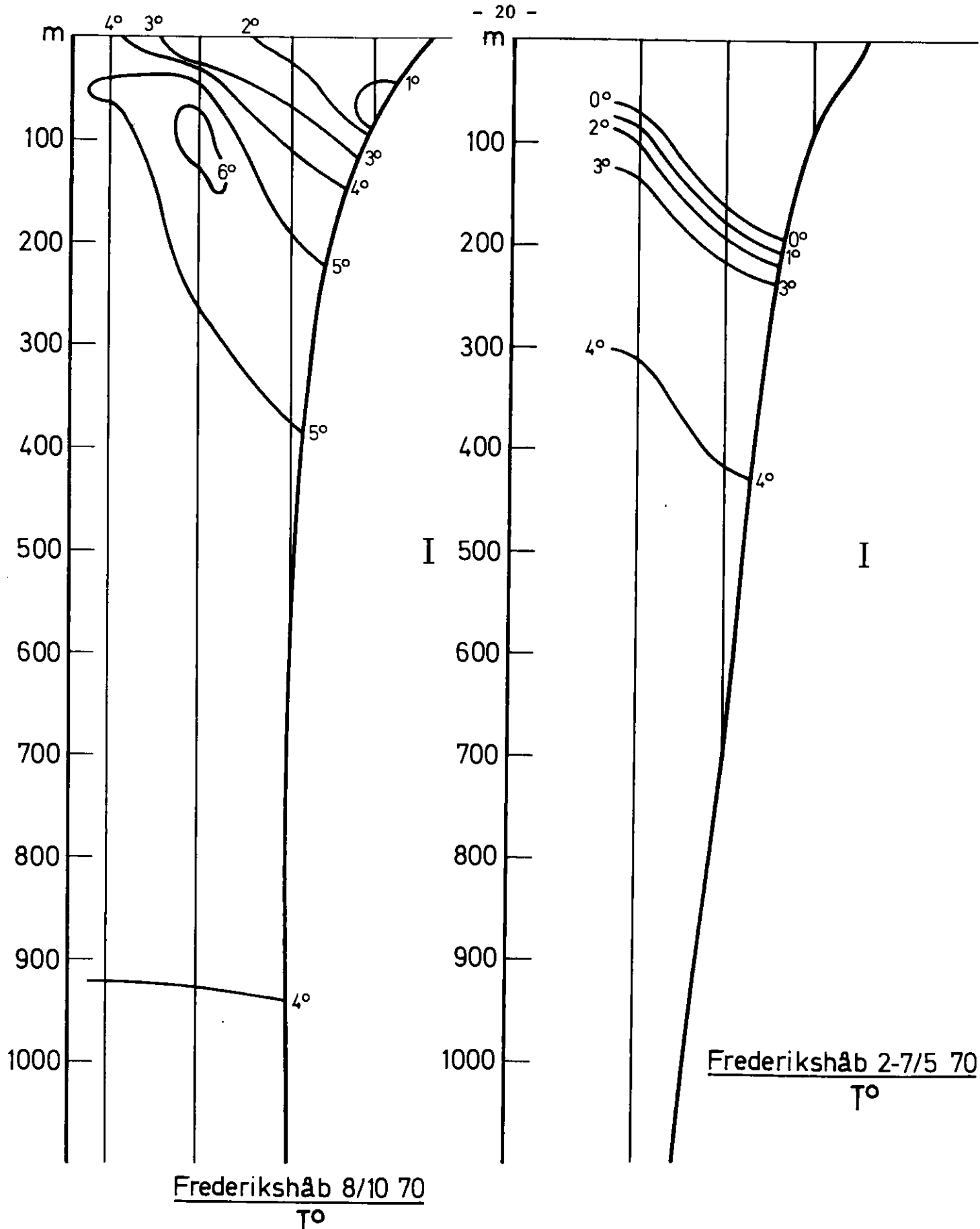
Fig. 2. Temperature sections off Frederikshaab (I) for May and October 1970.
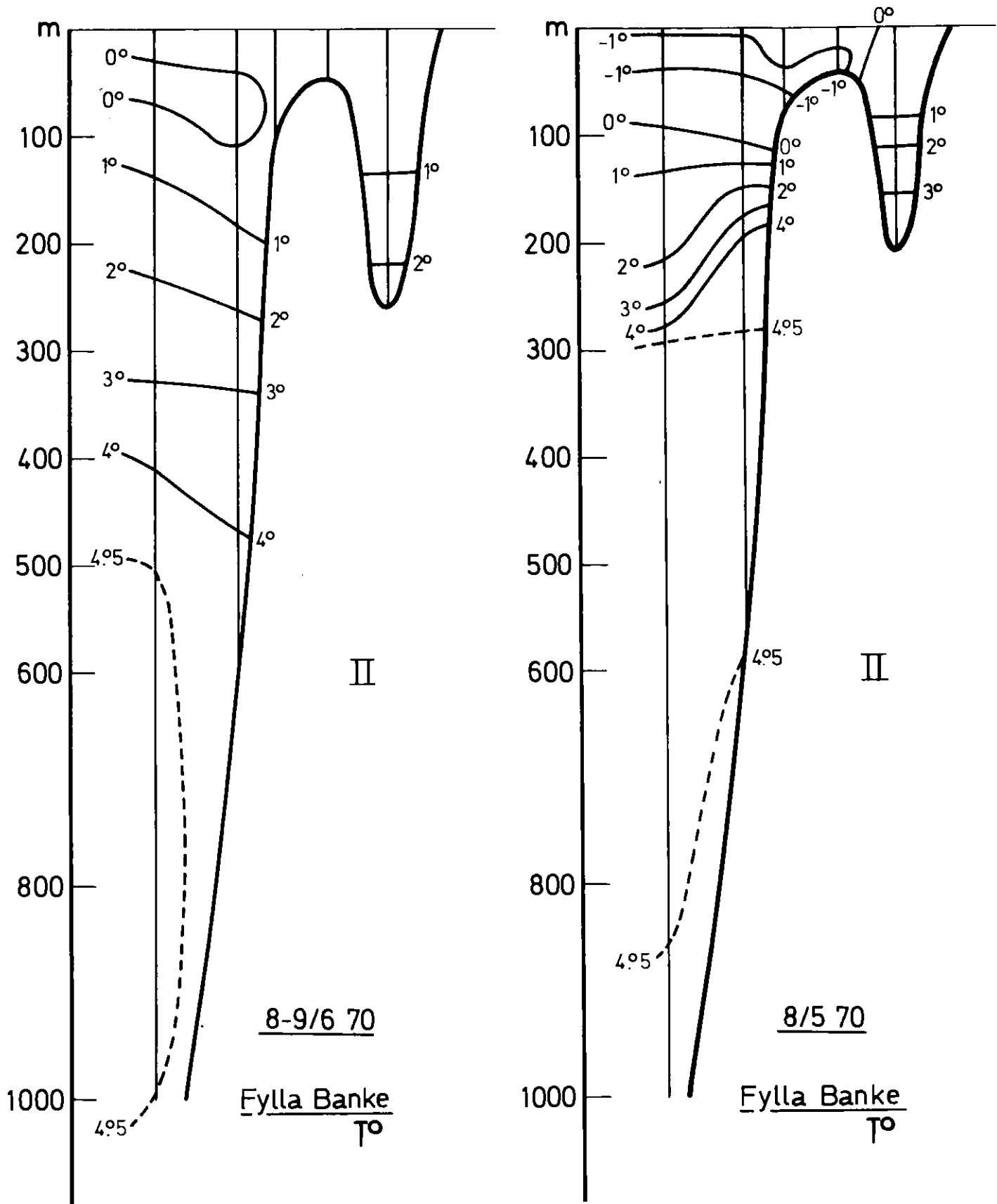
Fig. 3. Temperature sections across Fyllas Bank (II) in May and June 1970.
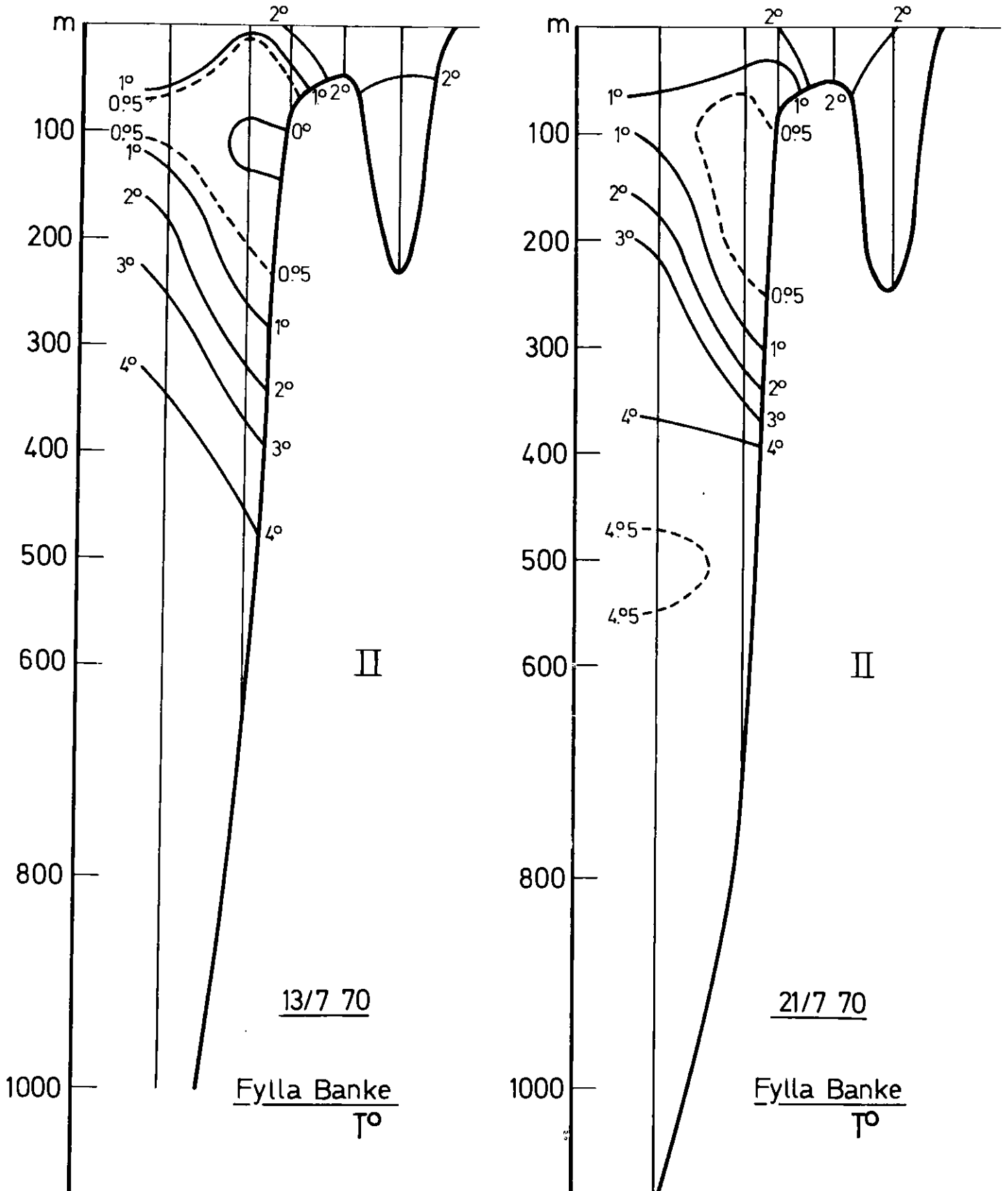
Fig. 4. Temperature sections across Fyllas Bank (II) in July 1970.
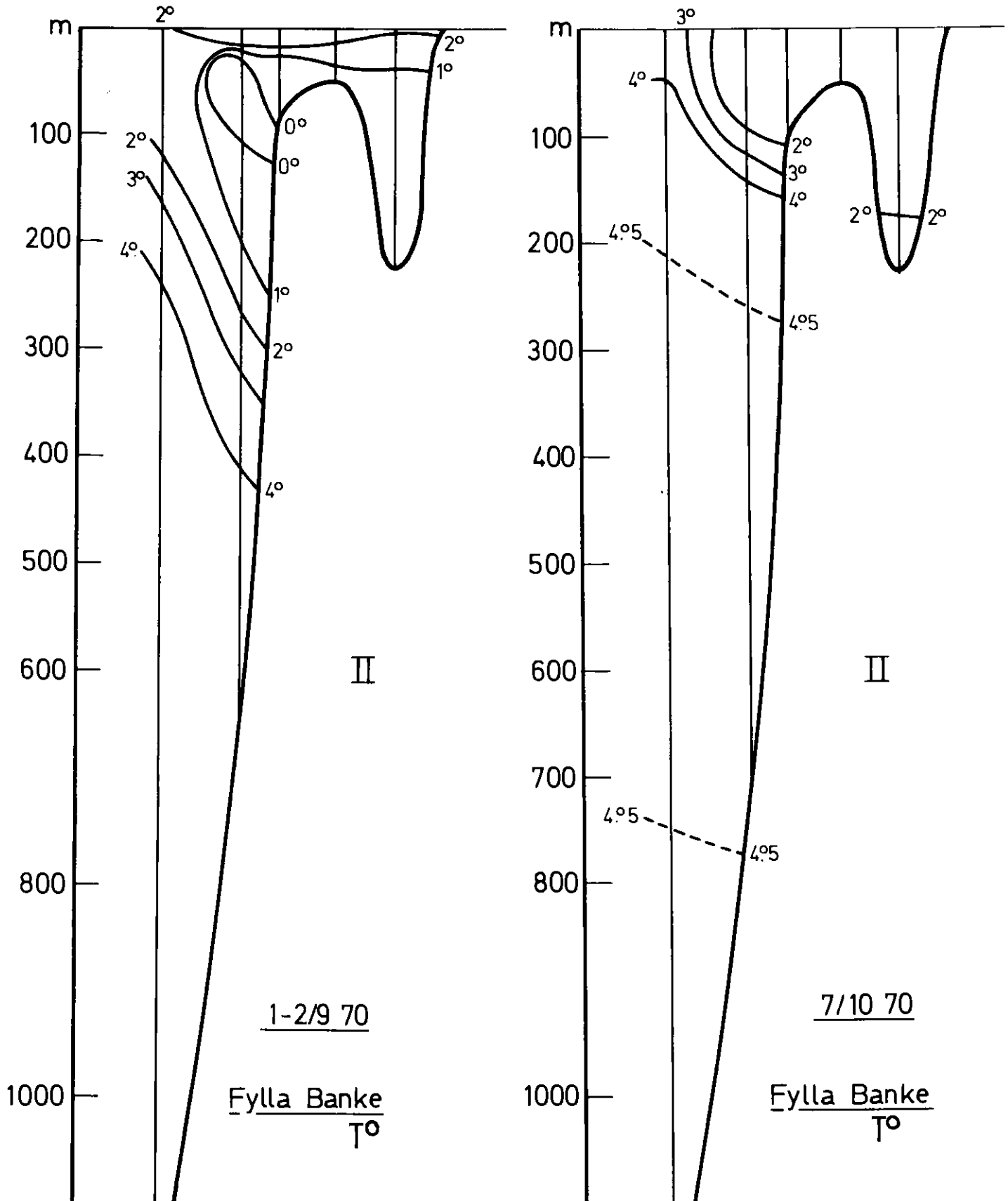
Fig. 5.   Temperature sections across Fyllas Bank (II) in September and
October 1970.
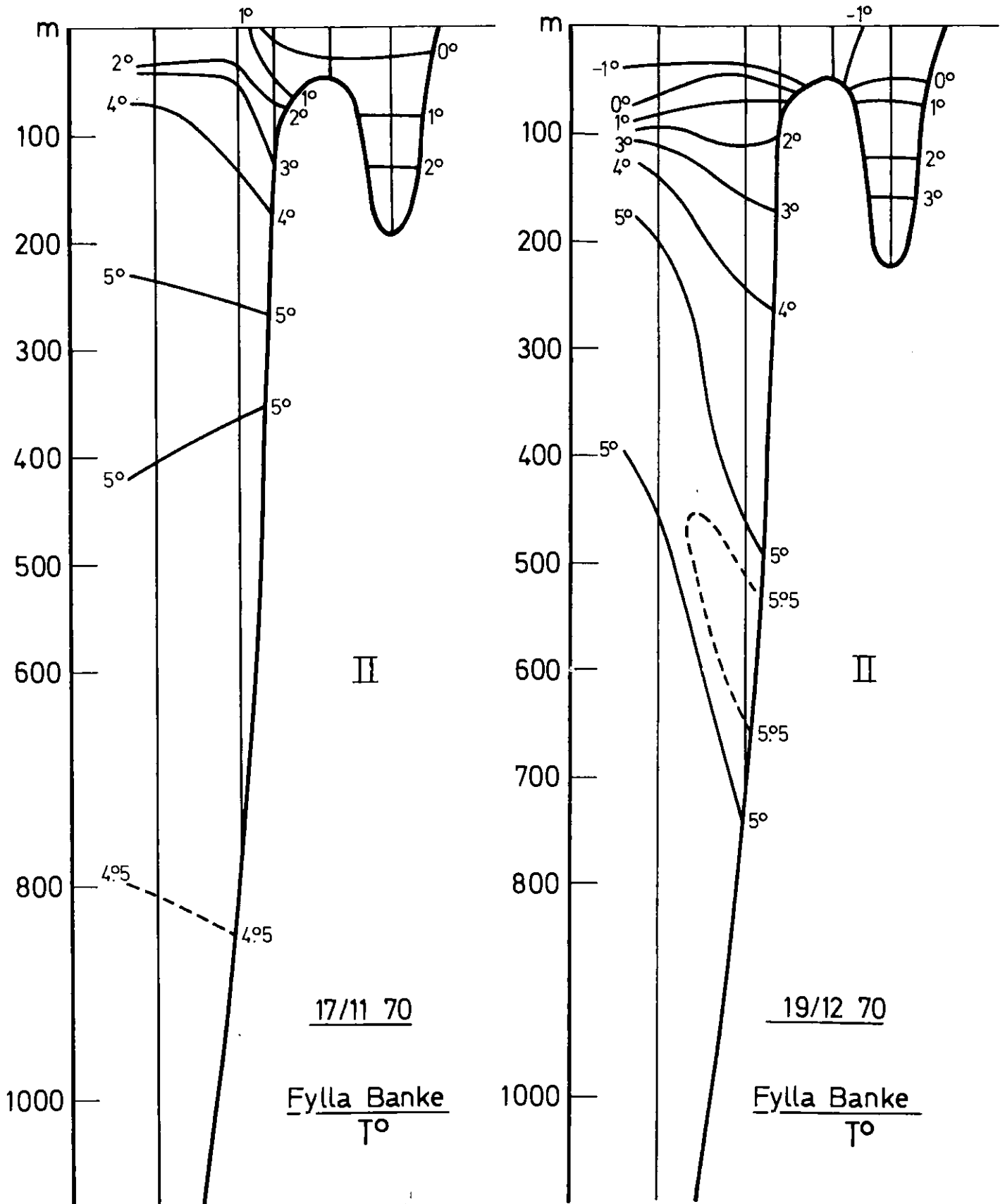
Fig. 6. Temperature sections across Fyllas Bank (II) in November and December 1970.
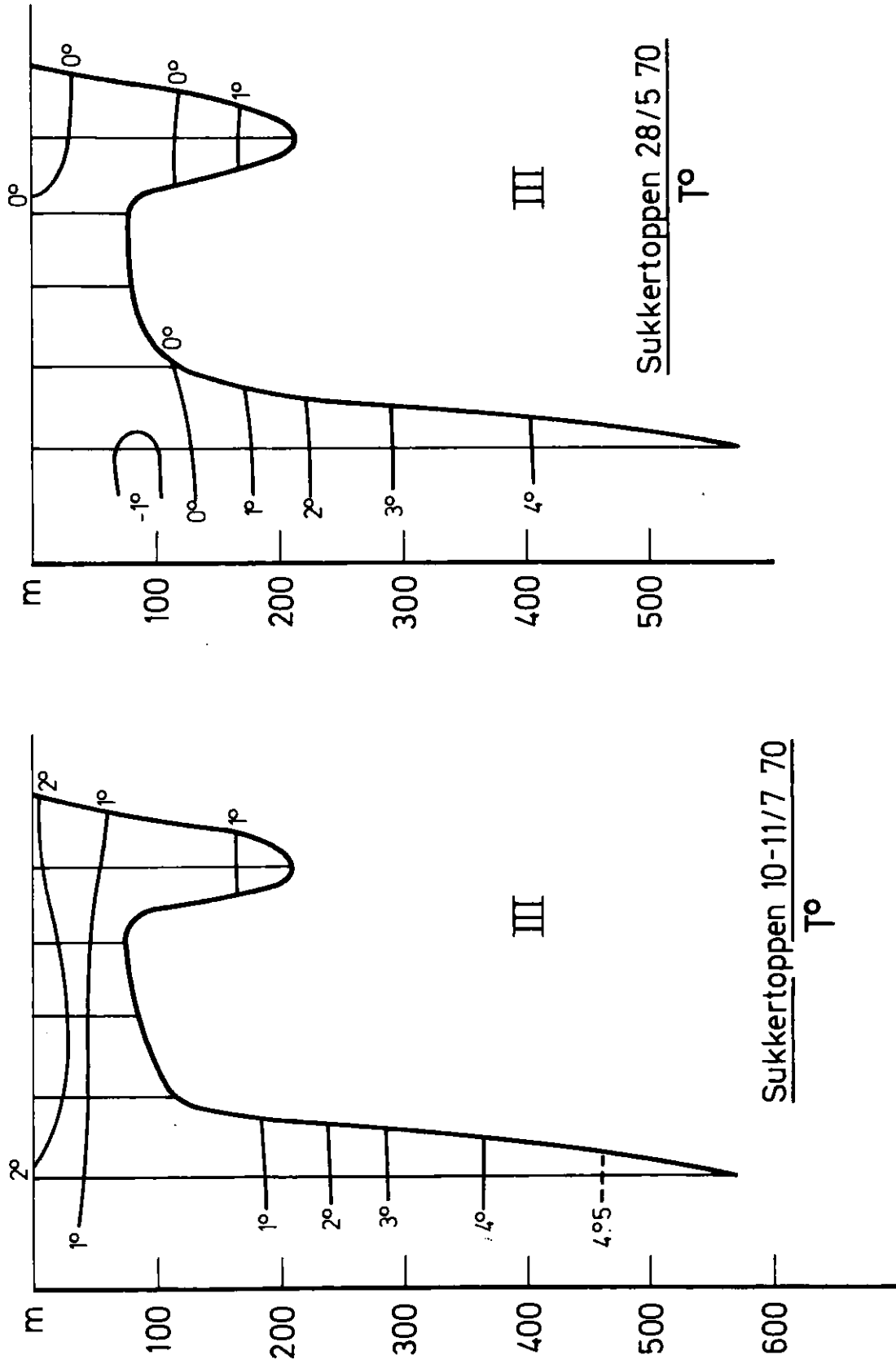
Fig. 7. Temperature sections across Lille Hellefiskebanke (III) in May and July 1970.
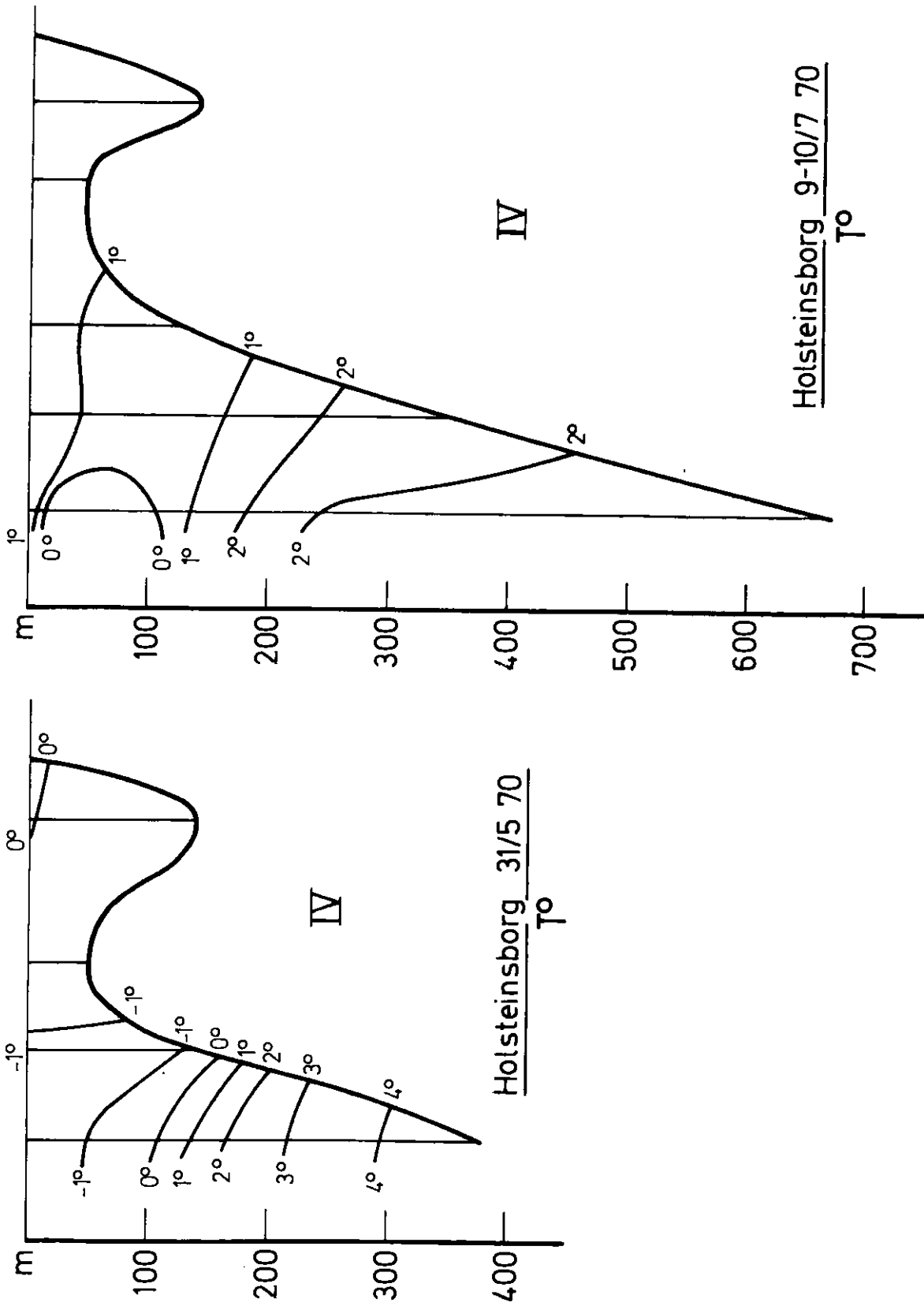
Fig. 8. Temperature sections across Store Hellefiskebanke (IV) in May and July 1970.
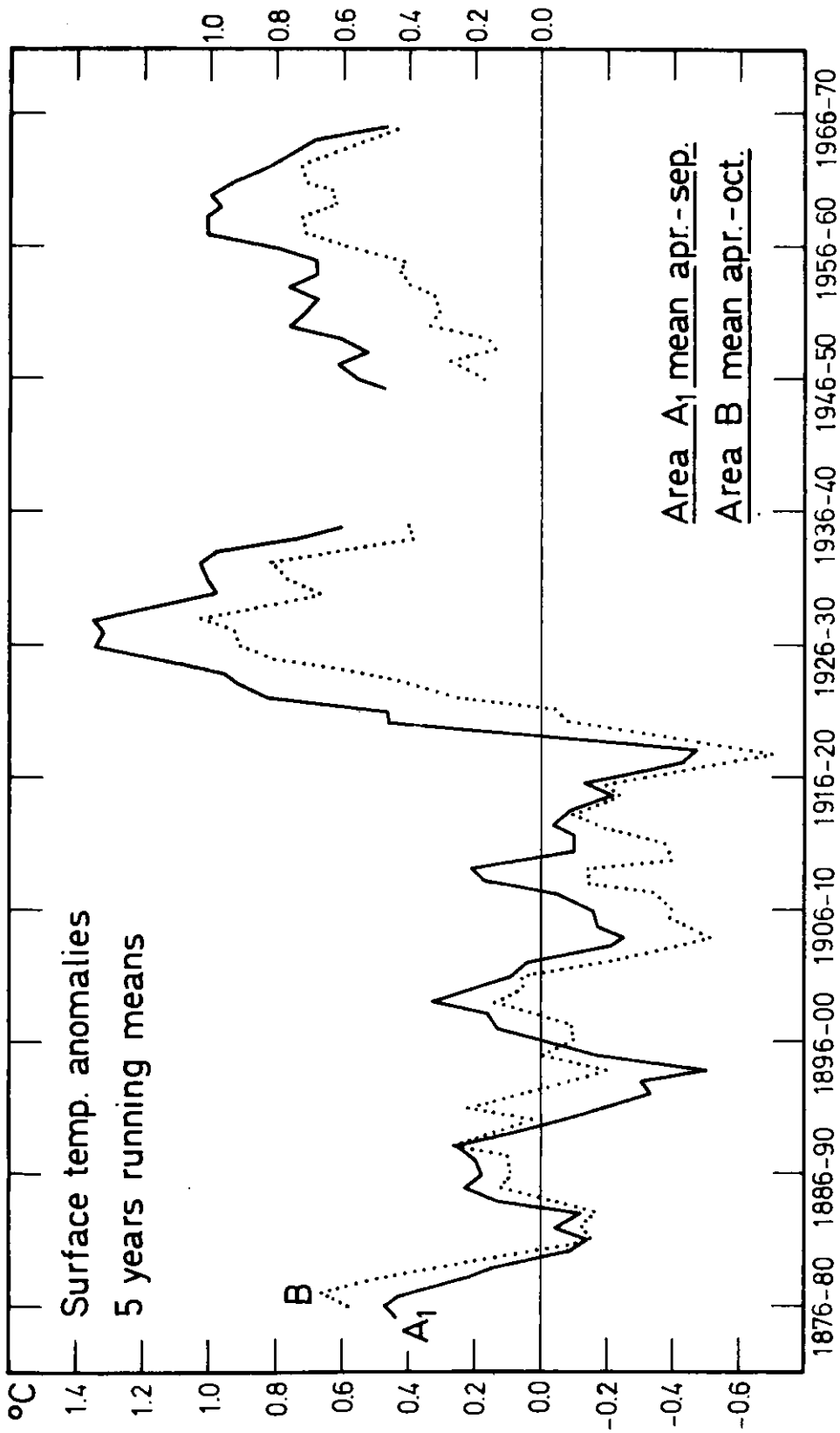
Fig. 9.   Sea surface temperature anomalies, 5-year running mean.
A₁ (solid line): West Greenland area.
B (dotted line): South Greenland area.

3. Environmental studies in ICNAF Div. 3P and 4V in spring 1970[1]

<div style="text-align:center">

by R. L'Herrou and J.P. Minet
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In spring 1970, R/V *Thalassa* completed a cruise in ICNAF Div. 3P and 4V to study the stocks of fish. During the cruise, various hydrographic observations were made. Temperatures were taken with bathythermograph from 0-300 m after each trawl haul. From 13-17 April, temperature and salinity measurements were made over a network of 28 stations. Conjointly, vertical plankton hauls were made.

A. Hydrographic conditions

I. Distribution of surface and near bottom temperature

At the surface (Fig. 1), cold waters of 1-2°C flow out of the Gulf of St. Lawrence and extend along the coasts of Cape Breton Island. A lobe of 2-3°C water spreads to the centre of the Laurentian Channel with an overlay of 5-6°C water rising from the bottom to the western slopes of Saint Pierre Bank. In addition, on the eastern plateau, 2-3°C water extends from the Newfoundland banks.

Near bottom (Fig. 2), as at the surface, there is a progression of Gulf of St. Lawrence waters along the shores and banks of Nova Scotia. South of Burin Peninsula, two cold lobes (0°C), resulting from mixing of waters from Labrador and Newfoundland, are found near the eastern part of Saint Pierre Bank and give rise to a very strong thermal gradient (1°-7°C) along the western slopes of the Bank.

II. Hydrographic sections - temperatures and salinities

Five sections containing a total of 28 hydrographic stations were occupied at the positions listed in Table 1 and referred to in Fig. 3.

At each station, Nansen reversing bottles were lowered to standard depths. Two hundred and fifty-eight temperature samples were taken, using Richter & Wiese protected and non-protected thermometers. Temperature corrections were made on board, using the Culbertson method. For salinity studies, 258 sea water samples, collected in duplicate, were analyzed in the laboratory using the Auto-Lab induction salinometer (Sydney, Australia).

1. Section I (Stations 04-08) - Burin Peninsula to the southern tip of Saint Pierre Bank (Figs. 4A and B)

Continental shelf waters consist of a surface layer which is slightly warmer in early spring (1.15-1.25°C) and an intermediate cold water layer of Labrador origin (0.88-0.95°C and 32.00-32.20°/oo) which spreads to Saint Pierre Bank without overflowing from the slope. In the channel separating the Newfoundland coast and the northern slope of Saint Pierre Bank, there is a residue of water which was formed in the winter with below 0° temperatures (-0.13 to -0.26°C) and higher salinities (32.20-32.50°/oo).

At approximately 140 m, a lobe of water of warmer and more saline gradient than surface and underlying waters (3.78°C and 33.59°/$_{oo}$) appears on the south shores of Saint Pierre Bank. Moreover, this water, arising from a mixture of intermediate slope and surface waters, sends a second lobe to the 75-m level at Station 08.

From 200-280 m, there is a very strong temperature gradient (5 degrees in 80 m) and salinity gradient (33.04-34.11°/$_{oo}$) which becomes slope water clearly influenced by warm open sea waters (7.0°C and 34.11°/$_{oo}$ at 300 m).

2. Section II (Stations 10-14 - South Banquereau Bank to South Saint Pierre Bank (Figs. 5A and B)

Again, a cold layer extends over Saint Pierre Bank (Section I) and here, overflows to the southeast slope of the Bank (-0.11 to 0.99°C at 75 m). Parallel to this are two lobes of intermediate slope water influenced by the Atlantic: the first is on the southwest slopes of Banquereau Bank (7.0°C and 34.72°/$_{oo}$) at 200 m; the second is on the southeast slopes of Saint Pierre Bank (7.84°C and 34.76°/$_{oo}$) at 220 m and extends to the centre of the Laurentian Channel (8.07°C and 34.60°/$_{oo}$) at 100 m. This warm water, therefore, enters the Laurentian Channel on the left and especially on the right of the section, thus isolating a mixture of colder water between 250 m and the bottom (6.00-4.50°C and 34.65-34.84°/$_{oo}$).

3. Section III (Stations 15-24) - Cape Breton to South Banquereau Bank (Figs. 6A and B)

Lying near the Cape Breton coast (Stations 23 and 24) is very cold and much less saline water (-1.00 to 0.0°C and 31.00-31.20°/$_{oo}$) produced from the Gulf of St. Lawrence and spreading southeast. An intermediate cold layer, warm at the surface, extends over the shelf to the shores at 100 m, without overflowing the slope (2.00-4.00°C and 32.50-32.70°/$_{oo}$). Between 150 and 250 m warmer intermediate slope water is observed, originating from the open sea and washing the southern slopes of Banquereau Bank (6.00-7.00°C and 34.00-34.50°/$_{oo}$); at 300-2,500 m, this water gives way to deep slope water whose temperature (4.50°C at 300 m, 3.50°C at 2,000 m) decreases and salinity (34.60°/$_{oo}$ at 250 m, 34.92°/$_{oo}$ at 300-2,500 m) increases with depth.

4. Section IV (Stations 25-29) - Across Laurentian Channel, north of Misaine Bank to north of Saint Pierre Bank (Figs. 7A and B)

As in Section III, a cold lobe (1.00°C and 32.00°/$_{oo}$) produced by the Gulf of St. Lawrence from a mixture of Labrador water and St. Lawrence estuary water spreads to the shores of Nova Scotia. In addition, water originating from the Newfoundland Banks is found on Saint Pierre Bank and in the middle of the Laurentian Channel, at 100 m. Above this cold intermediate water resulting from a successive mixture, there is a slightly warmer surface layer originating from the Newfoundland coast. Beneath this cold intermediate layer, the intermediate slope water is clearly evident on Saint Pierre slopes, at 200-250 m (6.95°C and 34.50°/$_{oo}$). This advance of water clinging to Saint Pierre Bank draws an accumulation of overlying waters (2.00-5.00°C and 33.00-34.00°/$_{oo}$) from the Nova Scotia shores. From 300 m to the bottom of the Laurentian Channel, deep slope waters are always present (5.14°C at 300 m and 4.54°C at bottom; 34.66°/$_{oo}$ at 300 m and 34.88°/$_{oo}$ at bottom).

5.   Section V (Stations 30-34) - Cabot Strait (Figs. 8A and B)

This section shows more clearly again the relative position of the different formations of water. As in Section IV, the outflow of Gulf of St. Lawrence water along the coast of Cape Breton Island is clearly apparent (-1.00 to 0.0°C and 3.00-31.50°/₀₀). Along the south coast of Newfoundland, to the right of the section, the 1.50°C isotherm and 31.80°/₀₀ and 32.00°/₀₀ isohalines show an accumulation of mixed water (Labrador and Newfoundland) which progresses towards the Gulf of St. Lawrence. Under the cold intermediate layer (1.50-3.00°C and 32.50-33.50°/₀₀), the advance of the intermediate slope water makes its influence felt up to this level, and also along the shores of Newfoundland (5.00-6.00°C and 34.00-34.50°/₀₀). Below 300 m, the deep slope waters (5.11-4.57°C and 34.72-34.89°/₀₀) are again found.

B. Zooplankton distribution

Vertical plankton hauls were made with a 72-cm diameter Hensen net which is raised from the bottom to the surface at 1 m/3 sec. A total of 133 stations were occupied. The volume of total plankton collected in each sample along with an inventory of eggs and larvae of fish collected were recorded.

I. Quantitative zooplankton distribution

Plankton volume was measured by displacement of filtered sea water (in $cm^3/10\ m^3$) using a distribution card (Fig. 9) which shows that, in the spring, all sections studied showed light concentrations of plankton. However, concentrations are heavier in some zones of the southern part of Saint Pierre, Banquereau and Misaine Banks.

In comparing plankton distribution with surface (Fig. 1) and near bottom (Fig. 2) temperatures, it is noted that zones with heavier concentrations are those with 0°-3°C temperatures, while zones with lighter concentrations are those with 3-6°C temperatures on the bottom and 3-4°C at the surface.

II. Inventory of fish eggs and larvae

The following table lists the eggs and larvae of fish which have been identified in the plankton samples:

Eggs		Larvae	
Species	No.	Species	No.
Gadus morhua (cod)	108	*Ammodytes dubius* (sandeel)	189
Hippoglossoides pl.		*Gadus morhua* (cod)	3
platessoides (American plaice)	375	*Sebastes m. marinus* (redfish)	138
		Sebastes m. mentella (redfish)	28
		Hippoglossoides pl. platessoides (American plaice)	13

No distribution table is given for the larvae of American plaice (*Hippoglossoides pl. platessoides*) as their number is too small. The distribution of eggs (Fig. 10) shows that the spawning, although of little importance, is found spread along the bank areas on either side of the Laurentian Channel in which there are few, if any, eggs found. The limited number of larvae taken confirms that the spawning from March-May, with a maximum in April, is of small magnitude.

Cod eggs are also scarce. This is explained by the fact that April is the end of the spawning period. On the other hand, only three larvae were taken which suggests that recruitment was very weak in the area studied.

Redfish larvae are fairly well represented if one considers that it is only the beginning of the reproduction period for both the *marinus* and *mentella* types of redfish.

Conclusion

Although these observations contribute to a better environmental knowledge of the area studied, they are nevertheless insufficient since they are limited to one time of the year.

In order to define all phenomena and to follow their development in time, a seasonal study will be undertaken beginning in July 1971 by R/V *Cryos* which is attached to the laboratory of l'Institut des Pêches Maritimes at Saint Pierre and Miquelon. The 28 stations presented here (Table 1) will provide a background for the study which will be complemented by 69 bathythermographs taken every 20 nautical miles. A plankton haul will also be made at each station.

Table 1. Positions of hydrographic stations.

Date	Section	Station	Latitude	Longitude
13.IV.70		04	46° 35' 5 N	55° 46' 7 W
		05	46° 10' 0 N	55° 47' 0 W
	I	06	45° 50' 0 N	55° 45' 0 W
14.IV.70		07	45° 25' 9 N	55° 44' 0 W
		08	44° 56' 1 N	55° 47' 0 W
		10	45° 11' 0 N	56° 05' 0 W
		11	45° 01' 0 N	56° 25' 5 W
	II	12	44° 47' 8 N	56° 44' 0 W
		13	44° 30' 5 N	57° 10' 6 W
		14	44° 23' 0 N	57° 26' 0 W
15.IV.70		15	43° 50' 2 N	57° 40' 0 W
		16	44° 05' 8 N	57° 55' 8 W
		18	44° 23' 0 N	58° 13' 0 W
	III	19	44° 40' 2 N	58° 30' 2 W
		20	44° 56' 2 N	58° 47' 0 W
		22	45° 12' 1 N	59° 03' 0 W
		23	45° 27' 8 N	59° 20' 0 W
16.IV.70		24	45° 44' 2 N	59° 36' 7 W
		25	45° 41' 0 N	58° 55' 0 W
		26	46° 04' 6 N	58° 14' 8 W
	IV	27	46° 17' 0 N	57° 53' 5 W
		28	46° 32' 0 N	57° 27' 5 W
		29	46° 56' 5 N	56° 45' 6 W
17.IV.70		30	47° 34' 1 N	59° 18' 7 W
		31	47° 29' 0 N	59° 26' 2 W
		32	47° 14' 7 N	59° 47' 0 W
	V	33	47° 06' 0 N	59° 59' 5 W
		34	47° 00' 6 N	60° 06' 7 W
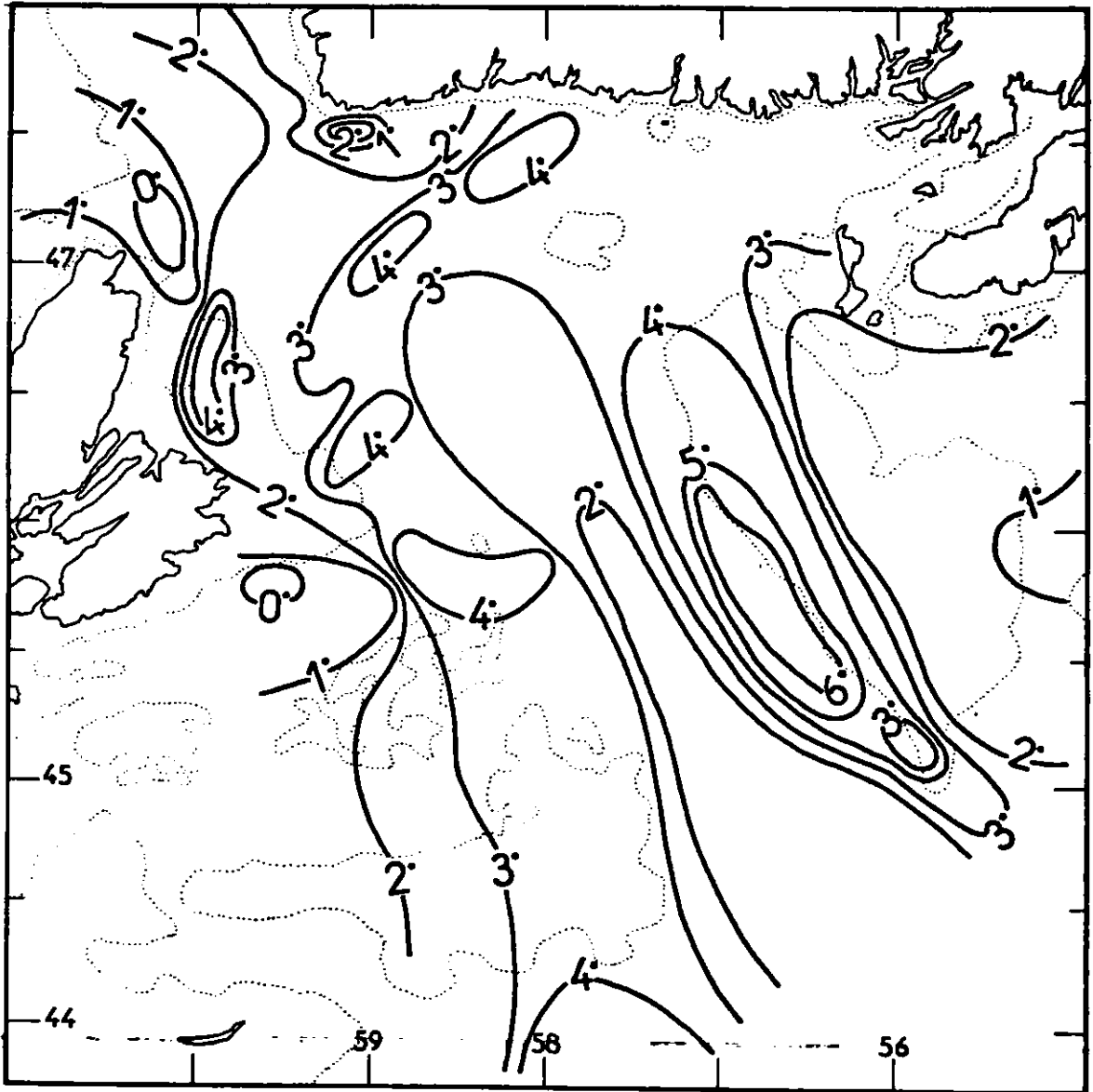
Fig. 1.   Distribution of surface temperature.
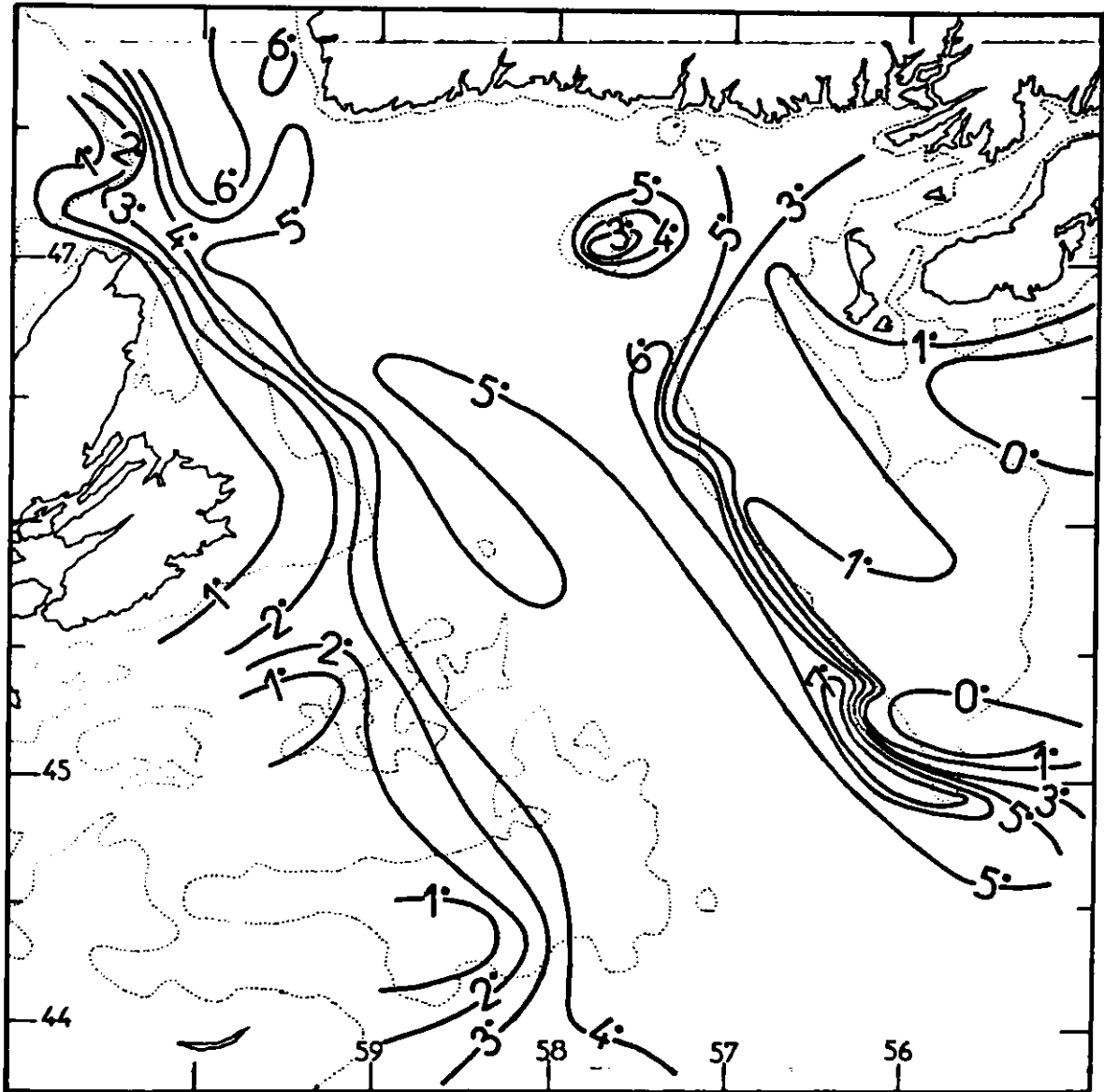
Fig. 2. Distribution of near bottom temperature.
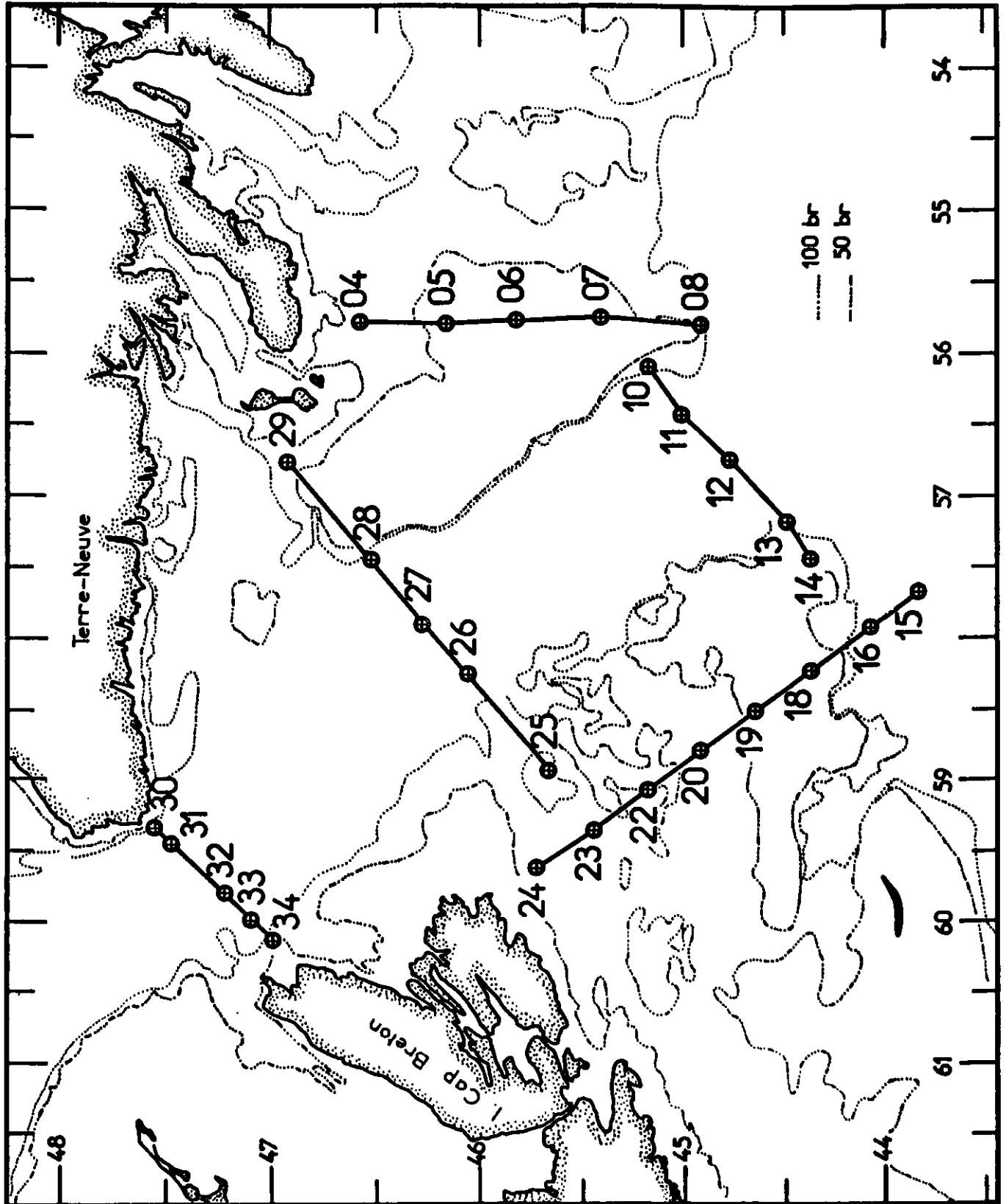
Fig. 3. Locations of hydrographic stations.
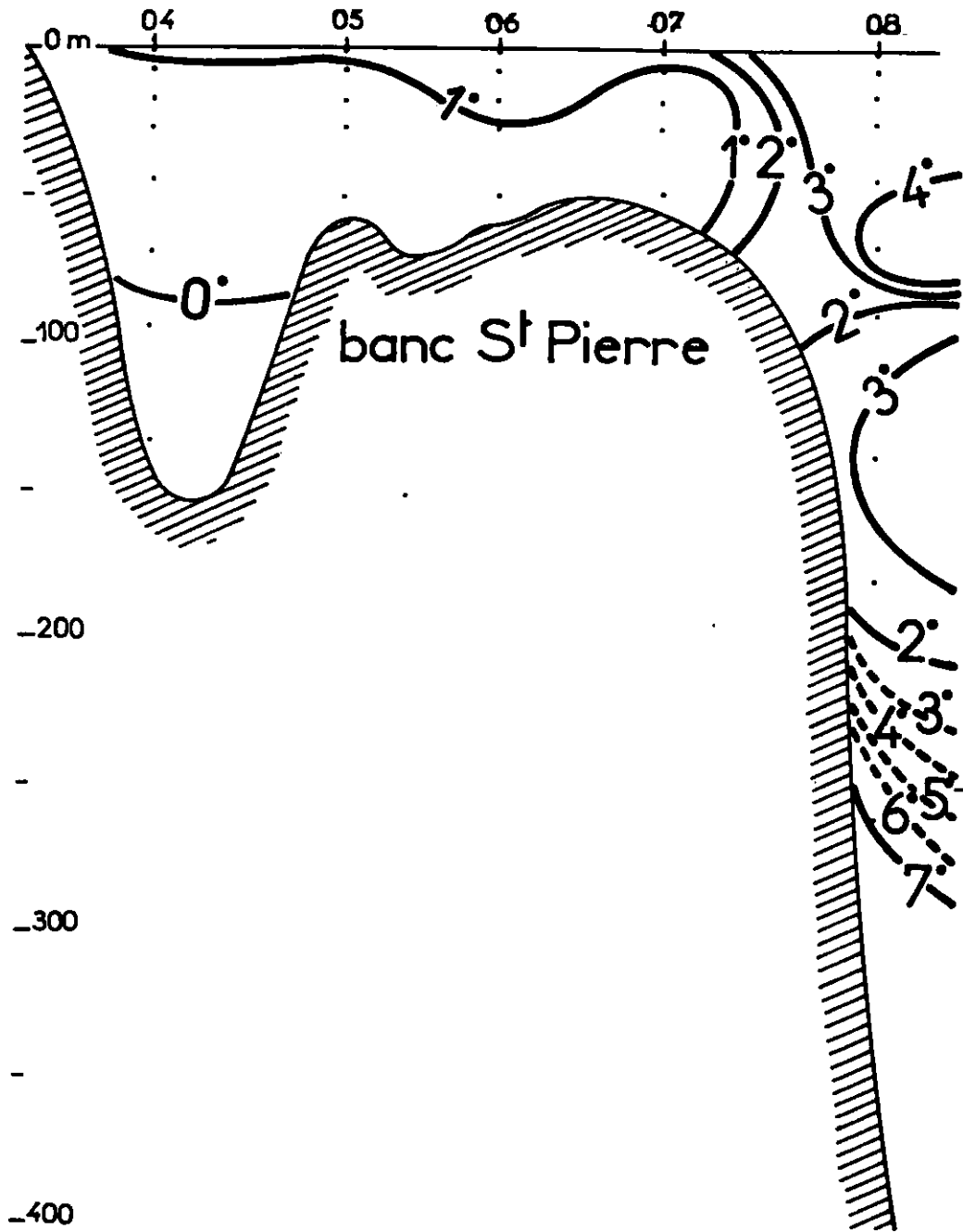
Fig. 4A. Temperatures – Section I – Burin Peninsula/South of Saint
Pierre Bank.
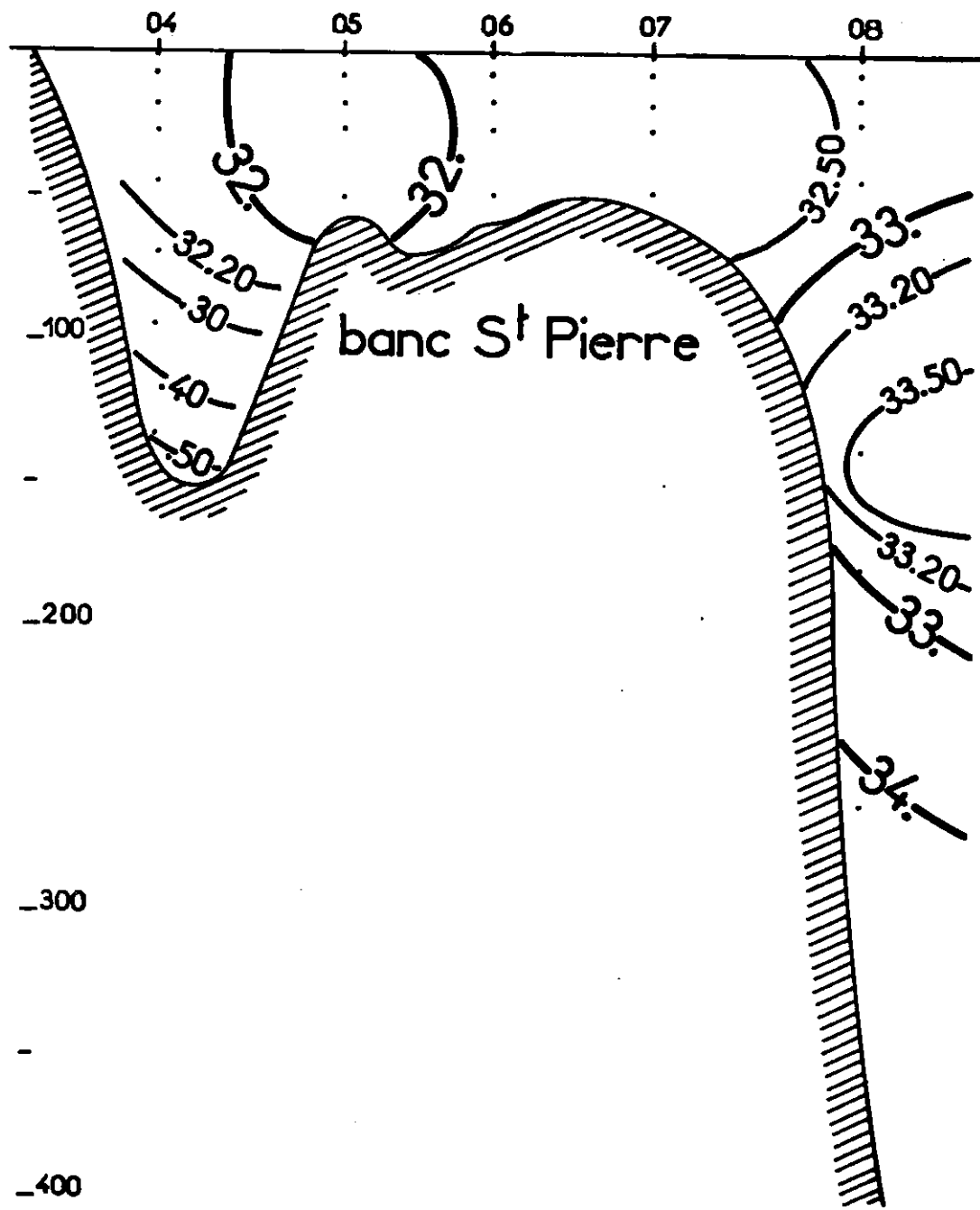
Fig. 4B. Salinities – Section I – Burin Peninsula/South of Saint
Pierre Bank.
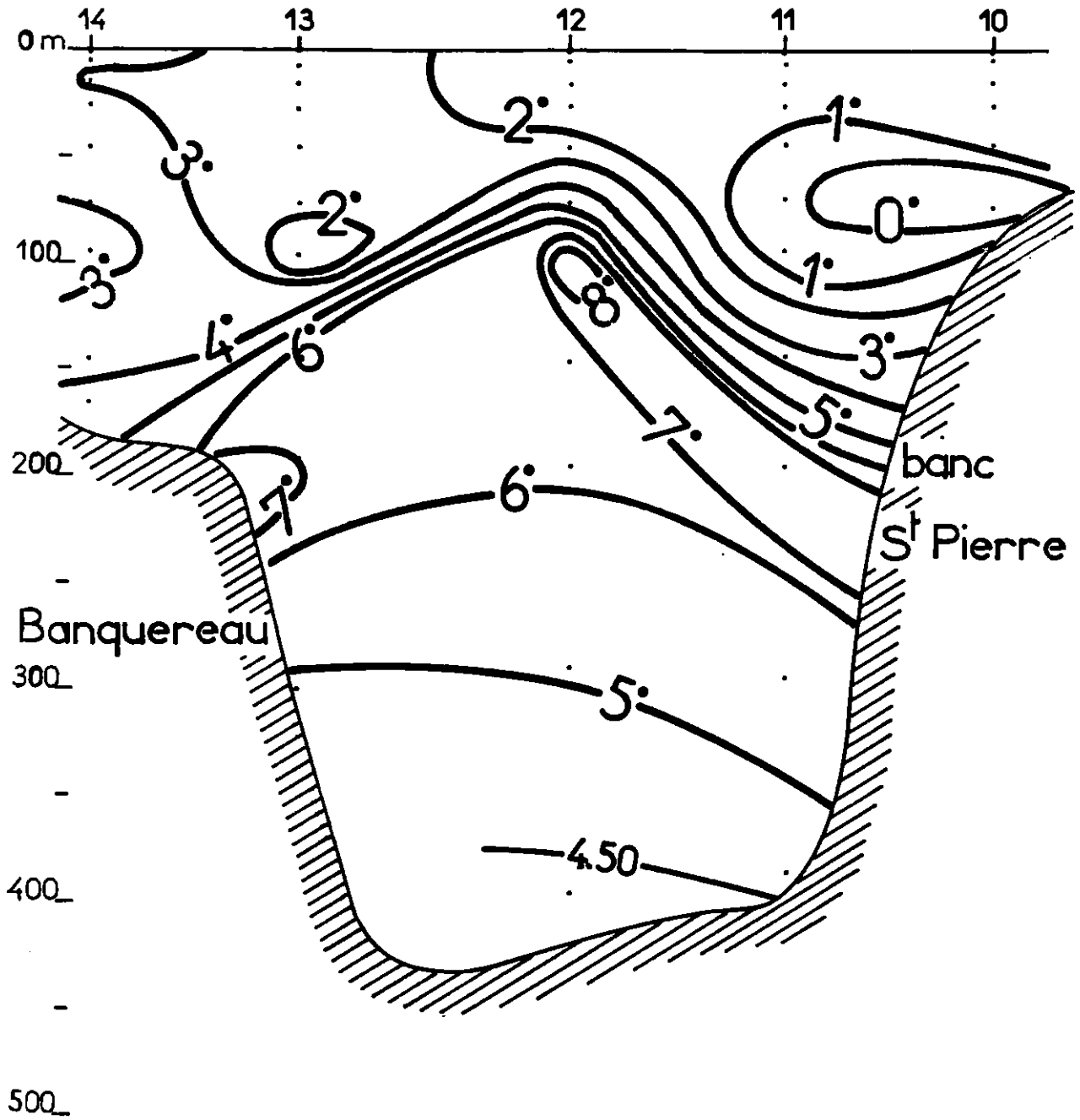
Fig. 5A.   Temperatures – Section II – South of Banquereau/South of
           Saint Pierre Bank.
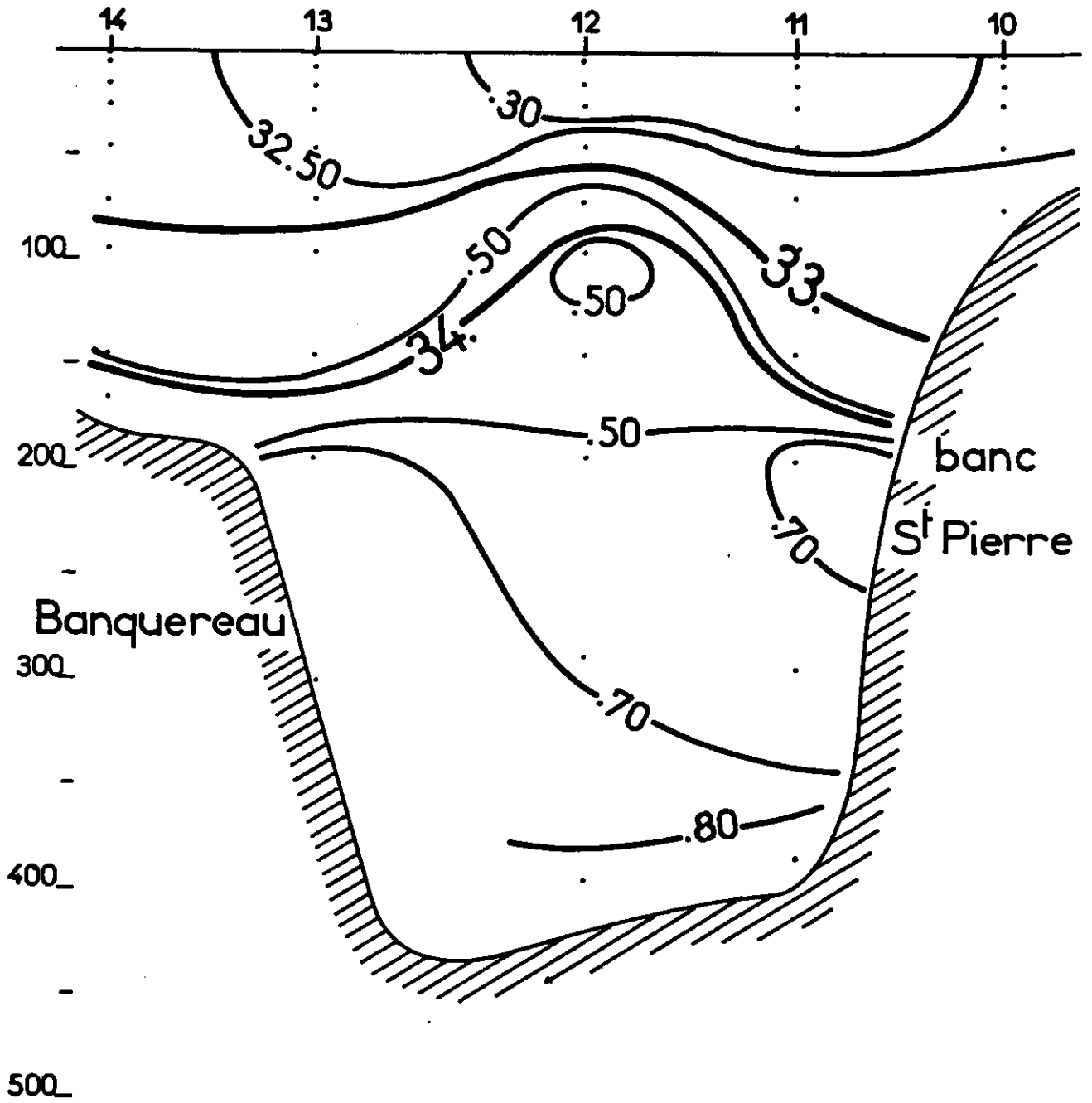
Fig. 5B. Salinities – Section II – South of Banquereau/South of Saint Pierre Bank.
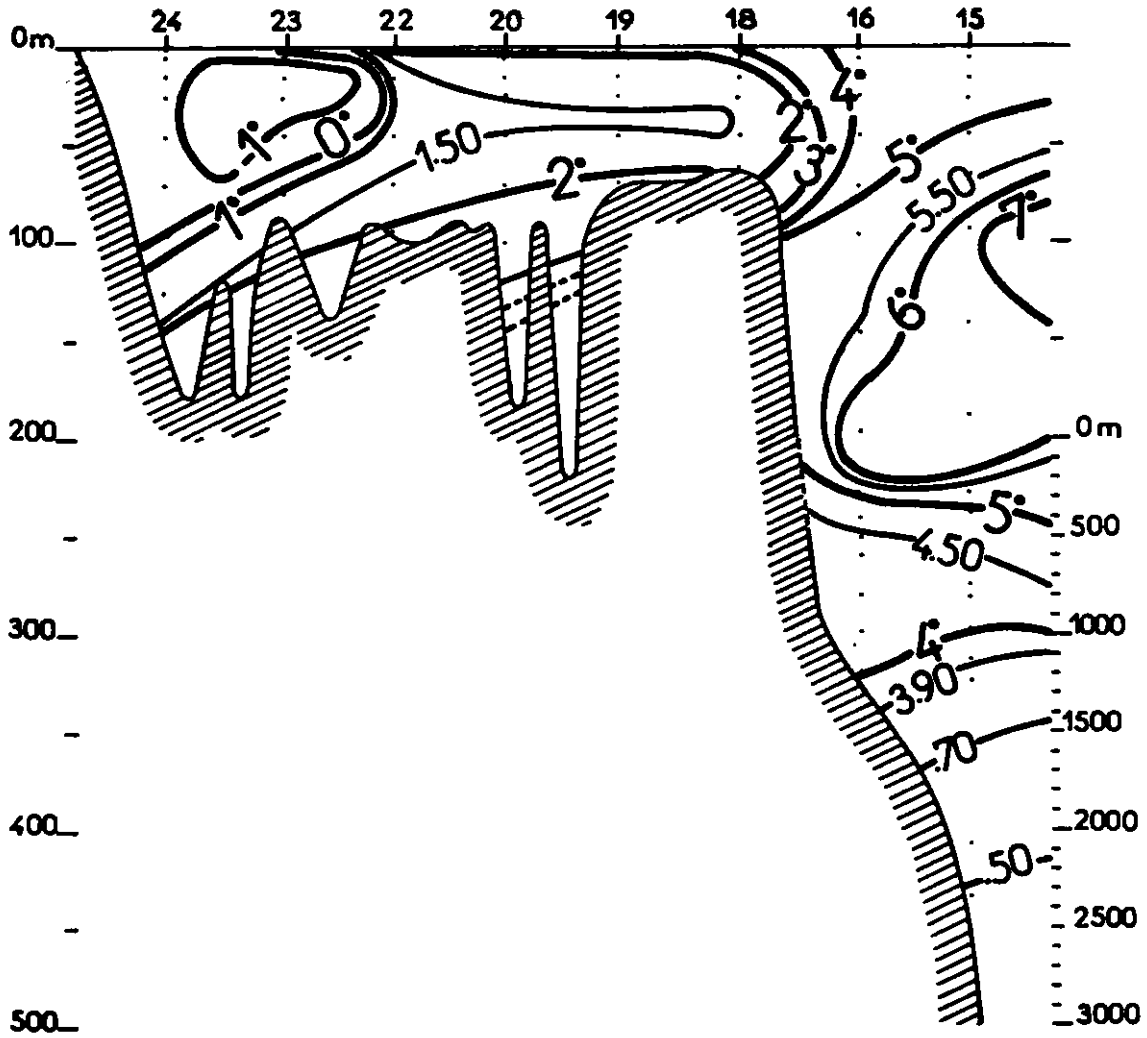
Fig. 6A. Temperatures - Section III - Cape Breton/South of Banquereau.
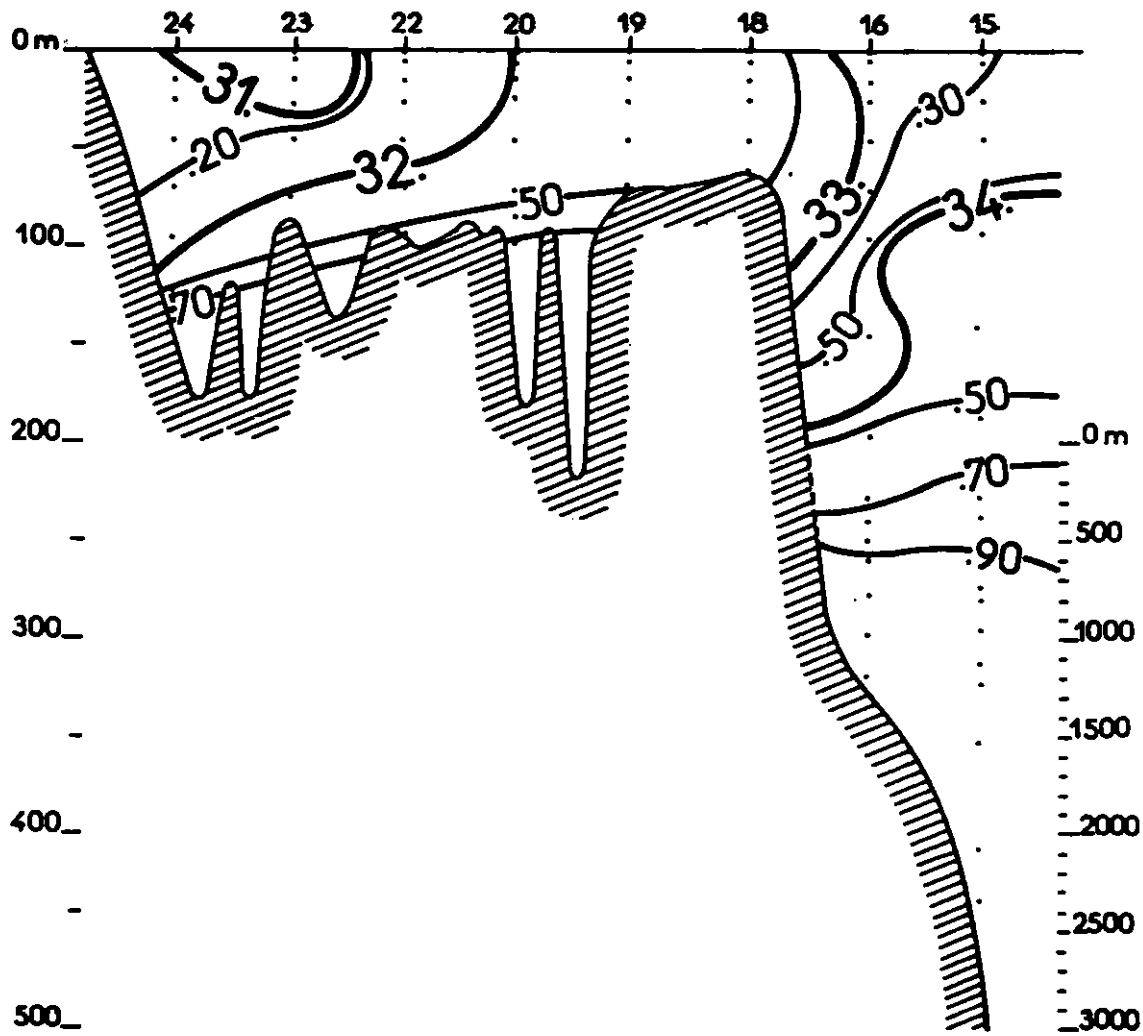
Fig. 6B. Salinities – Section III – Cape Breton/South of Banquereau.
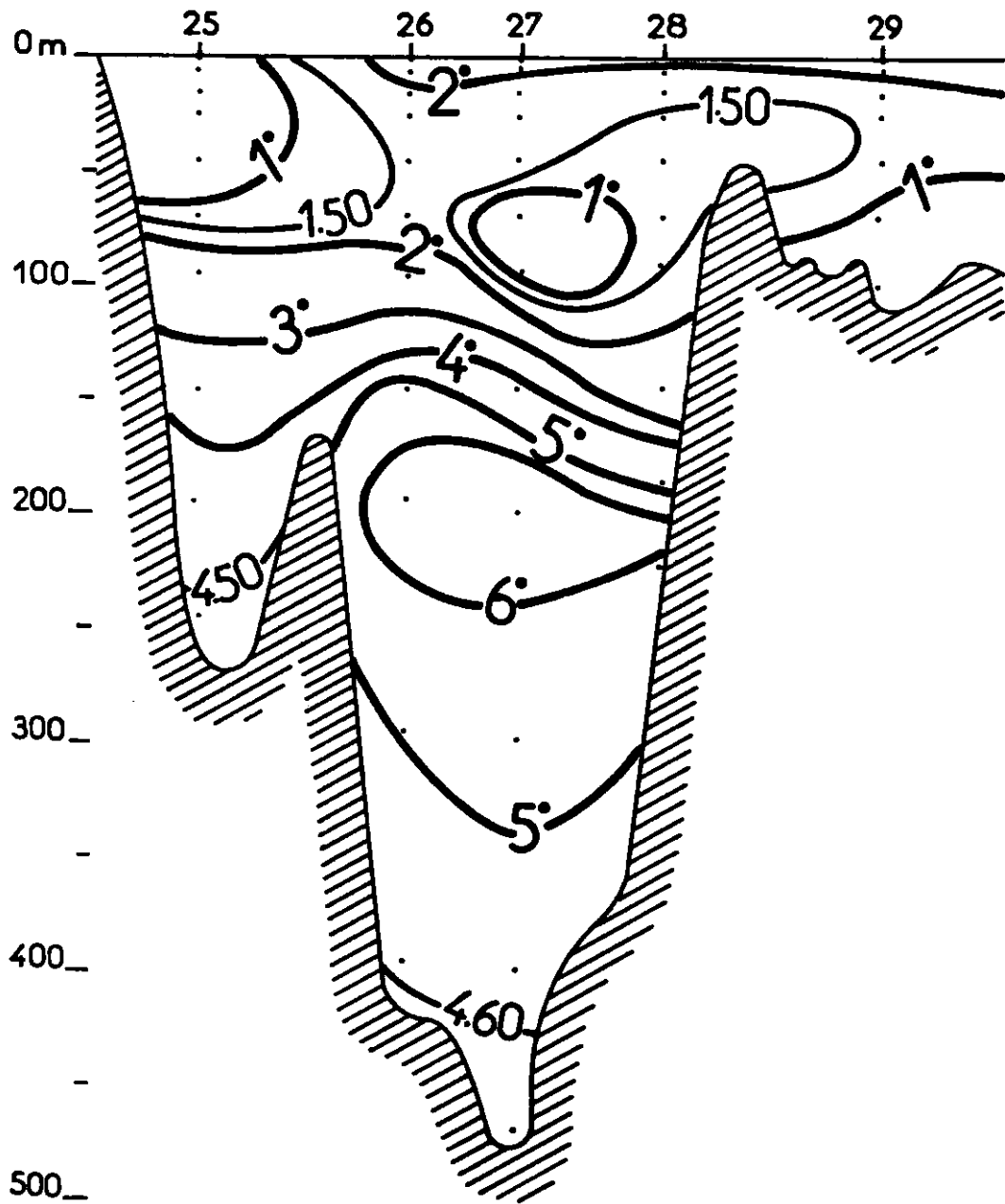
Fig. 7A. Temperatures - Section IV - North of Misaine Bank/
North of Saint Pierre Bank.
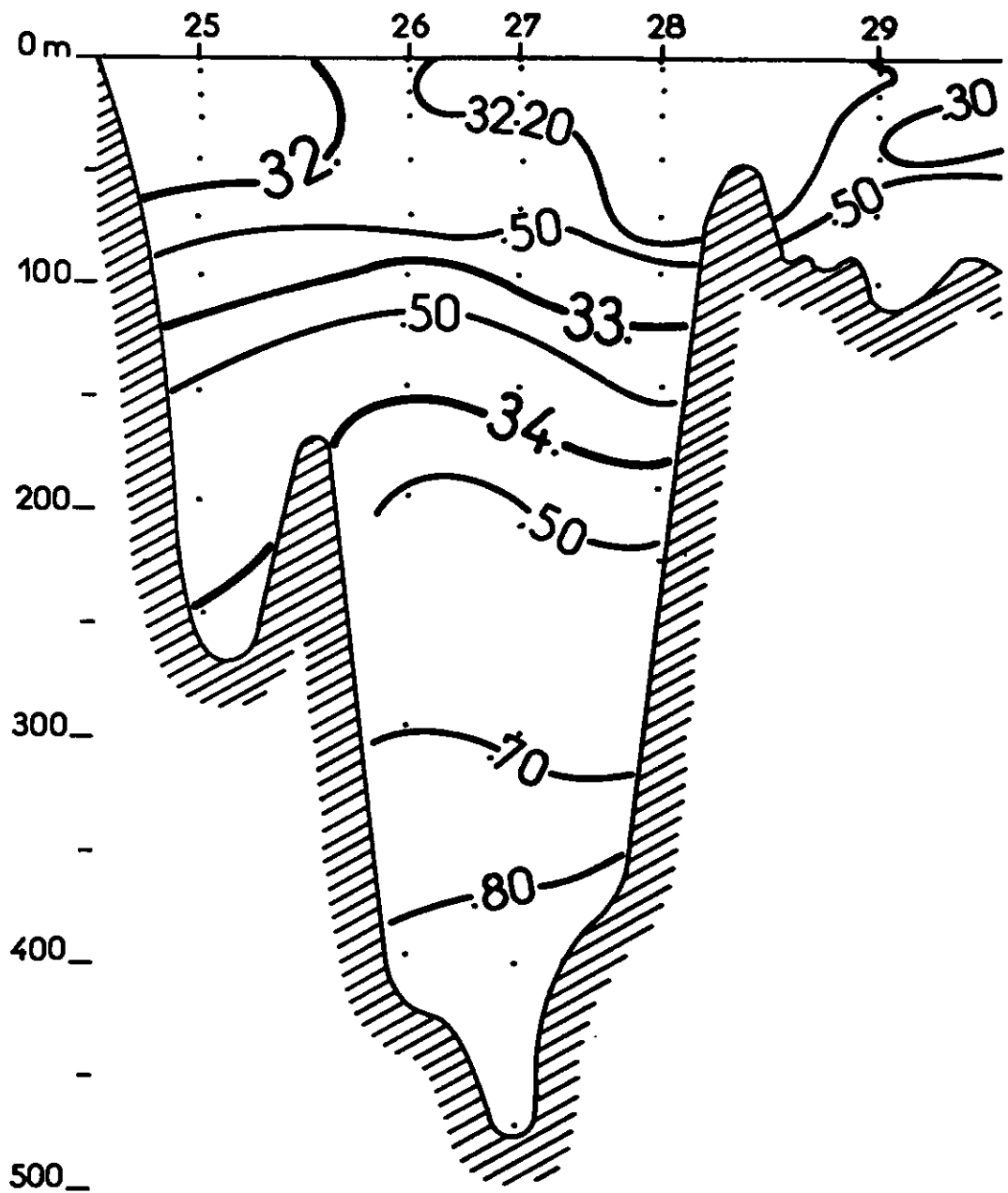
Fig. 7B.   Salinities - Section IV - North of Misaine Bank/
North of Saint Pierre Bank.
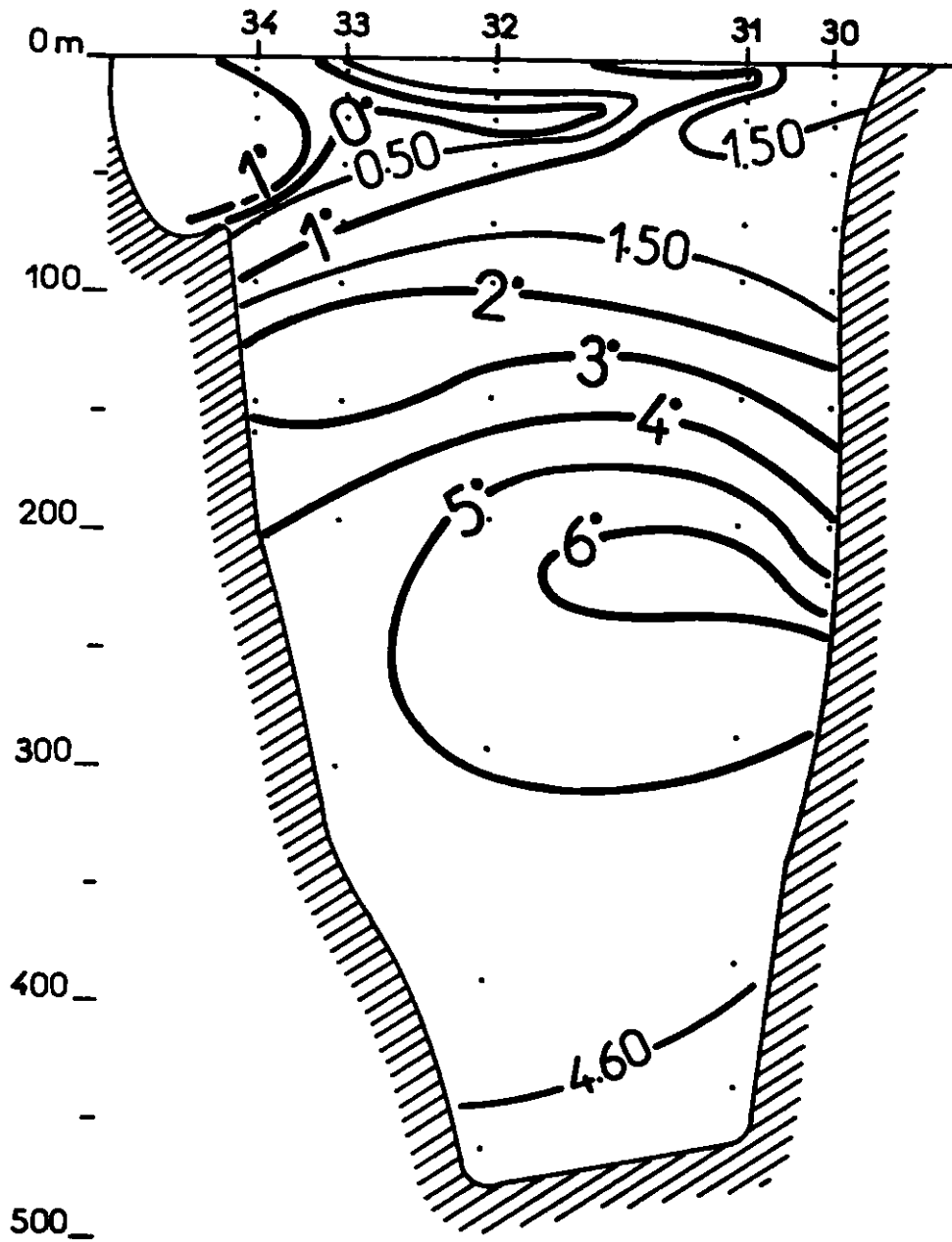
Fig. 8A.   Temperatures – Section V – Cabot Strait.
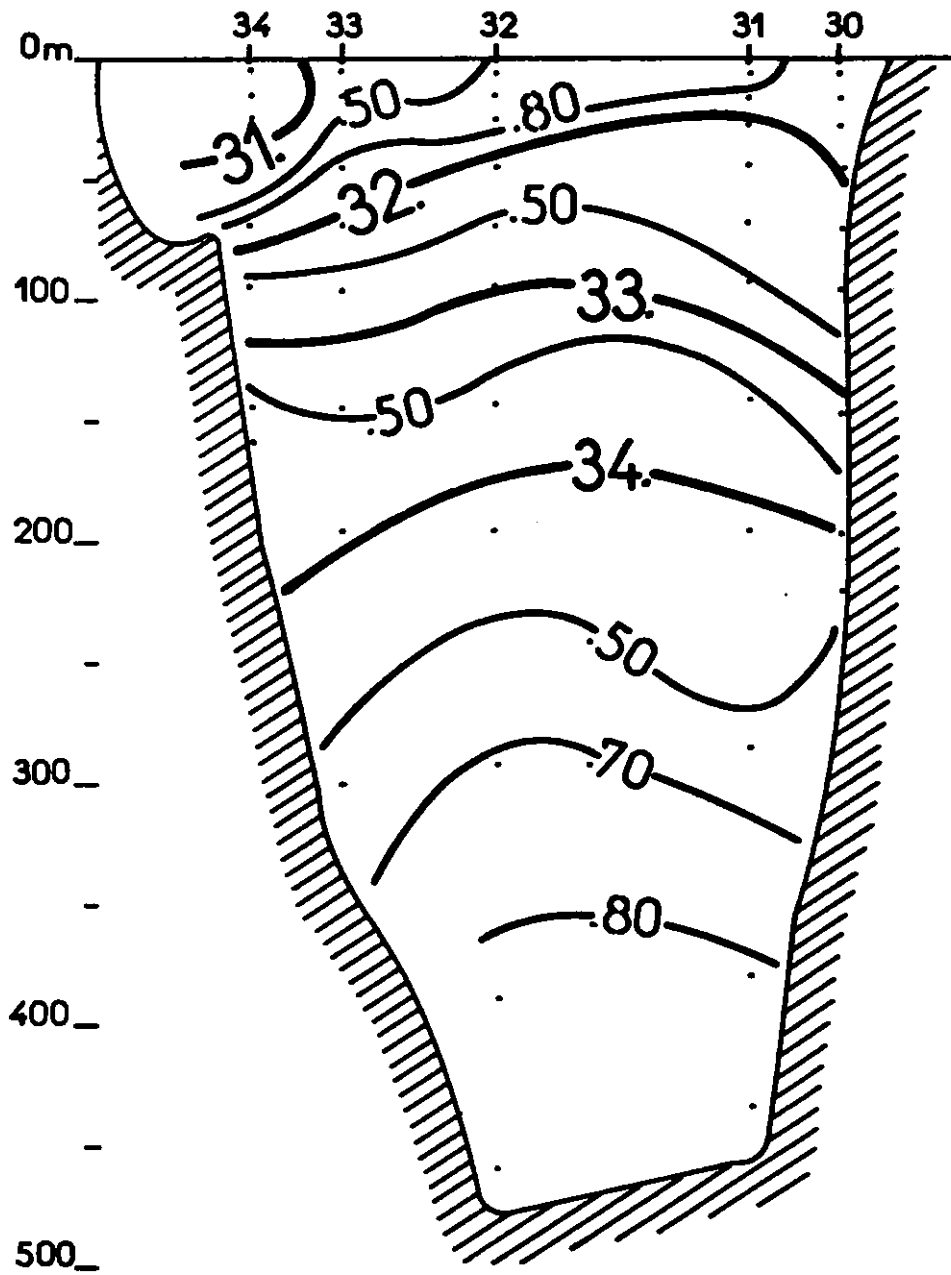
Fig. 8B. Salinities - Section V - Cabot Strait.
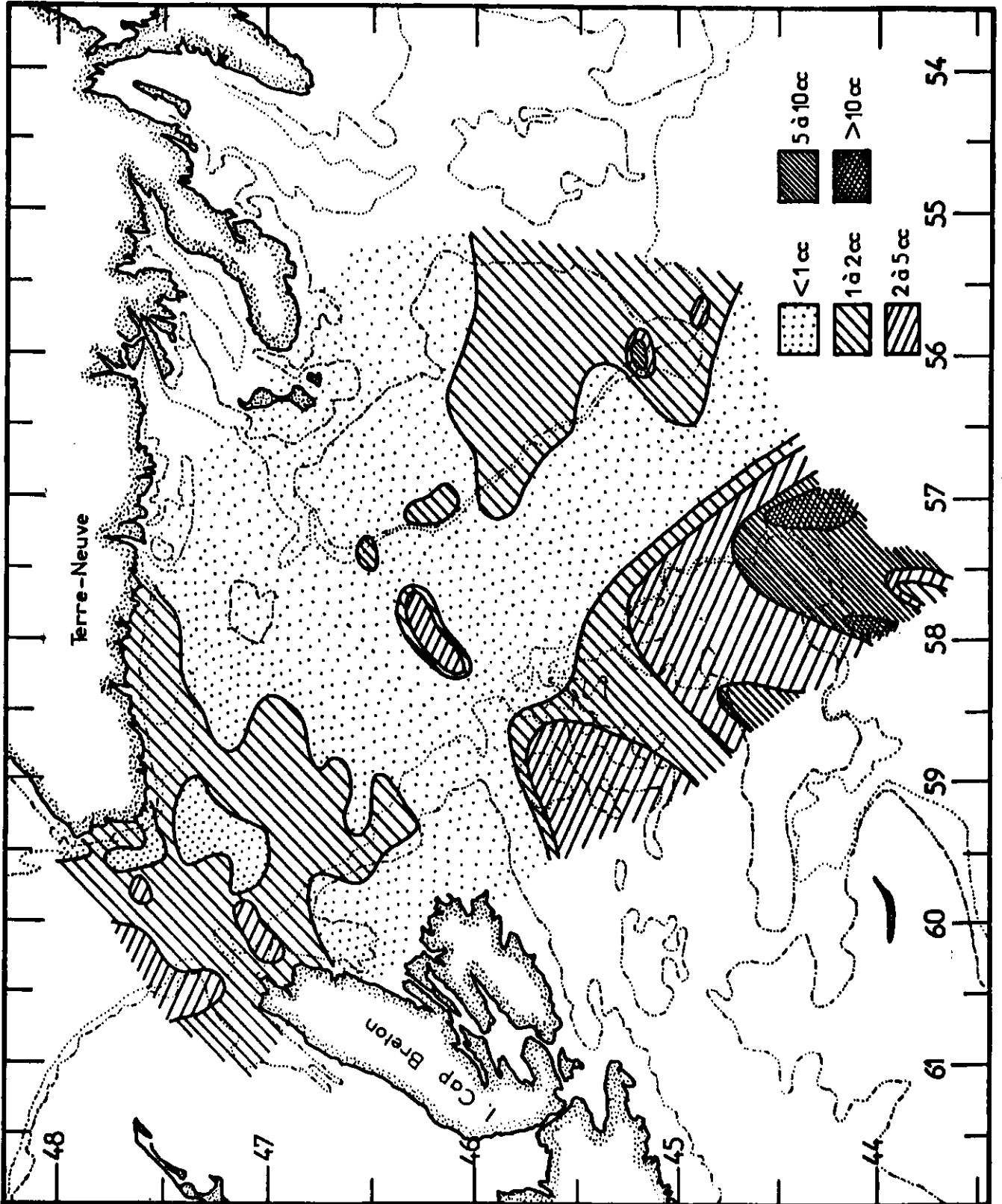
Fig. 9. Zooplankton distribution.

- 48 -
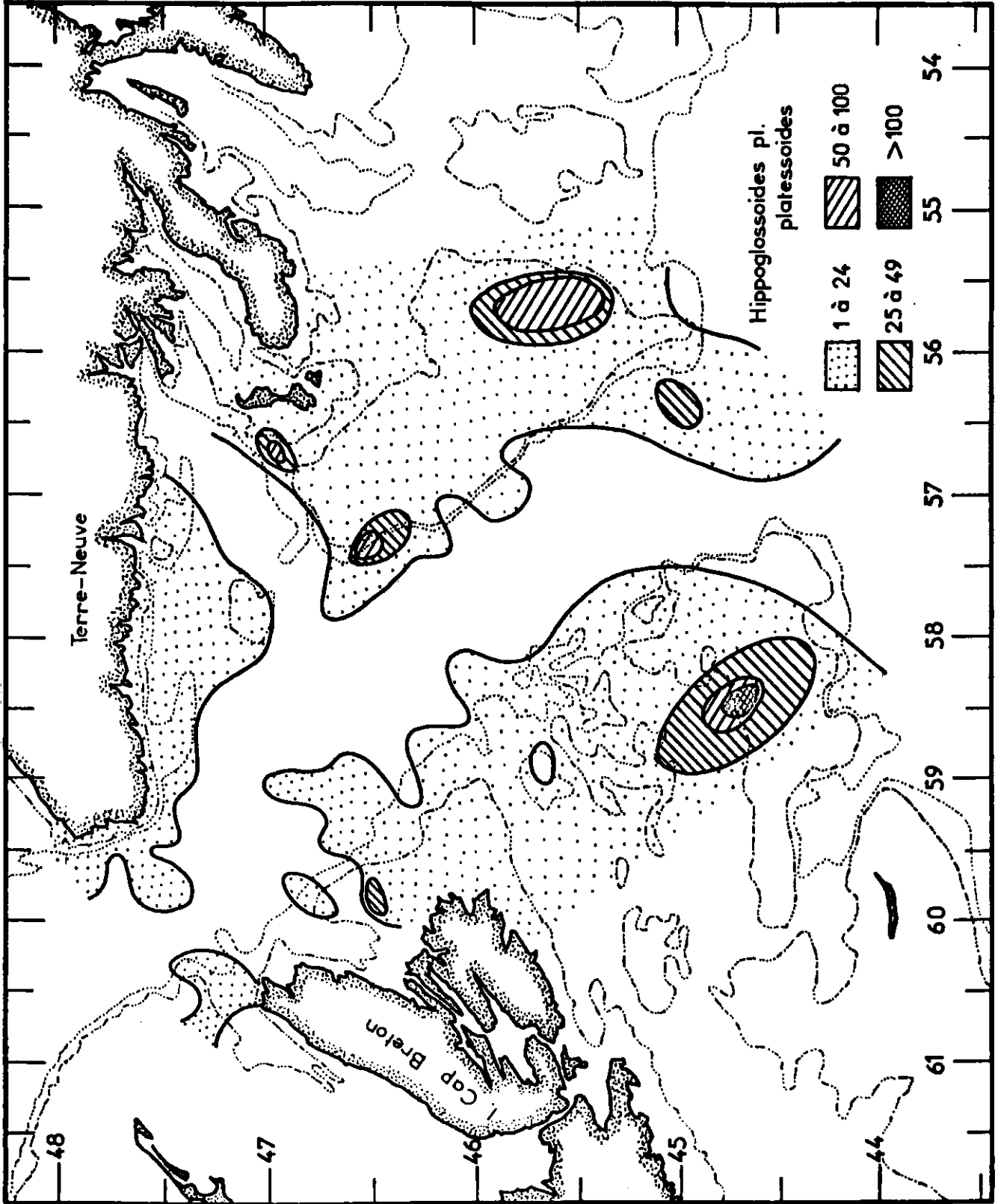
Fig. 10. Distribution of American plaice eggs: *Hippoglossoides pl. platessoides.* (No. of eggs/m² of surface).

4. Hydrographic conditions in the Northwest Atlantic in 1970[1]

by V.V. Burmakin and B.P. Kudlo
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In 1970 R/V *Perseus III*, *Rossiya* and *Protsion* conducted oceanographic research for PINRO in Subareas 1, 2 and 3. More than 1,100 hydrographic stations were occupied over standard sections during six cruises. The main portion of the hydrographic work was completed by R/V *Protsion*. Temperatures and salinities, as well as oxygen and phosphorus concentrations and other hydrochemical elements, were determined at most of the stations. Mean estimates of temperature and salinity on the sections for different water masses and branches of currents were calculated in the boundaries determined by Elizarov (1962) and Burmakin (1971).

Subarea 1

In August 1970, hydrographic investigations were conducted by R/V *Perseus III* in the northern part of Davis Strait between 62°30'N and 65°30'N (Div. 1C-1D). Treatment of the data obtained by means of the dynamic method showed that a secondary cyclonic vortex with low current velocities was located in the central part of the area investigated. This vortex developed on the northern periphery of the vortex of the Labrador Sea.

Comparison of the dynamic charts with charts of isotherms and isohalines obtained during the same survey shows good agreement between circulation, and temperature and salinity. The central part of the cyclonic vortex is characterized by the highest temperatures at all depths. The same result is obtained, if we compare the dynamic chart and distribution of salinity. At the surface in the area of the vortex it is above 33°/oo (the maximum is 33.28°/oo). The water temperature fluctuated here from 3° to 4.4°. Especially great is the similarity between the surface currents and the temperature at 100 m, where the influence of summer warming is insignificant. The 1° isotherm at this depth is nearly the same in pattern as the isolines of dynamic heights in the area of the vortex, with below zero temperatures over Tovqussaq Bank. It seems that the circulation field can be judged indirectly from observations of water temperature, and best from those at the 100-m level.

Estimates of discharge through Davis Strait on Sections 11-A and 10-A were also obtained by means of the dynamic method (Table 1).

The results seem to contradict the present point of view on water transport through Davis Strait from the Baffin Sea into the Atlantic. It is quite possible that the results of calculations of water discharge were affected by the fact that no observations were made in coastal waters. Nevertheless, the predominance of discharge through the Strait in the northern direction in August 1970 allows us to make a supposition concerning the availability of great fluctuations of water exchange through Davis Strait.

It is possible to estimate the temperature conditions on Lille Hellefiske and Fyllas Banks in August from observations made on Sections 10-A and 11-A.

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[1] Submitted to the 1971 Annual Meeting of ICNAF as ICNAF Res.Doc. 71/91.

Table 1. Water discharge through Davis Strait in August 1970.

Section	Date	Position	Discharge to the North	Discharge to the South	Total Discharge (to the North)
10-A	14-16 August	65°27' 64°59' 65°18' 54°69'⁻57°36'⁻60°47'	3.59	2.36	1.23
11-A	4-5 August	63°57' 63°03' 63°41' 53°08'⁻58°56'⁻62°30'	8.88	6.98	1.90

In Table 2, prepared by courtesy of I.I. Svetlov, these data are compared with data from observations made in previous years (though the data are not given for one and the same date).

Table 2 shows that the temperature of both components of the West Greenland Current was lower in Div. 1C-1D (Sections 10-A and 11-A) in August 1970, the 0-50-m layer being coldest in the years under consideration.

Table 2. Mean water temperature of the warm and cold components of the West Greenland Current by depth layers in some years and months.

Date	Section	Depths (m)						
		0-50		0-200		50-200		200-500
		warm comp.	cold comp.	warm comp.	cold comp.	warm comp.	cold comp.	warm comp.
3 August 1959	10-A	2.40	–	1.52	–	1.11	–	3.40
19 August 1963		3.82	–	2.62	–	2.20	–	3.32
8-9 August 1964		3.31	–	2.01	–	1.48	–	3.51
10-12 August 1967		3.08	–	1.38	–	0.56	–	4.14
14-16 August 1970		2.57	–	1.62	–	1.30	–	4.03
3 August 1964	11-A	4.09	3.96	4.24	3.55	4.25	3.36	4.90
16-18 August 1969		2.20	1.31	2.00	1.71	1.90	1.70	4.36
4-5 August 1970		1.95	1.48	1.48	1.05	1.29	0.98	4.06
13 September 1961	8-A	7.52	4.44	6.85	5.36	6.66	5.66	5.52
23-24 September 1963		4.26	2.02	5.63	3.24	6.14	3.76	5.59
1-2 September 1970		3.86	0.64	4.24	1.42	4.37	1.70	4.73
19-21 October 1962	8-A	6.32	3.44	6.12	4.16	6.06	4.52	5.04
30-31 October 1963		4.96	–	5.45	–	5.62	–	5.26
27-29 October 1964		6.61	4.84	6.53	5.21	6.52	5.38	5.39
16-19 October 1966		6.59	2.60	6.27	3.25	6.17	3.50	5.60
25-26 October 1970		2.82	0.13	4.07	1.18	4.49	1.55	5.13

According to data obtained from Section 8-A in September and October, temperatures 1-4° lower than in some previous years were also registered in Div. 1F.

As far as one can judge from such fragmentary data, water temperature in August-October 1970 was lowest on the West Greenland Shelf, as compared with the temperature for the same months in the years under comparison. Cooling was especially marked in the surface layer and tended to increase from August to the end of the year.

Subareas 2 and 3

Temperature

The comparative characteristics of temperature conditions for Subareas 2 and 3 in 1970 was shown by the mean temperature in the 0-200 m layer on standard hydrologic Sections 8-A, 7-A, 6-A, 4-A, 3-A, 2-A, 1-A, and 44-A. In Table 3, the temperature is given for each month when the observations were made. The deviation of each mean temperature from its annual mean estimate on the date of observation is also given. Curves of seasonal variations of water temperature of the 0-200 m layer for each section (jet, water mass) were constructed from all available data obtained by the research vessels of the Polar Institute and the International Ice Patrol (see the paper by V.V. Burmakin, ICNAF, 1971). These curves allow us to estimate the anomaly of the mean temperature on each section on the date of observation.

Table 3 shows that in January 1970 temperature anomalies in the 0-200 m layer were positive on all sections made on the Grand Bank and Cabot Strait and fluctuated from 0.06 to 1.94°. The highest anomalies were recorded on Section 1-A on the southwestern slope of the Grand Bank. A negative anomaly (-0.44°) on Section 2-A recorded on the southern slope of the Grand Bank was the only exception to these positive anomalies.

Beginning in February, the anomalies were negative or near the norm in the whole of the Subarea 3. This was observed to the end of August.

In Subarea 2 observations were made in May and showed a positive anomaly of +0.20° (Section 8-A, intercept B). In September positive anomalies were still found, but by the end of October negative anomalies (-0.04°) were observed in the main branch of the Labrador Current (B).

In autumn in Subarea 3 the anomalies were negative on the northeastern (Section 7-A) and southeastern (Sections 4-A and 3-A) slopes of the Grand Bank, whereas in the south (Section 2-A) and in Flemish Cap Channel they were slightly positive (+0.06).

In September positive anomalies were observed in Cabot Strait and on the southwestern slope of the Grand Bank (Sections 44-A and 1-A), but they were about 3 times smaller than those in January.

Thus, at the beginning of 1970, waters in Subareas 2 and 3 were warm, in spring and summer temperatures were below the norm and at the end of the year an insignificant warming was observed in the western part of Subarea 3, whereas the waters in the east of the Grand Bank became considerably colder. Evidently, this can be explained by the simultaneous increase of intensity of the Labrador Current, which caused the cooling on the eastern slope of the Grand Bank, and

of the Gulf Stream, that warmed the western part of the Bank.

Table 3. Mean temperature of the 0-200 m layer and its anomalies on standard sections in the areas of Labrador and Newfoundland in 1970.

Month	Section							
	8-A(B)	7-A	6-A(G)	4-A	3-A	2-A	1-A	44-A
JANUARY								
Date	-	-	3	7	9	25	12	17-18
t	-	-	4.01	3.95	0.79	1.43	6.39	3.50
Δt	-	-	+0.25	+0.83	+0.06	-0.44	+1.94	+0.72
FEBRUARY								
Date	-	-	-	-	11	-	-	-
t	-	-	-	-	0.32	-	-	-
Δt	-	-	-	-	-0.52	-	-	-
MAY								
Date	4-5	17	19	15	16	-	-	-
t	0.18	0.90	1.39	2.05	0.48	-	-	-
Δt	+0.20	-0.20	-0.21	+0.04	-0.28	-	-	-
JUNE								
Date	-	-	-	-	-	-	-	19
t	-	-	-	-	-	-	-	4.08
Δt	-	-	-	-	-	-	-	-0.33
JULY								
Date	-	-	-	-	-	14	20	-
t	-	-	-	-	-	2.95	6.00	-
Δt	-	-	-	-	-	-0.09	-0.20	-
AUGUST								
Date	-	4	9	-	-	-	-	-
t	-	0.99	1.96	-	-	-	-	-
Δt	-	-0.80	-1.29	-	-	-	-	-
SEPTEMBER								
Date	4-5	22-23	-	-	-	-	24	27
t	1.32	1.70	-	-	-	-	7.45	4.95
Δt	+0.50	-0.67	-	-	-	-	+0.69	+0.53
OCTOBER								
Date	30	-	6	10-11	12	20	-	-
t	1.36	-	4.39	2.94	1.49	3.06	-	-
Δt	-0.04	-	+0.06	-0.77	-0.48	+0.06	-	-

The temperature of the 0-200 m layer, on Sections 4-A and 3-A, adjusted for 15 May, and on Section 8-A adjusted for 1 November, was compared with the norm (Table 4). On Sections 4-A and 3-A the norms were calculated for the

period 1936-41, 1949-54, 1956-59, 1961-63, 1968-69, and on Section 8-A(B), for 1958, 1962, 1964-68, In our previous reports to ICNAF, the norms for Sections 4-A and 3-A were those accepted by Elizarov (1962).

Table 4. Mean temperature of the 0-200 m layer on Sections 3-A, 4-A on 15 May and 8-A on 1 November for 1968-70, as compared with the norm.

Year	3-A, 15 May			4-A, 15 May			8-A, 1 November		
	t °C	norm	Δt	t °C	norm	Δt	t °C	norm	Δt
1968	1.85	0.49	+1.36	2.25	1.71	+0.54	0.50	1.00	-0.50
1969	0.80	–	+0.31	3.46	–	+1.75	0.50	–	-0.50
1970	0.44	–	-0.05	2.05	–	+0.34	0.60	–	-0.40

On Sections 3-A and 8-A the mean temperature was calculated for the stations situated within the cold component of the Labrador Current, and on Section 4-A, for the stations situated in the frontal zone of the waters of the Banks, of Labrador and North Atlantic waters.

Table 4 shows that, in spring and autumn 1970 on Sections 3-A and 8-A in cold Labrador waters, the temperature was below the norm, whereas on Section 4-A in the Frontal Zone it was above the norm. Signs of the anomalies, determined by two methods, coincide (Tables 3 and 4).

Concerning the three-year period, 1968-70, in 1970 the temperature on the southeastern slope of the Grand Bank was lower by 0.20-1.41° and insignificantly higher in the area of South Labrador, than in 1968 and 1969 (Table 4).

A comparison of charts of water temperature distribution in the near-bottom layer on the Grand, Green and St. Pierre Banks for the last three years shows that the temperature at the bottom in 1970 was higher than in 1969 and considerably lower than in 1968.

Salinity

Observations carried out in the intercept B of Section 8-A give information on salinity of the main branch of the Labrador Current on the Hamilton Bank (Elizarov, 1962). Average values of salinity in the 0-200 m layer in the intercept B, calculated from data collected by the International Ice Patrol and USSR research vessels for the period 1936-57 (15 sections) are taken from Elizarov (1963), and for the period 1958-70 (45 sections) are calculated by us. The results of these calculations are inserted into the graph (Fig. 1) in accordance with the date of each observation on the section. The figure shows that the many years' data used by us do not give complete information on the yearly variation of salinity, due to the fact that no observations were made in some months. However, the curve of the yearly variation of salinity can be drawn with a certain degree of approximation. If we accept the given curve for the "norm", it is possible to obtain the anomaly of salinity for every case observed on the section for the actual date of observation. Such a method

of calculation of the value of salinity anomalies (as well as anomalies of other hydrological parameters) makes it possible to define the hydrological conditions of the year, even if the results from few observations made at different times are available in the given year. In Fig. 1 the upper and lower curves show the yearly variations of the extreme values of the mean salinity of the Labrador Current.

The method described was used to estimate the salinity of the Labrador Current in 1969 and 1970. Table 5 shows that in June 1969 the salinity of the Labrador Current was somewhat increased, and by the end of the year the negative anomaly reached $1/4°/_{oo}$. As noted by Templeman (1970) on 4 August 1969, the salinity on the Seal Islands-Hamilton Bank section at a depth of 30 m and more was almost always below the mean, being measured at different stations, but close to values obtained in the last four years, pertaining to the period 1951-65.

Table 5. Mean salinity value and its anomaly of polar waters of the Labrador Current in the 0-200 m layer in accordance with the observations in 1969 and 1970 on Section 8-A.

Date	$°/_{oo}$	$°/_{oo}$
27-31 July 1969	33.49	+0.10
17-19 December 1969	33.50	-0.25
4-5 May 1970	33.85	+0.07
4-5 September 1970	33.58	+0.15
30 October 1970	33.59	+0.04

Observations in 1970 show that in the spring to autumn period the salinity of the Labrador Current was somewhat above the norm or near it.

Conclusions

1.   The secondary cyclonic vortex, which developed on the northern periphery of the circulation of the Labrador Sea, separated the West Greenland Current from the Baffin Island Current in August 1970. High temperatures and salinities are characteristic of the zone of the vortex.

2.   From August to October water temperature on the West Greenland Shelf was the lowest for the last ten years. The cooling was most marked in the surface layer and evidently increased from August to the end of the year.

3.   In the beginning of 1970 positive anomalies predominated in Subareas 2 and 3, in spring and summer of this year negative anomalies prevailed; by the end of the year some warming was observed in the western part of the Grand Bank and some cooling in the eastern part, and slight cooling at South Labrador.

4.   As compared with the norm, the mean temperature of the 0-200 m layer on the eastern Grand Bank adjusted for 15 May, and at South Labrador adjusted for

1 November, had anomalies of the same signs when compared with the curve of
the yearly temperature variation. However, the values of the anomalies differed
considerably.

5. In May-August 1970 in near-bottom layers of Subarea 3, the temperature
was higher than in the same months of 1969 and insignificantly lower than in
1968.

6. From May to October 1970, salinity in the core of the Labrador Current
was somewhat higher than the norm.

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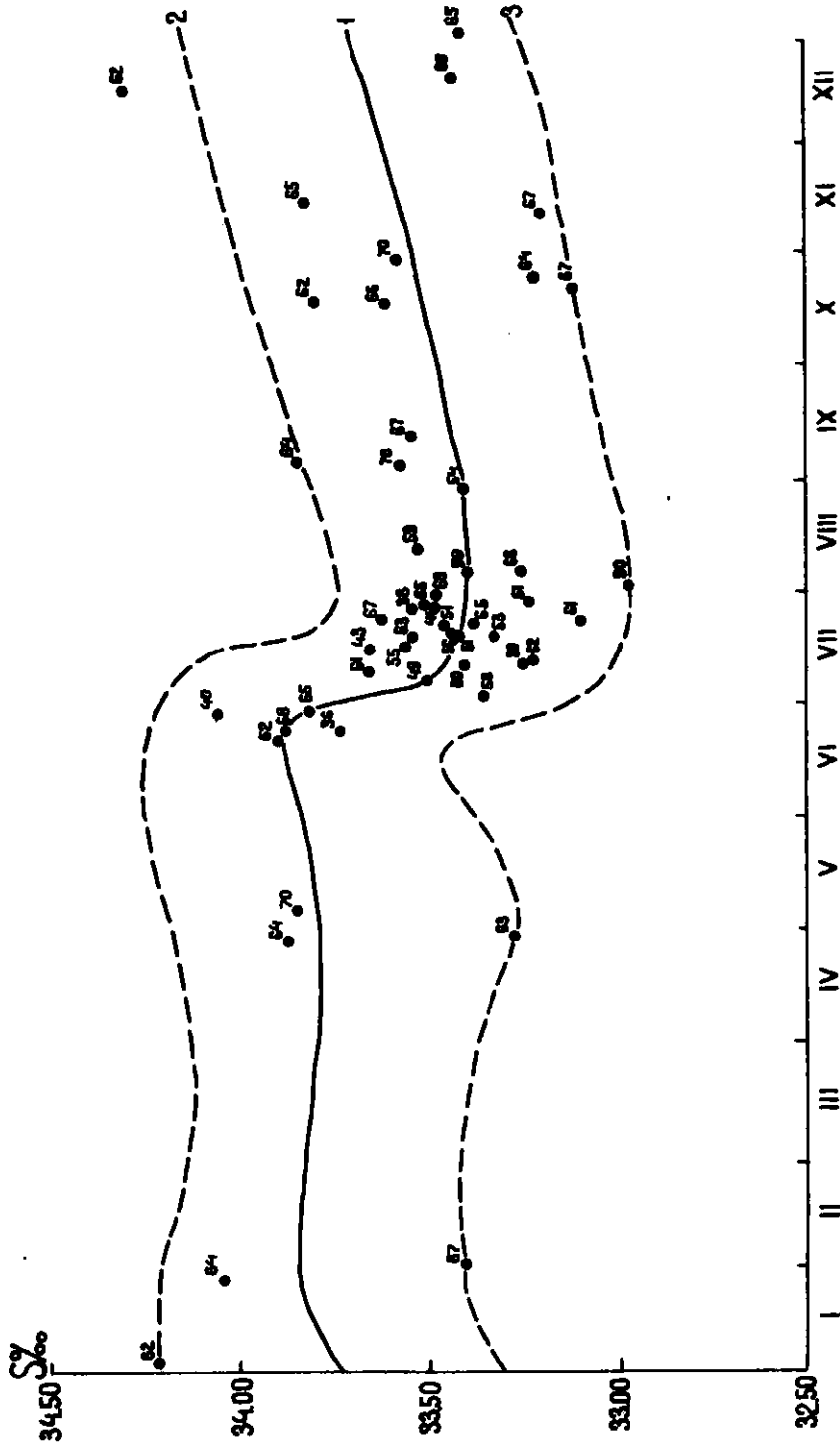
Fig. 1. Yearly variations of the mean (1) and extreme (2,3) values of salinity in the main branch of the Labrador Current on Hamilton Bank in the 0-200 m layer based on many years' data.

5. Selection of cod by polyamide trawl codends in ICNAF Div. 4Vn[1]

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Introduction

Recently the ICES/ICNAF Joint Working Group on Selectivity Analysis made an attempt to assess the effect of the physical properties of the netting yarns on the selectivity (ICNAF, 1970a and b). This attempt failed because until now very little data on the properties of the netting yarns used in selection experiments have been published. However, the Group thought that the elongation (extensibility) of the netting yarns is possibly one of the most important properties by which the selectivity might be influenced. Since this assumption was not yet substantiated scientifically, the Group proposed an international experiment to find out whether high elongation and high selectivity are positively correlated or not (ICNAF, 1970b, p. 4). Realizing that, in general, considerable time is needed for the preparation of such an international test, the Institut für Fangtechnik decided to start its own study of the relationship between elongation and selectivity already in the spring of 1970.

The cruise program also included the collection of selection data for a codend made of a definite polyamide netting yarn R 6,484 tex. According to a recommendation of the above-mentioned Working Group (ICNAF, 1970a, p. 49), this netting yarn has been introduced to replace manila as a new standard for selectivity purposes[2]. It was suggested "that, whenever possible, research vessels should use codends made of the new standard polyamide and collect selectivity data so that a large number of selection factors covering all species, seasons, areas, etc., be obtained as quickly as possible, ..." (ICNAF, 1970b, p. 4).

Another important item of the cruise program was the repetition of an experiment carried out with an extra strong codend in 1969 (Bohl, 1970). This experiment had shown that there is no significant difference between the selectivities of netting yarns of normal diameter and those which are unusually thick. Therefore, it was concluded that extra strong codends can be used to obviate the need for topside chafers. Since this is a matter of great consequence, it was thought advisable to confirm the result of the previous experiment by a second test.

Material and methods

The experiments were carried out during April 1970 on the Scotian Shelf between Cape Breton and Cape Smoky in depths ranging from 105 to 180 m (ICNAF Div. 4Vn). FRB *Walther Herwig* - a diesel-electric stern trawler of 83.23 m

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[1] Submitted to the 1971 Annual Meeting of ICNAF as ICNAF Res.Doc. 71/1.

[2] This applies to ICES only (C.Res. 1969/5:1,P.-v.Réun.Cons.int.Explor.mer 1969, p. 120). The Standing Committee on Research and Statistics of ICNAF has not yet adopted the new standard polyamide, but it recommended that the Subcommittee on Assessments examine the requirements for further selection experiments in relation to adoption of the new standard (Rec.18, *Redbook* 1970, Part I, p. 18).

total length, 1,987 gross tons, capable of developing 2,000 h.p.e. at 190 rpm
- used the German standard roundfish bottom trawl (140-ft groundrope).

The selectivities of four polyamide multifilament codends were studied.
Two of these codends have already been mentioned above, *viz.* those which are
made of the standard polyamide (R 6,484 tex) and the extra strong netting yarn
(R 17,465 tex[3]). The remaining two codends were procured especially to evaluate
the relationship between elongation and selectivity. The netting yarns of these
codends are made of one and the same kind and number of single yarns (article
no. N_t 3/500) and differ inasmuch as the yarn of the one codend is extremely
hard twisted (high twist factor) and untreated to produce a high elongation,
while the yarn of the other is medium twisted (low twist factor) and thermo-
fixed to produce a low elongation. In consequence of the different netting
yarn construction, there are also inevitable differences in some other physical
properties, *e.g.*, fineness, diameter and flexibility.

The properties of the netting yarns and codend nettings used in the experi-
ments were determined according to the ISO standards for testing methods. The
results are given in Table 1. The relation between load and elongation, which
is based on new netting yarns, is shown in Fig. 1.

During the experiments the covered codend technique was used. The topside
covers used were in accordance with ICES specifications. They were made of
single polyamide netting yarn (25 tex x 16 x 3, twisted), and the mesh opening
was about 60 mm. The inner underside of the codends was lined with small-
meshed netting similar to that of the cover.

The length composition of the catches was determined by measuring the
total fish length to the centimeter below. The mesh measurements were taken
immediately after each haul using an ICES gauge with an operating pressure of
4 kg.

In order to study the girth/length relationship of cod, the unconstricted
maximum body girth was measured to the nearest millimeter.

Results

During the course of the experiments a total of 51 successful hauls was
made. The catches, ranging from 0.6 to 6.1 metric tons, were of rather uniform
composition. Cod were always predominant; they represented in 32 hauls more
than 90%, in 12 hauls 80-90% and only in 7 hauls less than 80% of the catch
weights. The duration of tow varied from 30 to 120 minutes, but in most cases
(42 hauls), the trawl was towed for one hour.

The relative length composition of the total cod catch which consisted
of 66,258 specimens caught in the codends and 31,479 specimens caught in the
covers, is shown in Fig. 2. Fish of the 45.0-47.9 cm length-class were most
abundant. This fact proved extremely favourable for the experiments, because
the 50% retention length of the four codends used were found to be close to
the modal length of the fish aggregation. Thus, unusually large numbers of
specimens could be recorded within the selection ranges.

The selection data obtained from combined hauls are compiled in Table 2.

[3] The nominal fineness is R 18,000 tex.

Table 1. Information about codends and netting yarns used.

Codend no.	54	55	56	57
Material and type of fibre		Polyamide multifilament		
Construction of netting yarn of codend	Twisted	Plaited	Twisted	Twisted
Method of manufacture of codend		Double braided	Double braided	
		Hand-made		
Treatment of netting yarn of netting	Thermo-fixed	Untreated	Untreated	Thermo-fixed
Age of codend in fishing hours	55	35	0	0
Rtex (g/1,000 m)	6,484	17,465	6,588	5,655
Runnage (m/kg)	154	57	152	177
Diameter (mm)	2.9	≈ 7.0	3.1	2.7
Flexibility[1], wet (g)	48	246	375	30
Amount of twist in turns per meter (t/m)	74	—	100	62
Twist factor[2] $= \propto \text{tex} = t/m \times \dfrac{\sqrt{Rtex}}{1,000}$	188	—	256	147
Weaver-knot breaking load, wet (kp)	299	735	257	292
Breaking load, without knot, dry (kp)	355	854	254	306
without knot, wet (kp)	315	752	194	267
Breaking length, dry (km)	54.9	48.9	38.6	54.1
wet (km)	48.6	43.1	29.4	47.2
Knot breaking length, wet, 1/2 (km)	23.1	21.0	19.5	25.8
Elongation (%) at a load of				
5 kp	2.2	0.3	5.6	1.8
10 kp	4.3	1.1	9.1	3.3
30 kp	10.3	3.8	20.1	9.6
50 kp	13.9	6.2	25.7	13.1
1/2 weaver-knot breaking load, wet (kp)	23.8	21.0	38.8	21.5

[1] The flexibility (resistance against deformation) has been determined by means of the "Lötzener Method" described by v. Brandt and Carrothers (1964).

[2] The twist factor makes it possible to compare the amount of twist of netting yarns of different fineness.

Table 2. Compilation of cod selection data for grouped hauls.

Ship	FRV *Walther Herwig*, 83.3 m length o.a., 2,000 h.p.e.			
Gear	German standard roundfish bottom trawl, 140-ft groundrope			
Locality	ICNAF Div. 4Vn (off Cape Breton and Cape Smoky)			
Date	12-27 April 1970			
Experimental method	Topside cover of ICES specification			
Polyamide codend no. (comp. Table 1)	54	55	56	57
Designation	Standard	Extra strong	High elongation	Low elongation
R..tex	6,484	17,465	6,588	5,655
No. of hauls	18	15	12	6
Av. duration of haul (min)	59	58	63	70
Towing speed through water (kn)	4.7-5.3			
Depth range (m)	105-180	105-160	105-160	105-160
Type of mesh gauge	ICES gauge, 4 kg pressure			
Codend mesh size; mean ± s.e. (mm)	131.1±0.12	122.4±0.22	127.0±0.27	143.3±0.25
Range (mm)	121-144	109-134	112-144	132-158
No. of measurements	810	675	540	270
25-75% selection range (mm)	101	126	95	111
No. of cod in selection range				
Codend	5,680	6,912	5,532	5,968
Cover	5,225	5,803	5,353	6,663
Total no. of cod				
Codend	18,417	20,103	15,412	12,326
Cover	7,099	7,226	7,532	9,892
Av. quantity of cod/tow				
Codend (baskets)[1]	24 1/3	29 1/4	26 1/4	38 1/4
Cover (baskets)[1]	4 2/3	5 1/4	6 1/2	16 1/4
Av. quantity of by-catch[2]/tow				
Codend (baskets)	3 1/4	4 1/2	2 1/3	3
Cover (baskets)	1/2	1/2	1/3	3/4
Range of total catch/tow				
Codend (baskets)	10 1/4-56 1/4	10 1/2-76	5 1/2-43 3/4	24-59
Cover (baskets)	2-15 3/4	2-13 3/4	2 3/4-14 1/2	4 1/4-31 1/2
50% retention length (mm)	447	430	443	451
Selection factor	3.41	3.51	3.49	3.15

[1] The net weight of one basket filled with cod is about 68 kg.
[2] Mainly *Hippoglossoides platessoides*, skates and rays, *Sebastes* sp., *Glyptocephalus cynoglossus*; small quantities of *Clupea harengus*, *Melanogrammus aeglefinus*, *Pollachius virens*, *Anarhichas lupus*, *Cyclopterus lumpus*, and sporadically *Urophycis* sp., *Cottidae*, *Anarhichas minor*, *A. denticulatus*, *Hippoglossus hippoglossus*, *Reinhardtius hippoglossoides*, starfishes and sea-urchins.

The selection curves for combined hauls are shown in Fig. 3. They are based on smoothed percentages of retained fish (three-point moving averages). The curves are fitted by eye.

From Table 2 it can be seen that the extra strong codend gave a selection factor of 3.51, while the codend made of the standard polyamide yielded a factor of 3.41. Hence, the results obtained from the same codends in 1969 (Bohl, 1970) could be confirmed: there is no significant difference between the selectivity properties of extra strong and "normal" polyamide codends. This implies that the widespread use of such a robust codend as tested in the German experiments could be considered as a possible step towards the elimination of topside chafers.

As to the codends with different elongations (codend nos. 56 and 57), Table 2 appears to show that a low elongation is associated with a low selection factor, and *vice versa*: the selection factor of the netting yarn with 21.5% elongation was 3.15 and that of the netting yarn with 38.8% elongation was 3.49. However, taking into account that the two other codends used in the experiments were also characterized by low elongations (comp. codend nos. 54 and 55 in Table 1 and Fig. 1), and realizing that these codends gave selection factors of the same order of magnitude as the codend with the high elongation, it was rather doubtful whether the elongation was really the causative agent for the selectivity differences observed. Looking at all the data given in Table 2, it becomes obvious that the lowest selection factor obtained (3.15, codend no. 57, "low elongation") was based on the largest catches made during the tests. This suggests that this low selection factor could probably be attributed to catch size.

To look into this matter in more detail, an analysis of single hauls had to be made. Since cod were sufficiently numerous in most of the catches, reliable selection factors could be obtained for 44 individual hauls. Only with 7 hauls was it not possible to determine the selection factors quite precisely. These factors are queried in Tables 3-6, in which all the data are presented on a haul-by-haul basis.

In the following the unweighted mean selection factors calculated from single hauls are compared with the selection factors calculated from combined hauls.

Codend no.	54	55	56	57
Selection factor based on grouped hauls	3.41	3.51	3.49	3.15
Unweighted mean selection factor ± s.e. based on single hauls	3.44±0.03	3.50±0.05	3.50±0.05	3.16±0.02
Range of selection factors	3.28-3.65	3.16-3.78	3.27-3.80	3.10-3.25
Number of hauls	18	15	12	6

Table 3. Cod selection data for individual hauls; codend no. 54.

Haul No.	Date April 1970	Position	Depth (m)	Duration of haul (min)	Mesh size (mm)	50% Length (mm)	Selection Factor	Selection Range (mm)	No. of cod in Selection range		Total no. of cod caught		Quantity (baskets) of			
													Cod		By-catch	
									Codend	Cover	Codend	Cover	Codend	Cover	Codend	Cover
18	12	46°06'N 58°47'W	170—180	60	130.8	443	3.39	79	208	165	1,064	256	22 1/4	3	1 1/2	1
19	12	46°07'N 58°49'W	155	60	131.7	446	3.39	98	699	602	1,989	782	38 3/4	9 1/2	2 1/2	+
20	13	46°07'N 58°51'W	155	60	132.2	445	3.37	113	442	427	1,087	498	22	5 1/2	2	1/4
21	13	46°09'N 58°49'W	165	60	132.1	442	3.35?	107?	326?	261?	1,495	361	31 1/4	5	2	1/2
22	13	46°08'N 58°47'W	175	60	131.3	479	3.65?	97?	77?	75?	389	111	12 3/4	2	1 1/2	1/2
23	13	46°08'N 58°49'W	155	60	131.5	443	3.37	?	?	?	1,231	286	28	3 1/2	1 1/2	1/2
24	13	46°08'N 58°49'W	155	60	131.2	441	3.36	82	116	90	1,046	161	27 1/2	2 1/2	1 1/4	1/4
68	24	46°43'N 59°40'W	140—150	60	131.3	449	3.42	?	?	?	2,579	1,262	53	15	3 1/4	3/4
69	25	46°44'N 59°43'W	120	65	131.1	456	3.48	69?	404?	390?	1,661	665	39 1/2	8	3	1/2
70	25	46°44'N 59°42'W	140	60	130.7	457	3.47?	96	225	180	1,318	278	40 3/4	3 1/4	2 1/2	1/4
72	25	46°40'N 59°37'W	120—110	60	130.5	428	3.28	136?	248?	204?	936	378	21 1/4	3 1/2	3 3/4	1/4
73	26	46°44'N 59°44'W	110	60	130.8	435	3.33	87	297	287	738	403	13 1/4	4 1/4	3 3/4	1/4
74	26	46°43'N 59°41'W	140—130	60	130.9	461	3.52	98	218	202	700	299	21	3 1/4	3 3/4	1/2
75	26	46°43'N 59°42'W	130—145	60	130.8	462	3.53?	77	163	217	553	371	13 3/4	4	3 1/2	1/4
76	26	46°43'N 59°51'W	120	60	130.8	474	3.62	67	100	110	318	311	8	3 1/2	2 1/4	1/2
78	26	46°41'N 59°39'W	110	45	130.8	449	3.45	86	130	161	404	270	20	2 3/4	3 1/4	1/4
79	27	46°16'N 59°16'W	105—115	60	130.8	434	3.31	71	110	130	569	240	14 1/4	2 3/4	3 1/4	3/4
80	27	46°14'N 59°07'W	120	60	130.7	467	3.5?	85	74	81	340	167	11 1/2	1 3/4	3 1/2	1/4

- 63 -

Table 4. Cod selection data for individual hauls; codend no. 55.

Haul No.	Date April 1970	Position	Depth (m)	Duration of haul (min)	Mesh size (mm)	50% Length (mm)	Selection Factor	Selection Range (mm)	No. of cod in Selection range Codend	Cover	Total no. of cod caught Codend	Cover	Cod Codend	Cover	By-catch Codend	Cover
43	17	46°18'N 59°23'W	120-115	60	122.7	393	3.20	99	494	382	1,222	528	19 1/4	4 1/4	5 1/4	1/2
44	17	46°17'N 59°18'W	120	60	123.4	420	3.40	99	599	581	1,214	754	19 1/4	6 1/2	6 1/2	1 1/4
45	17	46°16'N 59°04'W	150-110	60	123.0	413	3.36	88	133	105	478	158	9 1/2	1 1/2	3 3/4	1/2
46	17	46°16'N 59°13'W	120	63	122.6	424	3.46	71	198	187	733	308	13 3/4	2 3/4	7 1/2	1/2
47	17	46°15'N 59°06'W	130-122	60	122.4	387	3.16?	116	226	172	794	238	14	2	5	1
48	17	46°17'N 59°15'W	125	60	122.2	420	3.44?	82?	97?	108?	338	179	5 3/4	1 1/4	4 3/4	1
55	18	46°43'N 59°42'W	125-118	30	123.1	417	3.39	79?	150?	99?	1,104	181	21 1/2	2	2 1/2	+
59	19	46°42'N 59°38'W	140-115	60	122.7	458	3.73	85	791	852	1,975	1,152	42 1/4	13 1/2	3 1/2	1/4
60	23	46°42'N 59°39'W	110-125	60	122.7	464	3.78	96	730	686	2,302	901	60	11 1/2	5 1/2	1/4
62	23	46°44'N 59°42'W	135	60	121.5	431	3.49	94	403	261	2,958	457	73 1/4	6 1/2	2 3/4	1/2
63	23	46°45'N 59°44'W	135	60	120.6	443	3.67	86	352	303	1,187	417	25 3/4	4 1/2	4 1/4	1/4
64	24	46°44'N 59°44'W	105-120	60	122.4	448	3.66	65	204	162	920	306	21 1/2	3	3 1/2	1/4
65	24	46°42'N 59°40'W	160	60	121.4	435	3.58	?	?	?	1,663	523	39	5 3/4	3 1/2	3/4
66	24	46°42'N 59°40'W	140-130	60	123.8	450	3.63	?	?	?	2,216	816	48 1/2	10	4	1/2
67	24	46°43'N 59°40'W	140	60	120.9	434	3.59	86	262	204	995	308	23 3/4	3 1/2	5 1/4	3/4

- 64 -

Table 5. Cod selection data for individual hauls; codend no. 56.

Haul No.	Date April 1970	Position	Depth (m)	Duration of haul (min)	Mesh size (mm)	50% Length (mm)	Selection Factor	Selection Range (mm)	No. of cod in Selection range		Total no. of cod caught		Quantity (baskets) of			
									Codend	Cover	Codend	Cover	Cod Codend	Cod Cover	By-catch Codend	By-catch Cover
25	13	46°08'N 58°49'W	160	60	132.0	447	3.39	84	221	186	1,293	295	31 3/4	4	1 3/4	1/2
26	14	46°08'N 58°50'W	160-140	60	128.7	444	3.45	79	312	306	1,382	470	32 1/2	5	1 1/2	1/2
27	14	46°09'N 58°50'W	140	60	129.0	440	3.41	?	?	?	1,550	424	36 1/2	5	2 1/2	1/2
28	14	46°09'N 58°51'W	160	60	128.1	419	3.27	96	186	144	958	230	20	2 1/2	1 1/4	1/4
29	14	46°09'N 58°51'W	160	60	127.4	481?	3.78?	65?	66?	92?	211	238	4 1/2	2 1/2	1	1/2
32	14	46°07'N 58°51'W	155	90	127.0	430	3.39	?	?	?	1,819	550	40 1/2	6	3 1/4	1/2
33	14	46°13'N 59°00'W	150	60	127.1	450	3.54	97	553	500	1,558	695	31 3/4	8	3 1/4	1/4
34	15	46°13'N 59°00'W	150	60	127.5	485	3.80	106	357	547	873	765	19	8 1/2	1 1/4	1/4
55	19	46°45'N 59°46'W	110-120	60	123.4	418	3.39	68	411	388	1,248	627	19 1/2	5 1/2	2 1/2	+
56	19	46°44'N 59°43'W	115-105	60	124.2	425	3.42	84	443	432	1,042	623	18 1/2	5 1/2	3	1/2
57	19	46°42'N 59°40'W	115-110	60	124.8	439	3.52	84	871	867	1,786	1,376	31 1/4	14	4 1/4	1/2
58	19	46°42'N 59°41'W	125-110	60	125.2	450	3.59	77	790	902	1,692	1,239	29 1/4	12	3	1/2

- 65 -

Table 6. Cod selection data for individual hauls; codend no. 57.

Haul No.	Date April 1970	Position	Depth (m)	Duration of haul (min)	Mesh size (mm)	50% Length (mm)	Selection Factor	Selection Range (mm)	No. of cod in Selection range Codend	Cover	Total no. of cod caught Codend	Cover	Quantity (baskets) of Cod Codend	Cover	By-catch Codend	Cover
37	15	46°11'N 58°57'W	150	90	144.9	471	3.25	88	198	164	780	272	22	4	2	1/4
38	15	46°11'N 58°54'W	160—150	120	144.3	453	3.14	113	540	501	1,420	701	31 1/4	9	3	1/2
39	16	46°17'N 59°17'W	105—120	60	142.8	454	3.18	120	1,730	2,102	3,290	3,173	56 3/4	29 1/4	2 1/4	1
40	16	46°17'N 59°15'W	120	45	142.7	448	3.14	107	969	1,158	1,895	1,614	32 1/4	15	3	1
41	16	46°17'N 59°19'W	120	50	142.6	451	3.16	98	1,130	1,275	2,327	1,959	42	19	3 1/4	1
42	16	46°18'N 59°22'W	120	55	142.6	442	3.10	91	1,231	1,284	2,614	2,173	44 1/2	20 3/4	4	1

For each codend separately, it can be seen that the selection factors calculated in two ways do not differ to any appreciable extent. This indicates that the selectivity was not negatively correlated with the catch size. Otherwise, provided that a sufficiently wide range of catch sizes was covered by each codend, the selection factors for grouped hauls would have been expected to be markedly lower than the unweighted mean selection factors.

The absence of a reciprocal relation between selectivity and catch size is also shown in Fig. 4, in which the selection factors derived from individual hauls have been plotted against the corresponding quantities of cod caught in the codends.

Thus, it remains an open question why the selection factor for the codend no. 57 was found to be significantly lower than the selection factors for the three other codends. The difference can neither be attributed to the elongation properties of the netting yarns nor to the catch sizes. Further experiments are needed to find out which property or properties of a netting yarn are of primary importance in determining its selectivity.

The result of 959 girth measurements taken during the course of the selection experiments is shown graphically in Fig. 5. The relationship between maximum body girth (G) and total length (L) is described by the regression equation $G = 0.538\ L - 3.80$ cm.

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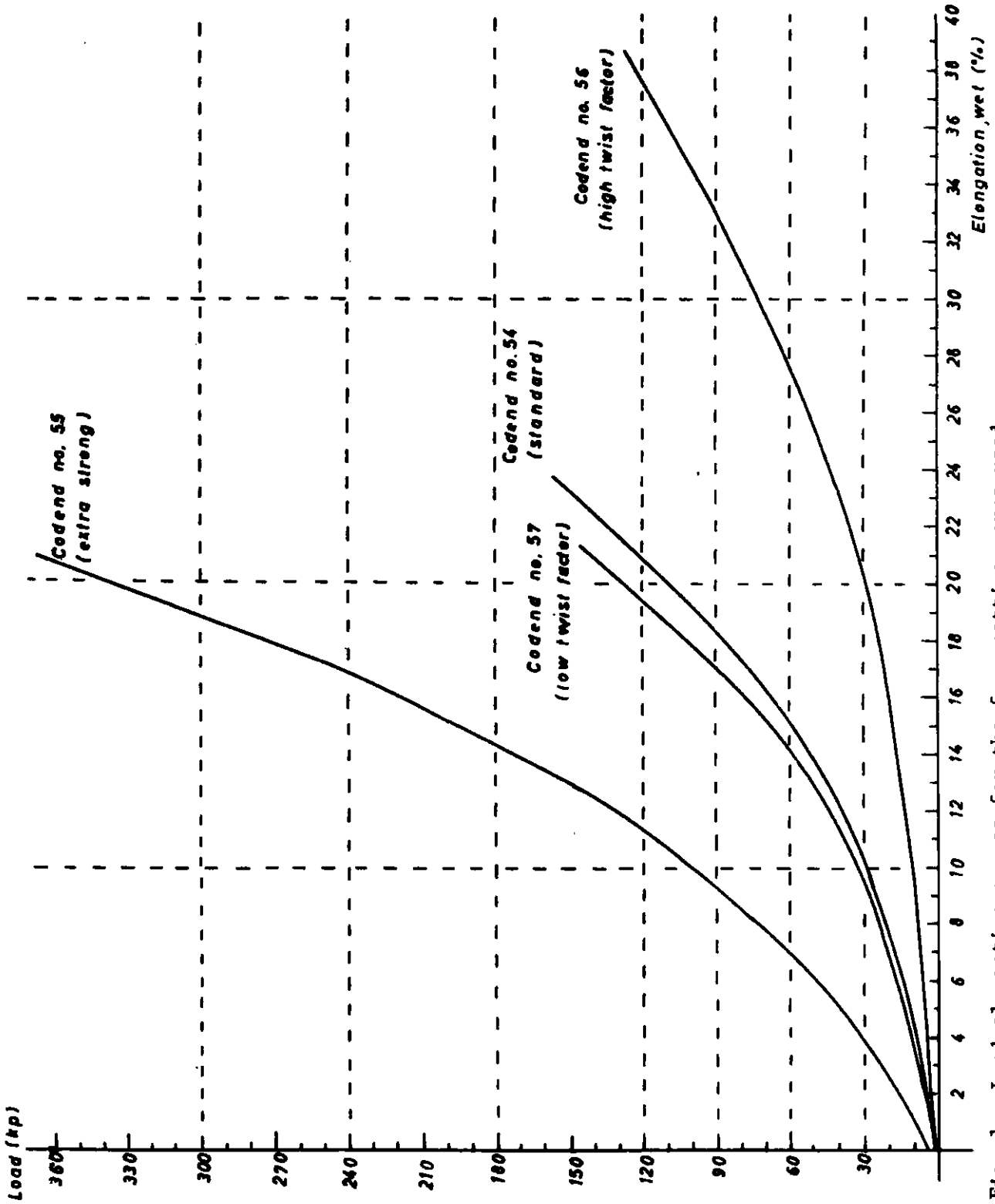
Fig. 1. Load-elongation curves for the four netting yarns used.
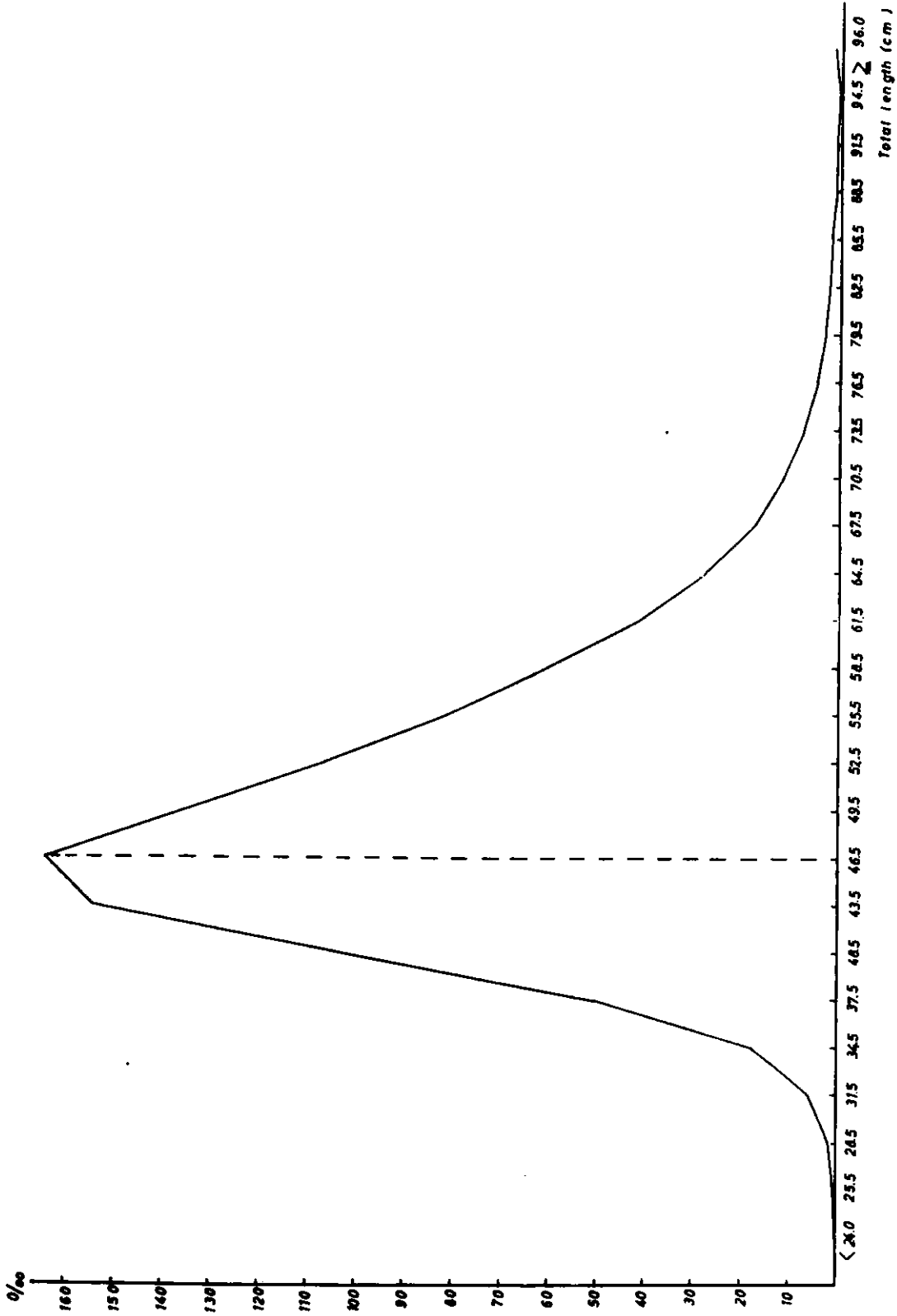
Fig. 2. Relative length composition of the total cod catch (codend plus cover) in 3-cm groups. (n = 98,007)
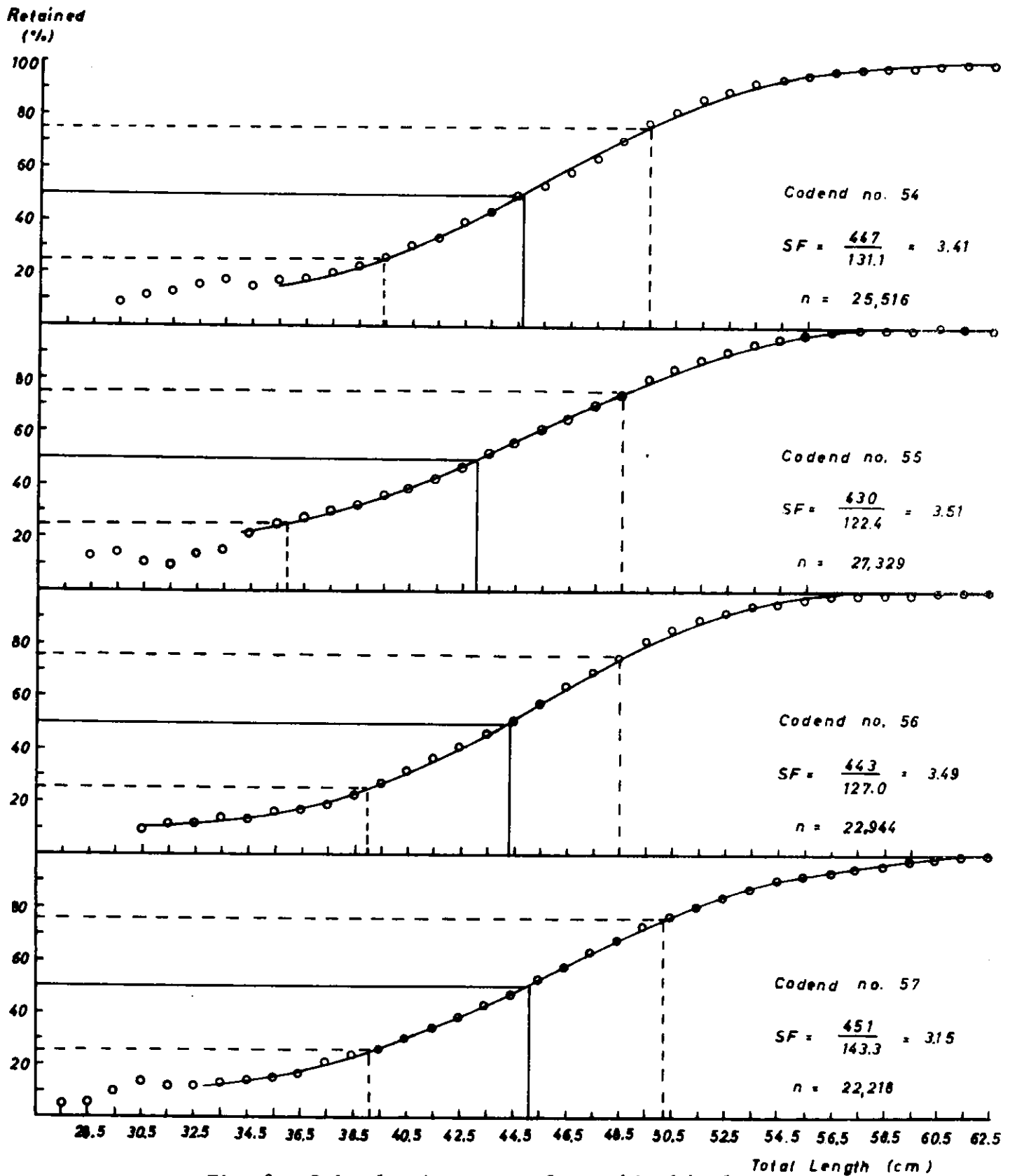
Fig. 3. Cod selection curves for combined hauls.
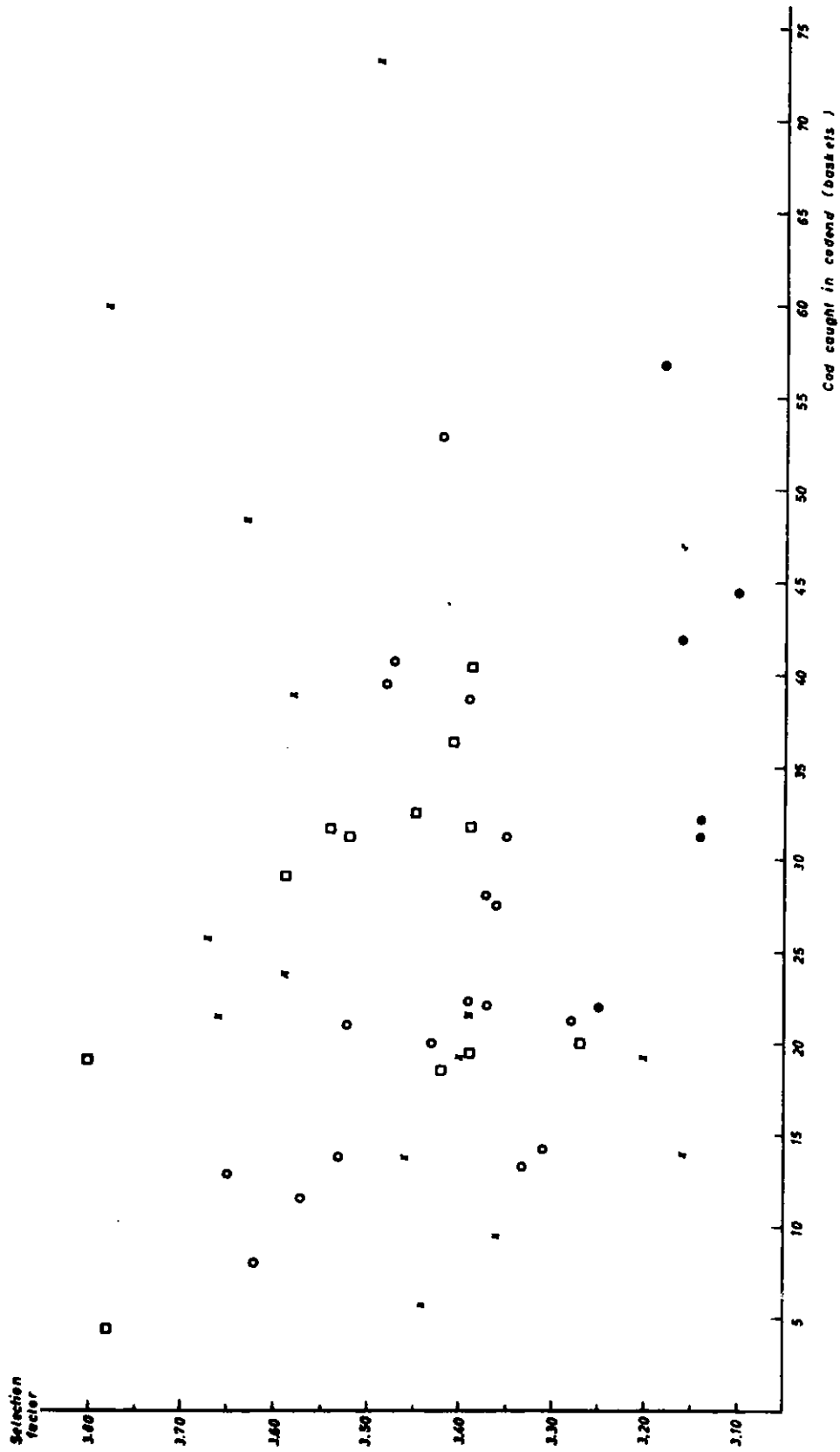
Fig. 4. Relation between selection factor and catch size.
o = Codend no. 54   □ = Codend no. 56
x = Codend no. 55   ● = Codend no. 57

G = 0.556 L - 1.08 cm
(n = 959)
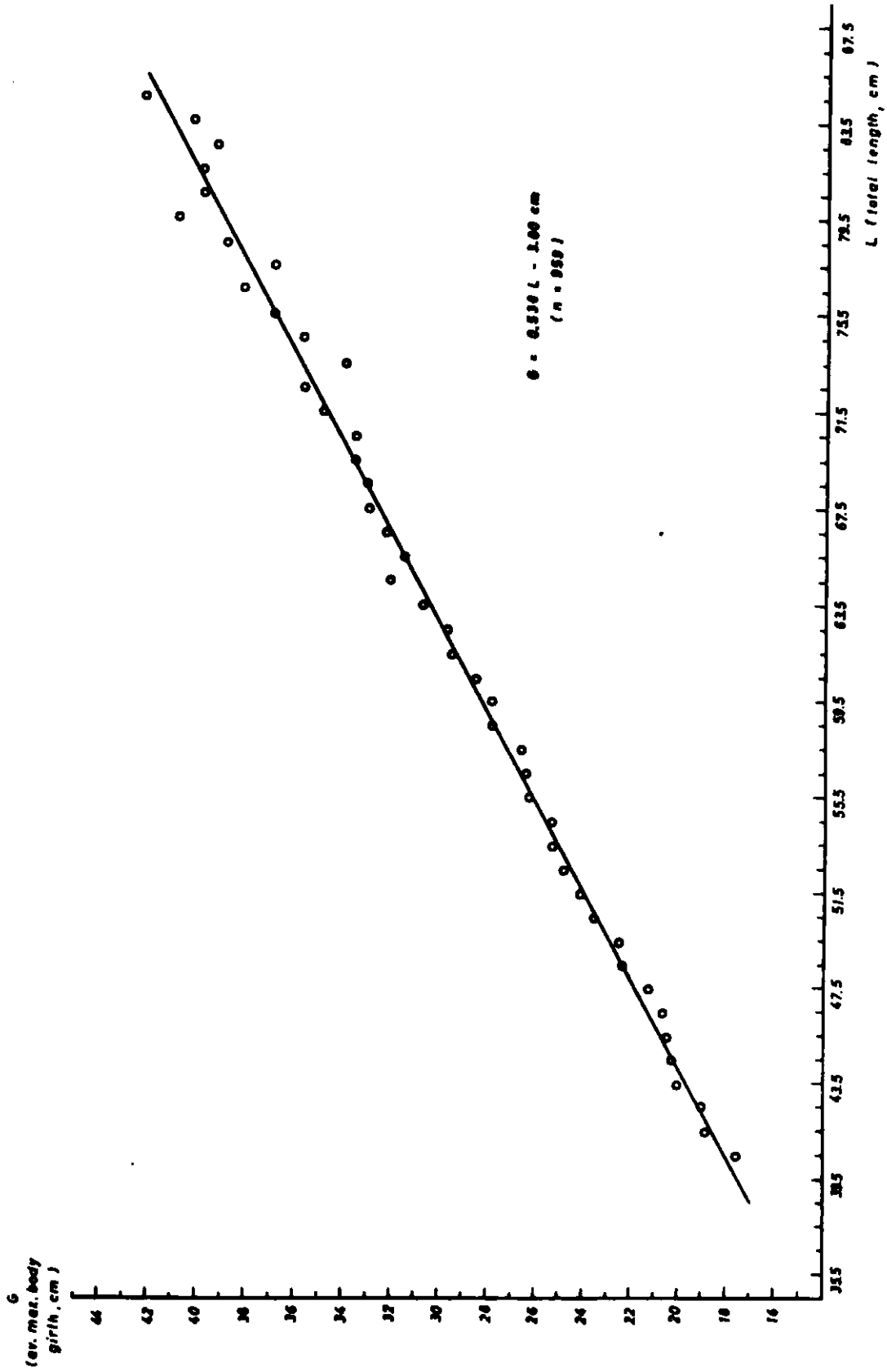
Fig. 5. Cod girth/length relationship.

6. Water temperature as an index of cod distribution
in Subarea 1 (West Greenland)[1]

by I.I. Svetlov
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The present paper is a continuation of the author's work on determination
of the relationships between water temperature and cod distribution on the
West Greenland banks (Svetlov, 1970). Asynchronous relationships by which it
is possible to forecast in advance the areas of the most probable cod concen-
trations are considered in the paper. A method for such forecasting was sug-
gested by K.G. Konstantinov and used for forecasting the fishery importance of
separate areas in the Barents Sea (Konstantinov, 1964; Konstantinov and Mukhin,
1964; Konstantinov, 1967a).

Some relationships between water temperature and fishery importance of
ICNAF Div. 1B are considered in the paper; Store Hellefiske Bank is in this
division where an intensive cod feeding is observed usually in summer and early
autumn (Rasmussen, 1957; Sidorenko, 1964).

Water temperature anomaly of the 0-50, 50-100, 100-200 m layers on the
station at 66°37'N, 57°05'W in July (Hermann,1967) and in the area off Godthaab
(64°11'N, 51°43'W) was taken as an index of the heat state of the sea (*Bulletin
Hydrographique*, 1959-1962). The fishery importance of Div. 1B as a percentage,
calculated as a ratio of cod yield in Div. 1B in the given month to the total
yield in all divisions of Subarea 1 in the same month was taken as an index of
cod distribution. While calculating the fishery importance of Div. 1B the
data on cod catches, taken by all fishing gears, were used. Data on catches
were obtained from Statistical Bulletins of ICNAF for the period 1954 to 1966
(ICNAF *Statistical Bulletin*, 1956-1968).

As no data on water temperature were available from the Godthaab station
since 1962 and from the station at 66°37'N, 57°05'W since 1966, the data on
catches for the last years were not included in the statistical analysis. Some
relationships that are considered below were obtained from the data available
by means of correlation analysis.

A. Water temperature anomalies in the 50-100 m layer in July (Fig. 1a and the
fishery importance of Div. 1B in November

The relationship between the temperature anomaly (Δt) in the 50-100 m
layer on the station at 66°37'N, 57°05'W in July and the fishery importance
(F) of Div. 1B in November is shown in Fig. 1b. The correlation coefficient
(r) is 0.851, whereas the range length N = 13, the error of correlation coef-
ficient (E) is 0.051; $\frac{r}{E} = 16.6$, *i.e.*, the relationship is real. The dependence
is characterized by the following equation:

$$F_{\overline{XI}} = 40.2 \, \Delta t_{\overline{VII}50-100} + 27.5 \tag{1}$$

[1] Submitted to the 1971 Annual Meeting of ICNAF as ICNAF Res.Doc. 71/86.

where: $\Delta t_{\overline{VII}50-100}$ = temperature anomaly in the 50-100 m layer on the station at 66°37'N, 57°05'W in July.

$F_{\overline{XI}}$ = fishery importance of Div. 1B in November.

The relationship shows that if the temperature increases, then the fishery importance of Div. 1B will also generally increase. Table 1 illustrates the fitness of the equation (1).

Table 1. Actual and calculated values of fishery importance (F) of Div. 1B, anomalies and errors in percentage from the long-term amplitude ($A = F_{max} - F_{min} = 60.7$).

Year	F_{act}	F_{calc}	$E = F_{act} - F_{calc}$	$\dfrac{E}{A}$	$\dfrac{E}{A}\%$
1954	11.9	19.5	- 7.6	0.12	12
1955	18.0	32.5	-14.5	0.24	24
1956	15.2	11.4	+ 3.8	0.06	6
1957	4.6	8.7	- 4.1	0.07	7
1958	2.5	11.4	- 8.9	0.14	14
1959	3.7	7.4	- 3.7	0.06	6
1960	4.6	11.4	- 6.8	0.11	11
1961	28.2	31.5	- 3.3	0.05	5
1962	31.6	31.5	+ 0.1	0.00	0
1963	50.5	47.6	+ 2.9	0.05	5
1964	63.2	35.5	+27.7	0.46	46
1965	41.7	43.6	- 1.9	0.03	3
1966	53.7	51.6	+ 2.9	0.03	3

Equation (1) shows that in 84% of cases the error was not greater than 20% of the amplitude of the forecasting index.

B. Water temperature anomalies in the 100-200 m layer in July and cod distribution in Div. 1B in November

Water temperature anomalies in the 100-200 m layer on the above-mentioned station (66°37'N, 57°05'W) in July and fishery importance of Div. 1B in November (Fig. 2) were compared. The relationship between the comparative values (the length of the range N = 13) is expressed in terms of the correlation coefficient r = 0.800; error E = 0.067; $\dfrac{r}{E}$ = 11.9, the equation is represented as:

$$F_{\overline{XI}} = 26.8\ \Delta t_{\overline{VII}100-200} + 23.7 \qquad (2)$$

where: $\Delta t_{\overline{VII}100-200}$ = water temperature anomaly in the 100-200 m layer on the station at 66°37'N, 57°05'W in July

$F_{\overline{XI}}$ = fishery importance of Div. 1B in November.

Table 2 illustrates the fitness of equation (2).

Table 2. Actual and calculated values of fishery importance (F) of
Div. 1B, anomalies and errors in percentage from the long-
term amplitude $(A = F_{max} - F_{min} = 60.7)$.

Year	F_{act}	F_{calc}	$E = F_{act} - F_{calc}$	$\frac{E}{A}$	$\frac{E}{A}\%$
1954	11.9	10.3	+ 1.6	0.03	3
1955	18.0	18.3	- 0.3	0.00	0
1956	15.2	18.3	- 3.1	0.05	5
1957	4.6	15.7	-11.1	0.18	18
1958	2.5	15.7	-13.2	0.22	22
1959	3.7	13.0	- 9.3	0.15	15
1960	4.6	13.0	- 8.4	0.14	14
1961	28.2	18.0	+ 9.9	0.16	16
1962	31.6	21.0	+10.6	0.17	17
1963	50.5	37.1	+13.4	0.22	22
1964	63.2	34.4	+28.8	0.49	49
1965	41.7	45.1	- 3.4	0.06	6
1966	53.7	69.3	-15.6	0.26	26

Equation (2) shows that in 69% of cases the error was not greater than
20% of the amplitude of the forecasting index.

From Figs. 1 and 2 it may be seen that in separate years some anomalies
in general regularity were registered. An especially large anomaly was
observed in 1964: when water temperature in July decreased, the fishery
importance of Div. 1B in November decreased.

In accordance with the hydrological observations (Svetlov, 1966), water
temperature in 1964 along almost the whole of the west coast of Greenland was
above the norm. But in July on the station at 66°37'N, 57°05'W, it was 0.1-
0.3° below the average temperature of the 50-100 m, 100-200 m layers. It is
supposed that the lower water temperature could be the result of the expansion
of the cold Canadian Current which, in July 1964, came near this station;
whereas, the heat level of 1964 for the whole Subarea 1 was fairly high
(Bratberg, 1965; Hansen and Hermann, 1965; Meyer, 1965). Perhaps, therefore,
the cod concentrations observed in Div. 1B to November caused a sharp increase
of the fishery importance of this division.

C. Water temperature anomalies in the 50-100 m layer in July and fishery
   importance of Div. 1B in December

Comparison of the water temperature anomaly in the 50-100 m layer in July
on the station at 66°37'N, 57°05'W and fishery importance of Div. 1B in
December showed a direct relationship. The correlation coefficient r = 0.828;
n = 13; E = 0.063 (Fig. 3); $\frac{r}{E} = 13$. The relationship is expressed by the
following formula:

$$F_{\overline{XII}} = 32 \ \Delta t_{\overline{VII}50-100} + 23 \tag{3}$$

where: $\Delta t_{\overline{VII}50-100}$ = water temperature anomaly in the 50-100 m layer on the station at 66°37'N, 57°05'W in July

$F_{\overline{XII}}$ = fishery importance of Div. 1B in December.

The values of the fishery importance (Table 3) were calculated for the assessment of the fitness of equation (3).

Table 3. Actual and calculated values of fishery importance (F) of Div. 1B, anomalies and errors in percentage from the long-term amplitude (A = F_{max} - F_{min} = 44.4).

Year	F_{act}	F_{calc}	E = F_{act} - F_{calc}	$\dfrac{E}{A}$	$\dfrac{E}{A}\%$
1956	2.9	10.2	- 7.3	0.16	16
1957	0.6	5.8	- 5.2	0.12	12
1958	0.4	10.2	- 9.8	0.22	22
1959	0.1	7.0	- 6.9	0.16	16
1960	16.0	10.2	+ 5.8	0.13	13
1961	28.7	26.2	+ 2.5	0.06	6
1962	42.0	26.2	+25.8	0.58	58
1963	41.1	39.0	+ 2.1	0.05	5
1964	39.4	35.4	+ 4.0	0.09	9
1965	14.5	35.8	-21.3	0.48	48
1966	44.5	42.2	+ 2.3	0.05	5

D. Water temperature of the 0-50 m layer on the Godthaab station in October and fishery importance of Div. 1B in June of the next calendar year

One more type of dependence between water temperature of the 0-50 m layer in October on the Godthaab station and fishery importance of Div. 1B in June of the following calendar year is represented in Fig. 4. The correlation coefficient (r) of this relationship is 0.70, (N = 10), E = 0.11, $\dfrac{r}{E}$ = 6.4, the regression is:

$$F_{\overline{VI}n+1} = 23.3\ t_{\overline{X}0-50} - 43.5 \tag{4}$$

where: $t_{\overline{X}0-50}$ = water temperature of the 0-50 m layer on the Godthaab station in October

$F_{\overline{VI}n+1}$ = fishery importance of Div. 1B in June of the following calendar year (n - year of temperature observations).

The values of fishery importance calculated due to equation (4) are represented in Table 4.

In the calculations of the fishery importance due to equations (3) and (4) in 80% of cases the error was not greater than 20% of the amplitude of fore-casting index. The estimate of the fishery importance value due to equations

Table 4. Actual and calculated values of fishery importance (F) of Div. 1B, anomalies and errors in percentage from the long-term amplitude (A = $F_{max} - F_{min}$ = 46.9).

Year	F_{act}	F_{calc}	$E = F_{act} - F_{calc}$	$\frac{E}{A}$	$\frac{E}{A}\%$
1954	0.4	2.7	- 2.3	0.05	5
1955	1.8	3.1	- 1.3	0.03	3
1956	0.5	0.9	- 0.4	0.00	0
1957	4.8	8.0	- 3.2	0.07	7
1958	1.8	20.1	-18.3	0.39	39
1959	47.3	23.4	+23.9	0.51	51
1960	12.1	16.1	- 4.0	0.08	8
1961	18.8	17.3	+ 1.5	0.03	3
1962	19.8	24.8	- 5.0	0.11	11
1963	7.1	5.2	+ 1.9	0.04	4

(1-4) was made for those years which are indicated in Tables 1-4.

Asynchronous character of the above considered relationships is a peculiar feature. This fact is of great importance for fishery forecasting. It is known that fish do not react immediately; also, their migration from one area to another takes time (Konstantinov, 1967b). The equations of relationships obtained above provide a means of forecasting the fishery importance of Div. 1B from 4 to 8 months in advance.

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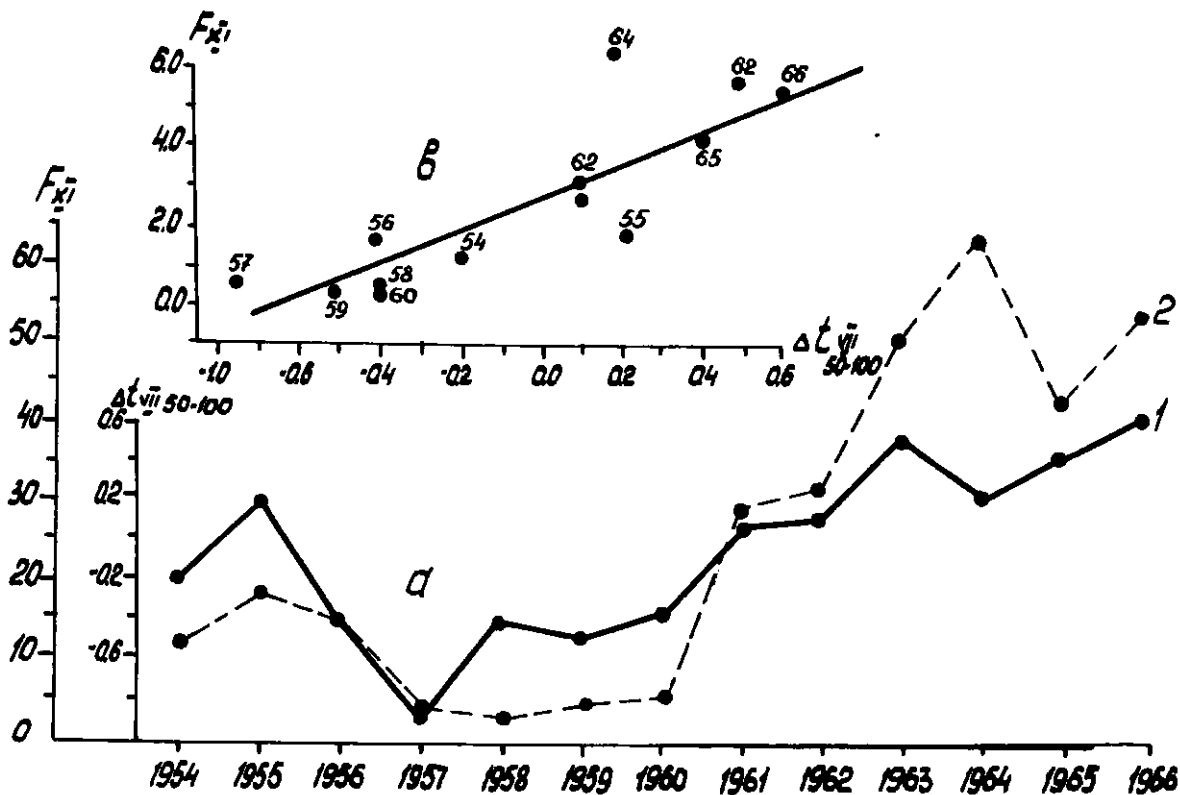
Fig. 1. Comparison between the fishery importance (F) of Div.1B in November
and temperature anomaly in the 50-100 m layer on the station at
66°37'N, 57°05'W in July:
a) water temperature anomaly (1) and fishery importance (2),
b) the relationship between them.
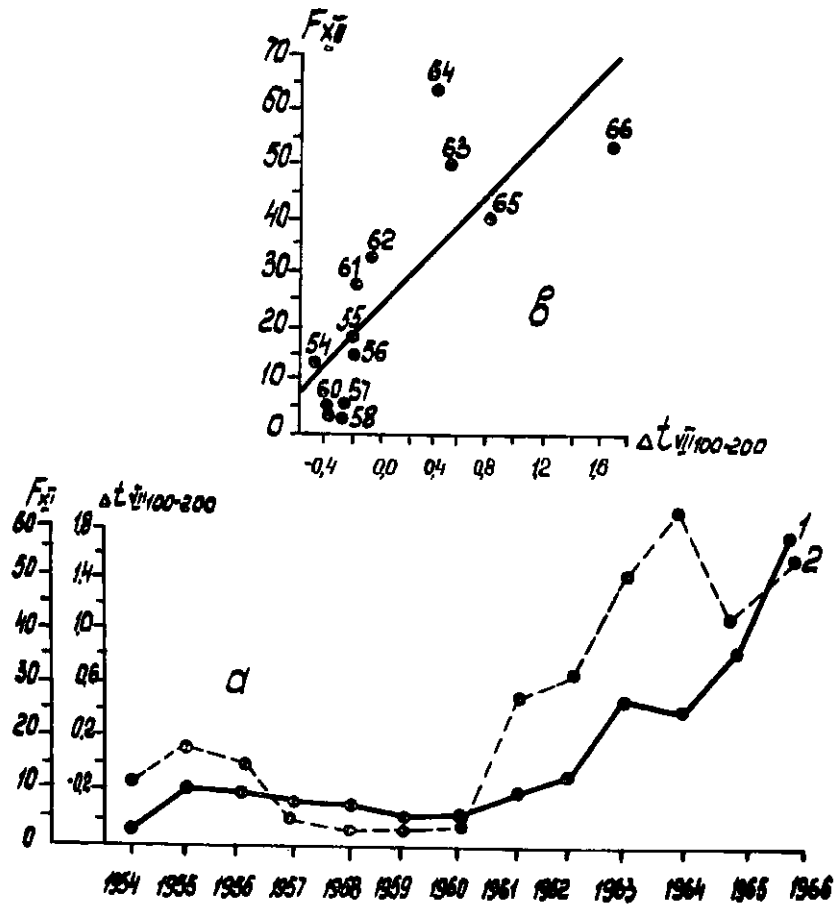
Fig. 2. Comparison between the fishery importance (F) of Div.1B in November and water temperature anomaly in the 100-200 m layer on the station at 66°37'N, 57°05'W in July:

a) water temperature anomaly (1) and fishery importance (2),
b) the relationship between them
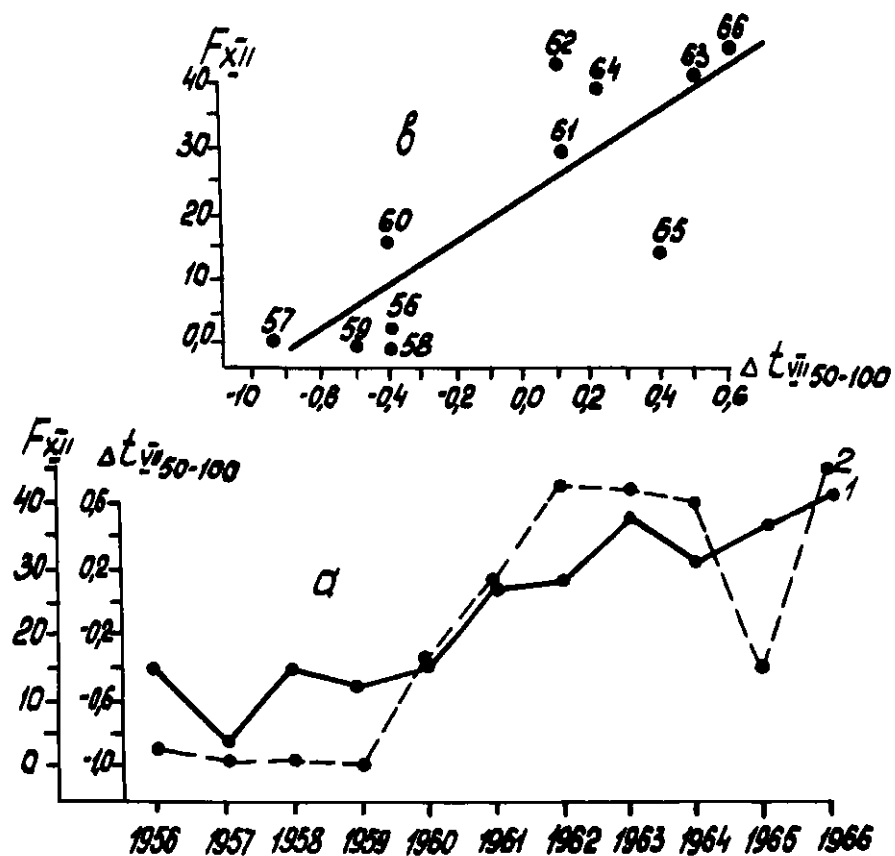
Fig. 3. Comparison between the fishery importance (F) of
Div.1B in December and water temperature
anomaly in the 50-100 m layer on the station
at 66°37'N, 57°05'W in July:

a) water temperature anomaly (1) and fishery
importance (2),

b) the relationship between them
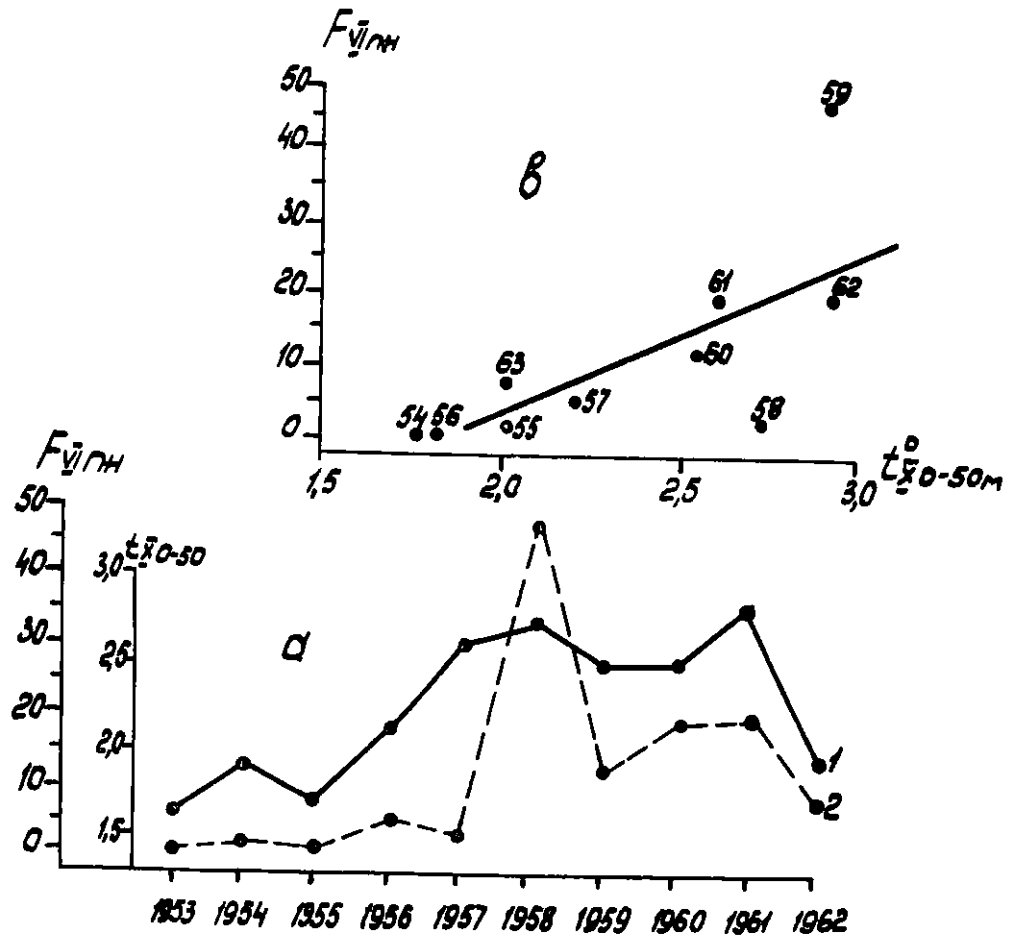
Fig. 4. Comparison between the water temperature of the 0-50
m layer in October and the fishery importance
$(F_{\overline{VI}n+1})$ of Div. 1B in June of the following calendar
year (n - year of temperature observations):
a) water temperature (1) and fishery importance (2),
b) the relationship between them.

7. On haddock spawning in the Northwest Atlantic area[1]

by V.P. Serebryakov
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In the Northwest Atlantic area haddock are distributed from Greenland to Cape Hatteras. But, more or less detailed studies of haddock spawning have only been made for the areas of New England and Georges Bank. For the other areas there are some data on distribution of mature haddock and only scrappy data on distribution of eggs and larvae (Walford, 1938; Bigelow and Schroeder, 1953; Chase, 1955; Marak, 1960; Colton and Temple, 1961; Miller, Colton and Marak, 1963; Colton, 1965).

The author has tried to study the location of spawning areas as well as the drift and habitats of young haddock off Newfoundland and the Scotian Shelf. Data on maturity stages obtained by research vessels of the Polar Research Institute of Fisheries and Oceanography (PINRO) in field conditions in 1954 and in 1957-1963 were used in this paper. The maturity stages were determined as recommended for cod by Sorokin (1957). Ichthyoplankton samples were also collected in 1959-1963 by the research vessels of PINRO and by those of the Prospective Fish Scouting Service. Conical egg nets with 80-cm diameter opening were mainly used during the experiments. Usually, a vertical haul was made from the bottom to the surface and a 15-minute oblique haul while drifting or circling. A total of 2,000 stations were completed during the period of investigations in the Northwest Atlantic from Greenland to Georges Bank. Some haddock were caught in the cod and redfish fisheries near West Greenland, but they were scarce in number, and it was, therefore, impossible to obtain representative data on seasonal changes in gonad condition. Haddock eggs were observed in Greenland waters in April, May and June. The numbers are not high, no more than 11 per vertical haul.

In Labrador waters eggs were not observed, although the adult fish are found in trawl catches.

Off Grand Bank, the haddock fishery may be very effective in certain years. The possibility of haddock spawning in this area was suggested earlier by some scientists (Needler, 1930; Thompson, 1939; Grosslein, 1962). Haddock with gonads at the pre-spawning and spawning maturity stages were observed in this area from March to September. In June, the largest number of haddock with running eggs were observed in the southern part of the Grand Bank and on its southwestern slope and in May in the areas of Saint Pierre and Green Banks. Distribution of haddock eggs in the waters of Grand Bank indicate spawning in this area, but, as few eggs are observed, the spawning is not heavy. According to data on maturity stages and egg distribution, a mass spawning takes place in the areas of Saint Pierre and Green Banks. The spawning peak is observed in late May-early June. Shestov (1967) considers that the spawning takes place mainly on the southwestern slope, at the border of ICNAF Div. 3O and 3N, at depths of 60-160 m and in temperatures of 3.0°-6.0°. According to Shestov, the western part of the southwestern slope of the Grand Bank is the second spawning area. None of the authors pays any great attention to spawning areas located on the southern slopes of Saint Pierre and Green Banks. But, from data on egg distribution, one can confirm that spawning in these areas is much heavier than in the areas of the Grand Bank. Main spawning areas near Saint

Pierre and Green Banks can be observed at depths of 80-250 m, and spawning takes place in slope waters in temperatures of 3.0°-6.0°. The location of haddock spawning areas in the Grand, Saint Pierre and Green Banks is given in Fig. 2.

In the period 1961-1966, PINRO conducted regular investigations on the distribution of young haddock off Newfoundland Banks. These investigations showed that the young haddock are observed on the southwestern slope of the Grand Bank (Nevinsky, 1962) and also that young haddock more than 15 cm in length were distributed over the area. Bulatova (1962) analyzed the catches of young haddock for 1954-1961 and concluded that the young specimens were distributed only on the southern slopes of Grand Bank and on its southern part and on the southern slopes of Saint Pierre Bank. The young, up to 25 cm in length, are distributed at lesser depths than fish 26-35 cm in length. Investigators, thus, concluded that the young haddock inhabit the southern part of Grand Bank and its southern slope and the southwestern slope of Saint Pierre Bank. The fingerlings were distributed mainly on the southern and southwestern slopes of Saint Pierre and Green Banks, with the greatest concentrations being observed in the southern part of Grand Bank (Fig. 3).

Thus, the largest concentrations of eggs, larvae and fingerlings of haddock are found on the southern and southwestern slopes of Saint Pierre and Green Banks.

Analysis of the age composition of the young haddock showed that from Saint Pierre and Green Banks to the eastward, *i.e.*, to the southern part of the Grand Bank, the numbers of older specimens of the young increase in the catches while the one-year-olds decrease (Shestov, personal communication).

A total scheme of haddock spawning is suggested as follows. A single stock of Newfoundland Bank haddock spawns on the southern and southwestern slopes of Saint Pierre and Green Banks and on southern part of the southwestern slope of the Grand Bank at depths of 80-25 m and at near-bottom temperatures, 3.0°-6.0°. Apparently, the eggs and larvae do either not drift from the spawning areas, or they drift to the southwest in the low velocity current and then are carried out to the areas adjacent to the spawning areas.

Correspondingly, the fingerlings settle to the bottom either in the spawning areas or in areas adjacent to them. The young move to Grand Bank, mainly its southwestern slope.

Some scientists consider that two independent haddock stocks inhabit the Newfoundland Banks (Grosslein, 1962), *i.e.*, a Saint Pierre and Green Bank stock and a Grand Bank stock.

Sometimes Grand Bank haddock are found in good numbers. An insignificant spawning within the Bank waters can hardly ensure a great abundance for an independent stock. In addition, in the case of the availability of an independent stock, a great number of haddock fingerlings should be observed in this area.

Shestov (1967) has suggested that a single stock of haddock inhabits the waters of Grand, Saint Pierre and Green Banks, whose origin is from the spawning areas of the southern and southwestern slopes of Saint Pierre and Green Banks. Data obtained by the author confirm this suggestion.

Two stocks inhabit the waters of the Scotian Shelf, one of them is located in the northeastern part of the Shelf, north of the Scotia Deep, the other one on the southwestern part of the Shelf.

Spawning haddock are observed on the Scotian Shelf in April, May, June (Fig. 1). Dannevig (1919) noted the distribution of larvae in the Sable Island area in May. Thompson (1939) showed the distribution of haddock fingerlings on Banquereau Bank. Young haddock are distributed over Misaine and Banquereau Banks, southeast of Sable Island over the Shelf slope and on Emerald Bank (Fig. 3).

Grosslein (1962) showed that the peak of spawning on the Scotian Shelf is in April. The distribution of haddock eggs in May testifies to the fact that spawning probably takes place mainly in May. It should be said here that in April the survey program took place only partially on the Scotian Shelf.

Usually, haddock spawning takes place sometime later than that for cod in the same areas, and it is unlikely that the Scotian cod make an exception.

The drift of haddock eggs and larvae is determined by the direction and the speed of the current, flowing out of the Gulf of St. Lawrence and dominating the Scotian Shelf. The speed of this current is high - up to 94 cm/sec over Misaine and Banquereau Banks (Klimenkov and Pochorukov, 1962). In the case where the eggs are drifting in the upper 20-m water layer, they will be carried in the water masses to the southwest along the Shelf (Walford, 1938; Miller, Colton, and Marak, 1963; Colton, 1965). But, sometimes the upper water layer (up to 100 m in depth) on the Scotian Shelf is freshened (<31°/₀₀) and becomes cool (Klimenkov and Pochorukov, 1962). The density of this layer is, naturally, decreasing. Kisljakov (1958) showed that the cod eggs are drifting with the deeper layers when the upper layer is freshened. The behaviour of haddock eggs should be the same in similar environmental conditions. Thus, it can be suggested that haddock eggs and larvae are drifting in the deep water layers. The rate of speed is less at great depths (Colton and Temple, 1961) and the temperature higher. Correspondingly, the rate of development is greater and the duration of the period of the pelagic development is less. This means that, in spite of a rather high current speed and low temperatures in the upper water layers over the Scotian Shelf, the eggs and larvae are not carried off the limits of the Shelf. In any case, such conclusions can be made for ICNAF Div. 4V, 4W. It is possible that they are not carried far away from the spawning areas. This can be confirmed from the distribution of haddock fingerlings off Emerald Bank, in the areas where the greatest catches of eggs were taken.

Discussion of results

In the northwest part of the Atlantic Ocean haddock are spread from Labrador to Cape Hatteras, they can also be observed near Greenland. In the ICNAF Area, haddock are most abundant off Nova Scotia and New England. Some local stocks of haddock are observed in these areas, they are characterized by different number of vertebrae. Previously, scientists supposed that two haddock stocks existed off Newfoundland. From the above data it is possible to say that only one haddock stock inhabits the Newfoundland Banks area. This stock originates from the spawning areas located in the southwestern and southern slopes of Saint Pierre and Green Banks and in the western part of the southwestern slope of the Grand Bank. Because of drift conditions, haddock of

Newfoundland Banks are isolated from the Scotian Shelf. Stocks of adult fish of these areas probably mix very little, as the number of vertebrae differs greatly enough. The location of spawning areas on the one hand, and the drift pattern of eggs and larvae on the other hand, suggest that there are two haddock stocks inhabiting the northeastern and southwestern parts of the Shelf respectively. The number of vertebrae for haddock of these two stocks differs, though not greatly, a fact which suggests there is considerable mixing of these two stocks. It is characteristic that the greatest number of vertebrae (54.19) are from haddock inhabiting the shores of the Cape Breton Island, the area of the lowest water temperature during the spawning period. An independent haddock stock inhabits the area of Georges Bank, the number of their vertebrae is almost the same as for haddock of the Newfoundland Banks.

In the Northwest Atlantic haddock spawn from February to July. The spawning peak does not coincide in time for different areas. Off Newfoundland Banks, spawning is observed late in May-early in June. In the Nova Scotia area, spawning takes place in May. On Georges Bank, spawning reaches its apogee in May-April, though haddock spawn there in January and even in December, and some spawning individuals and eggs are observed in July and in August.

Thus, in the Northwest Atlantic the length of the spawning period for haddock is greatest in southern areas, on Georges Bank. In the northern areas, the spawning period begins earlier and is shorter. Haddock spawning is observed at depths from 40 m to 250 m in 3°-6° temperature. As noted above, the lowest temperatures were registered for the Scotian Shelf. Comparing the location of the spawning areas to the distribution of near-bottom temperatures during the spawning or pre-spawning periods, it can be concluded that the time of haddock spawning in the various areas is determined by the meandering of the warm currents. This is especially apparent on the southern slopes of Saint Pierre, Green Banks and on the western part of the southwestern slope of Grand Bank.

The haddock eggs and larvae drift is unique for each different area of the northwestern Atlantic. In the areas off Newfoundland Banks, eggs and larvae are carried off the spawning grounds to the southeast. Their drift pattern is like that of an incomplete circle. The shorter the distance from the spawning area to the centre of the circular water motion, the shorter is the drift of eggs and larvae from their spawning area. The centre of the current is probably displaced in different years and, in this connection, the picture of eggs and larvae drift changes as well. But, those changes probably do not affect the general character of the drift.

In the Nova Scotia area, the drift may be determined by a strong Cabot Current, as was shown earlier. In this case, eggs and larvae of the Scotian Shelf are carried from the northeastern part of spawning areas to the southwest, and from the spawning grounds off Browns and LaHave Banks northwesterly, i.e., to the eastern part of the Gulf of Maine and Passamaquoddy Bay. When eggs and larvae are not in low salinity surface water layers, but in deeper layers with an oceanic salinity, they will not be carried a great distance. In all cases, the extent of drift in space and time is not too great, being much less than that for cod in the northern areas.

During the passive pelagic period of life, survival depends greatly on the whole complex of different conditions and on the areas, where larvae have been carried at the fingerling stage, when the bathypelagic and near-bottom mode of life begins. It can be supposed that this process is determined by

the current intensity, when the eggs and larvae are being carried by powerful currents like that in the North Atlantic.

The drift of eggs and larvae may depend on wind currents. This is observed, when they are drifting in waters with slow current speed, *i.e.*, in turbulences and rotations, which, in their turn, depend on wind conditions. Carruthers (1951) investigated the influence of the wind conditions on the abundance of haddock year-classes in the North Sea for the period 1929 to 1949. It appeared that relatively rich year-classes prevailed in the years when northerly and earterly winds dominated, but they were poor in the years with mainly northerly and westerly winds. Of 20 year-classes, only two (1946 and 1947) were exceptions to this regularity.

In the Northwest Atlantic, analogous investigations were made for Georges Bank haddock. Chase (1955) obtained a correlation coefficient of 0.766±0.057 between the size of haddock year-classes and favourable winds for the period of investigations 1928 to 1952.

Of course, the strength of a year-class is determined not only by the wind regime and this factor is of great significance only under certain conditions.

It can be considered that the survival of eggs, larvae and fingerlings is more closely related to wind when the spawning grounds are adjacent to areas with environmental conditions unfavourable to their development, and if they are brought there they will die. This conclusion can be related to the haddock spawning areas off Faroes (Saville, 1965) and Georges Bank. The spawning areas located on Saint Pierre, Green Banks and on the southwestern slope of Grand Bank are affected by the factors described above.

The winds from the south and southwest provide favourable conditions for haddock development on Newfoundland Banks during their spawning and drifting periods, and those from the north and northeast - the unfavourable ones. Thus, it is possible to make some preliminary conclusions. If the winds blow from the south, the year-classes will be abundant in April-October; if they blow from the north, they will be poor.

In conclusion, it may be said that some other conditions for survival are overlapping the effect of wind, especially those of extremely warm or cold years.

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(a)

(b)

(c)
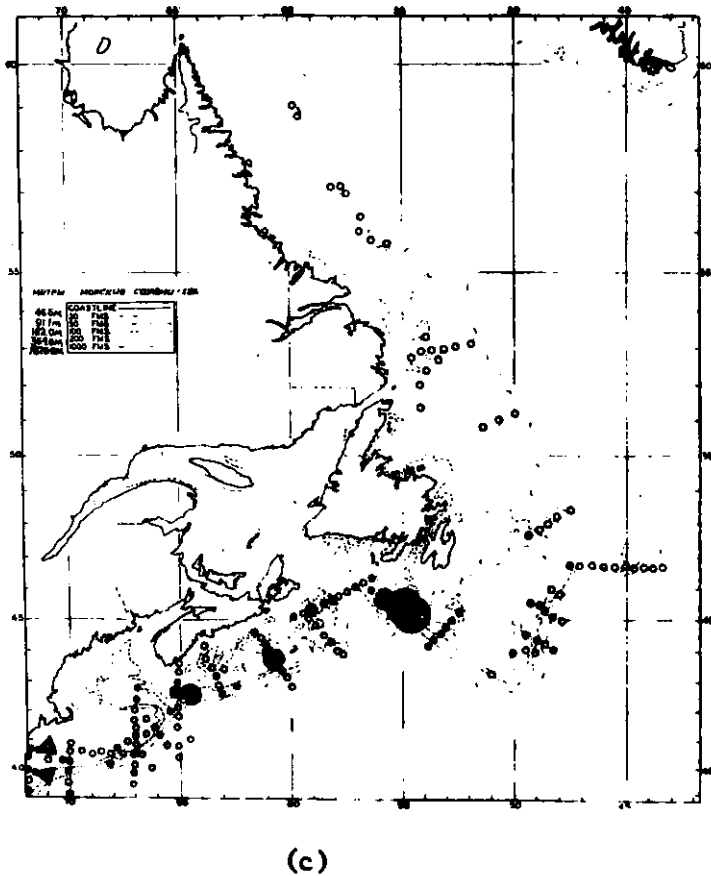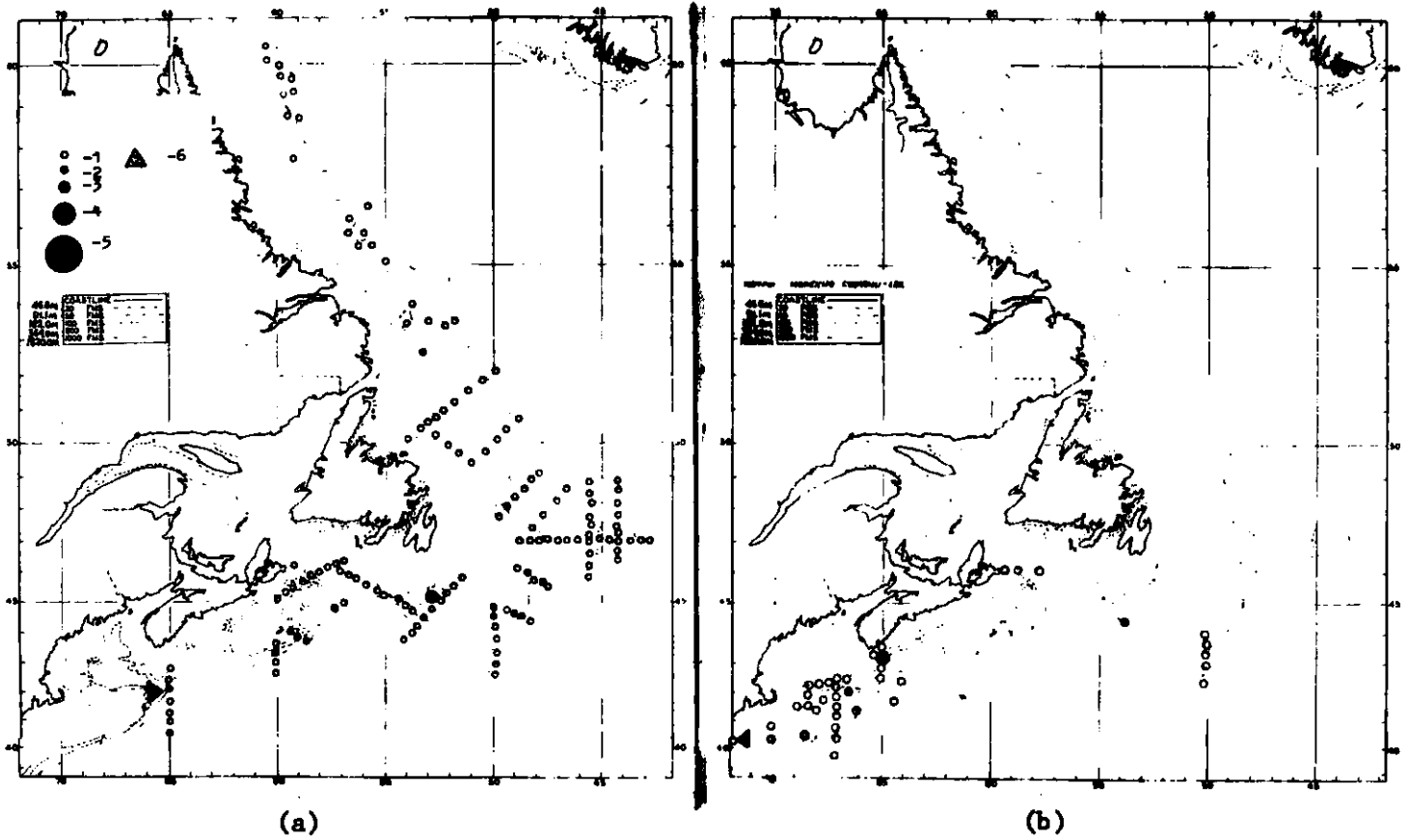
Fig. 1. Distribution of haddock eggs
         and larvae:
         a) in April
         b) in May
         c) in June

         Conventional signs:
         1 - no eggs
         2 - 1-5 eggs
         3 - 6-10 eggs
         4 - 11-20 eggs
         5 - 21-50 eggs
         6 - larvae
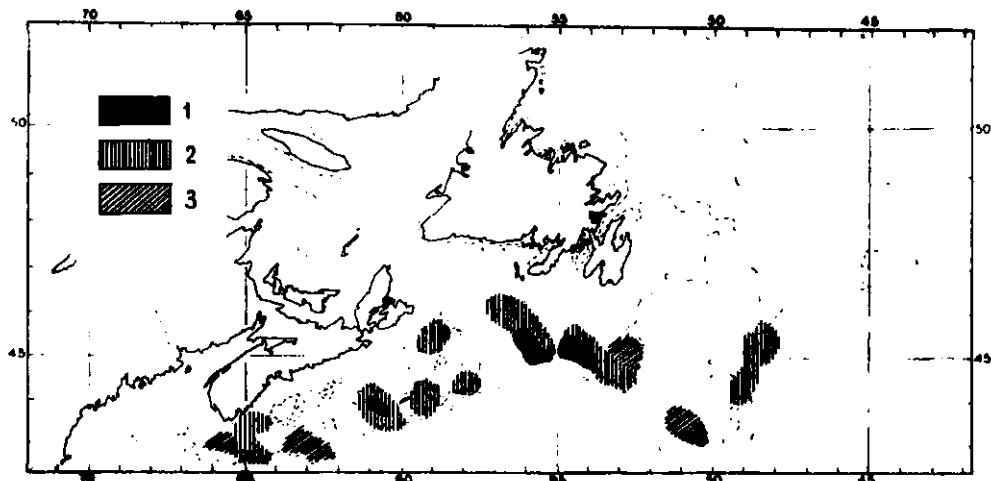
Fig. 2. Distribution of haddock spawning areas.
Conventional signs:
1. Intensive spawning
2. Not intensive spawning
3. Spawning areas, preliminary determination
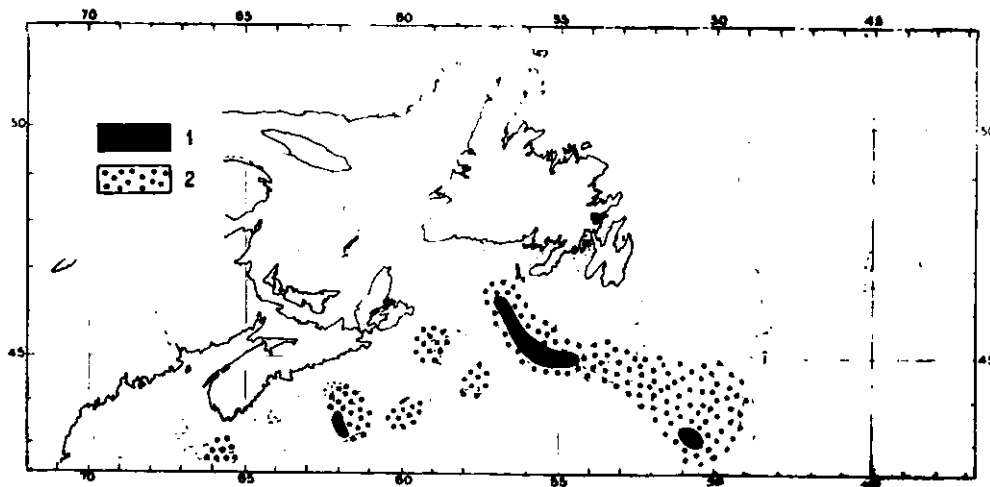
Fig. 3. Distribution of young haddock
Conventional signs:
1. Distribution of fingerlings and one-year-olds
2. Distribution of young specimens
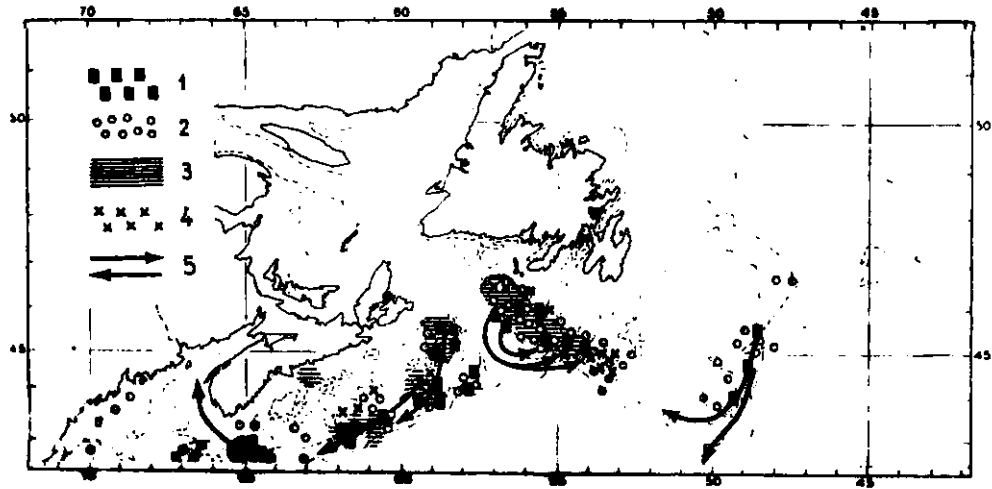
Fig. 4. Distribution of spawning grounds, eggs, larvae, fingerlings and migration paths of haddock
Conventional signs:
1. Spawning grounds
2. Egg distribution
3. Larvae distribution
4. Fingerling distribution
5. Drift paths

8. The retention inside the Bay of Fundy of herring larvae spawned off the southwest coast of Nova Scotia[1]

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Introduction

The seasonal distribution of larval herring in relation to the physical and biological environment in the Bay of Fundy-Gulf of Maine region for the years 1967 to 1969 as shown by cruises at three-month intervals has been described by Tibbo and Lauzier (1970). Three additional short cruises at approximately fortnightly intervals were carried out in the fall of 1969 to follow in more detail the dispersal of larvae from spawning grounds off the southwest Nova Scotia coast, this being one of the major sources of larvae in the region (Tibbo, *et al.*, 1958). The area studied is now the scene of a large fishery for pre-spawning and spawning adults (Iles and Tibbo, 1970) but the extent to which the stock contributes to the juvenile fisheries for herring in the Bay of Fundy and Gulf of Maine is not known with certainty and more detailed knowledge of larval movement from the spawning area was thought likely to make a contribution towards the solution of this problem.

Methods

The cruises were undertaken from the St. Andrews Biological Station of the Fisheries Research Board of Canada on M/V *E.E. Prince* during the periods 7-10 October, 28-30 October, and 14-17 November. The two October cruises covered the entrance to the Bay of Fundy and an area off the Nova Scotia coast north of latitude 44°32'; the November cruise surveyed the southern side of the entrance and much of the Bay of Fundy itself.

As far as possible sampling was based on a rectangular grid, station distances varying with circumstances from about five to about ten miles. An Isaacs-Kidd 2-m trawl (1.6 mm codend mesh) was towed at 5 knots and most of the water column was sampled.

A telemetering device on the trawl allowed the calibration of gear depth to warp length so as to estimate the leeway required to avoid bottom contact. About 5 m was allowed in shallow water and a little more than 10 m for deeper water. It was assumed that the water column above these depths was adequately sampled. The gear was lowered rapidly to the maximum depth of the tow and hauled step-wise during the 30-minute towing period to approximate an oblique tow.

Bathythermograph records were taken at each station and surface temperatures and salinities measured.

Plankton samples were sorted and analyzed at the St. Andrews laboratory. Fish larvae were identified and counted and total lengths of herring larvae were measured on the whole of small samples and on at least 100 of larger samples. Estimates of numbers of invertebrates in broad systematic categories were made for each station.

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[1] Submitted to the 1971 Annual Meeting of ICNAF as ICNAF Res.Doc. 71/98.

Larval escapement from gear

The high towing speed was designed to reduce larval avoidance of gear to a minimum. Such avoidance is usually demonstrated by markedly increased catches at night compared with day-time catches (Bridger, 1956). Table 1 lists day and night catches (numbers per tow) for each of the three cruises and for all taken together. There were no systematic differences that cannot be easily explained on the basis of differences in larval abundance in areas sampled at day and at night time.

Table 1. Comparison of day and night catches of herring larvae.

Cruise	Day		Night		
	Tows	Average No/Tow	Tows	Average No/Tow	Total Number of Larvae
7-10 October	28	465	22	283	19,242
27-30 October	30	126	16	468	10,318
14-17 November	18	191	10	282	6,307
All cruises together	76	266	48	324	35,867

That larval escapement was certainly reduced for the Isaacs-Kidd trawl is indicated by comparison of catches made at the same day-time station by a 1 m (60 mesh/inch) net hauled vertically (and thus more slowly) and the Isaacs-Kidd trawl hauled at 5 knots. Only larvae less than 14 mm total length were caught in the 1-m net, whereas a full size range up to 26+ mm was caught in the Isaacs-Kidd.

Herring larvae develop considerable short-burst swimming power at 15 mm as the caudal fin develops (Blaxter, 1962).

Results

Larval distribution and abundance

Larval numbers were plotted for each station and contour lines drawn at different levels of abundance to give results shown in Figs. 1-3 for the three cruises separately.

The results for the first cruise showed two areas of concentration of larvae, a small one at the southwest end of the Grand Manan Channel and a much larger and more dense one off the southwest coast of Nova Scotia which blankets the known spawning grounds of the Nova Scotia fall spawners (Tibbo, et al., 1958; Das, 1968). Within this area the highest concentrations occurred a few miles to the northwest of Trinity Ledge and a similar distance from Lurcher Shoal.

The westerly and southerly limits of this larval concentration were clearly delimited; if, as is thought likely, the main spawnings occur on

Trinity Ledges and Lurcher Shoals, then there was a general dispersion from this area but movement out of the area was restricted to the north and east; towards St. Mary's Bay and, on the outside of this Bay, along the north shore of Digby Neck into the Bay of Fundy proper. There is little evidence of larval movement across the entrance of the Bay of Fundy towards Grand Manan, nor on the northern side, of larvae moving out of the bay along the New Brunswick coast towards the Grand Manan channel. It should be noticed that relatively few larvae were found at the head of St. Mary's Bay itself.

By the end of October larval numbers had declined sharply (Fig. 2) both because of mortality and movement out of the area, but it is not possible to estimate the effect of each of these separately. The areas of high concentration had contracted, and the one immediately off the Nova Scotia coast had split up into northerly and southerly components. The reduction in larval numbers was much more marked in the Lurcher Shoals area and the western section of the survey area. An overall increase in density at the head of St. Mary's Bay towards its north side was indicated, however, suggesting a net accumulation of larvae there.

Again, there was little sign of transport across the entrance of the Bay of Fundy and the concentration of larvae at the southwest entrance to the Grand Manan channel was still evident and had moved only a very short distance.

The November cruise, extending into the Bay of Fundy, completed the pattern suggested by the two earlier cruises. The path of transport of larvae along the northern shore of Digby Neck could be seen as confluent with a large area of concentration centered at a point 15 miles southwest of Saint John and extending northwards and eastwards, up to Chignecto Bay and Minas Basin (Fig. 3). Densities were relatively high, implying an accumulation and retention of larvae in the area. There was also indication of a more even spatial dispersal of larvae in this area which is demonstrated in Fig. 4. This compares, for the three cruises, the frequency distribution of numbers of larvae/tow, divided into conveniently grouped cells. A higher proportion of the tows for the November cruise has high numbers of larvae and the frequency distribution was less asymmetric than for the two October cruises.

The westward limit of distribution was a little west of Saint John; no larvae were recorded west of Point Lepreau, so that again, there was no indication of transport of larvae out of the Bay of Fundy along the northern side.

Larval length distributions

Inspection of length-frequency distributions of larvae from individual tows for the first October cruise indicated size differences between areas. Five areas were separated; around Grand Manan, the southern part of the area off the southwest Nova Scotia coast, the entrance to St. Mary's Bay, the southern entrance to the Bay of Fundy, and lastly, the head of St. Mary's Bay, i.e., above the passages connecting the bay to the Bay of Fundy. Similar area differences were found for the results of the second October cruise and data for both cruises are presented for each area in Fig. 5.

The smallest larvae were found near the entrance to St. Mary's Bay, i.e., near Trinity Ledges; most were below 13 mm total length at the beginning of October and represent, probably, the products of a recent spawning in the vicinity. Larvae to the south and west of St. Mary's Bay were larger and those

nearer the entrance to the Bay of Fundy and around Digby Neck larger still.
Considering these three groups together, there was a suggestion, at least, of
three modes each, possibly, representing larvae spawned at different times
during the season. For the first October cruise larvae at the head of St.
Mary's Bay were distinctly larger than those at the mouth; very few were
smaller than 15 mm total length.

Finally larvae in the Grand Manan area were larger on average than in the
other areas and showed a much wider range of size, from 11 mm to 34 mm total
length.

By the end of October larvae in each of the areas were larger, although
only marginally so for those at the head of St. Mary's Bay. The differences
in average size for the other areas varied from about 3 mm to about 7 mm which
is consistent with larval growth rates given by Tibbo, *et al*. (1958) and Das
(1968) for larvae from the same general region.

There was no indication of an influx of smaller larvae in any area so
that it is highly improbable that any new spawning had occurred.

The length distribution for the November cruise had a wide range, from
about 10 mm to about 40 mm and had also a more even spread of length (Fig. 5);
this is consistent with the hypothesis that these larvae represented accumula-
tion of larvae transported into the Bay from Nova Scotia spawnings over the
spawning season as a whole, or over a large part of it.

Discussion

Evidence has been steadily accumulating that larvae from fall spawnings
off the southwest Nova Scotia coast are transported northwards and thence
northeast along the southern side of the Bay of Fundy along a non-tidal inflow
associated with the Gulf of Maine eddy (Tibbo, *et al*. 1958; Tibbo and Légaré,
1960; Das, 1968; Tibbo and Lauzier, 1970).

This study demonstrates such a transport and indicates that the path of
transport might be quite narrow (Fig. 2). However, a corresponding transport
out of the bay along the northern New Brunswick side, which would be associated
with the same current system (Tibbo and Lauzier, 1970) is not indicated by
these results. Instead, there is evidence, both from the distribution and
abundance of larvae and from length frequency distributions, that larvae trans-
ported into the bay on the southern side are retained in the shallow areas of
the upper part of the bay. This could be the result of a slackening off of
the current system which begins in the fall (Bumpus and Lauzier, 1965), and
results in almost a closed circulation within the Bay of Fundy during the
winter. It is now suggested that larvae retention inside the Bay of Fundy may
involve larval behavioural and activity patterns of the kind described by
Graham (in press) to account for overwintering larval concentrations in
estuaries along the Maine coast.

That such mechanisms may exist is suggested by the retention of larvae
at the head of St. Mary's Bay. It was shown above that in early October most
of the larvae at the head of this bay exceeded 15 mm in length, the same length
at which the development of the caudal fin confers a marked increase in swim-
ming ability, whereas, larvae at the entrance to the bay were smaller, implying
that maintenance of position is a function of swimming ability. This does not

imply that St. Mary's Bay is itself a major overwintering area for the larvae
of the Nova Scotia stock, neither its size nor the density of larvae found
there match up with the size of the stock or of the fishery it supports (Iles
and Tibbo, 1970), although it is not excluded as a possibility that larger
densities of larvae may occur in the bottom 5 m, not sampled by these surveys.

    The occurrence of larval concentrations during the fall, at the southwest
end of the Grand Manan channel might be construed as evidence of transport out
of the Bay of Fundy but the similarity in length distributions between early
and late October samples (and allowing for intervening growth) noted above
makes it far more likely that these represent a relatively stationary popula-
tion originating in the area itself. Das (1968) cites instances of spawning
being recorded in this area.

    On the other hand, larvae have been reported well inside the Bay of Fundy
during the fall and winter on many occasions. Tibbo, *et al*. (1958) record
such occurrences in the fall of 1956 and in the fall and winter of 1957-58,
Tibbo and Légaré (1960) in the fall and winter of 1958-59, Das (1968) in early
1961 and in the fall of 1962, and Tibbo and Lauzier (1970) in the autumn and
winter of 1967-68 and 1968-69.

    The question then arises whether the upper part of the Bay of Fundy is
the major area for overwintering larvae from the Nova Scotia spawnings and if
so, what is the pattern of movement of post larval fish after their first
winter. It is assumed by Das (1968) that the movement of these post larvae
will be dictated by the non-tidal drift current system set up in the area which,
as it develops in the spring, would carry any overwintering larvae out along
the New Brunswick coast. It is suggested now that passive drift by larvae,
although undoubtedly important during the early stages of development, becomes
less important as they develop even relatively modest swimming powers, so that
the dispersal of the young of the Nova Scotia stock may not be as widespread
as has been supposed. Certainly, "brit" (yearling) herring were also caught
during the November cruise well inside the Bay of Fundy and that a return of
brit and sardine (two-year-old) herring may be in the direction of the Nova
Scotia side of the entrance to the Bay of Fundy cannot be excluded. Iles (1970)
produced some evidence to question the commonly held hypothesis that the Nova
Scotia spawning provides recruits to the sardine fishery of the New Brunswick-
Maine coast, suggesting that sardine populations on both sides of the Bay of
Fundy are distinct. While neither that evidence, nor the implications of this
study are in any way conclusive, they do suggest that more detailed study of
the overwintering larval populations of the Bay of Fundy and attempts to com-
plete the life cycle by adequate sampling of later stages are likely to con-
tribute much to what is still the major herring problem in the region - the
origin of the sardines of the Bay of Fundy-Gulf of Maine.

    If the hypothesis suggested by this study can be substantiated, it will
have important implications.

    The Nova Scotia fall spawning stock would neither contribute to nor be
directly affected by the Gulf of Maine-New Brunswick fisheries for brit (year-
ling) and sardine fisheries and could be treated as a convenient unit for
management purposes. Again, if the Bay of Fundy is a major overwintering area
for larval herring, opportunity is created for the study of larval ecology of
a discrete population, and the possibility of estimating total abundance at
late larval or subsequent stages, if these can be adequately sampled, might
allow prediction of subsequent recruitment levels.

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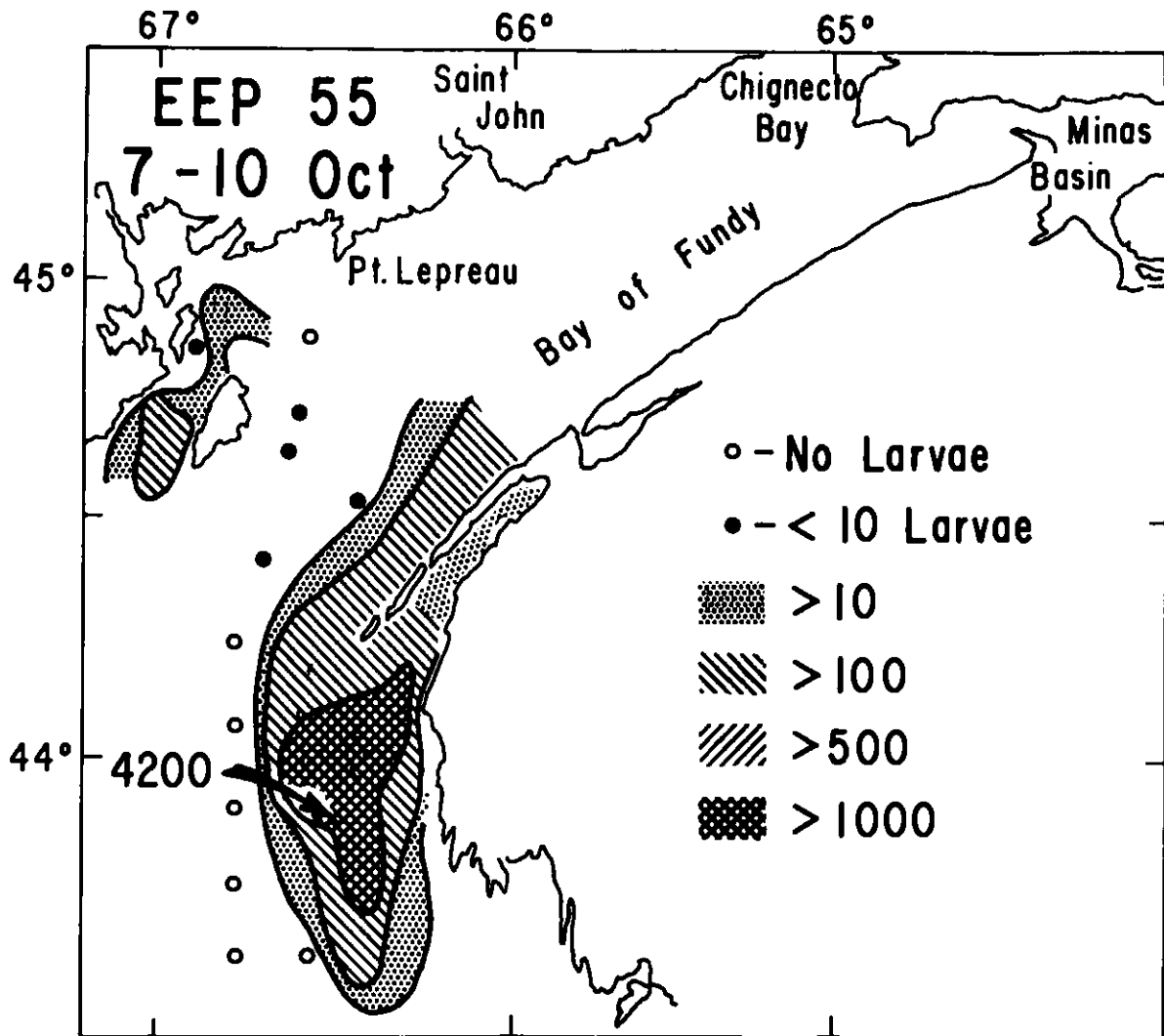
Fig. 1. Herring larval distribution and abundance in the Bay of Fundy - Nova Scotia southwest coast area. 7-10 October 1969.
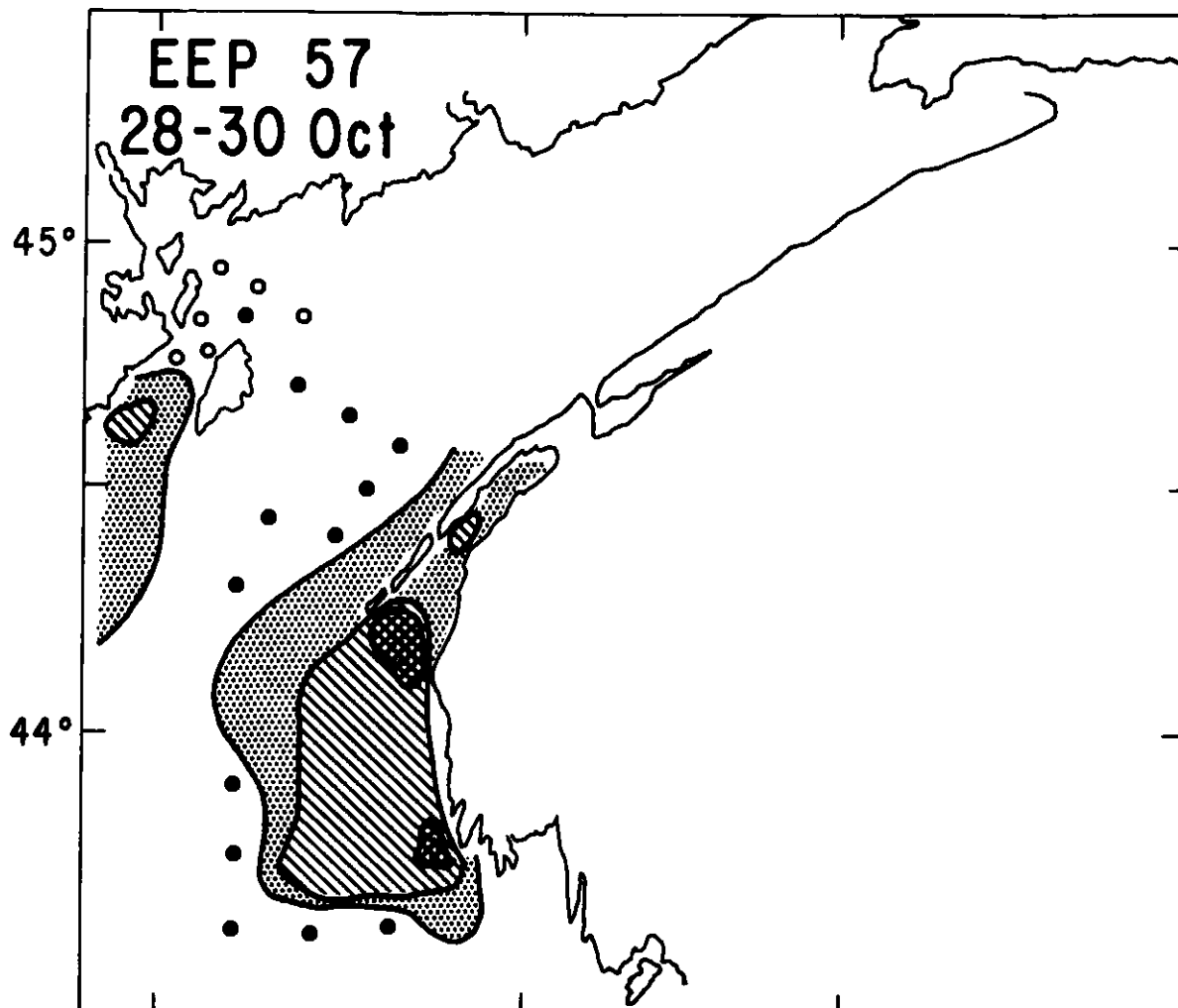
Fig. 2. Herring larval distribution and abundance in the Bay of Fundy -
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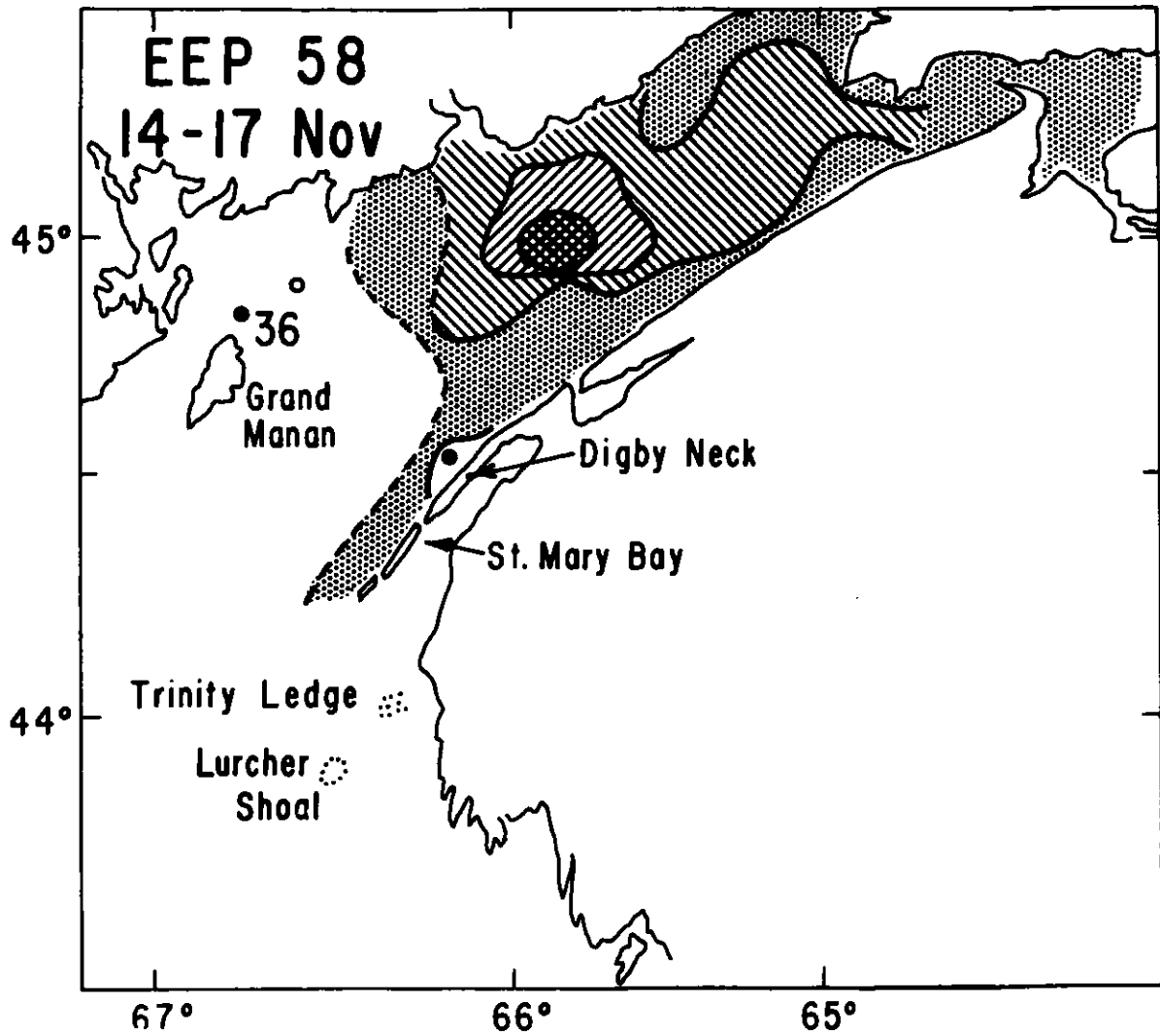
Fig. 3. Herring larval distribution and abundance in the Bay of Fundy -
Nova Scotia southwest coast area. 14-17 November 1969.
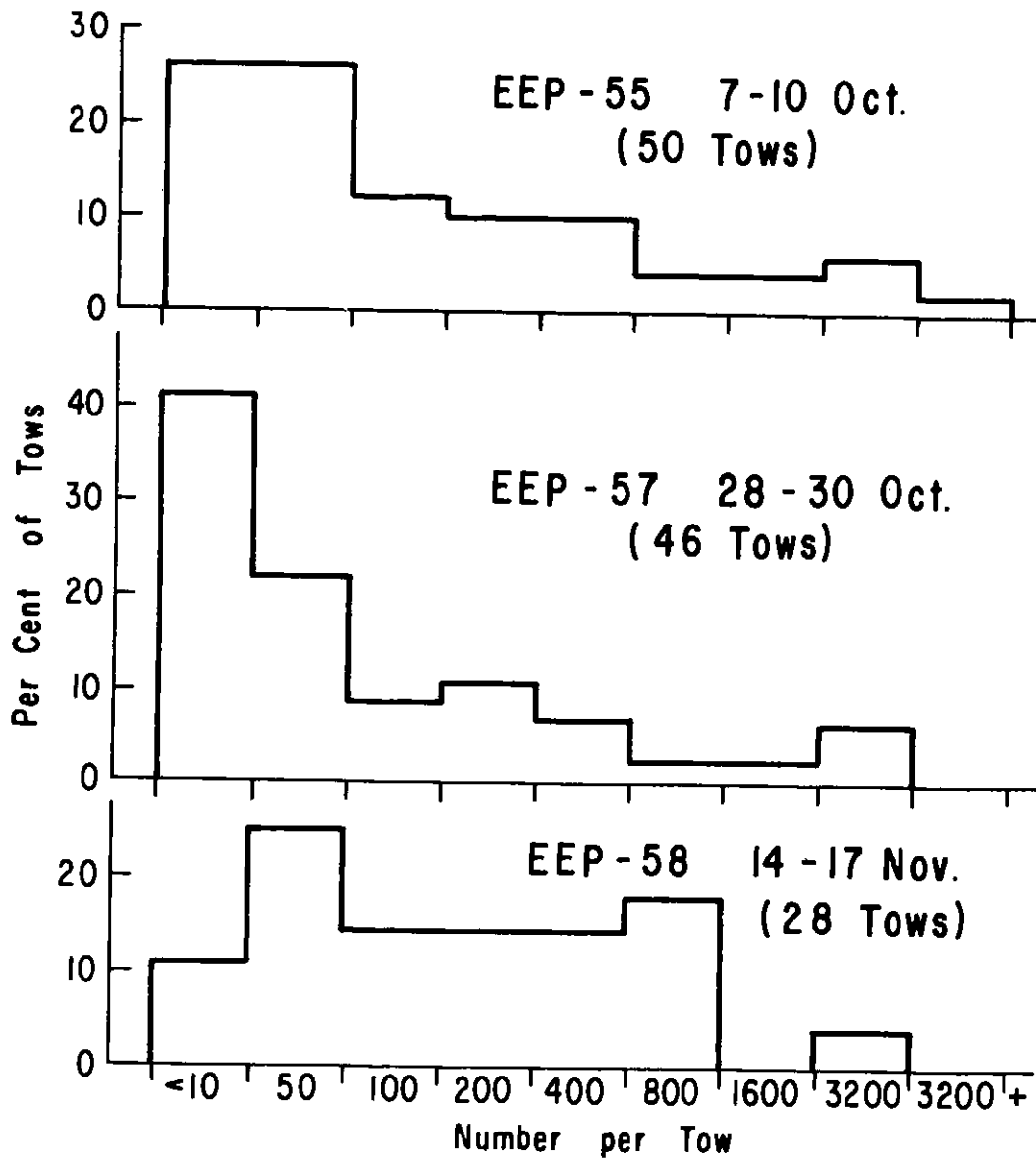
Fig. 4. Frequency distribution of number of larvae per tow for the three cruises.
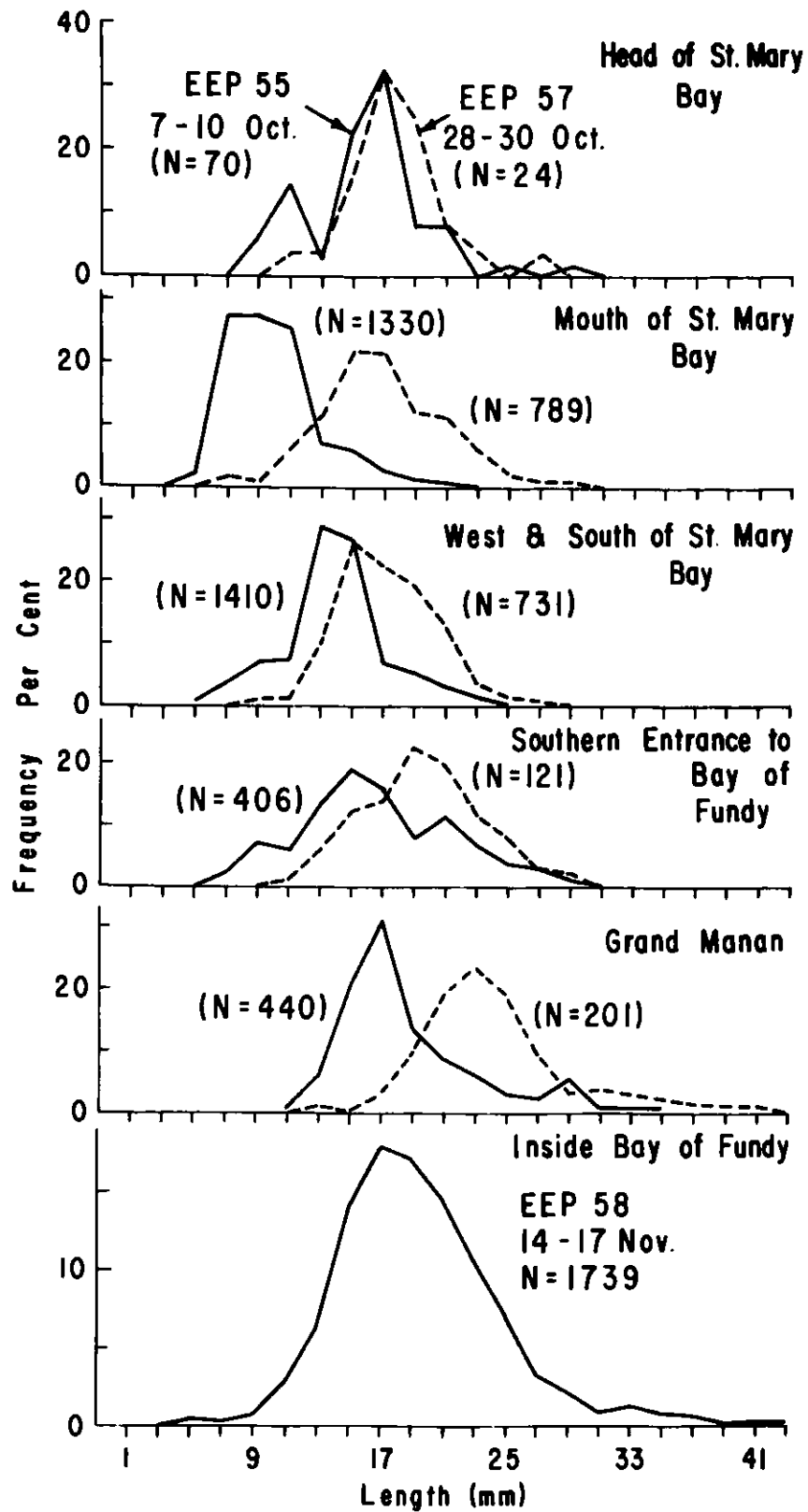
Fig. 5. Comparison of larval length frequency
distributions for the three cruises
(see text).

9. Status of the Southwest Newfoundland Herring Stocks, 1965-70[1]

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Introduction

Prior to 1965 the Newfoundland herring fishery was associated largely with the demand for herring as bait for the cod fishery and the sporadic demand for pickled herring products as food, especially during and immediately following World Wars I and II. In 1946 there was a peak landing of 75,000 metric tons, all of which were taken in coastal waters by gillnets and beach seines. Subsequently annual landings decreased to less than 10,000 tons in the early 1960's when the demand for herring as food was very low and most of the herring caught were utilized as bait. Purse-seining was introduced to the south coast of Newfoundland in the autumn of 1964 and landings from that area rapidly increased to 130,000 metric tons in 1968. This report considers the upsurge in herring landings in the light of recent knowledge on the size, distribution, biology, and migratory behaviour of the stocks.

Mobile fleet landings

In the autumn and winter of 1964-65 large concentrations of herring were found to overwinter in the fjords along the south coast of Newfoundland between Port aux Basques and Bay D'Espoir (Fig. 1, Areas J1 and J2). From a single fishing vessel in 1964 the seiner fleet participating in the winter fishery increased rapidly to 55 seiners during the 1969-70 season. In addition 10-15 vessels acted as carriers for some of the smaller seiners. Most of the herring are landed at processing plants at Harbour Breton, Burgeo and Isle aux Morts, and seiners account for more than 90% of the Newfoundland herring yield annually.

The southwest Newfoundland fishery begins in November and continues uninterrupted until April (Table 1). In July to October 1969 herring taken in the southwest part of the Gulf of St. Lawrence were landed in Newfoundland for the first time. Annual seiner landings increased from 7000 metric tons in 1965 to nearly 160,000 tons in 1969. The decrease to 148,000 tons in 1970 is largely due to greatly decreased catches in the autumn of that year.

The major winter fishery occurs mostly in the fjords and bays along the south coast in Areas J1 and J2 (Fig. 1, Table 2), which yielded 127,000 tons in 1969 and 119,000 tons in 1970. Up to 1968 the fishery took place largely in Area J1, but during the winter of 1969 and more so in 1970 the western half of the southwest coast (J2) yielded the largest quantity of herring.

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[1] submitted to the 1971 Annual Meeting of ICNAF as ICNAF Res. Doc.71/121.

Seiner landings from catches in other parts of the Newfoundland area have been relatively small and the fisheries based on localized stocks. Along the west coast of Newfoundland (Areas K and M) seiner landings ranged between 3000 and 6000 tons annually with most of the herring taken in November and December in or near Bonne Bay up to 1968 and more recently in Hawke's Bay. The small Fortune Bay stock (Area I), which yielded nearly 12,000 tons to seiners in 1968 but less than 5000 tons in 1969, showed some improvement in the winter of 1970 with a yield of 8000 tons (Table 2). However, the small stock in Areas G and H, which yielded over 6000 tons to seiners in the spring of 1968 remained at a very low level of abundance in 1969 and 1970. This stock was greatly affected by phosphorus poisoning in Placentia Bay (H) during the winter and spring of 1969 when a high proportion of the adult population (estimated at more than 80%) died.
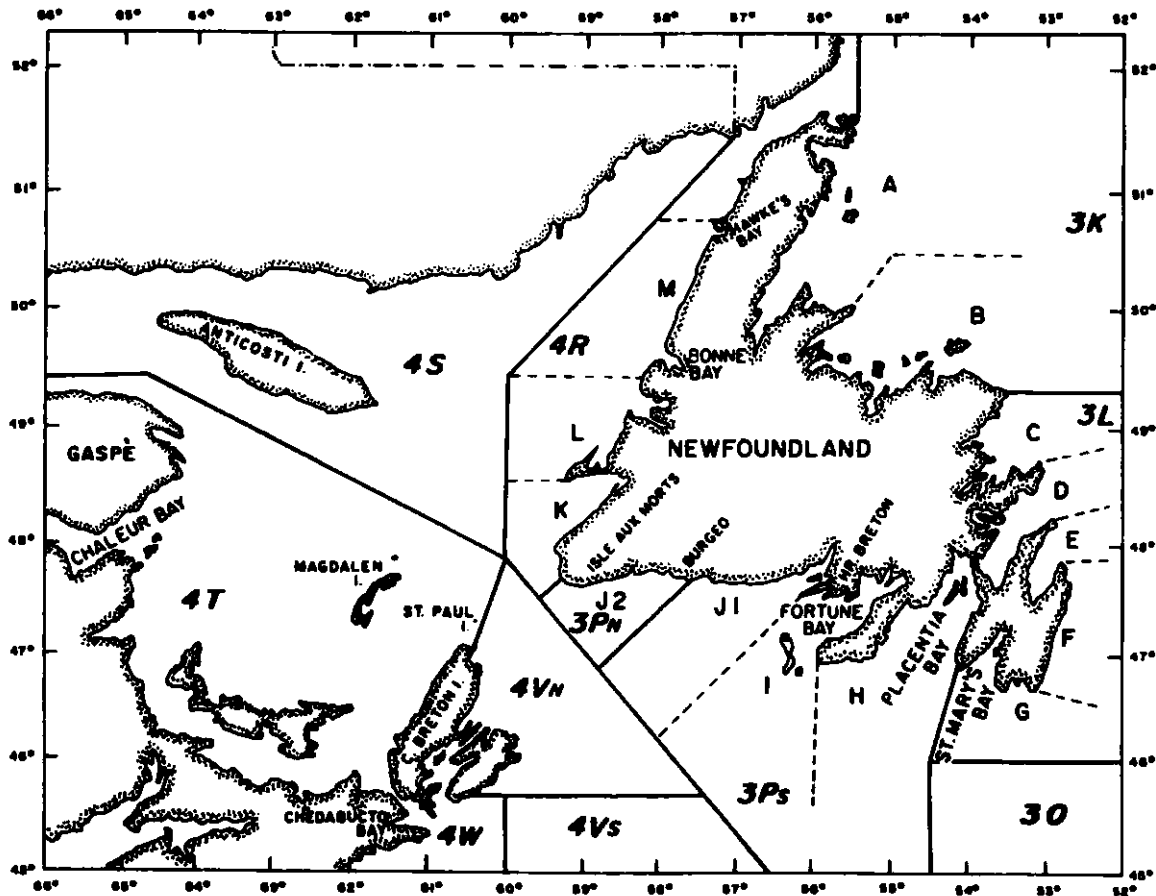
Fig. 1.   Map of the Gulf of St. Lawrence-Newfoundland area for reference to place names and statistical areas mentioned in the text.

Table 1. Monthly distribution of seiner landings (metric tons)
in Newfoundland, 1965-70.

Month	1965	1966	1967	1968	1969	1970
Jan.	395	3,285	16,807	23,379	42,028	51,691
Feb.	763	4,098	11,962	22,870	33,118	30,833
Mar.	303	4,445	10,057	22,814	21,998	31,014
Apr.	313	1,864	11,848	11,294	8,645	14,055
May	392	-	1,375	2,501	2,377	1,963
Jun.	-	-	-	-	-	-
Jul.	-	-	-	-	1,686	477
Aug.	-	-	-	-	3,478	332
Sep.	-	-	-	-	737	31
Oct.	-	-	-	1,057	552	220
Nov.	1,534	4,013	7,247	12,631	11,071	1,873
Dec.	3,264	8,257	22,778	46,438	33,564	15,211
Total	6,964	25,962	82,074	142,984	159,254	147,700

Table 2. Area distribution of seiner and midwater trawler landings
(metric tons) in Newfoundland, 1965-70.

Area	1965	1966	1967	1968	1969	1970
GH	23	612	1,302	6,278	220	290
I	19	-	4,567	11,662	4,827	7,971
J1	3,331	15,324	57,102	82,918	42,906	30,036
J2	472	4,054	10,408	26,450	84,020	88,612
K	-	492	672	1,793	240	28
M	3,119	5,480	5,452	3,903	2,340	2,946
Nfld.	6,964	25,962	79,503	133,004	134,553	129,883
4T	-	-	2,571	9,633	21,503	14,741
4V	-	-	-	347	3,198	3,076
T+V	-	-	2,571	9,980	24,701	17,817
Total	6,964	25,962	82,074	142,984	159,254	147,700

In recent years the seiners (and occasionally midwater
trawlers) landings at Newfoundland ports have enlarged their sphere
of fishing activity to the southern Gulf of St. Lawrence (4T) and
northeastern Nova Scotia (4V). Division 4T catches (Table 2) came
mostly from the Magdalen Islands (Bird Rocks) and northern Cape Breton
(St. Paul Island), and the 4V catches from Sydney Bight and Chedabucto
Bay. In 1969 Newfoundland herring landings from these regions totalled
25,000 tons, taken mostly in November and April, but in 1970 the yield
was substantially less due to a poor fishery at Magdalen Islands in
the fall.

Catch statistics for the 1971 winter fishery along southwest
Newfoundland (Areas J1 and J2) are not yet fully available, but infor-
mation from plant officials and seiner captains indicate that the
herring yield may not exceed one-half of that recorded for the winter
of 1970.

Status of the Southwest Newfoundland herring stock

Investigations began in 1965 to elucidate the size, distribution,
biology and migratory behaviour of the herring stocks which support the
winter purse seine fishery (Hodder, 1967; Hourston, 1968). These were
intensified in 1969. Efforts were continued to improve the collection of
information on area of capture through log book records and port inter-
views. The sampling of seiner landings was carried out at the major
ports of landing and several thousand herring were examined annually for
information on their biology. During the past 2 years the seasonal
migratory behaviour of the stock has been determined by meristic studies
and tagging.

There has been a gradual increase in the average size of herring
taken along southwestern Newfoundland since the purse seine fishery began
in 1965 (Fig. 2). The modal size (total length to the 0.5 cm below)
increased from 32 cm in the winter of 1966 to 34 cm in the autumn and
winter of 1970-71. Similarly the average length increased by about 2 cm
over the 6-year period. More than 95% of the herring were in the 30-36
cm length range.

The composition of the samples by maturity stages indicates a
mixture of spring and autumn spawners, the latter comprising two-thirds
or more of the seiner catches. Immature herring were rare in the samples.
The relative proportions of spring and autumn spawners in the samples
taken for ageing are given in Fig. 3.

Age determinations, based on otolith readings, reveal that the
southwest Newfoundland winter fishery since its inception has been
largely dependent on a very abundant 1958 year-class of autumn spawners
and a smaller 1959 year-class of spring spawners (Fig. 3). Both the
length and age frequencies indicate a lack of substantial recruitment to
the adult stock.
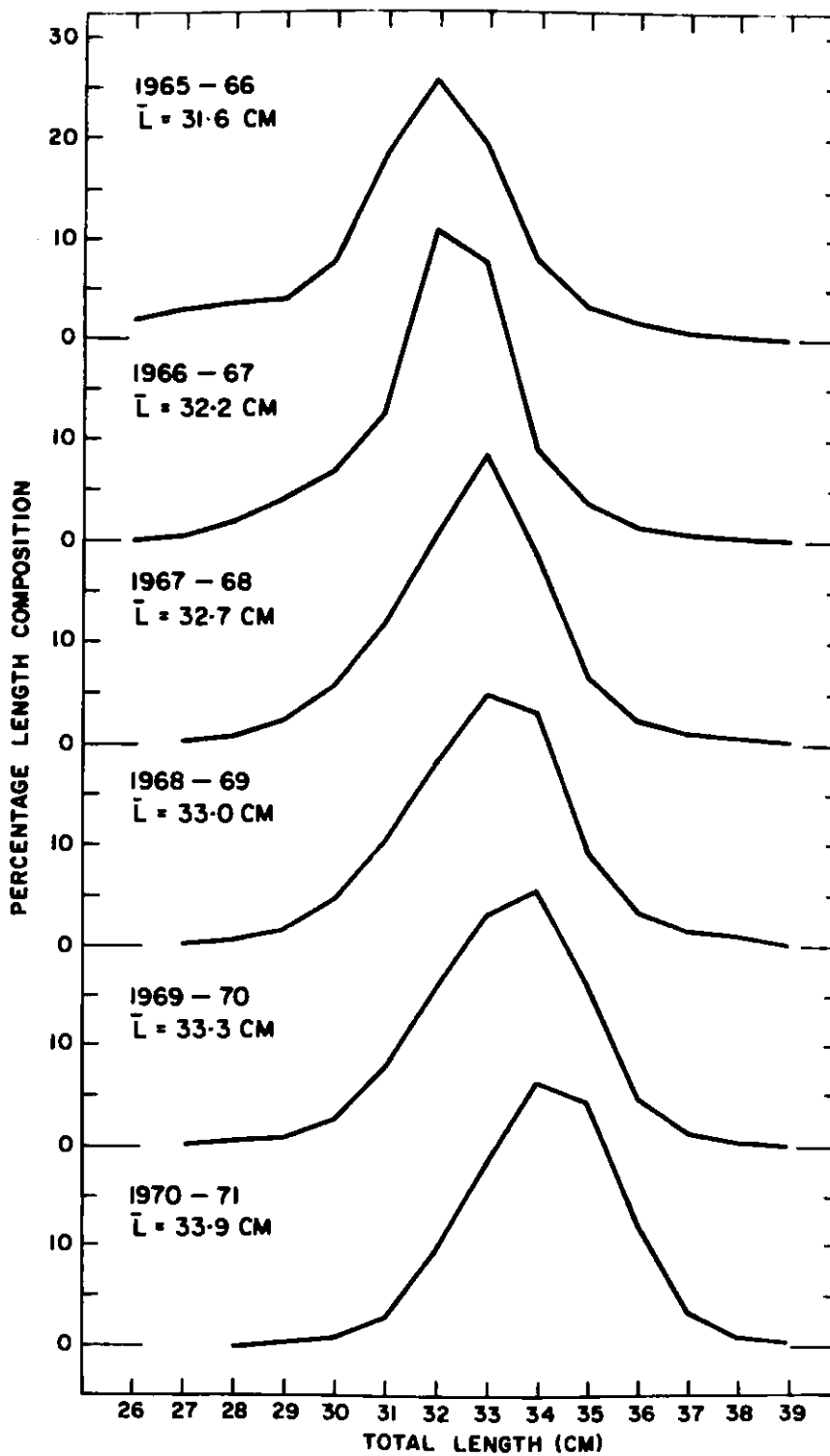
Fig. 2.   Length composition of herring sampled from the southwest
Newfoundland fishery, 1965-66 to 1970-71 seasons.
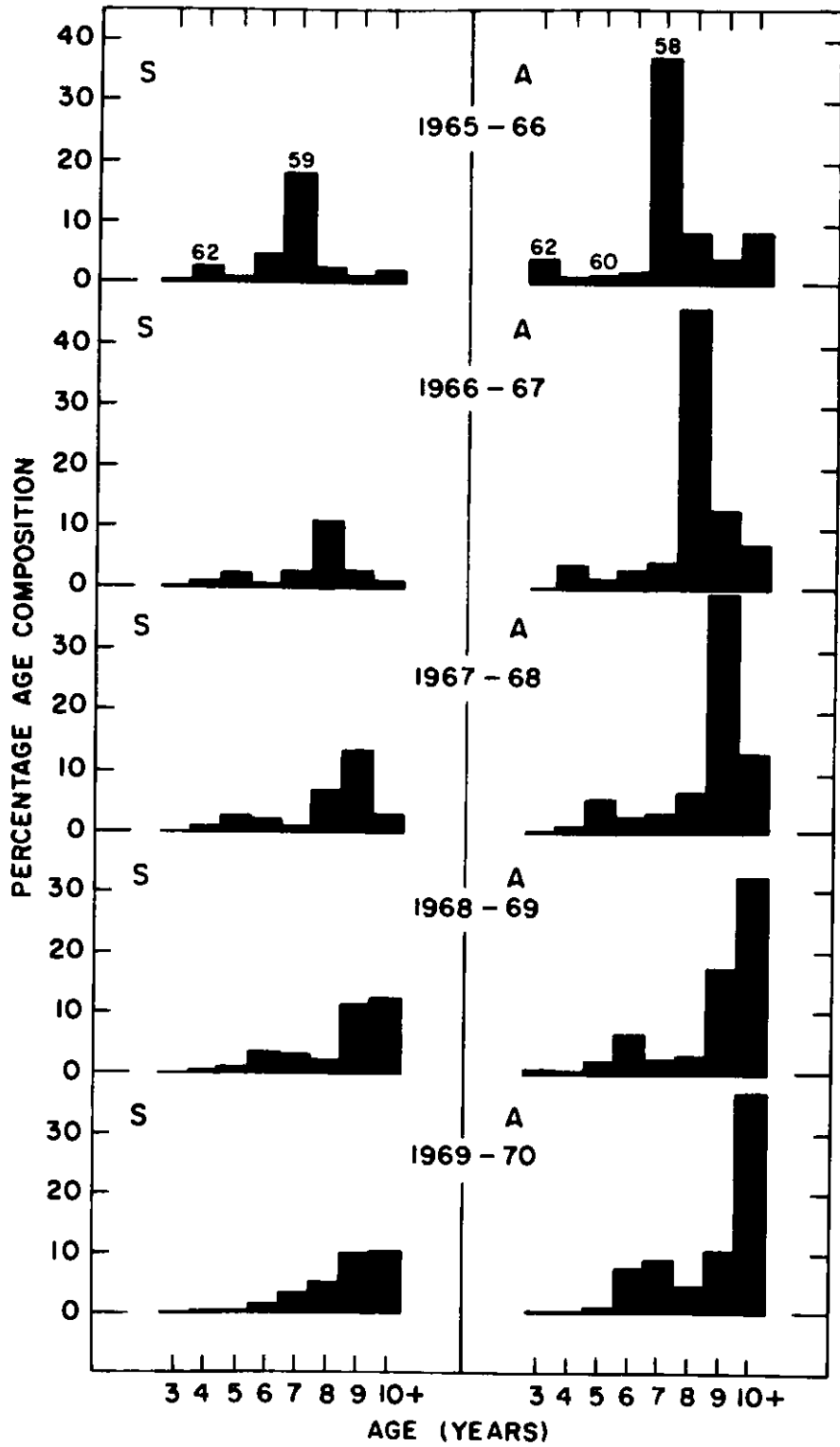
Fig. 3. Relative age composition of spring (S) and autumn (A) spawning herring sampled from the southwest Newfoundland fishery, 1965-66 to 1969-70 seasons.

The predominance of autumn-spawning herring in the great concentrations which arrive in southwestern Newfoundland in November indicate that autumn spawning must be very extensive in Northwest Atlantic waters. However, no extensive autumn-spawning areas in Newfoundland waters were known prior to the development of the purse-seine fishery. In the autumns of 1968 and 1969 surveys along southern Newfoundland for recently hatched herring larvae produced no evidence of extensive spawning, despite the large numbers of autumn spawners which overwinter in the fjords there.

The distribution of seiner catches at the start of each season indicate that herring arrive from the westward in late November and within a few days are distributed widely in the fjords along the southwest coast. After January the fishery gradually shifts westward and the last catches for the season are usually made off the southwest corner of Newfoundland in April (Fig. 4). For about 3-4 weeks prior to the appearance of herring in southwest Newfoundland waters in late November, there is a fairly intense fishery at Magdalen Islands. Also, about a week after the herring leave Newfoundland in April, a short spring fishery again occurs in an area between St. Paul Island and Magdalen Islands, followed by a substantial summer fishery in the southwestern part of the Gulf of St. Lawrence during June to September.

In 1969 herring samples from seiner catches at Magdalen Islands in November were compared with samples taken from catches in the coastal waters of southwestern Newfoundland in late November and early December (Hodder and Parsons, 1970). In summary the study showed that there was no significant difference between areas for all of the biological characters examined (length, age, maturity condition, vertebral numbers, pectoral, dorsal and anal fin ray numbers, and *Anisakis* nematodes), although for nearly all of the characters very significant differences were apparent between spring and autumn spawners which were present in the samples from both areas in about the same proportion. The analysis thus supported the hypothesis that the winter fishery along southwest Newfoundland is largely dependent on herring schools which migrate eastward from the southern part of the Gulf of St. Lawrence in the autumn.

Both the eastward movement of herring from the southwestern Gulf of St. Lawrence to southern Newfoundland in the autumn and the westward movement in the spring have recently been confirmed by tag recaptures from more than 80,000 tagged herring which were released in March, May and August 1970 in southwest Newfoundland, at Magdalen Islands and near the Gaspé Peninsula respectively (Hodder and Winters, 1970; Winters, 1971a; Beckett, 1971). The absence of tag recaptures from a substantial purse seine fishery in Chedabucto Bay during the winter of 1971 (J. S. Beckett, 1971) and the recovery of only 2 tags during the 1971 winter fishery along southwest Newfoundland from the liberation of 3400 tagged herring in the northeastern part of the Gulf of St. Lawrence in early December 1970 (G. H. Winters, personal communication) suggest that the southern Gulf of St. Lawrence-southwest
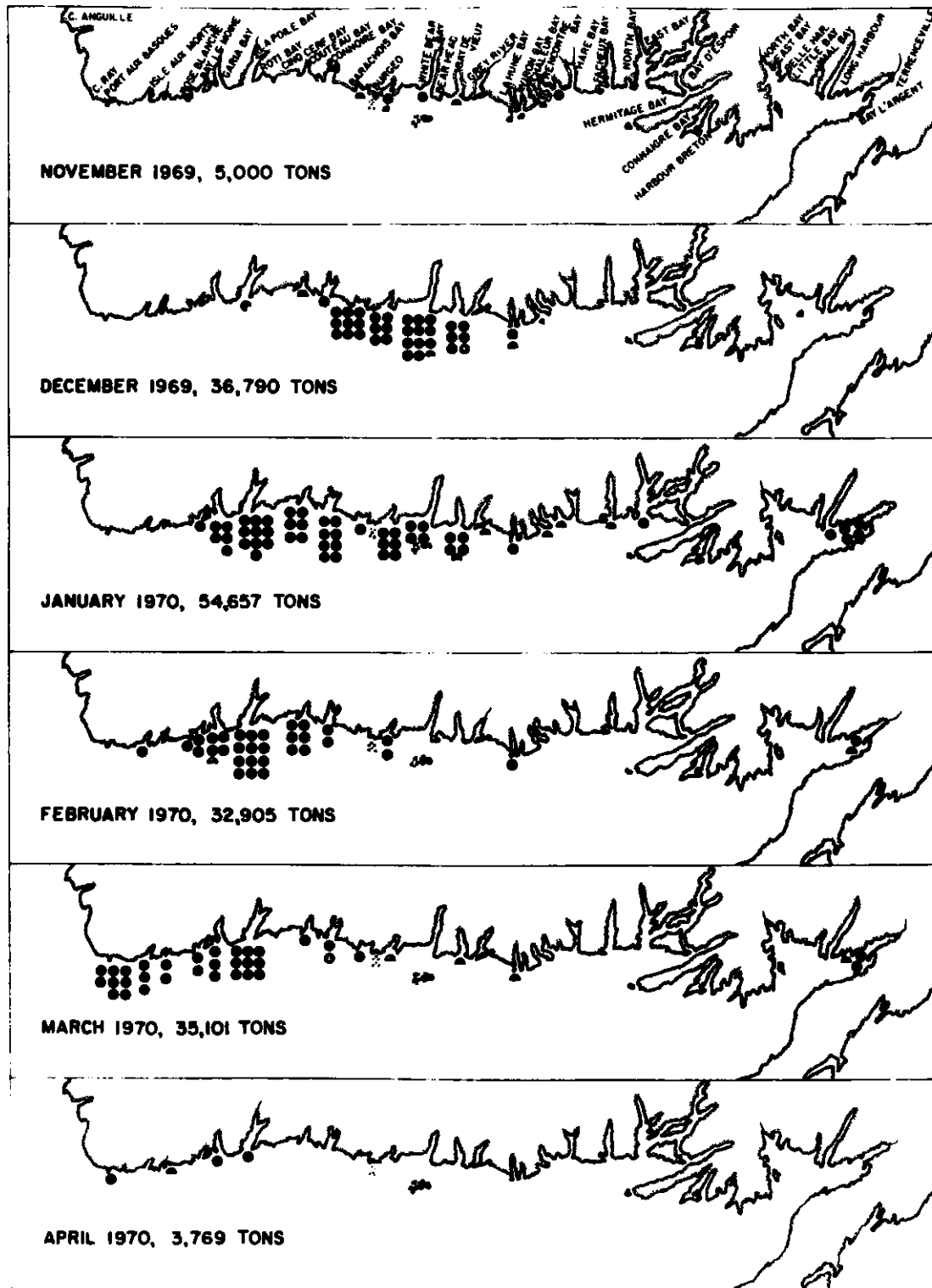
Fig. 4. Monthly distribution of seiner catches along southwestern Newfoundland during the 1969-70 season. (Each full dot represents 1000 tons of herring.)

Newfoundland stock complex of adult herring does not deviate significantly from its seasonal east-west migration route, nor does it appear that the stock, at least when it is in southwest Newfoundland waters, is supplemented by a significant influx of herring from other areas.

Preliminary estimates from tagging data indicate that the stock size of the southwest Newfoundland herring population was about 400,000 tons at the start of the 1969-70 winter fishery and about 250,000 tons at the beginning of the 1970-71 season (Winters, 1971b). The "exploitation rate" was estimated at 4-5% per month. If a similar rate applies for the summer fisheries in the southern Gulf of St. Lawrence, the annual rate for the stock as a whole would be about 40-50%.

Conclusions

The recent increase in Newfoundland herring landings is due to the development of a substantial autumn and winter purse seine fishery in the fjords along the western part of the south coast. Concurrent with the development of this fishery was a rapid expansion of the summer fishery in the southern part of the Gulf of St. Lawrence. Consequently, the question arises as to whether or not these fisheries can continue successfully if the same stocks are being fished almost continuously at different times and places along their migratory route.

Recent studies show that herring samples taken during the autumn along southwestern Newfoundland differ in certain biological features from samples taken in other areas of Newfoundland and Labrador and on the northern part of the Scotian Shelf, but are very similar to those taken at Magdalen Islands just prior to the start of the Newfoundland autumn and winter fishery. In the spring the herring schools migrate westward to Magdalen Islands and later in June and July to the Gaspé Peninsula-Chaleur Bay region of the Gulf of St. Lawrence.

About the time that the herring leave the Newfoundland coast in the spring some separation of spring- and autumn-spawning herring is evident from samples taken from seiner catches near the end of the season in early April. The short fishery at Magdalen Islands in late April and early May is based mostly on herring schools heading for shallow water to spawn, but a few catches consist mostly of autumn spawners. However, the latter probably disperse to a large extent and ultimately move westward to the southwestern part of the Gulf, where they feed during the summer and spawn in late summer and early autumn.

The winter fishery along southwest Newfoundland is almost entirely on adult herring, that is, herring with gonads well-developed for spawning in the spring and herring which have only begun to recover from autumn spawning, the latter being dominant in the catches. The average size and age of these 2 spawning groups have gradually increased

over the past 5-6 years, and the fisheries have been maintained over
the period by the abundance of pre-1960 year-classes (1958 year-class
of autumn spawners and 1969 year-class of spring spawners). The
scarcity of immature herring in the southwest Newfoundland catches
suggests that annual recruitment to the stock occurs possibly during
the summer in the Gulf of St. Lawrence. Age composition data indicate
that recruitment has been relatively poor in recent years.

Between the autumns of 1969 and 1970 the stock size in
southwest Newfoundland waters is estimated to have declined by about
40%. The 1971 winter catch of herring in the same area is estimated
to be about 50% of that recorded for 1970. Part of the decline in
catch can be attributed to rather severe weather conditions during
the past winter, but part is undoubtedly due to poor recruitment of
young and to reduced abundance of older fish. Also the estimated
exploitation rate of 40-50% is dangerously close to the level at which
the Atlanto-Scandian stock began to collapse according to the report of
the Atlanto-Scandian herring working group.

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10. Feeding and migrations of the roundnose grenadier, *Macrourus rupestris*[1],
in the Northwest Atlantic and Iceland waters[2]

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This report summarizes the results of a study of some aspects of the feeding and migrations of the roundnose grenadier, *Macrourus rupestris*, in the Northwest Atlantic and Iceland waters.

The material for the study was collected from 1967 to 1970 in the Iceland, West Greenland, Baffin Island, Labrador and the northern Newfoundland Bank areas.

Papers by Podrazhanskaya (1968, 1969) and Konstantinov and Podrazhanskaya (in press) give detailed analyses of the locality and diurnal rhythm of feeding, changes in the feeding habits with growth, and feeding habits at different depths as well as the food relations of the roundnose grenadier and other deep-water commercial fish species occurring within the same depth range, such as deep-water redfish and Greenland halibut. Therefore, this paper is limited to a general description of feeding and its seasonal dynamics. This will enable us to proceed to the pattern of feeding and spawning migrations of the roundnose grenadier.

The stomach contents of the roundnose grenadier show quite a number of forage species (52) represented mostly by planktonic and nectobenthic forms (*Themisto*, copepods, Euphausiidae, squid, fish). Only representatives of the order Polychaeta are associated with the bottom; shrimps (*P. borealis*, genus *Pantophilus*) also live close to the bottom. Sand, mud and stones are sometimes observed in the stomachs of the roundnose grenadier, which suggests that they may go to the bottom in search of food.

The qualitative composition of forage organisms and the frequency of their occurrence vary considerably within the months of observations. However, the data do not show any consistent pattern, except that the total indices and the degree of fullness of the stomachs increase from September to December (Fig. 1).

The possibility of the feeding of the roundnose grenadier becoming more intensive from September to December is supported by the fatness dynamics (Fig. 1). In the Northwest Atlantic the fat content (percentage weight of liver to weight of whole fish) of the roundnose grenadier increases from August reaching a maximum in December. In the Icelandic area, the fat content follows a downward trend from June and reaches a minimum in August.

Material collected on the fatness of the roundnose grenadier in some areas within the Northwest Atlantic (northern Newfoundland Bank and Baffin Island) has also been analyzed. Fig. 2 shows that in the northern Newfoundland Bank area, the fat content increases with the size of fish. This is typical of all Gadidae.

In the Baffin Island area, the fat content is somewhat stabilized irrespective of the size of fish. In this area the fish seem to accumulate and store

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[1] Common and scientific name as used in ICNAF Statistical Bulletin.
[2] Submitted to the 1971 Annual Meeting of ICNAF as ICNAF Res.Doc. 71/89.

a certain amount of fat.

It seems appropriate here to consider the question of the migration of the roundnose grenadier in some detail. Investigations conducted by PINRO in the North Atlantic over the past few years (1965-1970) have not revealed the spawning areas of the roundnose grenadier.

Zakharov and Mokanu (1970) suggested that the roundnose grenadier spawned in Icelandic waters. This seems quite likely and the material collected suggests that the eggs and larvae are carried passively by the Irminger Current from Iceland to the waters south of Greenland. From there the western branch of the West Greenland Current takes the young fish to Baffin Island and the waters of the Canadian and then the Labrador Currents take them to the northern Newfoundland Bank where they stay at depths of 600 to 900 m. On reaching a length of 40 to 50 cm, the roundnose grenadier start migrating back to their spawning grounds (Fig. 3).

Unfortunately, it does not seem possible to check and confirm the suggested pattern of migration by tagging experiments because the fish in trawl catches are always severely injured as a result of sharp drop in the pressure.

The suggested pattern of migration is based on the analysis of feeding, fatness, length-weight composition and sex ratio.

The fish, which have accumulated a certain amount of fat at Baffin Island, seem to start their pre-spawning migration to Icelandic waters. It is quite likely that here we have a situation similar to that for the Barents Sea haddock (Sonina, 1969). During the years when haddock feed on benthos, the duration of the feeding period and the time when the fish leave their feeding grounds usually depend on fatness. Haddock leave their feeding grounds having a fat content of not less than 4.5-5.0%. The sooner they accumulate sufficient fat, the earlier they leave the feeding grounds, i.e., the cessation of feeding and the migration from the feeding grounds are related to the accumulation of a certain amount of fat. The area where the roundnose grenadier feed before they leave for the spawning grounds appears to be the Baffin Island area. This is supported by the data presented in Table 1.

Table 1. The mean index of the degree of fullness of the stomachs of *Macrourus rupestris* in different areas of the North Atlantic.

Area	1967	1969	1970
Iceland	0.8	0.8	1.3
West Greenland	0.9	1.4	1.5
Baffin Island	1.5	1.8	2.4
Northern Labrador	1.5	1.8	1.7
Northern Newfoundland Bank	1.3	–	0.6

The size composition of the roundnose grenadier caught in the areas surveyed is shown in Fig. 4. It shows that the smallest fish occur on the northern Newfoundland Bank where the modal length is 45-47 cm. In the Baffin Island

area, the modal length is 60-62 cm and at West Greenland it is 78-80 cm. The largest fish occur at Iceland where they are on the average 20 cm longer than in the above areas. These data are in agreement with those obtained earlier (Savvatimsky, 1969; Pechenik and Troyanovsky, 1970) and may be taken as confirmation of the suggested migration pattern if it is assumed that as they grow they move back to their spawning grounds. Many fish species, for example the Labrador cod, are known to perform migrations of this kind (Serebryakov, 1967). The Labrador cod spawn mainly along the slope off northern Labrador, the larvae and young fish in earlier developmental stages drift southward to the northeastern slope of the Grand Newfoundland Bank and as they grow they come back to the northern Newfoundland Bank and Labrador areas.

Roundnose grenadier caught at 145-900 m in the northern Newfoundland Bank, Northern Labrador, Baffin Island and West Greenland areas in July-August 1970 were immature even at their maximum length of 108-110 cm. At southeast Iceland the population consisted of fish in the pre-spawning and spawning state in May and of spawning and spent fish in August (Table 2). Thus, it is quite likely that the waters of the Canadian and Greenland slopes are the feeding grounds for the roundnose grenadier and the areas from which the grown fish migrate to Iceland, the area where they were born. A similar migration pattern is followed by the Barents Sea herring which spawn mainly outside the Barents Sea along the northwest coast of Norway. From here the larvae and young fish are brought by the North Cape Current and are widely distributed within the Barents Sea (Marty, 1956).

Table 2. Maturity stages of *Macrourus rupestris* in Iceland waters.

Month	Sex	No. of fish	No. fish at maturity stages						
			1	2	3	4	5	6	6-2
May	males	38	3	28	3	2	2	-	-
	females	17	-	14	1	2	-	-	-
August	males	54	-	39	5	-	-	7	3
	females	106	-	59	11	1	-	1	34

It should be noted that the male-female ratio was found to be 2 to 1 in Canadian waters (Fig. 5) and 1 to 2 in Iceland waters.

The material available at present does not permit any definite conclusions but the females seem to mature and to arrive in the spawning area earlier than males.

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fat content %

degree of fullness

total index of fullness %...

month
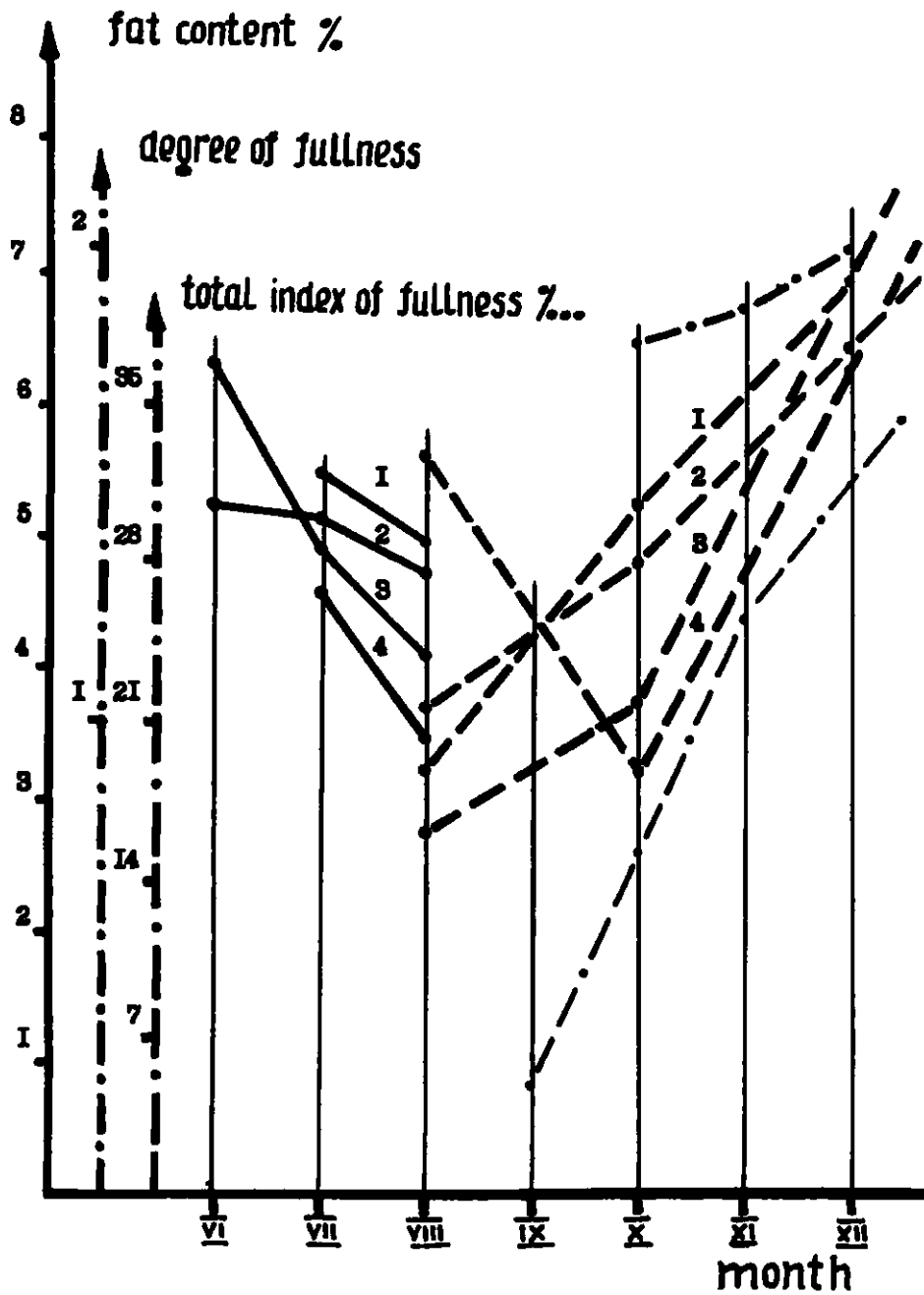
Fig. 1. Changes in the intensity of feeding and in the fat
content of *Macrourus rupestris* in different areas
of the North Atlantic in summer-winter 1967.
——————— Iceland
————————— Northwest Atlantic
Size groups: 1. 40-50 cm
2. 51-60 cm
3. 61-70 cm
4. 71-80 cm
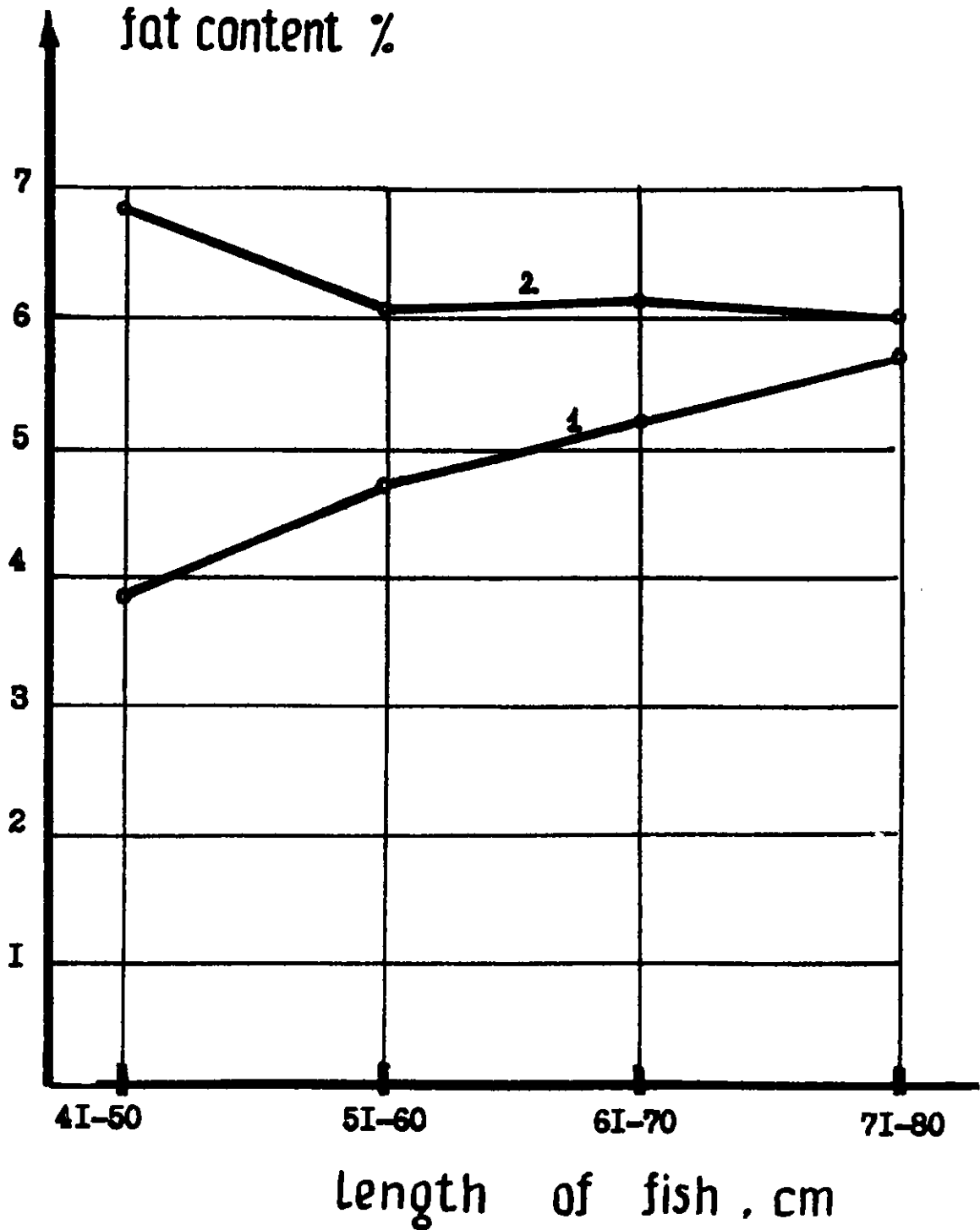
Fig. 2. Changes with size in the fat content of *Macrourus rupestris* in different areas of the Northwest Atlantic (July-August 1970).
1. Northern Newfoundland Bank
2. Baffin Island
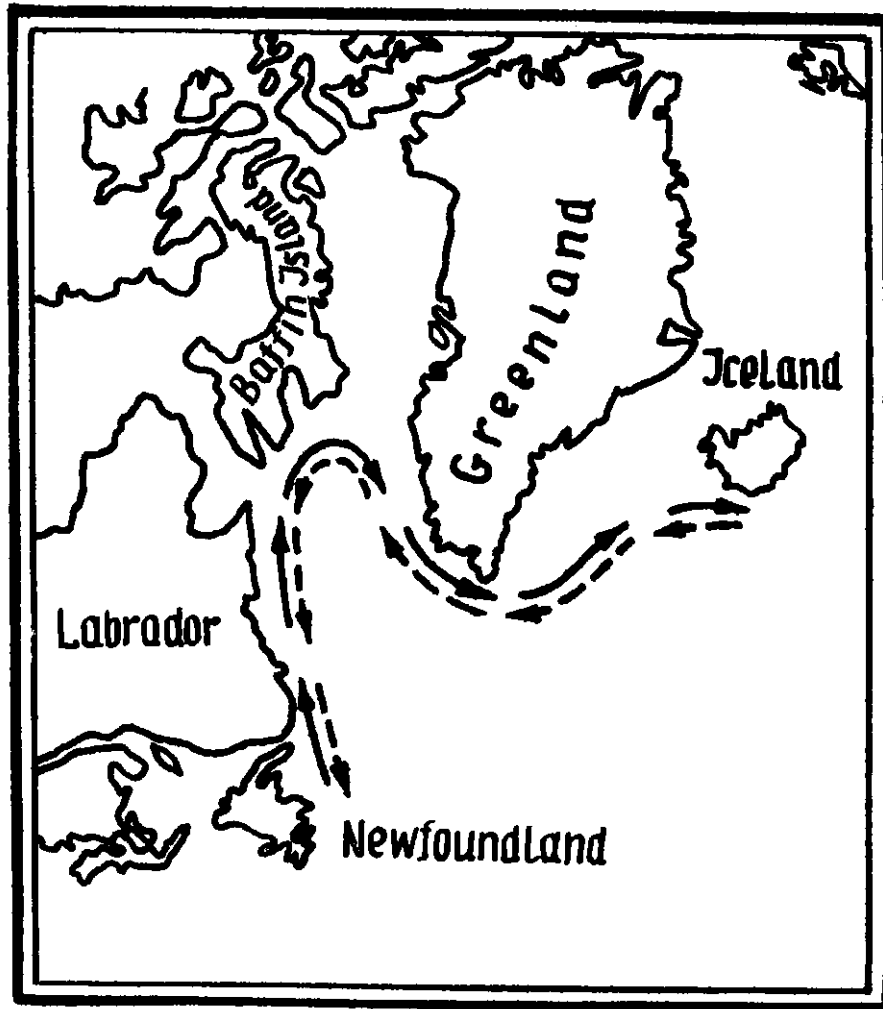
Fig. 3. Suggested spawning and feeding migrations of
Macrourus rupestris of North Atlantic.

spawning migration
feeding migration
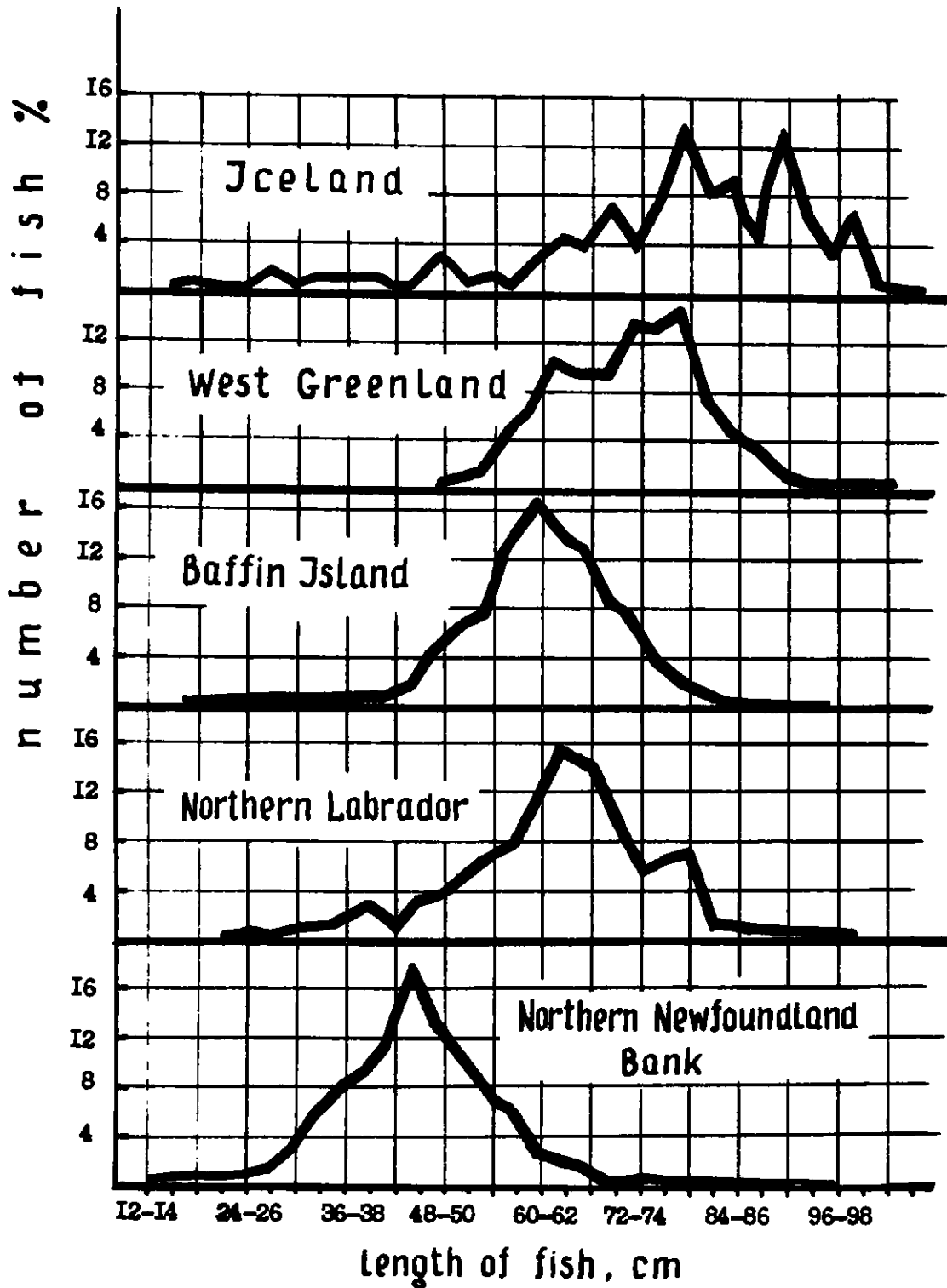
Fig. 4. Size composition of *Macrourus rupestris* caught in different areas of the North Atlantic in the summer of 1970.
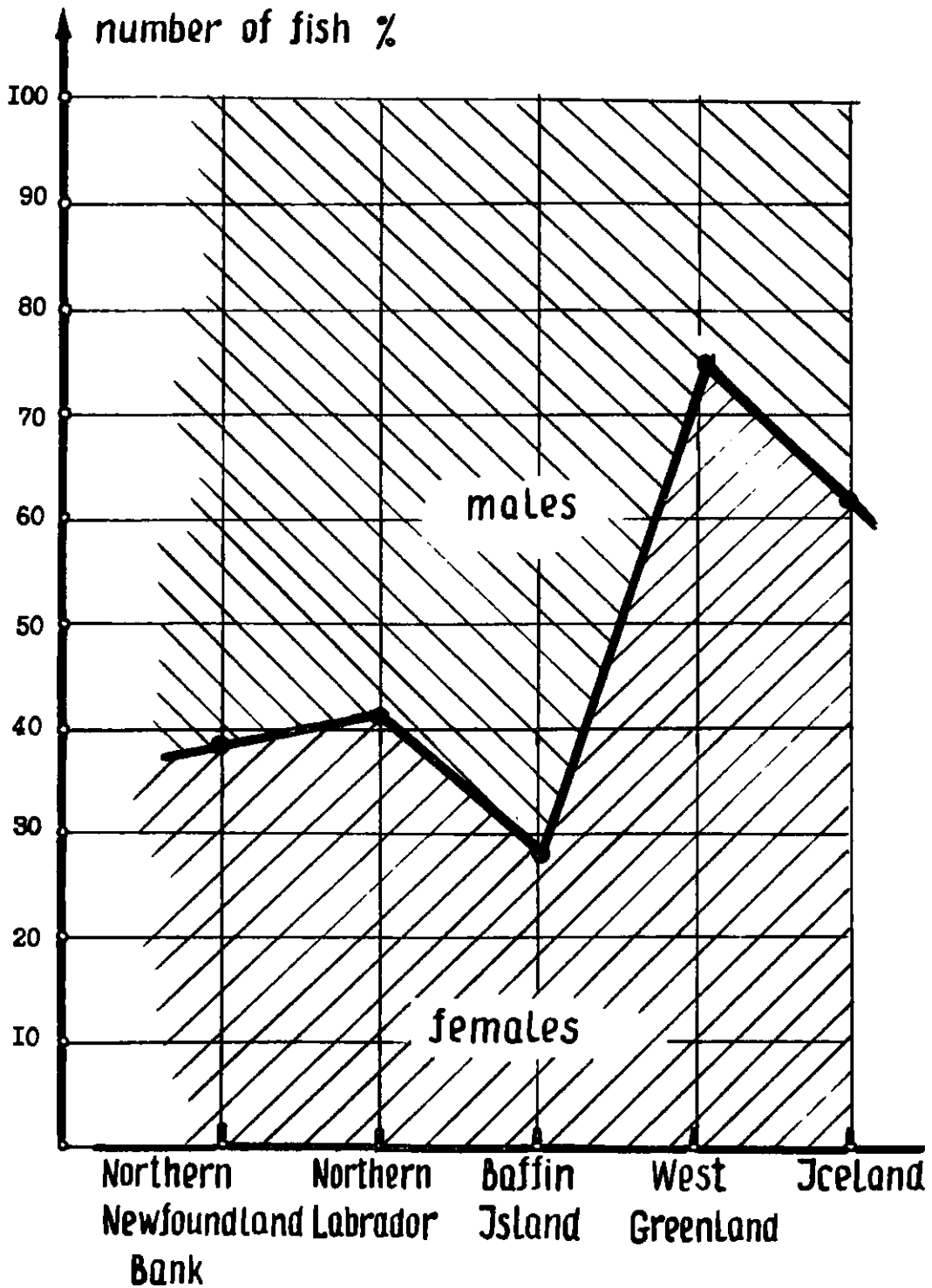
Fig. 5. Sex ratio of *Macrourus rupestris* in different areas of the North Atlantic in the summer of 1970.

11. Studies of the age and growth of roundnose grenadier (*Macrourus rupestris* Gunn)[1] in the North Atlantic, 1967-1970[2]

by P.I. Savvatimsky
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Introduction

Roundnose grenadier, a valuable commercial fish, is widely distributed in the eastern and western Atlantic Ocean along the continental slopes at depths from 180 to more than 2,000 m (Leim and Scott, 1966). Other grenadiers are abundant in different areas of the Atlantic and Pacific Oceans (ICNAF, 1968; Konstantinov and Noskov, 1968; Makushok, 1967; Pechenik, 1965; Rass, 1959; Savvatimsky, 1969; Trunov, 1968; Yanulov, 1962). However, the mode of life of roundnose grenadier as well as other species of grenadiers has been investigated very little due to their life in deep-sea areas, and only fragmentary data on their age and growth are available (Kulikova, 1957; Motais, 1960; Yanulov, 1962). In recent years the study of age and growth rate of roundnose grenadier in the North Atlantic has become very important due to the intensification of their fishery. The present paper is dedicated to this problem.

Material and methods

Attempts to determine the age of grenadiers by otoliths were not very successful. Preparations were made by several methods: non-polished cross-section of the otolith; burnt non-polished cross-section; burnt polished cross-section; cross-cut 0.5-0.6 mm thick, polished on both sides and set in resin (colophony) on the glass. Of the methods mentioned, best results are obtained using the last two methods; yet they are the most labour-consuming. However, these methods and others do not give sufficient accuracy. An error of about 2 to 4 years can be made because the rings in the central portion of the otolith are faint. The closeness of growth zones and their poor contrast create additional difficulties.

To increase the contrast of the zones, a section 10 microns thick was cut using the microtome. The otolith was first decalcified by means of prolonged exposure in Bouin's solution. Then it was put into alcohols of increasing concentration. The otolith was then sealed with paraffin and stained with haematoxylin. It was impossible to count all the rings because in making the preparation the central portion of the otolith was destroyed. In this case, the rings were clearly marked.

Age studies of grenadier from their otoliths indicate that the fish have a long life because the annual rings are situated close to each other and are numerous.

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[1] To date, there has been no agreement among investigators about the Latin nomenclature of grenadiers. In one case, the genus is spelled *Macrurus*; in another, *Macrourus*. Sometimes *Macrurus rupestris* is called *Coryphaenoides rupestris*. We have adopted the scientific name *Macrourus rupestris* and the common name roundnose grenadier, as used in the ICNAF Statistical Bulletin.

[2] Submitted to the 1971 Annual Meeting of ICNAF as ICNAF Res.Doc. 71/93.

The determination of grenadier age by scales when using ordinary methods is hampered by indistinctness of the annual rings; in addition, the scales have minute spines impeding their preparation for examination of the rings.

Staining of grenadier scales with different dyes did not produce more distinct annual rings.

Polarized light was used by Farran (1924), when determining age by scales. After being washed with a weak solution of alkali, the scales were examined by polarized transmitted light. Dark and light rings, that are parallel to the scale edges, were taken as annual rings. These rings were most clearly marked on the anterior spineless portion of the scales.

To confirm the fact that rings seen on the scales of grenadier by polarized light were annual rings, a comparative analysis of age determination of redfish and haddock was made by the regular method and by polarized light.

Farran (1924) who investigated the age of grenadiers of several species using scales and polarized light concluded that it was impossible to determine the exact age of each fish. In our experiments on several scales of the same fish, the number of rings seen by polarized light often proved to be different by 1-2, sometimes 3, rings. Comparatively, a small number of scales which differed from the others in number of rings was not taken into account. Scales were usually taken in the region just above the lateral line between the dorsal fins. Sometimes the scales could only be taken in the undisturbed areas of the body because scales are loosely attached in the scale pockets and during the trawl hauling great numbers of scales are lost. Dry scales become very fragile; therefore, one should protect the packets of collected scales from any physical harm. The edges of the scales are very thin and they can be damaged or broken when washed with a weak solution of alkali.

About 50% of scales in the collected samples are regenerated and no rings are found in the central portion. The remaining scales usually have the rings clearly marked along the edges, whereas they are most difficult to count in the central portion. All doubtful scales which are regenerated or all with illegible rings were discarded. Careful selection of scales for preparations allows us to determine the age of grenadiers with sufficient accuracy (Fig. 2).

Curves of linear and weight growth of grenadier were calculated according to the formulae $y = ax^b$, where x is the age of fishes expressed in years, y is the length expressed in cm or weight expressed in grams, and a and b are the parameters found.

Age samples of grenadier were taken in 1967 and 1969 from bottom trawl catches in different areas of the North Atlantic (Fig. 1). The age of 420 fish was determined by scales (Tables 1, 2).

Results of investigations

The length of fish of the same age varied slightly in all the samples (Fig. 2).

The curves of linear growth were calculated according to the formulae:

$y = 14.896x^{0.59}$ for males; and $y = 17.2x^{0.57}$ for females.

Table 1. Growth in length (cm) and weight (g) of roundnose grenadier in the eastern North Atlantic in 1967. (numerator – average length (cm); denominator – average weight (g))

Area	Date 1967	Depth (m)	Age groups																No. of spec.
			12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	
MALES																			
Iceland	17 Dec	600–610	61.0/500	65.0/700	67.0/900	–	74.0/1000	74.0/1078	75.0/1050	72.0/1080	74.0/1214	76.0/1300	76.0/1325	86.0/1500	87.0/1614	76.0/2100	77.0/1800	86.0/1750	57/57
	24 Aug	700–740	–	–	–	–	–	78.0/1250	75.0/950	80.3/1133	79.0/1225	87.0/1283	83.0/1275	86.0/1375	–	–	–	–	16/16
FEMALES																			
Iceland	17 Dec	600–610	–	–	72.0/1000	72.0/1060	69.0/1100	78.0/1270	84.0/1480	82.0/1488	84.0/1578	84.0/1616	87.0/1773	87.0/1760	87.0/1700	87.0/1700	93.0/2040	91.0/2100	97/99
	24 Aug	700–740	–	–	–	–	72.2/1212	79.3/1633	80.6/1483	84.4/1513	84.6/1563	87.1/1670	87.4/1714	92.2/1975	95.1/2033	95.0/1900	97.0/2000	104.0/2550	74/74

Table 2. Growth in length (cm) and weight (g) of roundnose grenadier in the western North Atlantic in 1967 and 1969. (numerator - average length (cm); denominator - average weight (g))

Area	Date	Depth (m)	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	No. of spec.
MALES																			
Baffin Land	1967 2 Oct	660-610	-	-	-	-	-	-	58.0/300	60.5/450	59.0/533	64.7/587	71.7/812	67.4/660	71.0/900	72.9/900	78.3/900	76.0/967	-	35 / 35
Central Labrador	8 Nov	500	-	-	-	-	-	-	-	63.3/525	-	62.0/575	72.1/771	71.2/817	75.1/905	76.6/950	82.1/1106	79.0/1110	83.0/1200	52 / 57
North Newfoundland Bank	13 Nov	700-740	-	-	-	-	-	47.0/250	50.0/350	62.5/550	65.5/550	66.3/566	67.0/681	71.4/810	71.0/800	74.0/893	75.8/1000	-	-	46 / 46
North Newfoundland Bank	1969 5-6 Nov	670-930	31.0/67	34.0/84	35.8/105	41.6/151	46.1/215	47.8/240	54.5/359	59.0/436	62.8/532	66.9/606	69.6/679	71.6/754	74.5/782	75.3/844	80.5/914	83.5/1145	84.0/1010	214 / 214
FEMALES																			
Baffin Land	1967 2 Oct	660-610	-	-	-	-	-	65.0/500	-	-	66.0/633	68.3/975	70.0/800	68.0/865	72.0/1000	79.0/1150	-	-	-	13 / 13
Central Labrador	8 Nov	500	-	-	-	-	-	58.0/450	65.0/650	66.5/675	73.0/1000	74.8/983	75.8/1030	75.7/1092	80.9/1169	79.5/1225	87.0/1350	-	-	33 / 33
North Newfoundland Bank	13 Nov	700-740	-	-	-	-	50.0/300	50.0/400	67.0/650	61.0/670	68.0/750	71.3/914	74.5/944	78.6/1000	78.0/1200	79.5/1113	79.5/1175	91.0/1400	-	41 / 39
North Newfoundland Bank	1969 5-6 Nov	670-930	35.0/93	37.0/114	39.5/154	45.4/218	52.4/313	58.8/384	62.6/555	66.1/630	70.4/793	72.7/804	74.3/878	76.2/904	83.5/1180	84.0/1138	-	-	-	63 / 63

The curves of weight growth were calculated according to the formulae

$$y = 8.77x^{1.66} \text{ for males and } y = 13.8x^{1.6} \text{ for females (Fig. 3).}$$

Females increase their weight and length somewhat faster than males. The rate of linear and weight growth according to the calculated curves is shown in Fig. 4. Length increments decrease while weight increments increase with age. Fish of commercial size (at an age of 9-14 years) have a length increment of about 3-4 cm a year, while weight increases in males by 60-80 g and in females by 80-100 g. At 19 years of age, males reach a length of 84 cm and weight 1,010 g, while females are 88 cm and 1,250 g.

Despite the fact that samples were collected in different months and years in areas situated a considerable distance apart (Fig. 1, Tables 1, 2), it was established that males have similar length at the same age. This was also true for females.

In the age sample taken on the North Newfoundland Bank on 5-6 November 1969, there were 277 fish from 31 to 88 cm in length and 3 to 19 years of age (Table 2). On conversion of age data into the length composition of catches taken at the same time and in the same area (about 2,562 specimens), it was found out that the bulk of the catches consisted of males 9 to 12 years and females 6 to 10 years (Fig. 5).

Changes in length and sex composition of roundnose grenadier catches taken on North Newfoundland Bank in 1967-1970

In recent years the major fishery for roundnose grenadier has been conducted on a very limited area of the North Newfoundland Bank where the greatest quantity of this fish was caught (Table 3). At present only feeding concentrations of grenadier are utilized. These are found at shallower depths than the adult fishes. From 1968 to 1969 in this area some changes in the length and sex composition of the catches took place. Fig. 6 shows the length composition of the catches taken in different years at approximately the same depths and during the same period of time (in order to exclude the effect of seasonal migrations of fish on the results of the analysis). The left part of the figure shows that from 1967 to 1969 the modal length of fishes decreased in the catches. In the right part of the figure, where annual deviations from the long-term mean values are presented, one can see that during these years the relative quantity of large fish in the catches has dropped sharply. When analyzing the data for the whole period of the fishery (from June to December 1967-1970, when 40,690 fish were measured), analogous changes were revealed in the length composition of grenadier (Fig. 7).

The sexual composition of the catches has also changed. From 1967 to 1969 the relative quantity of females dropped from 39.3% down to 30.8%. Females are larger than males, and apparently because of this they were subjected to fisheries to a greater extent than the males. Nikolsky (1958) believed that under rational exploitation of a stock, especially fishes with a long life cycle, in addition to the age and length composition of the fishes caught one should take into account the sexual composition required for perpetuating the stock, especially when there are differences in lengths of males and females and when a greater quantity of males or females are mainly exterminated by fisheries.

Table 3.   USSR yield (in tons) of roundnose grenadier, 1967-1969.

Year	Subarea			Total Yield
	1	2	3	
1967	-	-	15,902	15,902
1968	116	2,553	24,143	26,812
1969	68	651	11,682	12,401

On the North Newfoundland Bank the catch per unit of fishing effort has also dropped.

The data presented here on age and growth rate of roundnose grenadier allow us to make the following important conclusion: this fish has a long life cycle and a many-aged population structure, and hence one should regard with caution any intensification of the Roundnose grenadier fishery.

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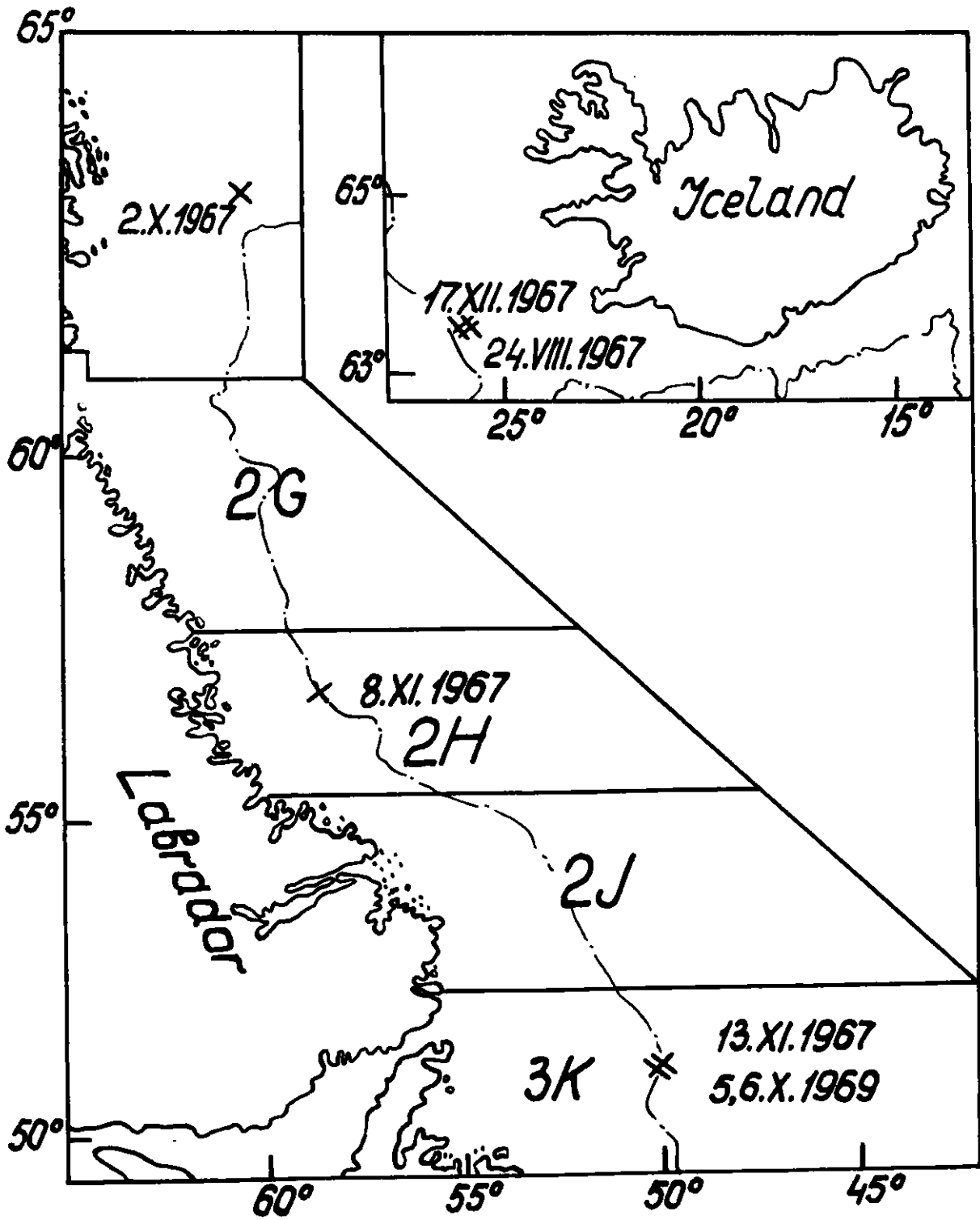
Fig. 1.   Areas and time of collection of age samples of roundnose grenadier in North Atlantic.
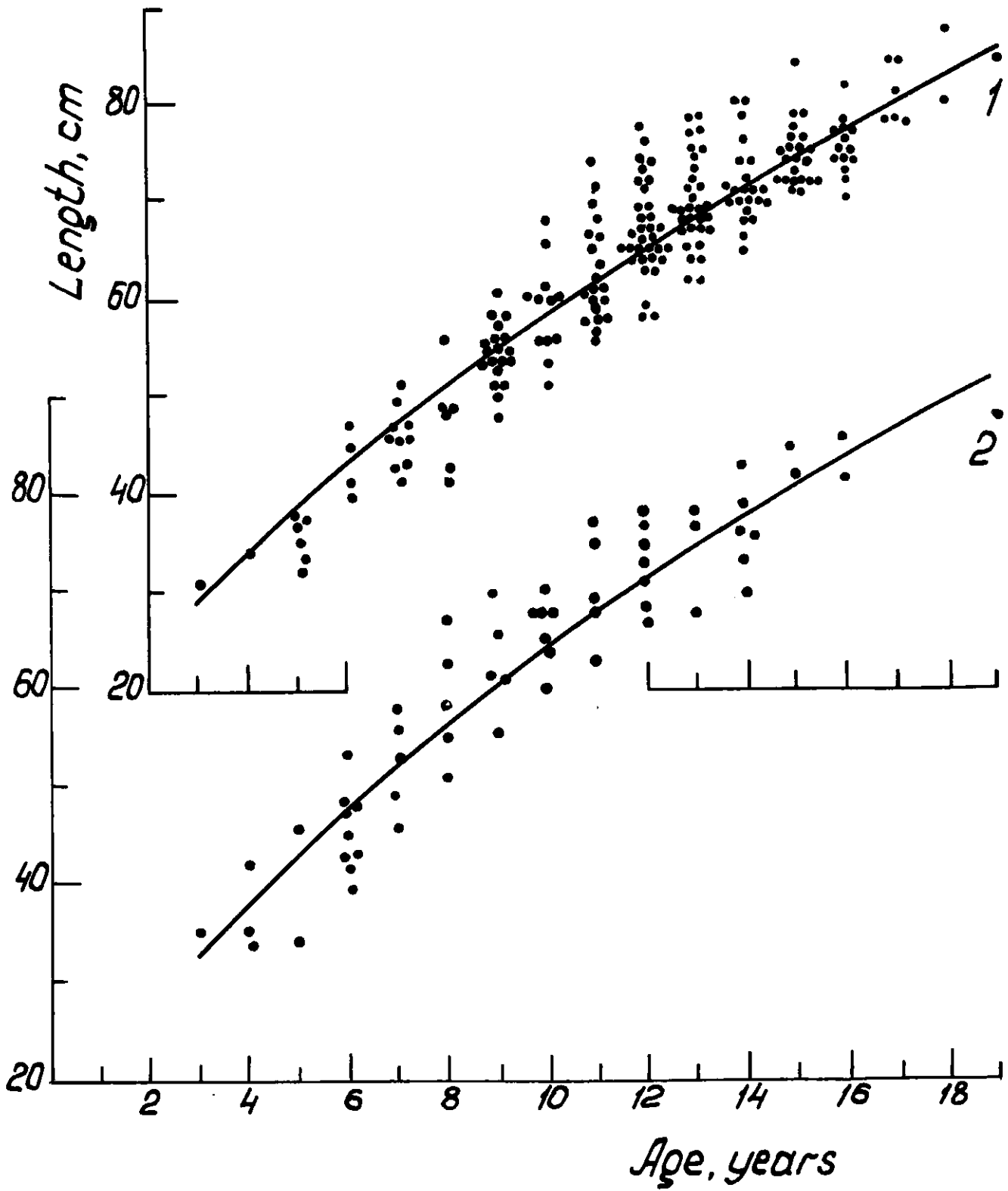
Fig. 2. Length of roundnose grenadier of different ages on the North Newfoundland Bank, 5-6 November 1969 (1 - males; 2 - females).
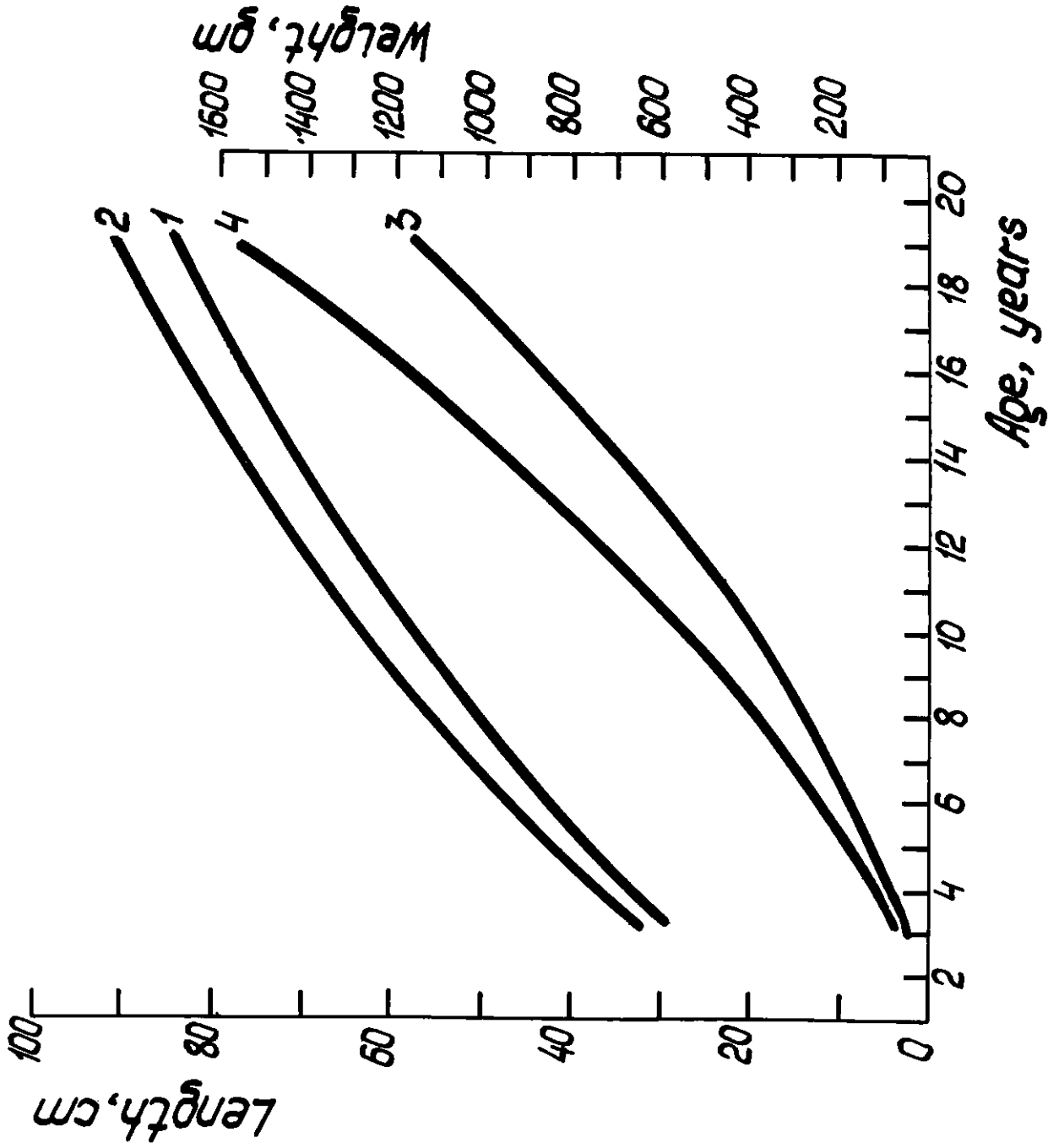
Fig. 3. Growth in length (1 - males; 2 - females) and weight (3 - males; 4 - females) of roundnose grenadier on the North Newfoundland Bank, 5-6 November 1969, calculated by the formula $y = ax^b$.
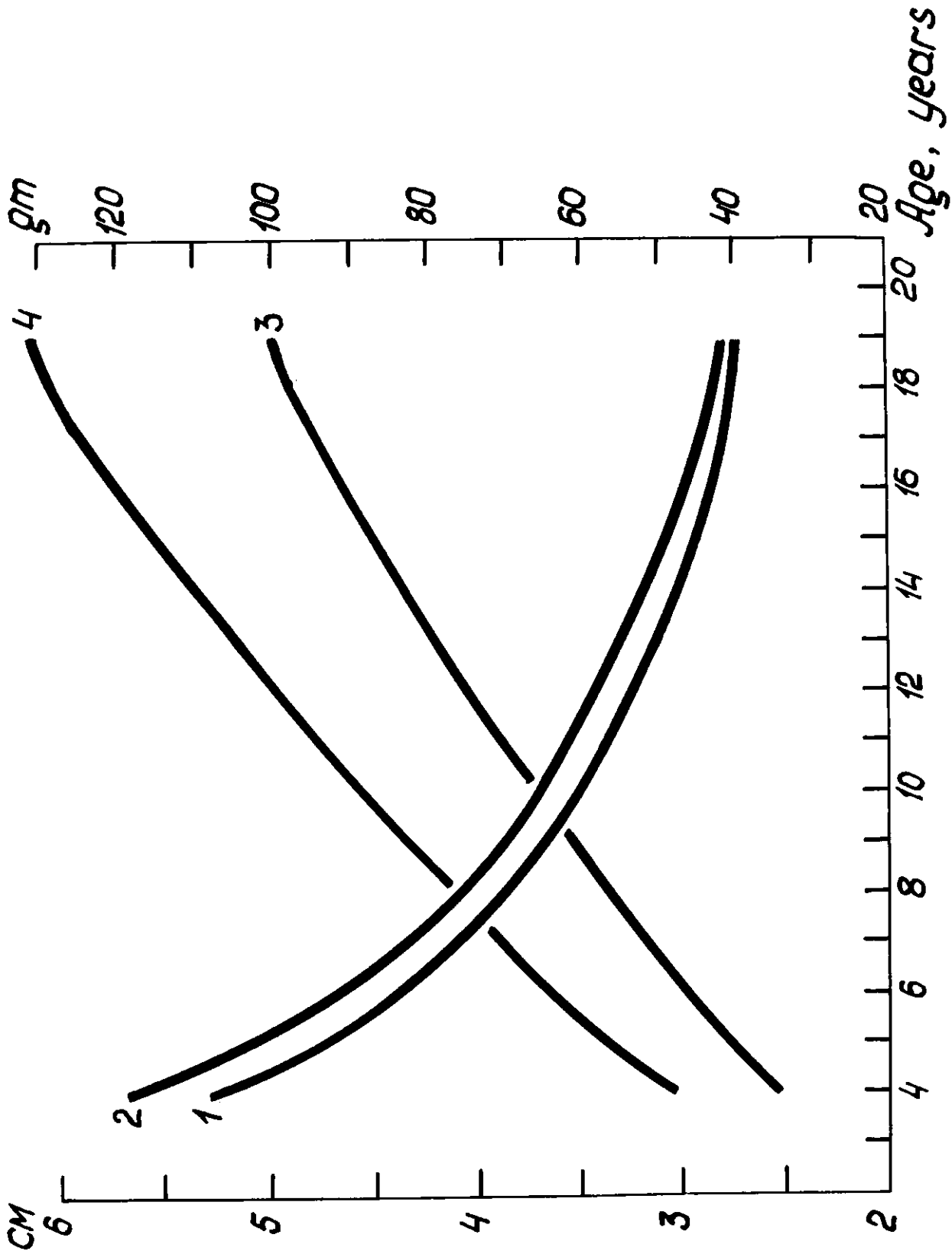
Fig. 4. Annual length (1 - males; 2 - females) and weight (3 - males; 4 - females) increments of roundnose grenadier at different ages on the North Newfoundland Bank, 5-6 November 1969.
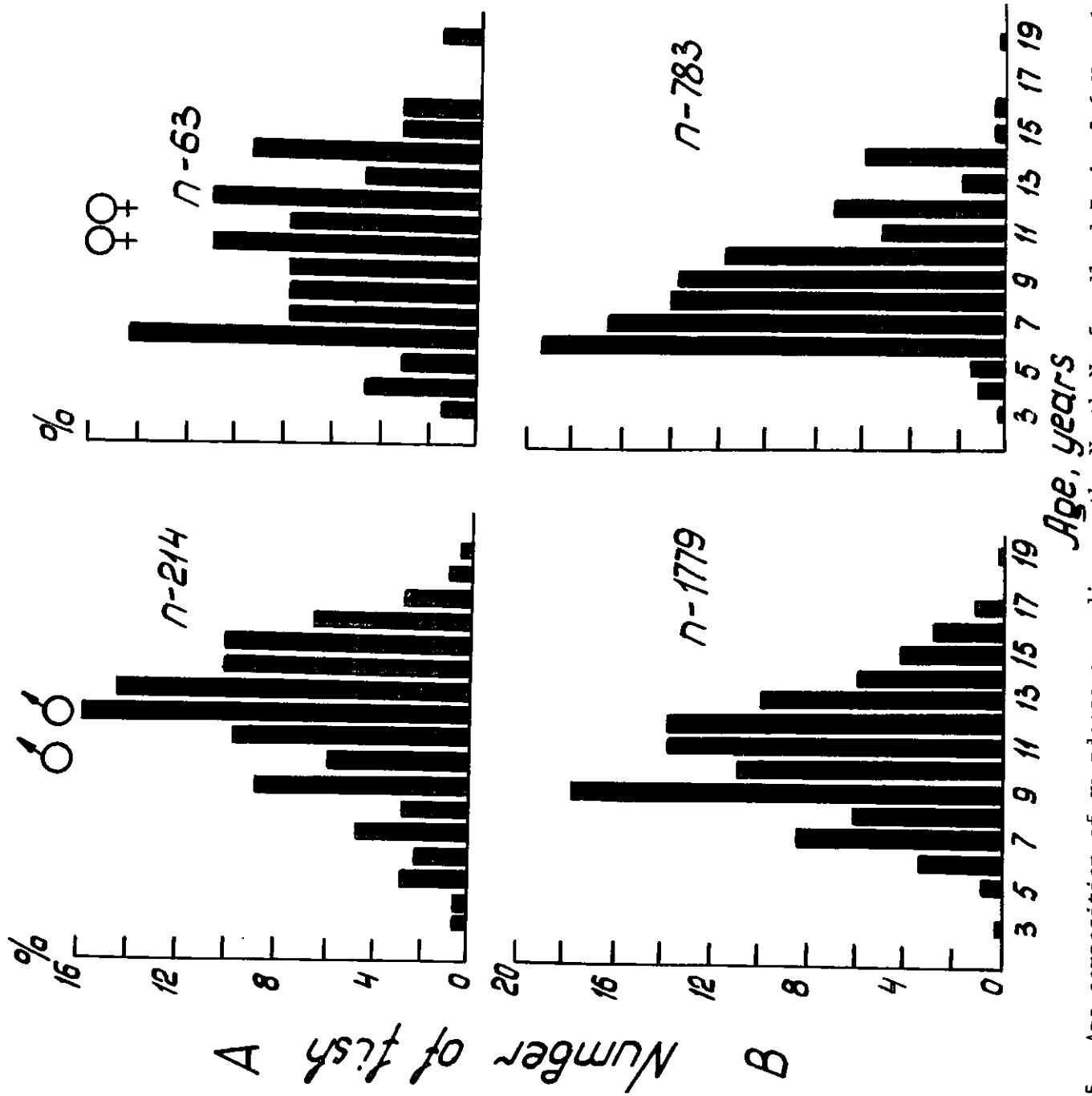
Fig. 5. Age composition of roundnose grenadier on the North Newfoundland Bank, 5-6 November 1969.
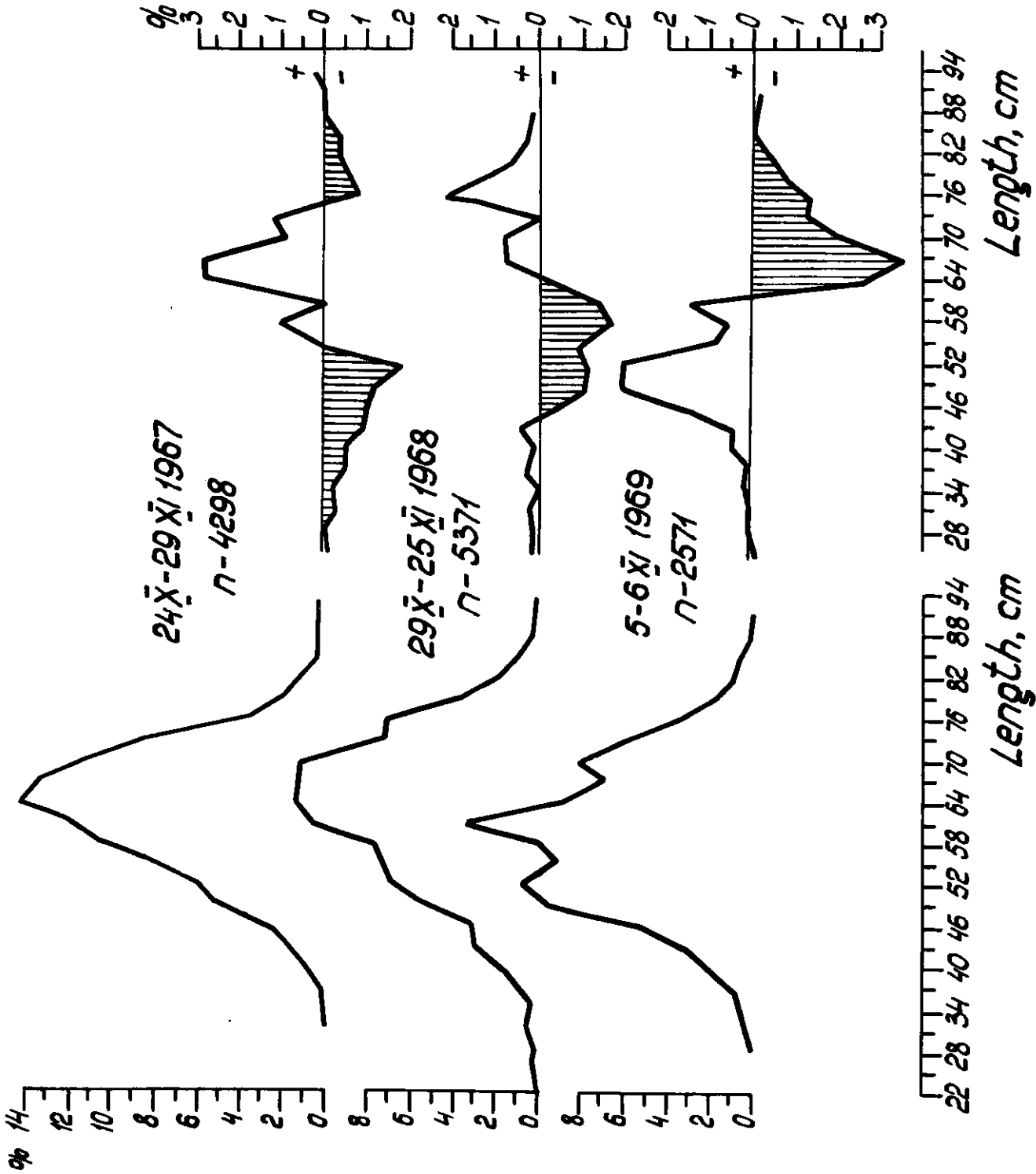
Fig. 6. Length composition of roundnose grenadier on the North Newfoundland Bank, October–November 1967–69.
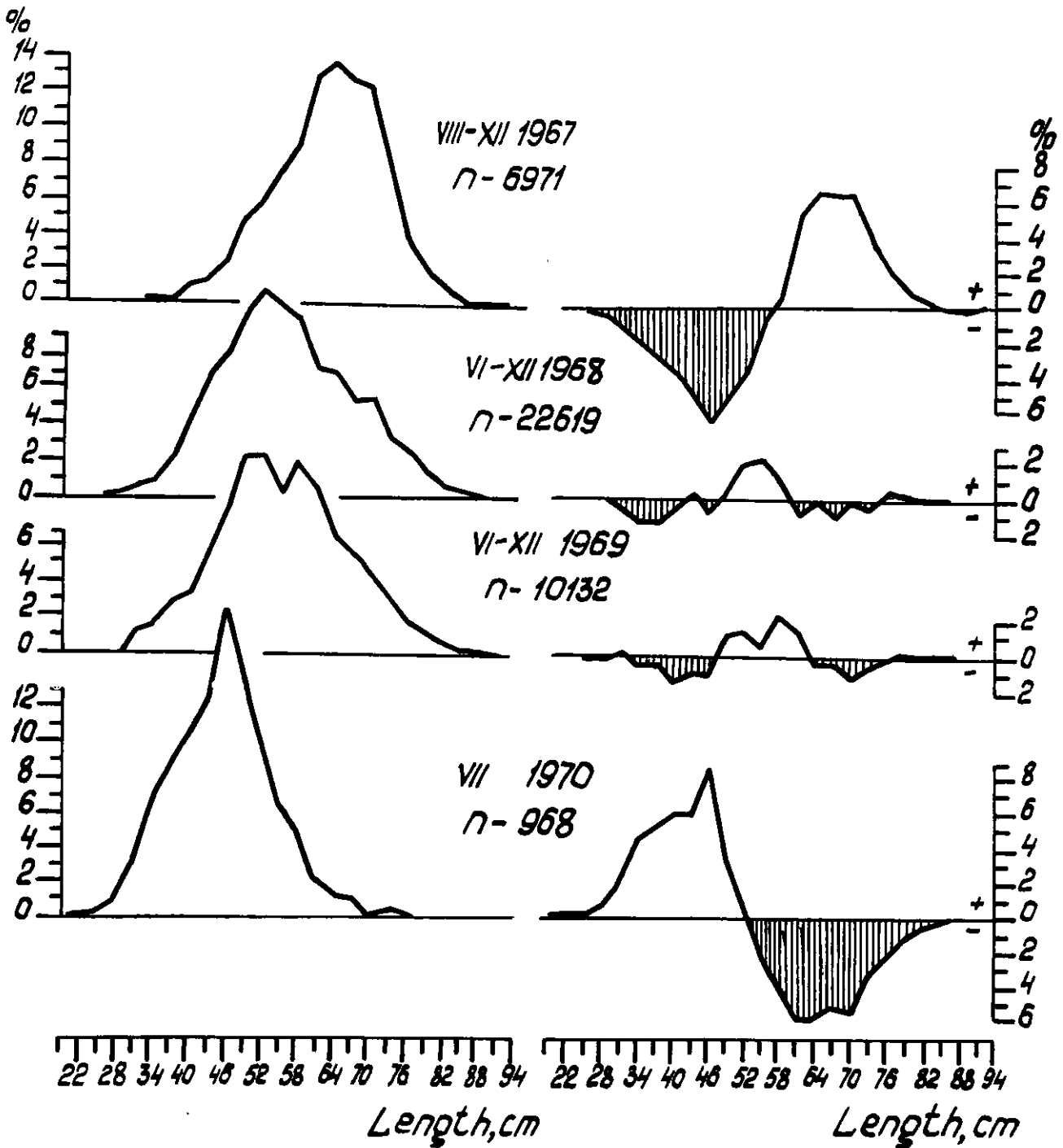
Fig. 7. Length composition of roundnose grenadier on the North Newfoundland Bank, June-December 1967-70.

12. Observations on selectivity and relative efficiency of salmon
drift nets in connection with population studies on salmon at
West Greenland[1]

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With the object of estimating the age and size distribution of the salmon
stock in Greenland waters, investigations on the selectivity of drift nets
were carried out in the autumn 1970 on some West Greenland fishing grounds.

The offshore salmon fishery at West Greenland is predominantly a drift
net fishery. Salmon long-lines are operated too, but only on a small scale.
Before 1969 Danish salmon vessels were exclusively equipped with multifilament
nets manufactured from twine of twisted synthetic fibres (polyester). Besides
using multifilament nets, two of the Danish vessels participating in the
Greenland fishery in 1969 also experimented with monofilament nylon nets
(polyamide). In the 1970 salmon fishing season, all the vessels, except one,
were equipped with monofilament nets, either exclusively as far as two boats
were concerned or as a supplement to the conventional multifilament nets.

The multifilament nets operated in Greenland waters are usually of the
type which was introduced in the Baltic salmon drift net fishery during the
first half of the sixties, Dimensions were generally 27 m long and 5-6 m deep;
mesh size: 160 mm (stretched mesh); mounting: generally the net proper is
mounted with strops to the float line. The net is hauled along the float line
by hand. A somewhat modified type was fished from the vessel *Polarlaks* in 1969,
as shall be referred to later on. Strops were inserted not in connection with
the float rope, but between the net proper and the footrope which was lightly
weighted.

Monofilament nets for salmon fishing are of various makes and qualities
as well, with respect to colour, thickness, elasticity of the twine as to kind
of knots. Dimensions were generally 34 m long and 5-6 m deep; mesh size:
130-160 mm; mounting: the net proper is fixed directly to the float rope and
connected to the footrope with strops. The gear is hauled along the footrope
by a special winch.

The present population study is based upon observations on the selectivity
of drift nets made on board the Danish commercial fishing vessel *Polarlaks*
during salmon fishing off the coast of West Greenland in the autumn 1970. The
report also includes some observations on drift netting from the same vessel
the year before. Available data on salmon catches of other vessels have also
been used.

When the investigation started in August 1970, *Polarlaks* was operating
609 monofilament nets distributed as follows:

[1] Submitted to the 1971 Annual Meeting of ICNAF as ICNAF Res.Doc. 71/65
(also ICES/ICNAF Salmon Doc. 71/9).

Mesh size	Numbers
130 mm	265
140 mm	135
150 mm	97
160 mm	101

In addition, 25 nets with 170-mm meshes were used experimentally during a part of the period of investigation. The nets were shot in chains of about 100, and within each chain, nets with small and large meshes were tied alternately.

During two periods, 1-7 and 10-17 September, while fishing in the areas about 69°45'N, 55°15'W and about 61°15'N, 49°00'W respectively, observations were made on catches by nets of different mesh sizes. The netted salmon were measured (fork length) and the mesh size of the corresponding nets was determined by a mesh gauge. Effort data were obtained by recording the number of nets of the various mesh sizes used and the fishing time of each chain of nets. However, as no correlation was observed between number of salmon retained and the time of fishing, the estimated catch-per-unit-effort values are only expressed as number of salmon retained per net unit.

Table 1 summarizes the observations made during fishing in the two areas concerned. The estimations are based upon measurements of 1,901 salmon. Catch-per-unit-effort data recorded from the fishing area 69°45'N, 55°15'W have been used in the calculations of selectivity for both areas, as corresponding data from the fishing area 61°15'N, 49°00'W are too scarce and, therefore, not sufficiently reliable. The results are presented graphically in Fig. 1. As the catches in nets of 170 mm were extremely poor, they are excluded from the diagrams. The same was the case with respect to nets of 160 mm in the southernmost area.

Table 1. Number of salmon in 5-cm length-groups retained per 100 monofilament nets in relation to mesh size. Data from commercial catches at 69°45'N, 55°15'W, 1-7 September, and at 61°15'N, 49°00'W, 10-17 September 1970.

5-cm length-groups (fork length) (cm)	69°45'N, 55°15'W Mesh size (mm)					61°15'N, 49°00'W Mesh size (mm)		
	130	140	150	160	170	130	140	150
95 - 100	0.1	-	-	-	-	-	-	-
90 - 95	-	-	-	-	-	-	-	-
85 - 90	0.1	0.3	0.4	0.6	-	0.1	-	-
80 - 85	0.4	1.4	1.1	2.5	-	0.2	0.5	0.5
75 - 80	1.3	-	0.9	1.5	1.3	0.2	-	-
70 - 75	4.3	2.4	2.8	3.4	-	2.4	2.5	4.8
65 - 70	19.7	18.6	9.6	4.5	1.3	20.4	18.2	11.5
60 - 65	24.4	14.9	5.8	2.1	2.5	26.6	14.9	4.3
55 - 60	10.2	3.6	1.3	0.7	-	10.1	5.4	0.9
50 - 55	1.2	0.3	0.2	-	-	1.6	-	-
45 - 50	0.1	-	-	-	-	-	-	-
Total number of salmon per 100 nets	61.7	41.5	22.0	15.3	5.1	61.7	41.5	22.0
Number of salmon	765	257	103	81	4	492	153	46

For the sake of comparing the relative efficiency of nets fished from
Polarlaks with nets of corresponding mesh sizes operated from other vessels,
all available information on catch-per-unit effort of a range of mesh sizes is
shown in Table 2. The data are listed according to vessels, date and fishing
area.

Table 2. Number of salmon retained per 100 monofilament nets in relation
to mesh size. Information from four commercial vessels at West
Greenland, August-October 1970.

Vessel No.	Date	ICNAF Div.	Number of salmon per 100 nets of Mesh size (mm)				Basis of calculations (No. of nets)
			130	140	150	160	
II	30-31 August	1B	76.0	57.8	18.8	-	1,000
I	1-7 September	1A	61.7	41.5	22.0	15.3	2,720
III	6 September	1B	74.0	-	32.0	18.0	300
III	5-7 September	1B	64.0	-	29.0	-	600
II	1-7 September	1A	94.6	72.7	24.3	-	3,100
II	11-21 September	1E	96.3	86.3	-	-	1,300
IV	17 September- 6 October	1E	-	45.6	23.4	-	5,820

An attempt has been made to estimate the length frequency of the salmon
population in Greenland waters. For this purpose a formal model of gill net
mesh selection has been used which implies the following assumptions: 1) Mean
and standard deviation of the length frequency distribution of the salmon
retained is proportional to mesh size. 2) Fishing power of nets is independent
of mesh size. The application of the model to the material did not, however,
lead to results on which an estimation of a probable length frequency distri-
bution of the salmon population could be based. The reason may be either that
the assumptions made are not valid or that the observations were too few.

Considering the remarkable decline in catch efficiency from the smallest
to the largest meshes, it cannot be rejected that, on account of certain pro-
perties attached to the nets, the fishing power of the various nets may depend
on mesh size. One such property may be the elasticity of the monofilament
twine. According to tests of tension and breaking strength the twine of the
nets in question can be stretched about 20% before breaking. Consequently,
the effective mesh size within certain limits depends on the strain applied.
Supposing that the strength of a salmon is proportional to the size of the
individual, it might be expected that the number of escaping big salmon entering
large meshes will be relatively greater than the corresponding loss of small
salmon in nets of small meshes.

Since the study of net selection failed to give any results, the observa-
tions only provide rather uncertain information on the age and size composition
of the stock of salmon in West Greenland waters. Some conclusions are, however,
drawn as shall be mentioned in the following.

In spite of the significantly different selectivity of the nets operated,
average length of salmon retained by nets of different mesh sizes varies

relatively little as shown by following means:

Mesh size:	130 mm	140 mm	150 mm	160 mm
69°45'N, 55°15'W	64.8 cm	66.1 cm	68.1 cm	72.2 cm
61°15'N, 49°00'W	63.7 cm	65.1 cm	67.2 cm	-

Unless the properties attached to monofilament nets as mentioned above reduce their fishing power considerably with increasing mesh size, the figures seem to indicate a relatively small proportion of A.2+ salmon in the population at West Greenland.

Length distribution of the catches made in the two areas where the majority of the fishery took place during the first half of September, revealed a certain variation of stock composition at West Greenland, as shown in Table 1 and Fig. 1. The proportion of salmon of 75 cm and above - roughly speaking age-group A.2+ - in nets of different mesh size was as follows:

Mesh size:	130 mm	140 mm	150 mm
69°45'N, 55°15'W	3.0 %	4.3 %	10.8 %
61°15'N, 49°00'W	1.0 %	1.3 %	2.2 %

Differences in condition of salmon taken in the two areas could also be demonstrated. Based on length and weight measurements of a representative sample of 49 and 99 salmon caught at 69°45'N, 55°15'W and 61°15'N, 49°00'W, the condition factor of the two populations was estimated to be 1.02 and 1.07 respectively (fork length and round weight). The difference is statistically significant $(0.05 > P > 0.025)$.

As the ability of gill nets to retain fish of a given size depends on the condition of the fish, differences in length composition of corresponding age-groups of salmon caught in the two areas might be expected. Such differences could not be found, as seen in Fig. 1.

In default of estimates of stock composition and gear selectivity, relative exploitation rates of the individual length- and age-groups cannot be evaluated. It may, however, be pointed out that the highest yield of a length-group per unit of gear was obtained of individuals between 60 cm and 65 cm by nets with the smallest mesh size used, $i.e.$, 130 mm. The mean length of the population of A.1+ salmon, therefore, is supposed to be less than 65 cm at the time of investigation, which suggests that the smaller individuals of this age-group are exploited less than the bigger individuals even by nets of 130-mm meshes. It cannot be excluded, that nets with still smaller meshes might have taken even more salmon per net unit.

Differences with respect to selectivity and catching efficiency of multifilament nets of 160-mm meshes in relation to monofilament nets of various mesh sizes are shown in Tables 3 and 4. Unfortunately, the material does not allow an exact separation of the catches by monofilament nets with respect to mesh size. Referring to Table 4, monofilament nets are put together in two groups, 130-mm + 140-mm nets and 150-mm + 160-mm nets. In the former group,

Table 3. Number of salmon in 5-cm length-groups retained per 100 nets in relation to type of twine and mesh size of nets. Data from commercial fishing within the area 67°00'N-67°37'N and 54°15'W-55°00'W, 18 October-2 November 1969.

5-cm length-groups (fork length) (cm)	Number of multifilament nets 160 mm	Number of monofilament nets 130 mm + 140 mm
95-100	-	0.05
90- 95	0.2	0.1
85- 90	0.3	0.5
80- 85	1.4	1.8
75- 80	2.3	4.1
70- 75	11.8	15.8
65- 70	11.8	16.8
60- 65	4.3	6.0
55- 60	0.5	1.0
50- 55	-	0.05
Total number of salmon per 100 nets	32.7	46.3
Number of salmon measured	210	1,131

Table 4. Number of salmon retained per 100 nets in relation to type of twine of the nets. Information from two commercial vessels at West Greenland, October-November 1969, and August-November 1970.

Vessel No.	Date	ICNAF Div.	Multifilament nets 160 mm	Monofilament nets 130 + 140 mm	Monofilament nets 150 + 160 mm	Basis of calculations (No. of nets)
I	1969 18 October- 2 November	1B	32.7	46.3	-	6,260
II	1970 10-31 August	1B	27.8	-	18.3	4,000
	1-15 September	1A	25.1	-	13.4	3,680
	25 September	1D	6.0	-	3.5	700
	26 September- 13 November	1B	24.6	-	14.8	7,050

the two mesh sizes are represented by 65% and 25% respectively, while the remaining 10% consists of nets of 150 mm and 160 mm. The latter group of nets is exclusively represented by 150-mm and 160-mm nets in the ratio 2:1. On account of differences in length of the two net types in question, values of catch per 100 multifilament nets are converted in order to make them comparable to catches of monofilament nets.

It appears from the tables that multifilament nets of 160 mm are superior to monofilament nets of, roughly speaking, the same mesh size in catching salmon, but are outnumbered by monofilament nets of 130 mm and 140 mm.

A comparison between the length distribution of catches by 160-mm multi-filament and 130- + 140-mm monofilament nets (Fig. 2) discloses an amazing uniformity in spite of the differences of mesh size. This probably implies that nets of same mesh size but made of different sorts of twine, monofilament and multifilament, are not only different as to catching efficiency but also with respect to selectivity. Apparently, the two kinds of net do not possess a uniform catching ability; this may be explained in different ways, *a.o.* (1) Multifilament nets are, no doubt, more visible in the sea than monofilament nets. (2) Multifilament nets – either entirely lacking or only with a light footrope – are not so hard vertically stretched as the heavily weighted mono-filament nets. The latter are gill nets in the proper sense of the word, whereas, multifilament nets are retaining salmon more by entangling.
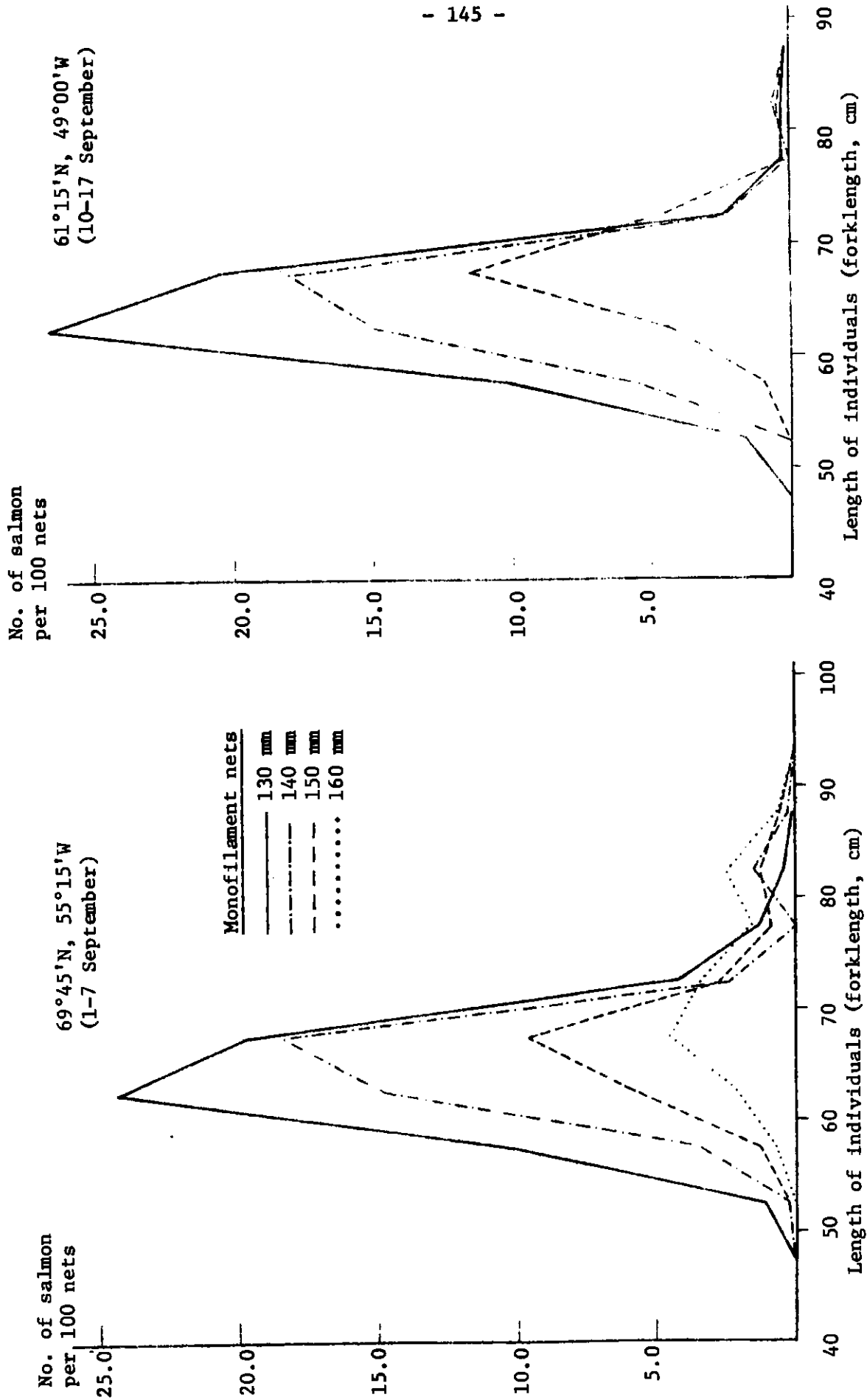
Fig. 1. Number of salmon in 5-cm length-groups retained per 100 nets during fishing in the areas about 69°45'N, 55°15'W on 1-7 September, and about 61°15'N, 49°00'W on 10-17 September 1970.
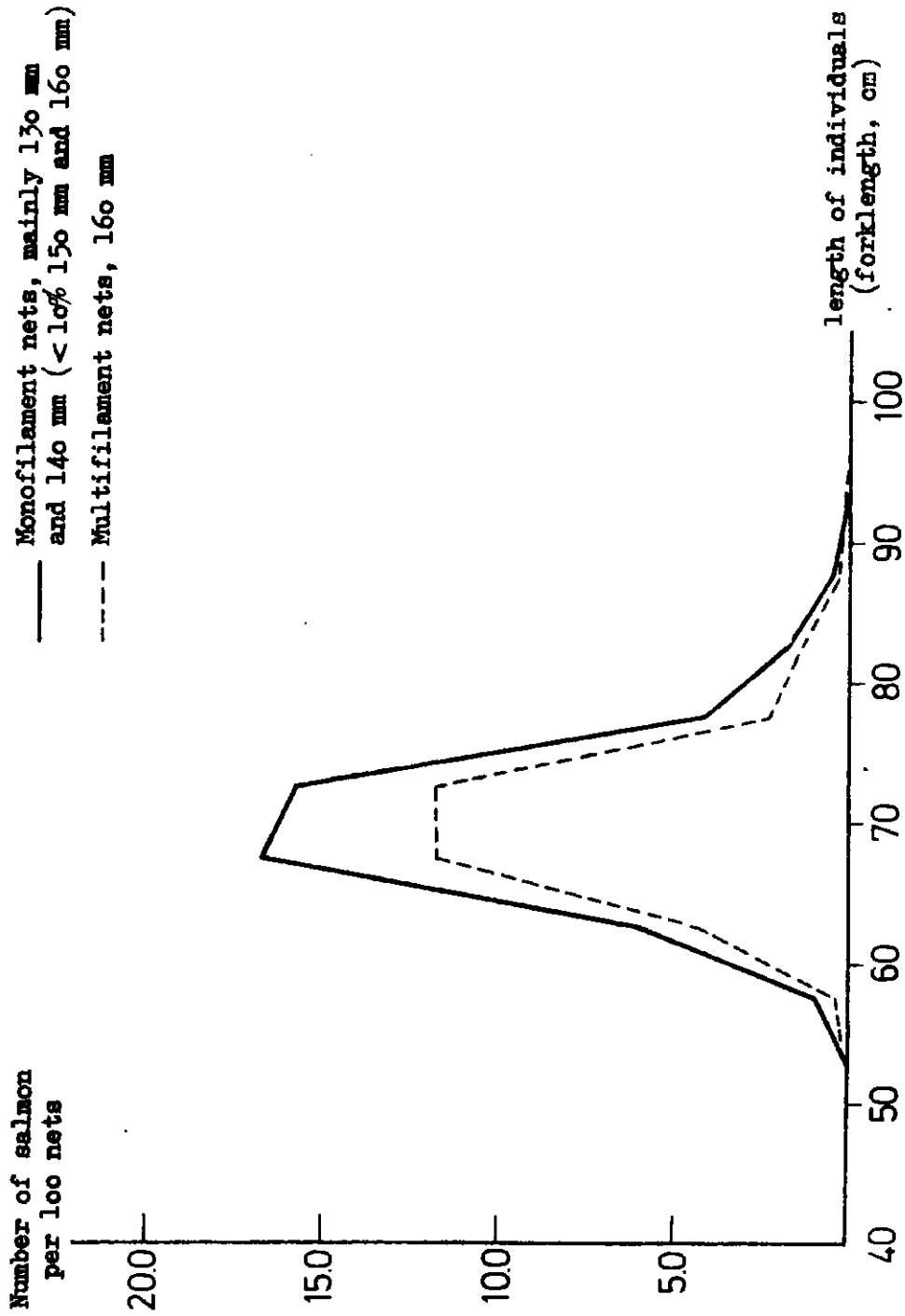
Fig. 2. Number of salmon in 5-cm length-groups retained per 100 nets during fishing within
the area 67°00'N-67°37'N and 54°15'W-55°00'W, 18 October-2 November 1969.

13. Recent scallop recruitment and apparent reduction in cull size
by the Canadian fleet on Georges Bank[1]

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Introduction

Trends in the Georges Bank fishery since the high abundance years of
1961-62 have reflected a continuing decline in scallop stocks. This lower
abundance of scallops and consequent increase in landed price has led to changes
in fishing practice by certain sections of the Canadian industry and, following
a small recruitment to the Northern Edge of the Bank in the fall of 1969,
smaller scallops were being exploited in 1970 than during years of good to
average abundance.

Population densities of scallops on the Northern Edge were assessed in
June 1970 by experimental fishing and bottom photography, and the sizes of
landed meats in commercial catches surveyed at three main ports in July-August
1970. These surveys considered together showed that small scallops being
landed by the fleet were probably caught within a limited area of new recruits
on the Northern Edge.

Status of the fishery

Combined Canadian and U.S. landings from Georges Bank reached a peak in
1962 at 15.6 million kg of meats (130,000 metric tons whole weight) following
the abundant recruitment of 1959 (Bourne, 1964) and have since declined by
64.5% to the 1970 figure of 5.5 million kg (46,000 metric tons whole weight)
(Table 1). This decline in overall landings has not been so evident from
Canadian landed figures, since Canada's share in the overall landings has
increased from 36% to 73% of the total between 1962 and 1970 as U.S. effort
on the grounds has fallen off. Canadian landings continued to go up until
1964, and since then have only declined by 32.6%. However, in order to main-
tain landings at the present level of 4 million kg of meats (34,000 metric tons
whole weight), the Canadian fleet has had to extend its operations from the
productive Northern Edge and Peak to less productive areas well within the
50-fathom contour, and to deep water below 50 fathoms on the northeastern edge
of the Bank. Canadian effort both in days fished per year and in hours dragged
per day has increased by 20-40% since 1962, the peak year for landings (Caddy
and Lord, in press).

Because an increasing proportion of the day has been spent dragging,
catch per day has underestimated the decline in abundance since the early
1960's. Thus, while catch per day dropped by 44% between 1961 and 1969, catch
per hour (as determined by log book analysis) fell by 80% over the same period
(Fig. 1).

Table 1.   Landings of scallop meats (millions of kg) from Georges Bank, 1957 to 1970.

	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
Total (USA and Canada)	8.6	7.7	10.4	13.3	15.3	15.6	13.9	12.1	6.0	5.9	6.4	6.0	5.8	5.5
Canada	0.8	1.2	2.0	3.4	4.6	5.7	5.9	6.0	4.5	4.9	5.0	4.8	4.4	4.0

Recent recruitment to the fishery

Late in 1969, reports were received of appreciable numbers of young scallops on Georges Bank for the first time since 1959-60. Positions given by fishermen suggested that the area of recent recruits was confined to the Northern Edge of the Bank between 66°35' and 67°15'W long. This area was surveyed in June 1970 and a population consisting predominantly of recent recruits was estimated to occupy approximately 80 square miles (274 sq km) of the Northern Edge of the Bank between 66°45' and 67°12'W, in 25-35 fathoms (50-70 m) (Fig. 2). Bottom photographs within the area showed population densities averaging 0.98/sq m, corresponding to a population of about 270 million scallops within the area of the concentration.

Calibration of the underwater camera allowed scallops in the photographs to be separated into three size groups: < 50 mm, 50-100 mm, and > 100 mm (Table 2).

Table 2.   Numbers and sizes of scallops in bottom photographs and dredge tows on the Northern Edge of Georges Bank (June 1970).

Size group	< 50 mm %	50-100 mm %	> 100 mm %	Total No.
Dredge contents	6.5	71.2	22.3	18,580
Bottom photos	25.0	65.7	9.3	2,830

From bottom photographs, it was estimated that only 10% of the population exceeded the commercial cull size noted in 1960-62 of 95-100 mm (Bourne, 1964); 25% of the population were smaller than 50 mm. In comparison, 22.3% of the dredge catches (using 3-inch internal diameter commercial rings) were larger than 100 mm, and only 6.5% smaller than 50 mm. Although some selection for larger scallops was being exerted by the gear, most of the fishable population in this area was smaller than 100 mm, and the largest catches contained the smallest scallops (Fig. 3). Three-ring scallops, with a modal size of 72.5 mm, were the dominant year-class in dredge hauls from within the area of high concentration. A small proportion of 2-ring scallops were also caught, although the actual abundance of this year-class was underestimated as judged from the bottom photos.

Meat sizes landed by the commercial fleet

Information on landed meat sizes was obtained for a single trip by 35 boats, representing 70% of the 50 Canadian vessels making regular trips to Georges early in 1970.

From each vessel, two 36-lb (16.3 kg) bags of scallop meats were picked at random from each third of the catch, and a 1-lb (0.45 kg) sample of meats weighed from each bag and counted. A 1-lb meat sample from each boat was frozen for later individual weighings of meats.

The mean numbers of meats per pound landed at three principal ports of landing for the offshore fleet were 43, 49, and 26 for ports A, B, and C respectively, although counts of up to 79 meats per pound were recorded at port B. A highly significant difference in the mean numbers of meats/lb was found between ports A and C, and B and C (p < 0.001). The total weight of landings was significantly correlated (p < 0.01) with the mean number of meats per pound in the catch, confirming research findings that largest catches were made in the area of recent recruits, landings per trip at ports B, A and C diminishing in that sequence (Fig. 4).

Meats per pound were converted to mean weights per sample (gm) and since no data are available for the shell sizes shucked by the fleet, estimates of mean shell lengths per sample were obtained using length-weight data published by Haynes (1966, Table 2) for Georges Bank scallops in the period April to September.

Mean shell lengths were plotted as histograms for each port (Fig. 5) and compared with mean shell sizes observed in unculled research tows on the Northern Edge in June 1970. Some culling for size seems to have taken place, as judged by comparison of the ascending side of the distributions from the three ports with that for the unculled research catch. However, since approximately half of the calculated mean shell lengths are below 85 mm for ports A and B, cull sizes for these two ports must be smaller than 85 mm, and probably fall between 70 and 85 mm. Half of the mean lengths for port C are below 100 mm, so that cull size for this port has probably remained close to the 95-100 mm cull size recorded for the Canadian fleet in the early 1960's.

Examination of log records from ports A and B for the first half of 1970 revealed a considerable expenditure of effort within the area of recent recruits, while boats from port C appear to have largely avoided this area (Caddy and Sreedharan, 1971).

Summary

Evidence from port surveys and research catches suggests that following a period of poor recruitment and an 80% drop in scallop abundance on the Bank, a limited recruitment of 3-ring scallops to the fishable population occurred on the Northern Edge of Georges Bank in 1969-70. Although the area of the concentration was small (approximately 270 sq km), the standing stock within it was estimated by bottom photography to be about 270 million scallops in June 1970. The mean length of scallops in the photographs was calculated to fall within the range 65-70 mm. From data in Haynes (1966), this corresponds to an average meat weight of 5 gm, and hence to a standing stock of approximately

1.4 million kg of meats in the area of the concentration. This is approximately one third of the Canadian catch from the Bank in 1969 (4.4 million kg meats). This recruitment was being exploited by vessels from two Canadian ports in 1970, and for these two ports cull size had fallen well below that being observed in the early 1960's. Vessels from a third major port were fishing elsewhere on the Bank and landing smaller catches of predominantly large scallops.

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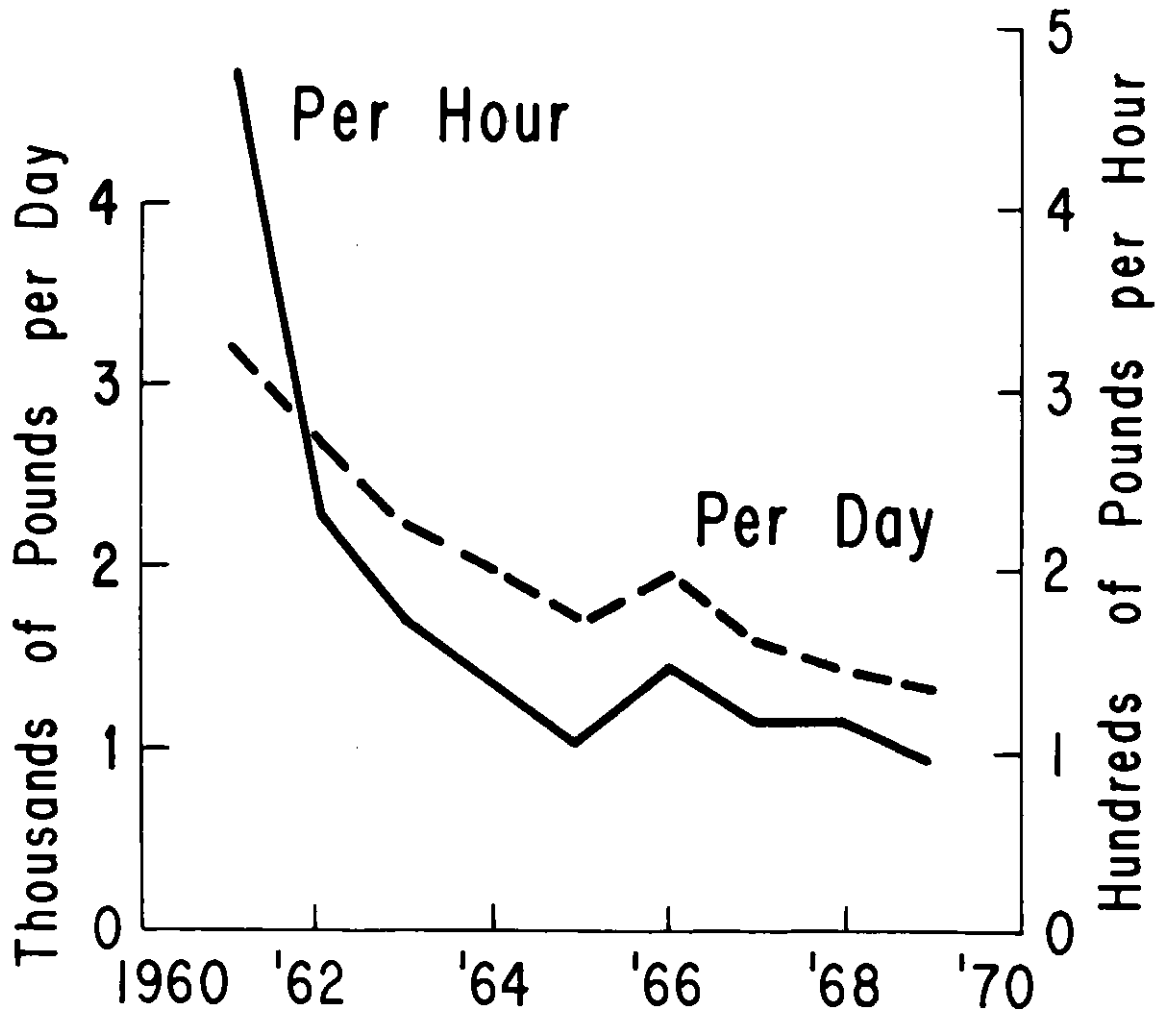
Fig. 1. Decline in two measures of catch/unit effort (Canadian fleet)
on Georges Bank since 1961 (1-1b scallop meats = 0.454 kg).
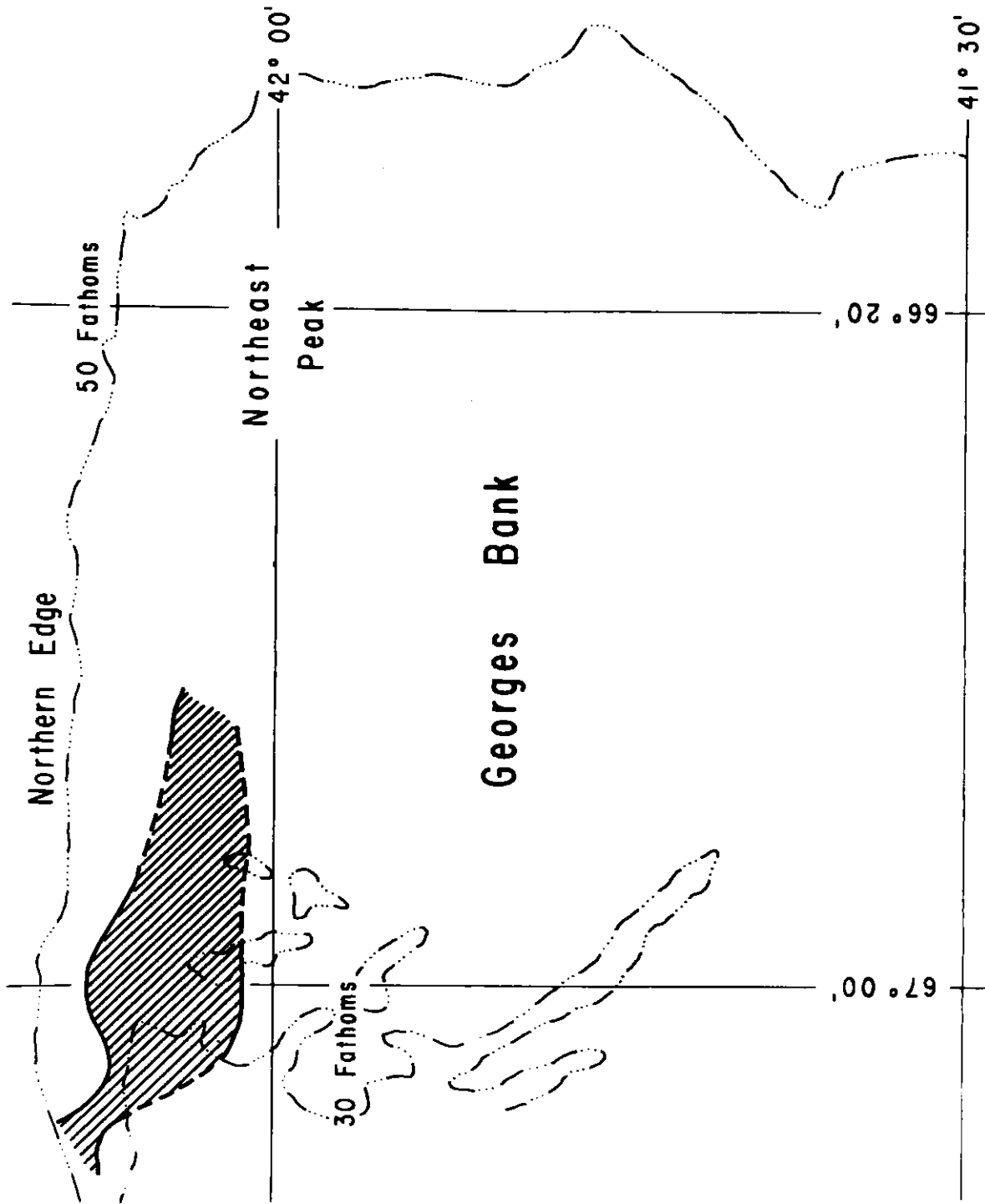
Fig. 2. Area of recent recruitment of scallops to the Northern Edge of Georges Bank discovered during a research cruise in June 1970 (1 fathom = 1.83 m).
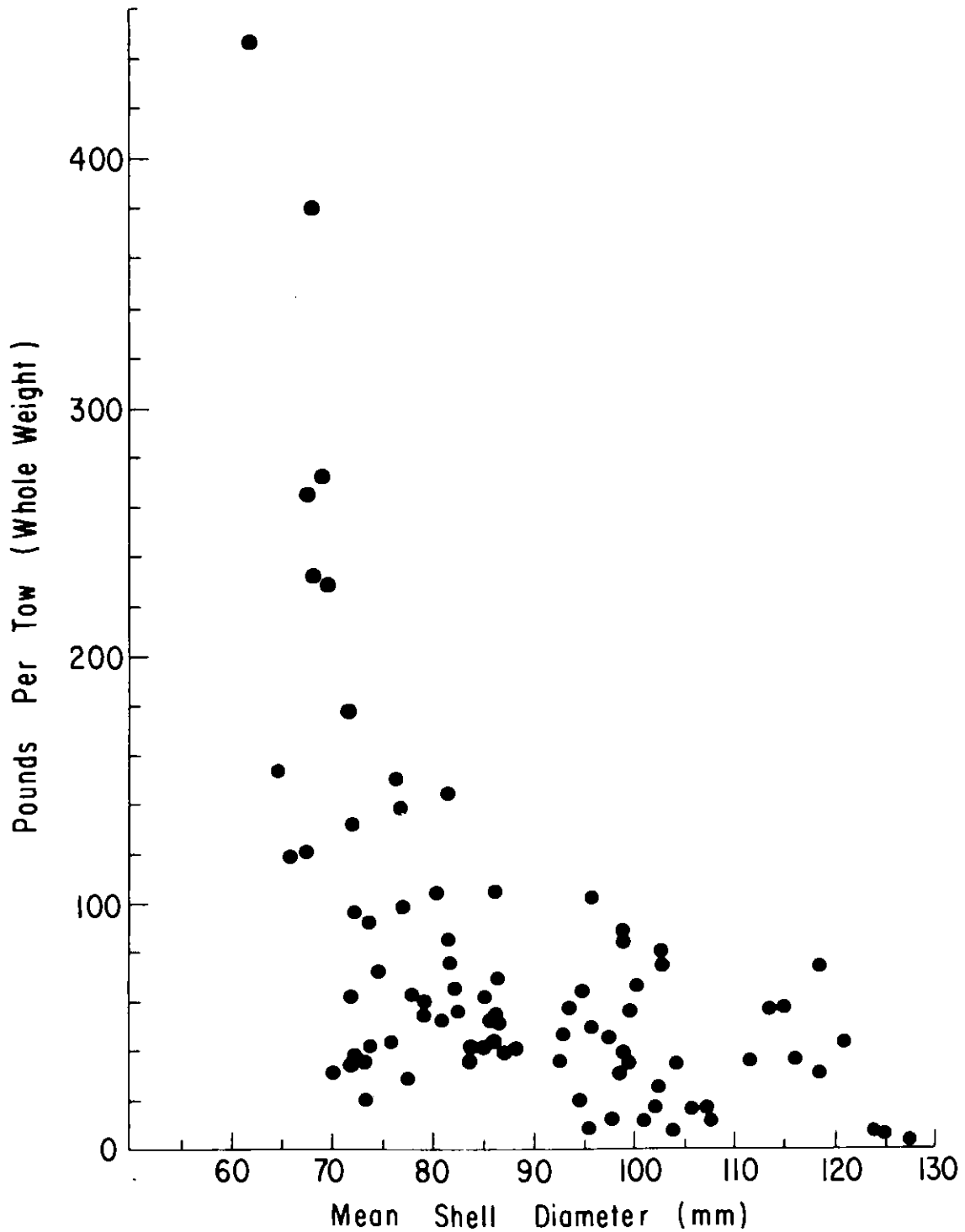
Fig. 3. Relationship between shell length and whole weight (1 lb = 0.454 kg) of scallops per tow made in June 1970 with a 2.4-m wide drag.
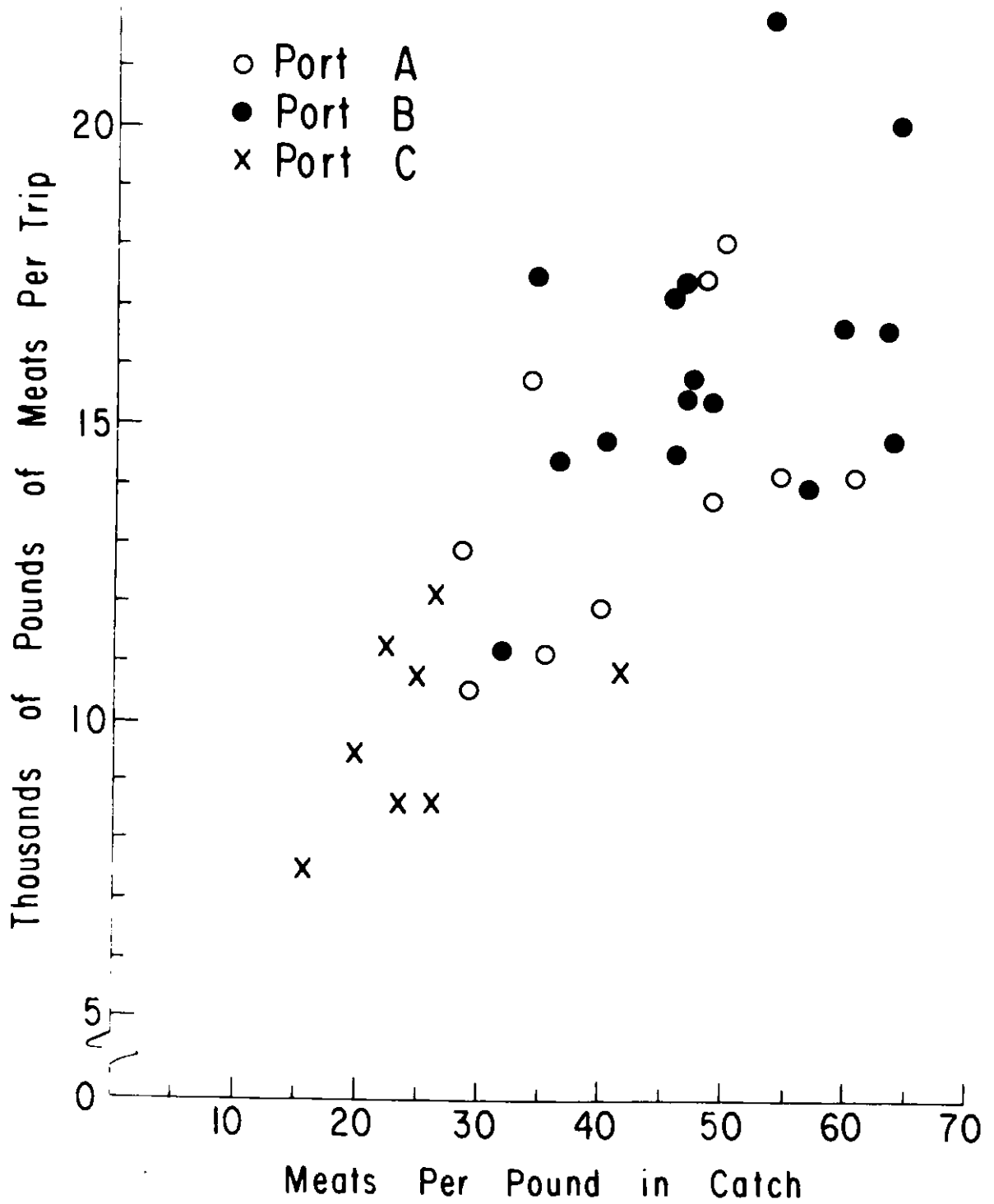
Fig. 4. Relationship between mean number of meats/lb in the catch, and weight of meats landed per trip at three Canadian ports by 34 vessels fishing Georges Bank in the period July–August 1970.
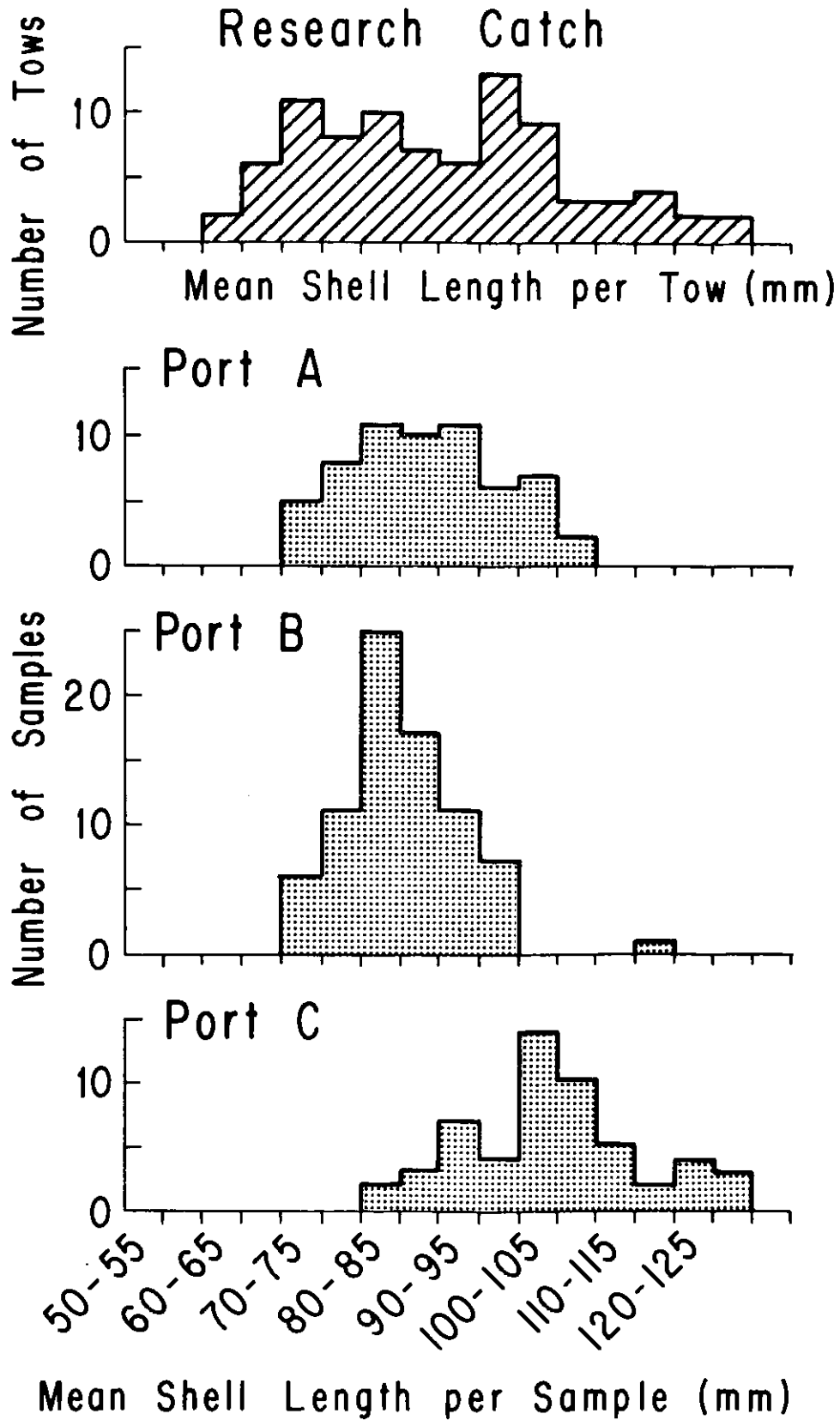
Fig. 5. Mean lengths of scallops caught on Georges Bank in the summer of 1970, based on measurements of shell size in the research catch, and conversions of mean numbers of meats per lb to estimates of mean shell lengths, using data from Haynes (1966).

14. Calculation of production of Harp seals in the Western North Atlantic[1]

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1. Introduction

Experience has shown that some differences in the biological features of harp seals and fish need to be stressed to fisheries biologists. First, *Pagophilus groenlandicus* Erxleben is a long-lived mammal in which mortality rates are low and rather constant. Consequently a large number of age-classes of approximately similar strength contribute to annual production, which therefore fluctuates little. The population dynamics of the species are in fact more like those of human beings than fish. Secondly, the yield is taken as newborn or a few weeks old young before virtually any mortality has taken place, for mortality in the first week or so has been measured at 0.01 or less (unpublished data of the author). Therefore, yield to the fishery is a simple fraction of production. Third, the species is aggregated at more or less constant density when the young are fished, regardless of the size of the aggregation or whelping group. (This density is ideally set by an individual distance which exists between adult females with pups, i.e. they are over-dispersed, but the density is further reduced by the inaccessibility to seals of the centres of large ice floes.) Therefore, catch per unit of effort will not change with increasing catch of young until this catch is well above sustainable yield, and such data will not be of much practical value.

Four general methods developed for estimation of production will be discussed here. They are: photographic aerial survey, capture-recapture tagging, study of escapement of year-classes after large and small catches of young, and study of total catch of young when there are grounds, from the first three methods, for believing that the catches of young are a high proportion of production.

Definitions used are as follows: 0-group seals are termed juveniles, approximately 1-5 year old harp seals are sexually immature, and adults are aged some 6 years and up. The Front ice is off the Labrador coast in Subareas 2 and 3, the Gulf of St. Lawrence ice is in Subarea 4.

2. Reproductive Rates

The maximum sustainable yield of young has been calculated (Sergeant, MS, 1969) at between 0.24 and 0.38 of production for observed extremes of reproductive rate. The reproductive rate recently measured in the Gulf (Table 1) would favour the lower yield but may not apply to the Front population, where it has not been possible recently to measure the reproductive rate accurately. In 1962 the reproductive rate at the Front was optimal (Sergeant, 1966), as it was in the White Sea under heavy exploitation of both young and adult seals (Yakovenko and Nazarenko, 1967).

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[1] Submitted to 1971 Annual Meeting of ICNAF as ICNAF Res.Doc. 71/7.

The suboptimal reproductive rate in recent years in the Gulf can be associated with an observed interaction between adults and young immatures at winter feeding grounds (Sergeant, MS, 1969). Segregation occurred and the adults appeared to be using the better feeding areas. Competition for food could affect rates of growth and reproduction. If the same lowered reproductive rate now exists at the Front, as seems likely from small data, then doubt is thrown on the assumption that the optimal yield is obtained from fishing the young animals only. However, it is difficult to reconcile the thesis, developed below, that total population has declined with postulated competition between age-classes. The question has not yet been resolved.

3. Aerial Surveys

The main apparent advantage of aerial surveys is that they give the only direct count or estimate, either of production, when applied to young seals or the adult females producing them, or of standing crop when applied to moulting groups of adults and immatures (Dorofeev and Freiman, 1928, and subsequent Soviet authors).

The main disadvantages are high costs of surveys and the need for completeness of each survey. Particularly, surveys of moulting groups must be simultaneous, since the groups may change position daily, and must be repeated to demonstrate patterns of aggregation. 'Ground' control is necessary to measure age and sex composition. Pilots must know how to find seals and at the same time the photography must be competent. No repeat is usually possible in the same year.

Surveys of whelping groups show that many young are invisible and few controls are possible. One control was achieved in Canada in 1967 when the industry decimated a group of seals just previously surveyed and detailed catch figures were available. Twenty thousand whelping adults had been estimated by aerial survey on 10 March. Thirty-five thousand young were taken on 13 and 14 March. Clearly, many adult females were in the water, either because they had not yet pupped, or had left the pup between episodes of suckling. This correction (0.57 of adults present in a group) might be applied to all counts made at the same stage of the reproductive cycle, but other variables, e.g. whether the seals are whelping on open pack ice with many leads, or on frozen-together shore ice affect their ability to enter the water. The sex ratio of whelping adults also is not accurately known, since on disturbance the males, present in some numbers ahead of mating time, enter the water more freely than the females attached to pups. Presumably, unwhelped females also enter the water readily. All these corrections might be entered into surveys, given repeated facilities of fixed-wing aircraft and helicopters, but total costs would be high.

Aerial survey was made of whelping groups in the Gulf and on the Front in 1970. The search was highly successful in that all whelping groups of seals were believed located, except that one Gulf group was located by another Government charter plane but not by the photographic plane, and its size was not precisely estimated.

However, the photography was poor. A 70-mm camera, used for

the first time in place of the usual 9 X 9" aerographic camera, proved
to have film lengths too short for continuous overlapping coverage of
the long axis of most seal patches. It was therefore necessary to load
the film magazine in mid-survey and the long lines could not be matched
afterwards when the mosaics of prints were mounted.

Results are shown in Table 2 with estimated major uncertainties
in accuracy. Catches in a fourth Gulf group which was not surveyed were
10,000 seals, bringing the Gulf estimate to at least 75,000 whelping adults
or young seals. Previous successful aerial surveys (Sergeant, MS, 1969)
gave estimates or indices of 100,000 young seals produced in the Gulf in
1964, and 215,000 produced on the Front in 1960.

The main value of the 1970 survey was that the relative sizes
of sets of whelping groups on the Front on the one hand, and in the
southern Gulf of St. Lawrence on the other, were compared visually within
a short space of time. They were approximately 5 to 3 or 2 to 1, the
Front having the larger set of groups. This estimate is confirmed from
the counts (Table 2) and is important in relation to the unsolved problem
of mixing of Front and Gulf groups, as follows:

In 1969, lack of ice in the southern Gulf had forced many Gulf
animals to whelp on the Front (Section 8). By 1970, the usual numbers of
animals had returned to the Gulf. Moreover, the Front has for many years
taken a heavier fishery than the Gulf, a trend which has been continued
since 1965 when the catch of young in the Gulf was regulated. In spite
of this long-continued difference in intensity of catch, the Front whelping
groups in 1970 were larger. Therefore, either the Front has not been
heavily exploited, which from the evidence presented below is unlikely,
or else the population of seals re-sorts itself annually between Gulf and
Front.

4. Capture-recapture Tagging

This method has been made possible mainly by a latening of the
starting dates for hunting young seals from 7 March to 12 March or later.
Tagging between 2000 and 3500 young seals has usually been possible from
an icebreaker or helicopter. The first figure represents, it is calculated,
about 2% of Gulf production, the second, 2% of Front production. The
interval between tagging and start of the fishery for young seals has
varied from no time to up to 2 weeks. The longer the interval, the greater
the chance of randomisation of the tagged seals through ice movement.
Mortality of young at or immediately after birth, as already stated, is
low and not likely much increased in the first few weeks (Popov, 1966).
Greatest errors come from a concentration of tagging and recoveries in
the same group of seals when other groups are not found or are inaccessible
to either tagging or recapture effort. I have determined also that
considerable variation occurs in catch returns of tagged seals from ship
to ship within one tagged group, apparently because of failure to achieve
randomisation of tagging. With such errors, sophisticated treatment seems
as unprofitable as for aerial survey, and the best validation has come
from three successive experiments in the Gulf, carried out in 1964, 1968
and 1970, which have given comparable estimates (Table 3). One experiment
has been performed on the Front. Resulting estimates of Gulf and Front

production, when compared, are in line with the 5/3 ratio between Front and Gulf production observed in 1970, and absolute figures are also broadly comparable when allowance is made for the incompleteness of aerial counts.

5. Study of Escapement After Varying Catch

Use of this method started from the observation from a number of age samples (one Danish, several Canadian) collected and analysed in 1953, that after an unusually heavy catch of young seals in 1951, the size of this year-class was consistently reduced. The same result was found after the next unusually heavy catch of young in 1956 and has been observed repeatedly thereafter, particularly following heavy kills of young in 1962 and 1963 (Figs. 1 and 2). The results should be particularly clear since 1961, when closing dates lowered the kill of age-groups older than the young (0-group), making the kill of older age-groups steady at about 35,000 annually as opposed to variable and up to 100,000 prior to 1961. Previously it was possible for a year-class of young, which had received light exploitation and consequently had survived well, to be exploited heavily at a later age, especially as the somewhat segregated 1-year-old moulting animals.

The problem is to quantify the strength of each year-class as a measure of the degree of its survival.

a. Using all age samples

A first, semi-quantitative method has been to sum the results of all age samples, allowing for various sorts of bias in these age samples which are known from long sampling to be steady, and the biological reasons for which are known. Thus, southward migrant seals lack younger age-classes, the number of immatures progressively increasing with increasing age (Fig. 1). In a real life table, they should of course decrease due to mortality. It is however known, from tagging results and from collection of age samples in West Greenland in winter, that the younger age-classes remain north in the winter up to 2 or 3 months longer than the main groups (Sergeant, 1965). The opposite bias occurs with samples from moulting groups at the icefields in April (Fig. 2, left). One and two year-olds are then over-represented. The reasons may be threefold: concentration and segregation of such immatures in the southern edges of the icefields most easily reached by ships, tameness of the young year-classes, and a movement (demonstrated by tagging) of young year-classes of Gulf seals to the Front at 1-3 years of age.

Few samples, chosen eclectically, have been "ideal", that is, corresponding to the expected age frequency distribution. Best were a West Greenland sample collected from many points by Danish scientists in 1953, and a unique sample of moulting seals collected in the northern Gulf in 1966. These samples were used to estimate mortality rates. No apology is made for the slight circularity in this argument, since much other unquoted evidence on the expected mortality rates of seals was used in regarding these samples as ideal. An ideal distribution, for example, reasonably gives higher mortality rates to the inexperienced immatures than to the adults. Table 4 shows sources of age samples used and their probable biases. Detailed age frequencies are shown in Appendix Table 1. Table 5 shows the result of combining all samples in

order to estimate the escapement or index of survival of each year-class
from 1960 to 1969. Clearly there is more accumulated evidence for
earlier year-classes. The index of survival is expressed in four
categories: very good rates as 3, good as 2, poor as 1 and very poor as 0.
These values are summed and then expressed as a proportion of the maximum
possible score (always 3). By this means a year-class which always showed
an index of 'very good' would score 1.00, one which always showed an index
of 'very poor' would score 0.00. Results of the analysis are plotted in
Figure 3. From the least squares fit, extrapolation down to survival
index 0.00 would occur at an estimated catch of 365,000 young seals,
which therefore represents an estimate of present production. Survival
to index 1.00 would occur at a catch of 115,000 young harp seals. The
precise biological significance of this figure is obscure but since it
measures "consistently good escapement of a particular year-class in all
age samples, as compared with other year-classes," it may represent
approximately the present sustainable yield. The ratio 115/365 = 0.32
whereas the sustainable yield of young seals has been calculated from
known mortality and fecundity rates at between 0.24 and 0.38 (mean, 0.31).
Presumably, below catches of 115,000 natural mortality increases in a
density-dependent manner, while above this value, an irreducible minimal
mortality of juveniles occurs. This mortality is believed, by
extrapolation back from mortality rates of immatures, to be about 0.20
on an annual basis (Sergeant and Fisher, MS, 1960).

   b. Using single sets of age samples
        This method is the same as above but confined to one set of
age samples at a time, so that variations in selectivity or bias between
sets of samples is eliminated. Within one set of samples, bias is seen
to be much the same each year (Fig. 2), so that by expressing catch and
escapement as proportions between one year and the next, this bias can
be eliminated. Thus true quantitative results can be achieved. For
proper formulation of the method I am much indebted to Dr. W. E. Ricker.

        Consider for example the two sets of samples seen in Fig. 2.
One is of seals sampled by net from a shore fishery at or near St. Anthony,
northeast Newfoundland, in January to March 1967, 1968, 1969 and 1970.
The second set comes from the ship fishery a few miles off this coast and
two months later, in April. The animals are then shedding their hair on
their annual moult and are shot. In the second set, a bias towards one
and two year-old animals is seen as compared with the first set.

        Let us consider the shore fishery only. In the first two
samples, year-classes 1966 and 1967 show up poorly as one year-old
animals but, in the third sample, collected in 1969, year-class 1968
appears in great strength. Now the catch of young seals in 1968 was
reduced to half the catch in 1967 or 1966, as the result of a late
starting date and temporary reductions in catching effort. The
association between low catch and enhanced escapement is seen also in
the moulting samples.

        We will assume that in successive adjacent years neither
stock nor production have changed by an appreciable amount, and that
natural mortality during age 0 is constant over this period (i.e. that
not even in 1968 was maximal sustainable yield taken).

Let S = stock excluding young (same in both years)
B = number of young just before harvesting (same in both years)
C = catch (known)
v = natural mortality rate after kill and before sample taken at age 1 (same in both years)
K = ratio of age 1 seals to S (known for each year).

We wish to estimate B. From the above we can write:

Survivors after catch = B - C

Survivors at age 1   = (B - C) (1 - v)

Age 1 divided by stock $= \dfrac{(B - C)\ (1 - v)}{S} = K$

$$\dfrac{K_1}{K_2} = \dfrac{B - C_1}{B - C_2} \qquad B = \dfrac{K_1 C_2 - K_2 C_1}{K_1 - K_2}$$

Table 6 shows the data and Table 7 the calculations using St. Anthony samples on the left side and icefield samples on the right, the mean of 1966 and 1967 catches and escapements compared with 1968, above, and 1968 compared with 1969, below.

For the 1966-1967/1968 comparison, from both areas, results are in good agreement. Using the Front catch figures, production is calculated at close to 200,000, while using total catch figures, production is close to 300,000. These figures represent estimates respectively of Front production and total production.

For the 1968/1969 comparison, the Front figure increases and the total figure decreases. This result may be associated with an apparent move to the Front in 1969 of some seals which would normally have whelped in the Gulf (see below, Section 8). With this known abnormal year, it is probably better to use the 1966-1967/1968 comparison as more normal. This is shown graphically in Figure 4, where values of K are plotted against catch C. The least squares line is fitted to data for the first three years only. For K equal to 0, estimates of catch = production are: for the Front - 192,000, for the total production - 283,000. Expected further samples will allow refinement of these estimates.

6. Use of Catch Statistics

a. Total catch
Table 8 shows recent catches of young, uncontrolled at the Front save by season and partial abstention (1968) but controlled in the Gulf by Canadian regulation and Norwegian abstention since 1965.

Inspection of Front catches of young from 1960 to 1970 shows that in no year have catches exceeded 187,000 in spite of heavy catching effort and uncontrolled (unregulated) catch. This is itself strong evidence that production on the Front does not exceed, and may be less than, 200,000.

Figure 2 and Table 5 showed that, after years of highest catch
(e.g. 1963, 1964, 1967) escapement of young was very low. Very low and
maintained low escapement after high total catches in 1963, higher than
normal in the Gulf, slightly lower than normal at the Front, suggest
the importance of mixing between stocks.

b. Whitecoats and beaters

Mr. T. Øritsland (MS, 1967) demonstrated a variant of this
method. If all the young are taken as whitecoats, none will escape to
be taken at one month of age as "beaters," hence the beater catch will
decline. He demonstrated a progressive decline in beater catches by the
Norwegian fleet, indicating that a progressively increased proportion of
production was being taken.

In order to convert to absolute production, the Canadian (and
other) catches of young must be added. Unfortunately Canadian catch
statistics did not separate whitecoats and beaters till 1966. In 1966
catches of young at the Front were not maximal (168,000), 1968 was a
beater season, and in 1969 the Gulf ice was abnormal so that some whelping
females from the Gulf probably moved to the Front. This leaves us 1967,
a year of maximal catch of young at the Front (187,000). Indeed in
this year beater catches were exceedingly low (1700 only) and whitecoat
catches 181,000. (An intermediate category of 'ragged jacket' accounts
for the rest.) The combined catch of 187,000 young seals at the Front
was therefore very likely close to total production.

7. Discussion

If the two populations mix, as now seems very probable, then
removal annually of a high proportion of Front production plus a
substantial amount of Gulf production will cause the population to
decline. In quantitative terms, if production now equals 300,000 and
actual removal averages 218,000 (Table 8) while sustainable yield is
125,000, the population as a whole must be declining. Is there any
direct evidence that this is so?

First, to revert to Table 8 and the method of Section 5a.
Larger maximal catches of young were taken at the Front in the 1950's
(up to 248,000) than in the 1960's (up to 188,000). This suggests a
decline in production since if anything, catching effort has increased,
due to experience of skippers and use of more powerful ships. Decline
was probably faster in the 1950's since large numbers of adult and
immature as well as young seals were then taken, until imposition of a
closing date in 1961. Perhaps also the Gulf population, managed since
1965, has contributed part of its production to the overexploited Front.
I do not think that the constant mean catches of young (Table 8) are an
objection to my thesis, as has been suggested by the sealing industry.
On the contrary, I think that they only mean that an increasing proportion
of young is being killed.

A second line of evidence comes from a long series of samples,
now extending over 20 years, from the net fishery on the North Shore of
the Gulf of St. Lawrence at La Tabatiere (Age reading of this series was
begun by Dr. H. D. Fisher and continued, with cross-checking of ages,
by the author). In the early 1950's this sample contained a lot of

older immatures or young mature adults, aged 4-6 years. In recent years
this proportion has declined (Fig. 1). This can only mean, either that
we are underfishing the adults so that they are accumulating, or that we
are overfishing the young seals, so that recruitment steadily declines
to the population as a whole. All the other evidence cited in this
paper favours the second hypothesis. Again, this evidence, so interpreted,
favours a high degree of mixing between populations, since it is unlikely
that the Gulf, from where these samples come, has itself been overexploited
under a controlled fishery.

8. Mixing of Stocks

        Some evidence has been discussed above. Further evidence is
as follows:

        In 1969, abnormally restricted pack ice in the southern Gulf
interfered with whelping of harp seals. After 32,000 young had been
killed, the hunt was called off by Government order. Careful Governmental
survey found only 6600 more young. There was no ice elsewhere in the Gulf.
Therefore an estimate of production in the Gulf in 1969 was less than
40,000. This is below the normal production estimated at some 100,000.
The other whelping seals must either have aborted at sea, or looked for
and whelped on ice elsewhere. There was no evidence for large numbers
of washed-up corpses of neonates, and the second alternative seems
logical. The nearest suitable ice was in Hamilton Inlet, Labrador, where
a large, compact herd whelped. Here, although the herd was in Canadian
territorial limits for the most part so that few Norwegian ships took
part in the whitecoat fishery, the total catch of young at the Front was
187,000 young animals, equal to any other maximum (Table 8). Is there
any evidence that Gulf animals were involved? I think so, extending the
method of Section 5b above.

        If many seals moved to the Front to whelp, escapement of the
1969 year-class will not be much below the expected level after a
total catch of 220,000 young (Fig. 3), i.e. fair to poor (index 1 or 2)
survival. But if they stayed in the Gulf and failed to whelp successfully,
then the total Front production was taken, as well as the reduced
production in the Gulf, so that escapement would have been very poor
(index 0).

        In fact, Front samples for 1970 (Tables 5d, e and 6) show
that escapement of the 1969 year-class was about one third higher than
for 1966 and 1967. If K, the ratio of one year-olds to total animals
in age samples (method of Section 5b) is plotted against Front catch for
the 4 years of available data from 1967 to 1970 (Fig. 4), in 1970 it
falls above the least squares line of fit of the other 3 years, giving
an increased value for production at the Front. But if plotted against
total catch in 1970, it falls somewhat below the line, giving a lowered
value for total production. This suggests to me that most animals which
did not whelp in the Gulf whelped on the Front.

        During 1969 the ratio of whelping animals was more than 187,000
on the Front to 40,000 in the Gulf, or higher than 4.5 to 1. In 1970,
aerial survey showed the ratio to be nearer 3:2. Therefore, animals had
returned to the Gulf. The effect of delayed whelping in the Gulf (and

on the Front too for animals that moved) due to poor ice was apparently reflected in abnormally late whelping in the Gulf in 1970. One large patch was actively whelping between about 8 and 16 March, as compared with normal dates of about 1 to 7 March. (This observation also suggests that the date of whelping in March is fixed by the date of mating in April of the previous year, and not by the date of implantation, which occurs in the arctic about the end of July.)

The simplest hypothesis available at the present time from all the above evidence is that the seals mix freely on the southward migration in January when they feed for some 2 months in ice-free waters before whelping. They then whelp on the nearest available ice, beginning in late February. While this hypothesis does not rule out the possibility of some homing to, for instance, Gulf waters by the same animals yearly, its truth would rule out the possibility that sharp morphological or biochemical differences might be detectable between the populations except for phenotypic influences on the young (e.g. differences in weather which could affect hair quality). A more serious consequence would be that if, as demonstrated above, the Front population is being heavily overfished, and, if the populations mix, this effect will spread to the Gulf population which will also decline. Probably this is happening now. Capture-recapture estimates in the Gulf show a progressive decline (Table 3), and an increase in percentage of recaptured young, and production in the southern Gulf has almost certainly now sunk below 100,000 young.

9. Are Any Seals Being Missed?

The possibility of far northern harp seals was explored by flights along the Labrador coast in 1960 (Sergeant and Fisher, MS, 1960). None were found in March north of Hamilton Inlet, the ice being unsuitable due to lack of open water leads until too far out to sea. If such seals exist, they must whelp in April, and may contribute to small numbers of whitecoats seen at the Front late in the season in some years. Catches from these would enter catch figures so that the methods of Section 5 have allowed for them.

More important are a variably sized herd in the northern Gulf, whelping on the rather small and variable amount of ice entering through the Strait of Belle Isle. From catch figures they were known to reach a maximum of perhaps 50,000 in 1965 and 35,000 in 1967. The minimum may be a few hundred seen, for instance, by survey in March 1970. Again such catches enter catch figures, since the seals are taken sometimes by the larger ships and regularly by longliners active in the northern Gulf in April. Thus this production has also been taken into account in the methods of Section 5.

If the method of Section 6a is applied to total catches it is seen that total catches in the 1960's did not exceed 280,000 (Table 8) less than our postulated 300,000 total production. Big production in the north, occasionally entering the catches, would surely raise catch levels occasionally to a higher figure. Therefore I think that such added northern production is negligible. Higher total catches in the 1950's, up to 350,000 young seals, can be attributed to a higher production at that time.

10. Management

The 1971 quota of 200,000 seals of all species assigned to ships is divided 50,000 to the Gulf and 150,000 to the Front. These could all be taken as young harp seals, since the estimated production in each area will allow such catches, and because the fishery for young seals, (beginning about 12 March) comes before the fishery for hood seals on the Front (beginning about 20 March) and the fishery for moulting adult and immature harp seals (beginning about 30 March). If this quota is fully taken as young harp seals some 50,000 young will be left available in each area, according to the present thesis, to be taken by smaller craft if these are not subject to the 200,000 quota. The numbers of these smaller vessels are known to be increasing rapidly as prices of harp seal furs remain firm.

In this way the proposed 1971 quota, as presently understood, would allow almost total destruction of the 1971 year-class of harp seals. If the population of western harp seals is to remain even at its present, reduced level, the quota must be cut to no more than 125,000 young harp seals taken by all agencies, or else the starting date for sealing must be made so late that the catch of the more highly dispersed "beaters" is no more than this figure. As with the International Whaling Commission a decade ago a major difficulty towards effective regulation is that there exists an excessive and growing catching fleet, the costs of construction of which must be amortized. I have previously suggested (Sergeant, MS, 1966) that the catching fleet should be halved, from some 24 to 12 large vessels, to maintain present sustainable yield and take it efficiently. Now in 1971, this measure would be inadequate. I now suggest that as many sealing ships as possible, most of which constitute a long-distance fleet, be diverted to fishing the stocks of crabeater seals *Lobodon carcinophagus* and other species in the Antarctic. Their biology, as seen from a pioneering Norwegian voyage, has been described by Øritsland (1970). The sustainable yield of harp seals could then be taken, and the stock possibly allowed to increase, by leaving such ships as are fit only for nearshore waters, together with the increasing fleet of longliners. While such a proposal is outside the scope of formal consideration by a regional organization such as ICNAF, possibly ICNAF should consider an approach to the Antarctic Treaty organization if a diversion of the kind suggested is recommended.

11. Summary

Present production of young harp seals in the western North Atlantic is calculated by four independent methods to be about 300,000 and declining. Under normal ice conditions some 200,000 are believed produced on the Front ice in Subareas 2 and 3, and 100,000 in the Gulf of St. Lawrence, Subarea 4. Shifts of population under abnormal ice conditions, and other evidence, suggest intermixing of stocks between the two subareas. The combined sustainable yield at present is estimated to be no more than 125,000 young harp seals. Present annual catches average 218,000 young and effort is increasing. Diversion of the more mobile part of the fleets to sub-Antarctic seal stocks is suggested as an alternative to continued overexploitation.

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Table 1. Reproductive rates of female harp seals collected in the Gulf of
St. Lawrence, 1965-1969.

Age at parturition (yrs)	Number				Percent pregnant
	Immature	With regressed corpus luteum	Pregnant	Total	
1	25			25	
2	35			35	
3	69			69	
4	77		2	79	2.5
5	74	1	21	96	21.9
6	35	4	65	104	62.5
7	14	1	81	96	84.4
8	7	5	66	78	84.6
9	3	2	51	56	91.1
10	4		50	54	92.6
11		5	43	48	89.6
12	1	2	31	34	
13	2	4	23	29	
14	1	1	39	41	
15		2	31	33	
16		1	23	24	
17		4	15	19	
18	2	1	11	14	
19	1	1	12	14	88.1
20		2	4	6	
21			4	4	
22			7	7	
23			2	2	
24			2	2	
25		3	1	4	
26			1	1	
27			1	1	
	350	39	586	975	

Table 2. Aerial photographic survey of whelping seals, 1970.

A. Gulf (March 8, 10)

March	Area (sq. miles)		Density (seals/sq. mile)		Total number	
	8	10	8	10	8	10
Group I	13	29	828	890	11,856	26,665
II	very	small	-	-	(1,000)	(1,000)
III	25	60	667	600	18,377	36,500*
						64,165

* Whelping not completed till ca March 16.

B. Front (March 14)

Group	Area	Density	Total number
I	-	-	(5,000)*
II	2	3,619	7,200
III	6	2,798	16,788
IV	95°	963.3	91,515
			120,503

* Cloud prevented photography.
° Area estimated from timed lines only.

Table 3. Results of capture-recapture tagging 1964 to 1970.

A. Gulf

Year	Tagged	Recaptured			Catches			Estimate of production from:	
		Ships	Planes	Total	Ships	Planes	Total	Ships	Planes
1964	2,971	782	876	1,658 (58.3%)	42,256	39,252	81,508	154,072	127,432
1968	2,219	1,055 (47.5%)			59,735			127,209	
1970	1,966	1,546 (78.4%)			(50,000)			63,000 from untagged patch plus at least 10,000 + 73,580 +	

B. Front

Year	Tagged	Recaptured			Catches			Estimate of production from Canadian ships[1]
		Canadian Ships	Norwegian Ships	Total	Canadian Ships	Norwegian Ships	Total	
1966	3,581	1,042	620	1,662	54,955	107,213	162,168	188,913

[1] Norwegian ships' recoveries believed incompletely reported.

Table 4. Sources of age samples analyzed in Table 5. Samples arranged in seasonal sequence.

Number	Location	Behaviour of animals	Season	Known biases
a.	Labrador	Migrating south	November-December	Few 1-4 year animals
b.	Northern Gulf	Migrating south	January	Few 1-4 and >10 year animals
c.	Western Gulf	Wintering	January-April	Few >5 year animals
d.	Front shore catch	Wintering	January-April	Good
e.	Front ship catch	Spring moult	April	Excess 1-2 year animals
f.	Arctic	Summering	July-October	Excess 1-2 years (Greenland) or too few 1-2 years (Baffin Island)

Table 5. Index of survival (escapement) of year-classes of harp seals 1960-69, assessed subjectively from the series of age samples identified in Table 4, as very good = 3, good = 2, poor = 1, very poor = 0. Data in Appendix Table 1. No data shown, where they exist, indicates an expected bias or inadequate data.

Year class	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
Sample										
1970										
e	----	----	----	----	----	2	2	0	3	2
d	3	3	3	1	2	2	2	0	3	2
c	----	----	----	----	----	----	2	3	2	1
b	3	2	2	1	1	3	----	----	----	----
a	1	2	1	1	2	3	----	----	----	----
1969										
f	2	0	1	2	1	3	2	1	3	----
e	----	----	----	----	----	----	----	----	2	
d	----	----	----	----	----	----	----	1	2	
c	----	----	----	----	----	----	2	1	3	
b	1	2	2	1	2	3	----	----	----	
a	2	2	2	0	1	2	1	1	2	
1968										
e	3	2	1	1	1	3	----			
d	3	2	1	0	1	1	1	1		
b	2	2	2	1	2	3	----			
1967										
f	2	2	2	1	2	2	----			
e	3	3	2	1	0	----				
d	3	2	1	1	0	1	1			
b	2	3	2	1	----	----				
a	2	2	2	2	----	----				
1966										
e	2	1	1	1	----					
b	3	2	2	----	----					
1965										
e	2	1	1	1	----					
b	3	3	----	----						
a	2	2	----	----						
1964										
b	3	2	----							
a	3	3	1	2						
1963										
e	3	3	1							
b	2	2	1							
a	2	3	1							

Table 5. Continued.

Year class	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
Sample										
1962										
f	2	2	----							
e	3	2								
b	-------									
a	-------									
1961										
e	----									
b	----									
Total	62	56	32	18	15	28	13	8	20	5
Maximal	72	72	63	51	36	36	24	24	24	9
Ratio = Index	0.86	0.78	0.51	0.35	0.41	0.78	0.54	0.33	0.83	0.56
Catch ($\times 10^3$)	156	169	207	270	266	183	252	280	156	220

Table 6. Escapement at one year of age, correlated with catch of young and expressed as percentage of total sample, for samples from (a) St. Anthony and (b) the Front icefields.

Year class	Catch of young (C) $\times 10^{-3}$		Number & percent of juveniles in samples from					
			St. Anthony			Front icefields		
	Front	Total	1 yr	Total	Ratio (K)	1 yr	Total	Ratio (K)
1966	180	264	18	315	.057	77	405	.190
1967	184	276	7	201	.035	84	576	.145
Mean	182	270			.046			.168
1968	98	155	87	205	.424	62	107	.579
1969	187	220	41	571	.072	105	431	.244

Table 7. Calculation of Front and total production comparing mean figures
of catch and escapement for 1966-67 with 1968 and 1968 with 1969.

Catch	Front		Total	
Age sample	St. Anthony	Front icefields	St. Anthony	Front icefields
Years compared	1966-67/68			
Estimated production	192,704	216,336	283,994	317,007
	(204,520)		(300,500)	
Years compared	1968/69			
Estimated production	205,205	251,824	233,295	267,343
	(228,514)		(250,319)	

Table 8. Catches of young harp seals X 10^{-3}.

Year	Gulf of St. Lawrence	Front	Total	5-yr mean
1950	31	195	226	
1951	90	229	319	
1952	63	135	198	223
1953	32	166	198	228
1954	74	101	175	233
1955	94	158	252	226
1956	93	248	341	215
1957	74	91	165	228
1958	90	51	141	208
1959	62	177	239	174
1960	85	71	156	182
1961	41	128	169	208
1962	89	118	207	214
1963	110	160	270	219
1964	84	182	266	236
1965	90	93	183	250
1966	84	180	264	227
1967	92	184	276	218
1968	57	98	155	
1969	33	187	220	
(1970 preliminary	57	150	207)	

Appendix Table 1. Age samples.

(a) Labrador (November of previous year to January of current year).

Age (yrs) nearly	1970	1969	1968	1967	1966	1965	1964	1963	1962	1961
1	21	5		6	1	4	43	26	6	
2	60	4		11	2	10	42	83	15	
3	67	29		17	3	24	50	54	16	
4	63	18		24	5	34	32	33	30	
5	68	11		30	7	24	32	26	21	
6	44	6		25	5	18	42	21	7	
7	24	11		27	4	15	29	8	14	
8	22	10		14		16	35	10	16	
9	25	11		10	4	4	23	12	13	
10	24	2		9	2	5	27	15	16	
11	13	3		11	1	5	18	14	10	
12	8	6		5		6	21	10	3	
13	8	1		6		7	20	9	11	
14	5	1		7		7	21	14	8	
15	10			7		10	7	11	23	
16	2	1		6	1	6	11	9	10	
17	9			3	2	5	12	11	4	
18	6	1		4		4	6	4	4	
19	6			6	2	4	14	12	6	
20	6	1		4		1	6	10	12	
21	1	1		4		2	6	6	2	
22	1				1	1	3	8	5	
23	3			1			5	10	3	
24	1			2		2	2	6	2	
25				1	2	2	6	2	3	
26						1	3	2		
27						1		1	3	
28				1			1	2	2	
29								3		
30				2				4		
30+							2		3	
N	497	122		243	42	218	519	439	266	

Appendix Table 1 (Continued). Age samples.

(b) Northern Gulf (January).

Age (yrs) nearly	1970	1969	1968	1967	1966	1965	1964	1963	1962	1961
1	5	9	11	12	10	4	10	18	20	16
2	12	20	48	42	29	17	31	52	50	65
3	32	49	68	46	42	45	74	86	74	100
4	55	69	56	37	44	72	64	90	95	126
5	77	71	39	58	42	71	65	80	95	39
6	38	49	54	72	50	66	40	56	33	52
7	35	60	41	64	33	39	27	32	46	43
8	64	59	39	43	19	32	11	36	42	27
9	66	43	17	31	14	18	10	22	29	28
10	82	40	18	27	8	9	6	25	18	24
11	61	38	14	14	10	10	11	24	14	15
12	42	22	14	15	5	12	5	20	17	20
13	37	20	7	10	7	16	6	11	11	16
14	30	16	9	16	7	8	3	17	13	7
15	32	24	10	12	7	8	4	22	21	12
16	27	18	6	4	7	6	2	15	7	5
17	30	11	9	9	3	5	4	13	9	3
18	21	11	4	7	1	2	1	9	11	2
19	17	5	5	4	1	6		4	1	
20	16	4	2	5	2	3	2	10	4	7
21	10	5	1	3	1	3		5	1	
22	9	2	3	4	1	1	2	5	6	
23	4				1	2		4	1	2
24	5	1		2		1		2	1	1
25	6		1	3		1	1	1	2	4
26	3		1		1	1		3		1
27	3		2					2		
28	4				2			3		2
29										
30	2					1	1	5		2
N	824	646	479	540	347	459	380	672	621	619

Appendix Table 1 (Continued). Age samples.

	(c) Western Gulf January-April		(d) Front shore catch January-April			
Age (yrs)	1970	1969	1970	1969	1968	1967
1	31	37	41	87	7	17
2	69	14	41	13	8	14
3	89	21	15	13	8	1
4	45	10	25	13	8	9
5	40	11	23	11	5	11
6	16	2	19	10	9	21
7	8	5	14	5	12	26
8	12	4	43	7	15	21
9	8	2	49	1	16	26
10	8	11	39	6	15	16
11	4	6	24	4	10	21
12	4	2	28	4	13	14
13	1	5	26	5	9	16
14		2	19	3	7	15
15	2	1	29	3	9	13
16	1	1	30	2	11	17
17		5	20	6	10	12
18	1		12	2	7	9
19	1	2	18	3	5	8
20	3		22	2	3	11
21	1		10	2	4	3
22		1	5	1	4	2
23			7	2	2	3
24		1	5		1	5
25			3			1
26			1			1
27					1	
28						1
29						
30			1		1	
30+					1	1
N	359	144	571	205	201	315

Appendix Table 1 (Continued). Age samples.

(e) Ships' catch of moulters. All or mostly from Front except 1966 when from Gulf.

Age (yrs)	1970	1969	1968	1967	1966	1965	1964	1963	1962	1961
1	105	62	84	176	120	32		111	201	122
2	98	2	77	61	100	13		121	245	34
3	11	6	48	18	39	13		106	61	25
4	17	1	20	18	40	15		55	56	30
5	18	2	17	29	45	23		46	39	11
6	12	4	23	46	45	22		61	17	13
7	15	1	27	40	44	7		67	15	15
8	8	6	39	30	31	2		66	16	9
9	13	2	23	23	15	2		63	17	8
10	18		26	16	17	5		72	6	17
11	13	3	19	23	23	1		70	8	10
12	20	1	18	18	17	7		51	13	3
13	12	2	16	14	15			57	6	4
14	6	2	24	19	17	5		56	9	6
15	11	2	20	20	14	4		42	12	1
16	13	2	20	14	14	2		54	4	5
17	7		11	18	10	1		36	12	4
18	7		17	20	17	3		24	5	2
19	7		16	21	10	3		18	4	3
20	6		11	15	11	1		18	9	2
21	4	1	6	8	8	2		17	1	
22	5	2	5	8	3	1		12	4	2
23	3	2	4	8	7			9		1
24	3	1	2	4	4			8	1	
25			1	4	2			4	1	1
26	1	1	1	1	4	3		4	1	1
27			2	3	1			1	1	

Appendix Table 1 (Continued). Age samples.

(e) Continued.

Age (yrs)	1970	1969	1968	1967	1966	1965	1964	1963	1962	1961
28	2				1			1	1	
29		1	1							
30				4						
30+					3					
N	431	107	578	679	677	167		1247	767	330
No. of ships	2	1	4	4^X	1	7		1*		1+

*USSR (Khuzin, 1963)

^{X}including 1 Norwegian

+USSR (from Popov and Timoshenko, 1965)

Appendix Table 1 (Continued). Age samples.

(f) Arctic, July-September.

Age (yrs)	Baffin Island 1969	1967	West Greenland 1962
0	9	5	275
1	23	11	37
2	11	25	19
3	19	13	3
4	23	9	1
5	12	17	3
6	17	20	2
7	9	14	3
8	9	10	1
9	19	14	2
10	14	9	1
11	11	14	
12	9	8	
13	8	10	2
14	17	12	
15	5	7	9
16	6	7	
17	5	6	
18	5	2	
19	10	5	
20	3	4	
21	1	3	
22	3	2	
23	6	1	
24	2	2	
25	1		
26			
27	1		
28			
29			
30			
30+			
N	264	232	358
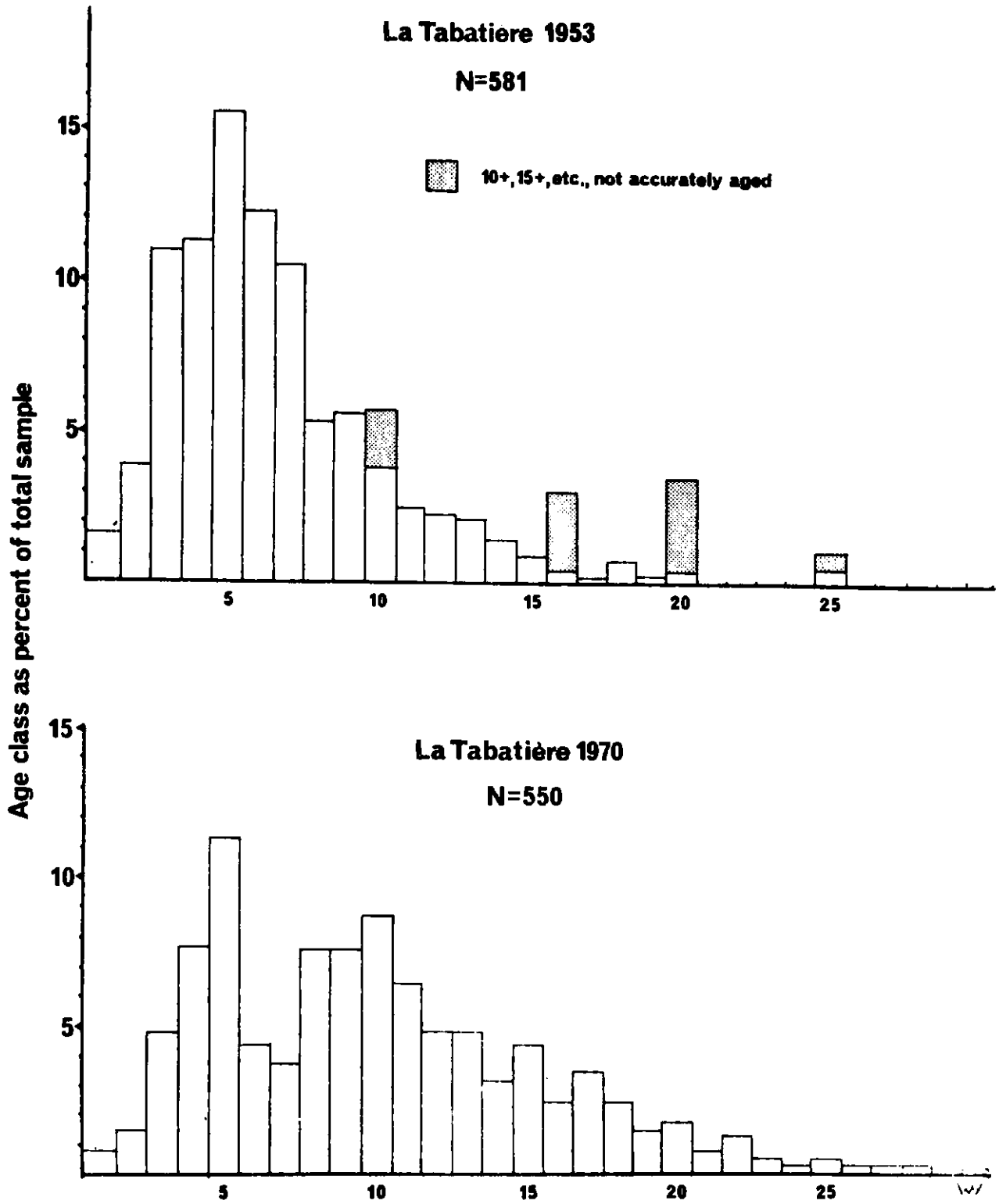
Fig. 1. Age samples of southward migrant seals from the same site, La Tabatière, in 1953 and 1970.
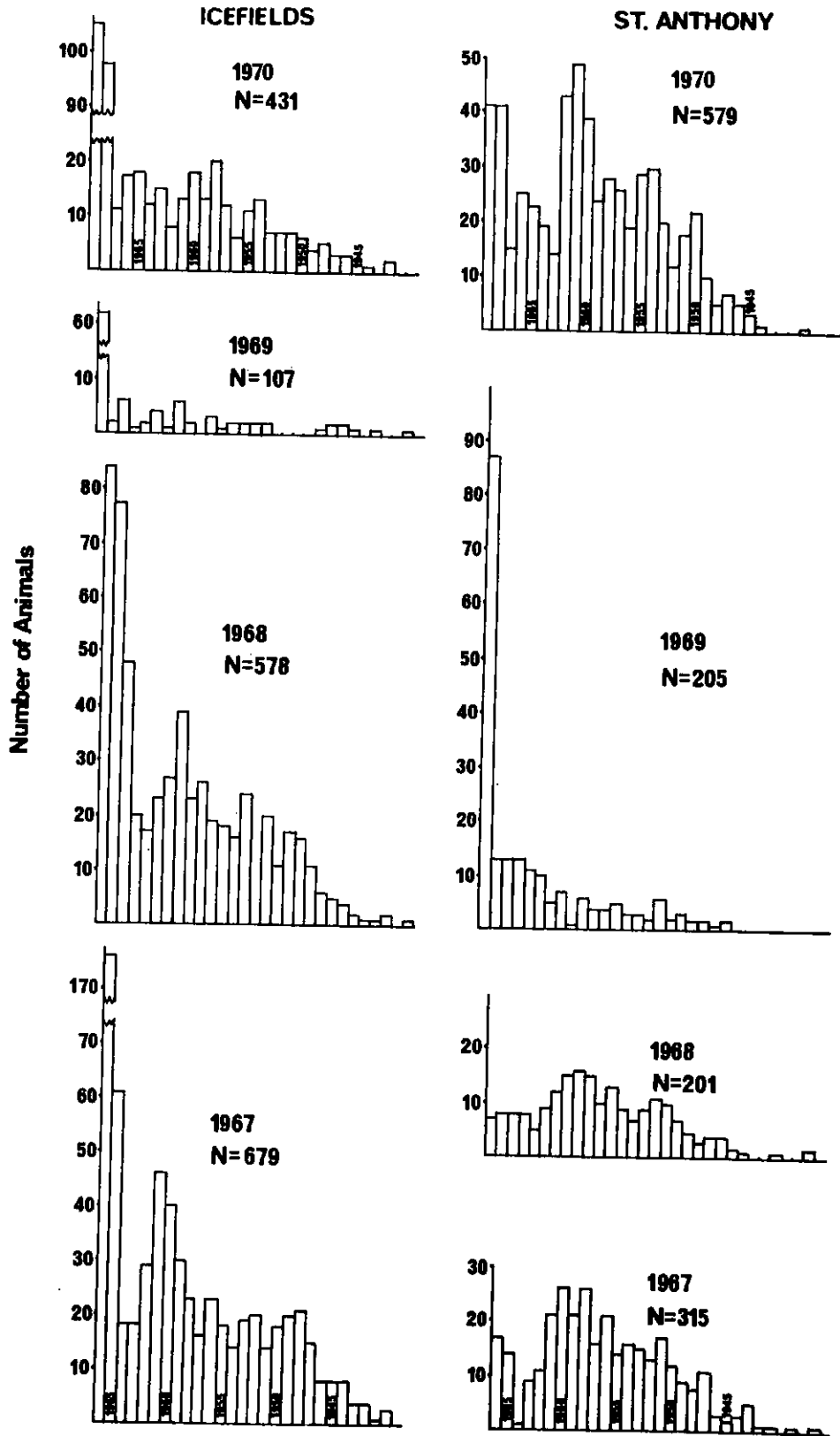
Fig. 2. Age samples from St. Anthony, Newfoundland, and the
Front icefields, 1967-1970.
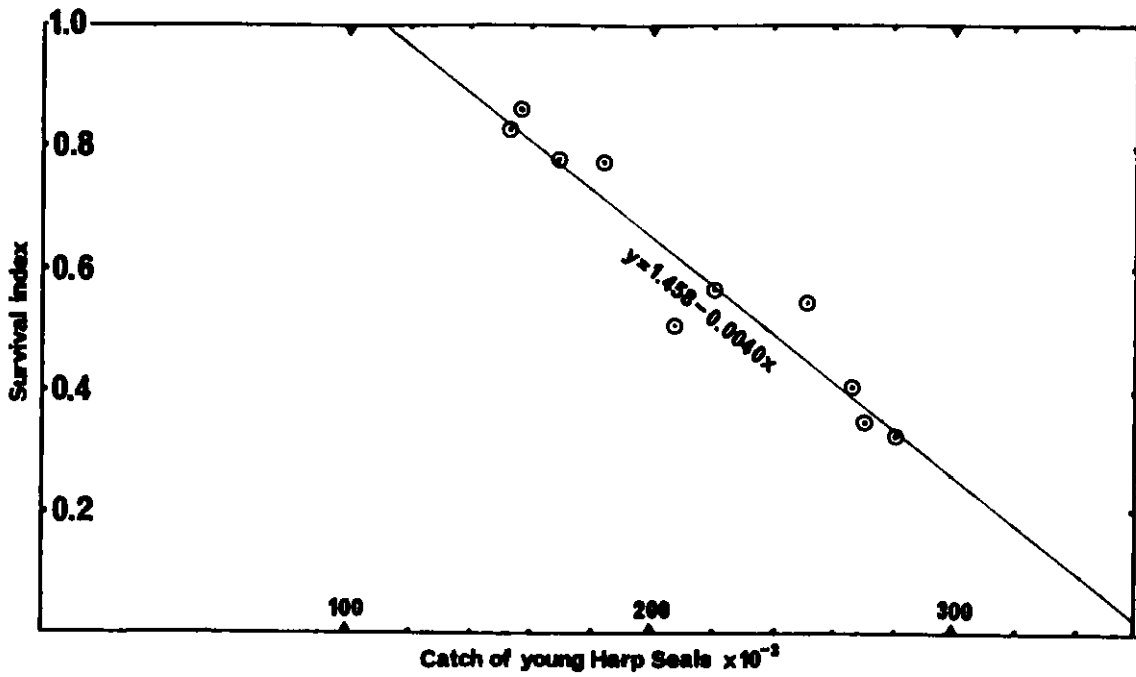
Fig. 3. Index of survival plotted against total catch for year-
classes 1960 to 1969. See text.
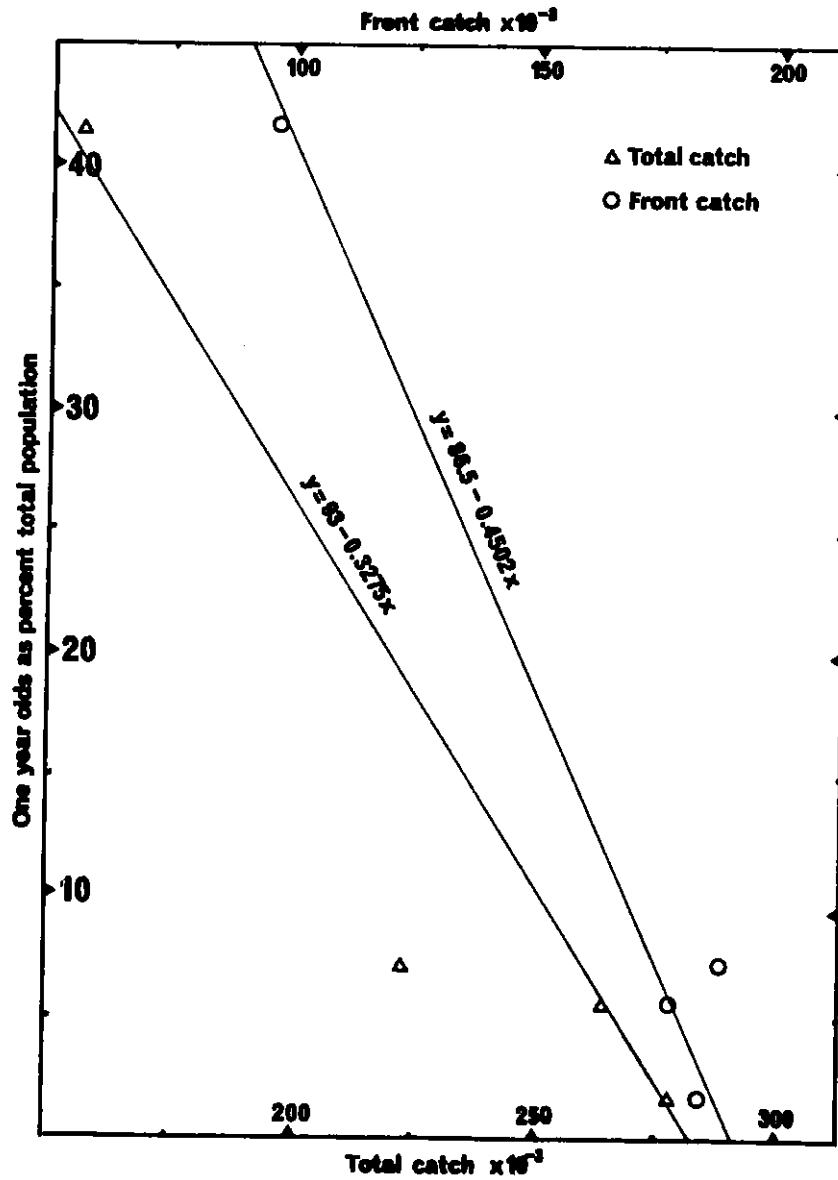
Fig. 4. Index K, the ratio of young to total seals
in four annual age samples (1967-1970) from
St. Anthony, Newfoundland, plotted against
total catch of young of the same year-class,
and catch of young at the Front, to show the
aberrant year, 1969. See text.

15. The status of Norwegian studies of harp seals at Newfoundland[1]

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Introduction

Recent Norwegian seal research at Newfoundland was started in 1964. Field work in that season was concentrated on collection of samples for blood protein studies and studies of breeding biology. In 1965 physiological studies were performed, and in 1967, 1969, 1970 and 1971 material and data were collected for general biological studies of both harp and hooded seals. No field work was done in 1966 or 1968, but a good sample for age analysis of harp seals was collected by sealers in 1968. Provisional results of these studies were reported to the ICNAF Panel A (Seals) in 1968 and 1969 (Naevdal, MS 1968; Øritsland, MS 1969a and b).

Some effort has also been made to revise and analyze Norwegian sealing statistics. Provisional analyses were reported to the ICNAF Seal Panel in 1966 and 1967 (Øritsland, MS 1966 and MS 1967b).

The purpose of this report is to summarize results at hand from Norwegian studies of harp seals at Newfoundland from 1964 to 1971.

Distribution of seals

Observed and reported ice edges and patches of seals have been plotted in 1965, 1967, 1969, 1970 and 1971 as shown in Figs. 1-5. In these years one, two or more separate harp seal breeding lairs have formed in the area from Hamilton Inlet southwards to Roundhill Island before the middle of March. During lactation these lairs drift south with the pack-ice, and may end up in the Strait of Belle Isle or Notre Dame Bay before the last moulted pups have taken to sea or been killed in late March or early April. Patches of juvenile seals, bedlamers, form in the area from Funk Island to Gray Islands off Notre Dame Bay or further north in late March. As bedlamers gradually mix with adult males in moulting patches in early April, the animals move north, and may be found off Hamilton Inlet or further north in late April.

Populations

Results from blood protein studies (Naevdal, MS 1968 and 1969) failed to reveal any significant difference between the breeding herds of harp seals in the North Atlantic.

A total of 127 harp seal pups have been tagged on the Front off Newfoundland-Labrador in 1969, 1970 and 1971. Out of these a total of 14 were recaptured in the hunting area before the seasons ended. Two animals have been recaptured off West Greenland in the autumn of the year they were tagged: one near Jakobshavn in August 1969 and one near Ritenbank in October 1970. Finally, two animals were recaptured on the Front during the hunting season 1971, one year after they were tagged. So far Norwegian taggings have not yielded definite

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[1] Revised version of paper submitted to 1971 Annual Meeting of ICNAF as ICNAF Res.Doc. 71/8.

information on the distinctness of harp seal populations, but none of the 441
harp seal pups which have been tagged near Jan Mayen through the years, has
been recaptured west of Cape Farvel.

Some 450 harp seal skulls which have been collected at Newfoundland (147),
in the Jan Mayen area (about 100) and in the Barents Sea, are deposited in the
Zoological Museum in Trondheim. No results are yet available from this collec-
tion.

Age composition of catches

Age-group frequencies in samples collected in 1964, 1967 and 1968 are
given in Table 1. Unfortunately, the small 1964 sample contains 33 specimens
of breeding females, and therefore it is not representative for moulting
animals. However, the other two samples are not "contaminated" in this way.
Data from samples of moulting animals collected in 1969 and 1970 are presented
in Table 2. An additional sample of 559 moulting harps collected in 1971
has not been processed yet.

Table 1. Age-group frequencies of moulting harp seals in Front area,
Newfoundland, from samples collected in 1964, 1967 and 1968.

Age-group	1964 No.	1964 %	1967 No.	1967 %	1968 No.	1968 %
1	3	2.4	55	19.6	135	19.2
2	6	4.7	31	11.0	74	10.5
3	8	6.3	5	1.8	42	6.0
4	11	8.7	6	2.1	27	3.8
5	7	5.5	19	6.8	30	4.3
6	12	9.4	22	7.8	20	2.8
7	6	4.7	19	6.8	46	6.6
8	5	3.9	13	4.6	38	5.4
9	5	3.9	5	1.8	31	4.4
10	8	6.3	8	2.8	28	4.0
11	4	3.1	13	4.6	22	3.1
12	4	3.1	6	2.1	12	1.7
13	3	2.4	5	1.8	15	2.1
14	3	2.4	10	3.6	18	2.6
15	5	3.9	10	3.6	14	1.9
16	4	3.1	6	2.1	12	1.7
17	5	3.9	8	2.8	15	2.1
18	8	6.3	9	3.2	26	3.7
19	4	3.1	9	3.2	21	3.0
20	0	0.0	4	1.4	16	2.3
21	4	3.1	4	1.4	10	1.4
22	2	1.6	1	0.4	17	2.4
23	2	1.6	3	1.1	8	1.1
24	3	2.4	2	0.7	7	1.0
25	1	0.8	2	0.7	3	0.4
26	0	0.0	1	0.4	5	0.7
27+	4	3.1	5	1.8	10	1.4
Sum	127	99.7	281	100.0	702	99.6
Undet.					35	(4.7% of total)

Table 2.   Age-group frequencies of moulting harp seals in Front
area, Newfoundland, from samples collected in 1969
and 1970.

Age-group	1969		1970	
	No.	%	No.	%
1	371	40.6	132	25.6
2	42	4.6	109	21.1
3	34	3.7	33	6.4
4	30	3.3	30	5.8
5	39	4.3	29	5.6
6	28	3.1	15	2.9
7	36	3.9	18	3.5
8	44	4.8	26	5.0
9	35	3.8	15	2.9
10	29	3.2	22	4.3
11	23	2.5	13	2.5
12	16	1.8	7	1.4
13	19	2.1	6	1.2
14	21	2.3	11	2.1
15	21	2.3	8	1.6
16	12	1.3	11	2.1
17	25	2.7	3	0.6
18	16	1.8	6	1.2
19	19	2.1	6	1.2
20	16	1.8	4	0.8
21	10	1.1	5	1.0
22	5	0.5	2	0.4
23	7	0.8	2	0.4
24	3	0.3	0	0.0
25	4	0.4	1	0.2
26	4	0.4	0	0.0
27+	6	0.7	2	0.4
Sum	915	100.2	516	100.2
Undet.	106	(10.4 of total)	26	(4.8 of total)

It is still an open question, however, whether the age-composition of
catches of moulting harp seals does represent the age-composition in the stock.
Impressions from field work in all hunting areas of the North Atlantic and
the information on distribution given in Figs. 1-5 suggest that adult males
gather in patches near the lairs of breeding females shortly after the forma-
tion of the breeding lairs. Somewhat later the juvenile seals of both sexes
congregate, and after the pairing season the patches of juveniles and the
adult males gradually mix to form moulting patches (in early April on the
Front). Adult females join these moulters in increasing numbers during April.

Information from counts of pelts in 1967, 1969, 1970 and 1971 on the
change in age- and sex-composition through April in patches of moulting harps
is available, and a summary of all counts is presented in Table 3 and in
Fig. 6B. Independent data from sampling for age analysis during April in 1967,
1969 and 1970 are presented in Table 4 and Fig. 6A. The data available up to

Table 3. Moulting harp seals in Front area, Newfoundland. Catch composition from counts of pelts by age-group (bedlamers and saddlers), sex and date in 1967, 1969, 1970 and 1971.

Date in April	Sample size	Juveniles				Adults			
		♂		♀		♂		♀	
		No.	%	No.	%	No.	%	No.	%
1967									
12 - 14	237	30	12.7	25	10.5	163	68.8	19	8.0
23	119	8	6.7	9	7.5	74	62.2	28	23.5
Subtotal	356	38	10.7	34	9.6	237	66.6	47	13.2
1969									
02 - 05	391	97	24.8	87	22.3	205	52.4	2	0.5
12 - 13	343	110	32.1	104	30.3	125	36.4	4	1.2
16 - 20	720	188	26.1	193	26.8	261	36.3	78	10.4
22	132	39	29.5	44	33.3	35	26.5	14	10.6
Subtotal	1,586	434	27.4	428	27.0	626	39.5	98	6.2
1970									
19	76	32	42.1	29	38.2	13	17.1	2	2.6
28 - 29	280	75	26.7	80	28.6	79	28.2	46	16.4
Subtotal	356	107	30.1	109	30.6	92	25.8	48	13.5
1971									
10	258	80	31.0	68	26.4	71	27.5	39	15.1
13	395	102	25.8	91	23.0	146	37.0	56	14.2
Subtotal	653	182	27.9	159	24.3	217	33.2	95	14.5
Summary, 1967 + 1969 + 1970 + 1971									
01 - 05	391	97	24.8	87	22.3	205	52.4	2	0.5
06 - 10	258	80	31.0	68	26.4	71	27.5	39	15.1
11 - 15	975	242	24.8	220	22.6	434	44.5	79	8.1
16 - 20	796	220	27.6	222	27.9	274	34.4	80	10.1
21 - 25	251	47	18.7	53	21.1	109	43.4	42	16.7
26 - 30	280	75	26.7	80	28.6	79	28.2	46	16.4
Total	2,951	761	25.8	730	24.7	1,172	39.7	288	9.8

now suggest that the proportion of juveniles of both sexes remains fairly constant through April, whereas the proportion of adult males decreases. The important point, however, is that adult females do not join these moulting patches in appreciable numbers before the second half of April. The data suggest that adult females constitute no more than 15-20% of the catches in late April. Corresponding data from the Jan Mayen area and the Barents Sea indicate similar changes through April in these areas (Øritsland, unpublished).

Further evidence derived from subsamples for age analysis is presented in Table 5 and Fig. 7. These data indicate a decreasing trend in the mean age of males and a definite increase of the mean age of females through April. The mean age and sex ratio of an age sample collected in the moulting season therefore will depend upon the date of sampling. To be comparable, samples from different years should be collected at comparable dates. Characteristics of the present samples, partly derived from Table 4, are given below:

Table 4. Moulting harp seals in Front area, Newfoundland. Catch composition from age samples by age-group (1-6 years and 7 years +), sex and date in 1967, 1969 and 1970. Because of inadequate dating, the 1967 subsamples marked with asterisks are omitted from the summary; they are, however, included in the total.

Date in April	Sample size	Juveniles ♂ No.	%	Juveniles ♀ No.	%	Adults ♂ No.	%	Adults ♀ No.	%
1967									
02 - 09*	180	65	36.1	43	23.9	65	36.1	7	3.9
13 - 15	84	14	(16.7)	10	(11.9)	50	(59.5)	10	(11.9)
23 - 26*	17	4	-	2	-	7	-	4	-
Subtotal	281	83	29.5	55	19.6	122	43.4	21	7.5
1969									
02 - 05	309	100	32.4	96	31.1	110	35.6	3	1.0
06 - 07	208	84	40.4	46	22.1	72	34.6	6	2.9
13	114	21	(18.4)	15	(13.2)	68	(59.6)	10	(8.8)
18 - 20	257	88	34.2	74	28.8	63	24.5	32	12.5
22	27	12	-	8	-	4	-	3	-
Subtotal	915	305	33.3	239	26.1	317	34.6	54	5.9
1970									
19	48	15	-	19	-	14	-	0	-
28 - 29	260	90	34.6	61	23.5	71	27.3	38	14.6
Subtotal	308	105	34.1	80	26.0	85	27.6	38	12.3
Summary, 1967 + 1969 + 1970									
01 - 05	309	100	32.4	96	31.1	110	35.6	3	1.0
06 - 10	208	84	40.4	46	22.1	72	34.6	6	2.9
11 - 15	198	35	17.7	25	12.6	118	59.6	20	10.1
16 - 20	305	103	33.8	93	30.5	77	25.2	32	10.5
21 - 25	27	12	-	8	-	4	-	3	-
26 - 30	260	90	34.6	61	23.5	71	27.3	38	14.6
Total	1,504	493	32.8	374	24.9	524	34.8	113	7.5

Year	No.	Percentage by date in April 1-10	11-20	21-30	Mean age	% ♂
1964	127	15.7	7.9	37.0	11.0	22.0
1967	281	64.1	29.9	6.0	8.5	72.9
1968	702	(5)	(90)	(5)	8.7	-
1969	915	56.5	40.5	3.0	6.7	67.9
1970	516	0.0	9.3	50.4	5.6	61.7

It is evident that no sample is strictly comparable to any of the others. It is assumed, however, that the 1967 and 1969 samples which both have a load in early April, can be compared. Tentatively, it may also be assumed that the 1968 sample, definitely loaded in mid-April, can be compared to the sample of 1970 which is loaded in late April. If this is accepted, it follows that the indicated decreasing trend of the mean age may be real.

Table 5. Moulting harp seals in Front area, Newfoundland. Mean age from age samples, by sex and date.

Date in April	♂		♀	
	No.	Mean age	No.	Mean age
1967				
02 - 09	130	8.4	50	3.1
13 - 15	64	(12.3)	20	(8.2)
22 - 26	11	-	6	-
Subtotal	205	9.8	76	5.1
1969				
02 - 05	210	8.0	99	1.7
06 - 07	156	8.2	52	3.1
13	89	(10.4)	25	(4.8)
18 - 20	151	7.0	106	5.1
22	16	-	11	-
Subtotal	622	8.0	293	3.6
1970				
19	29	-	19	-
28 - 29	161	7.0	99	6.1
Subtotal	190	6.9	118	5.4

Sex ratio

Counts of pups and juvenile seals were performed in 1967, 1969, 1970 and 1971. These data are shown in Table 6. A possible change with date in the sex ratio of pups is suggested by subsamples. The total ratios for pups and juveniles are very close to each other, both showing that males are slightly more numerous than females (51.0%).

Table 6. Sex ratio of harp seals in Front area, Newfoundland, 1967, 1969, 1970 and 1971.

Dates	Males		Females		Sum
	No.	%	No.	%	
Pups					
11 - 23 March 1967	241	48.2	258	51.7	499
25 March-10 April 1969	234	51.2	223	48.8	457
26 March-17 April 1970	534	51.3	507	48.7	1,041
23 March-06 April 1971	105	55.9	83	44.1	188
Subtotal	1,114	51.0	1,071	49.0	2,185
Juveniles					
12 - 23 April 1967	38	52.8	34	47.2	72
02 - 22 April 1969	434	50.3	428	49.7	862
19 - 29 April 1970	107	49.5	109	50.5	216
10 - 13 April 1971	182	53.4	159	46.6	341
Subtotal	761	51.0	730	49.0	1,491
Total	1,875	51.0	1,801	49.0	3,676

Sexual maturity of females

Data on age at first ovulation from known-age breeding and moulting female harp seals were collected in 1964 and 1967. An additional sample of 173 breeding females was collected in 1971, but these specimens have not been processed yet. The data from analyses of ovaries collected in 1964 and 1967 are shown in Tables 7 and 8. This information indicates that female harp seals mature in age-groups from 4 to 12 or 13 years. The age of 50 percent maturity was found to be about 6.5 for breeding and about 5.5 for moulting females. However, the small sample from moulting seals is hardly representative of the maturing age-groups (see discussion of age composition above) and can only give supporting evidence on age at maturity, whereas samples collected in the breeding lairs apparently are representative of the mature females. When age at first ovulation can be established as suggested in Table 7, samples of breeding females therefore may yield direct evidence on age at maturity in the stock. The actual age distribution of breeding females supports the data from ovary analyses (Fig. 8). The time-lag between maturity and breeding (Parturition) reflects the one-year sexual cycle and the somewhat lower fertility of newly-matured females.

Table 7. Harp seals in Front area, Newfoundland. Sexual maturity of breeding females collected 12-20 March 1964 and 11-23 March 1967.

Age at last ovulation	No.	Age at 'first' ovulation										
		4	5	6	7	8	9	10	11	12	13	14
4	0	-	-	-	-	-	-	-	-	-	-	-
5	2	1	1	-	-	-	-	-	-	-	-	-
6	11	2	3	6	-	-	-	-	-	-	-	-
7	7	1	1	4	1	-	-	-	-	-	-	-
8	8	-	-	4	3	1	-	-	-	-	-	-
9	2	-	-	-	1	0	1	-	-	-	-	-
10	6	-	-	1	1	3	1	0	-	-	-	-
11	3	-	-	-	-	-	2	1	0	-	-	-
12	8	-	-	-	2	3	0	2	1	0	-	-
13	9	-	-	-	-	-	1	2	4	2	0	-
14	7	-	-	-	-	-	1	1	2	0	2	1
	63											
Sum	(48)	3	5	14	5	4	4	3	5	2	2	1
%		6.3	10.4	29.2	10.4	8.3	8.3	6.3	10.4	4.2	4.2	2.1
Acc. %		6.3	16.7	45.9	56.3	64.4	72.9	79.2	89.6	93.8	98.0	100.1

Table 8. Harp seals in Front area, Newfoundland. Sexual maturity of moulting females collected 3-30 April 1964 and 14-26 April 1967.

Age	No.	Age at 'first' ovulation										
		4	5	6	7	8	9	10	11	12	13	14
4	10	0	-	-	-	-	-	-	-	-	-	-
5	5	0	1	-	-	-	-	-	-	-	-	-
6	2	1	1	0	-	-	-	-	-	-	-	-
7	5	0	3	1	1	-	-	-	-	-	-	-
8	2	-	1	0	1	0	-	-	-	-	-	-
9	2	-	1	0	0	1	0	-	-	-	-	-
10	4	-	-	3	1	0	0	0	-	-	-	-
11	3	-	-	2	0	0	1	0	0	-	-	-
12	1	-	-	-	-	-	0	0	1	0	-	-
13	1	-	-	-	0	0	0	1	0	0	0	-
14	1	-	-	-	-	-	-	1	0	0	0	0
	36											
Sum	(15)	1	6	1	3	1	1	1	1	0	0	0
%		6.7	40.0	6.7	20.0	6.7	6.7	6.7	6.7	0.0	0.0	0.0
Acc. %		6.7	46.7	53.4	73.4	80.1	86.8	93.5	100.2	100.2	100.2	100.2

Fertility

Date on the rate of births or pregnancies are not available. Therefore, data from ovaries of breeding and moulting mature seals sampled in 1964 and 1967 were analyzed in order to get some information on fertility. Presuming that mature females ovulate once every year, that ovulations alternate regularly between the two ovaries and that successful matings result in *corpora lutea* which are retained as visible *corpora albicantia* for at least three years after their formation, frequencies of *corpora* missing in the regular sequence were recorded for the three most recent breeding seasons. If these missing *corpora* indicate missed pregnancies, the counts suggest an overall fertility of about 92% among mature harp seals. An increase from about 90% in age-groups 6-12 to about 93% in older age-groups is suggested. There is also some evidence for an increase in overall fertility of about 1% from 1964 to 1967. The counts of *corpora* are shown in Table 9.

Pup catches and survival of year-classes

Tentative indexes of survival of year-classes based on relative frequencies of age-groups in samples from the Front, in relation to corresponding frequencies derived from data in a life table (Table 10) constructed by Sergeant (MS 1960) are given in Table 11. They are based on all available Norwegian age samples, and calculated by dividing relative frequencies in age samples by corresponding relative frequencies in column "Young excl." in Table 10. Weighted means have been calculated for each year-class, using factors roughly corresponding to the size of each age sample (1964:1, 1967:2, 1968:4, 1969:5 and 1970:3).

These indexes are offered as an attempt to quantify earlier rather subjective guesstimates of year-class survival for harp seals. Bearing in mind

Table 9. Fertility of sexually mature female harp seals in Front area, Newfoundland. Counts of *corpora lutea* and *albicantia*, and estimates of missing *corpora* for the three most recent breeding seasons (ovulations), presuming that ovulations alternate regularly between ovaries.

Age groups	Year of coll.	Breeding females			Moulting females			Total		
		No. count.	No. miss.	% miss.	No. count.	No. miss.	% miss.	No. count.	No. miss.	% miss.
6 - 12	1964	8	1		36	3				
	1967	68	8		12	1		124	13	9.5
13 - 18	1964	35	4		23	1				
	1967	91	4		16	2		165	11	6.3
19 up	1964	38	2		8	1				
	1967	80	7		9	0		135	10	6.9
Unknown	1964	23	3		9	2		32	5	
All	1964	104	10	8.8	76	7	8.4			
	1967	239	19	7.4	37	3	7.5	456	39	7.9

Table 10. Relative age-group frequencies of harp seals of the Northwest Atlantic derived from life table by Sergeant (MS 1960).

Age	Percent	
	Young incl.	Young excl.
0	18.6	—
1	11.4	14.0
2	9.0	11.0
3	7.4	9.1
4	6.3	7.7
5	5.4	6.6
6	4.9	6.0
7	4.4	5.4
8	4.0	4.9
9	3.6	4.4
10	3.2	3.9
11	2.9	3.6
12	2.6	3.2
13	2.3	2.8
14	2.1	2.6
15	1.9	2.3
16	1.7	2.1
17	1.5	1.8
18	1.2	1.5
19	1.0	1.3
20	0.9	1.1
21	0.8	0.9
22	0.6	0.7
23	0.5	0.6
24	0.4	0.5
25	0.4	0.5
26	0.3	0.4
27+	0.8	0.9
Sum	100.1	99.8

Table 11. Harp seal pup catches at Newfoundland and survival of corresponding year-classes expressed by relative frequency in age samples from the Front, Newfoundland, divided by relative frequency of age-groups in life table (Sergeant, MS 1960). Parentheses indicate estimated catches and size of age samples.

Year-class	Catch of pups Front 10^{-3}	Total catch of pups 10^{-3}	"Survival index" from age samples					Weighted mean
			1 1964 (127)	2 1967 (281)	4 1968 (702)	5 1969 (915)	3 1970 (516)	
1945	-	-	2.38	0.57	1.83	0.60	0.40	1.00
46	-	73	4.20	1.56	3.43	1.33	0.00	1.85
47	-	102	2.17	1.27	1.55	0.71	0.67	1.10
48	-	137	1.48	2.46	2.09	1.22	0.57	1.50
49	(169)	227	1.70	2.13	2.31	1.62	1.11	1.78
1950	(174)	226	0.92	1.56	2.47	1.62	0.73	1.61
51	(215)	319	0.86	1.00	1.17	1.20	0.92	1.09
52	(126)	198	0.97	1.57	0.81	1.50	0.80	1.15
53	(161)	198	0.86	1.38	0.83	0.62	0.33	0.74
54	(109)	175	1.62	0.64	1.00	1.00	1.00	0.99
1955	(159)	252	0.89	0.66	0.75	0.88	0.70	0.78
56	(245)	341	0.80	1.28	0.53	0.75	0.81	0.78
57	(71)	165	0.87	0.72	0.86	0.56	0.43	0.66
58	(56)	141	1.57	0.41	1.03	0.69	0.44	0.75
59	(181)	239	0.89	0.94	1.00	0.82	0.69	0.86
1960	(81)	171	1.13	1.26	1.10	0.86	1.10	1.04
61	126	179	0.69	1.30	1.22	0.98	0.66	1.00
62	(114)	214	0.43	1.03	0.47	0.72	1.02	0.74
63	(159)	278	0.17	0.27	0.65	0.52	0.65	0.52
64	(168)	273	-	0.20	0.49	0.65	0.48	0.50
1965	(90)	190	-	1.00	0.66	0.43	0.85	0.67
66	(167)	257	-	1.40	0.95	0.41	0.75	0.78
67	185	280	-	-	1.37	0.42	0.70	0.81
68	97	156	-	-	-	2.90	1.92	2.53
69	186	(238)	-	-	-	-	1.83	(1.83)

that age samples hardly are representative of the stock, it is worth attention that the "survival index" is rather consistently high or low through several or all age samples for some year-classes.

Revised sealing statistics for the ICNAF area up to 1968 have been published by ICNAF Headquarters (1970) and statistics for 1969 are available in manuscript (ICNAF, MS 1970). Provisional data on Norwegian sealing in 1970 also have been reported (Øritsland, MS 1970). The published Canadian statistics (ICNAF, 1970) are somewhat lacking in detail up to 1965, but Sergeant (MS 1967) has given some estimates of division between subareas. Canadian data for 1970 are not available. Some information on Danish (Greenland) and Soviet catches in the ICNAF area are included in the published statistics (ICNAF, 1970), but occasional French and U.S. catches have not been reported.

By and large, the available statistics seem to give a fairly good coverage for the years from 1947 to 1969, although somewhat lacking in detail before 1965.

In Table 11 the "survival indexes" are compared to total pup catches in the Front area and in the ICNAF area. No definite correlation has been discovered between survival index and estimated pup catch on the Front. Weighted index means in relation to total pup catches are plotted in Fig. 9. Plots for the years 1946-1959 show no obvious trend, but plotted values for 1960-1968 suggest that total pup catches higher than 170-180 thousand may have had an adverse effect on the survival of year-classes in these years.

Catch in relation to hunting activity

An attempt to calculate catch per unit of hunting activity for Norwegian sealing at Newfoundland is presented in Fig. 10, showing total Norwegian catches of harp seals (all age-groups) on the Front per unit of hunting activity for the years 1946-1970. The estimates are based on the formula

$$C/ \ n\frac{P}{T}$$

where C is catch in number of animals,
     n is number of ships, and
     $\frac{P}{T}$ is an average efficiency index:brake horse power per gross ton (mean values).

The data suggest that the availability of harp seals may have been reduced by some 60 percent during the years from 1955 to 1970. Catches per unit of activity are plotted against units of activity in Fig. 11.

Accumulated catch of year-classes

Estimated total catches by 1970 of some year-classes which were selected because pup catches in these years were exceptionally high, are shown in Table 12. To the actual catches of pups have been added the estimated catches represented by each year-class in each year. These estimates are based on actual catches of one-year-old or older seals, and "normal" relative age-group frequencies under the heading "Young excl." in Table 10.

Although the estimated catches of one-year-old or older animals should be recalculated from actual age-group frequencies in age samples, the accumulated catches may serve as a useful reminder. According to these estimates even the year-class produced in 1967 may have yielded more than 295 thousand seals by the end of the season 1970. For this year-class, however, the accumulated catch may be corrected, using actual age-group frequencies in Norwegian samples from 1968, 1969 and 1970:

Year	Percent in sample	Catch of one year or older	Catch of 1967 year-class
1967	–	–	280,442
1968	19.2	36,238	6,958
1969	4.6	55,472	2,552
1970	6.4	(33,403)	(2,138)
		Accumulated catch	292,090

From this it may be assumed that pup production in 1967 was at least 292 thousand.

Table 12. Total catches of selected year-classes of harp
seals in the Northwest Atlantic.

Year	Year-class			
	1951	1956	1963	1967
1951	318,626	–	–	–
52	15,266	–	–	–
53	8,240	–	–	–
54	8,134	–	–	–
1955	6,243	–	–	–
56	3,169	341,397	–	–
57	4,803	11,206	–	–
58	8,467	17,247	–	–
59	3,984	7,398	–	–
1960	5,413	9,473	–	–
61	797	1,349	–	–
62	4,105	6,841	–	–
63	2,358	3,980	278,350	–
64	2,171	3,799	10,855	–
1965	1,396	2,363	5,907	–
66	1,703	2,888	6,738	–
67	1,221	2,093	4,476	280,442
68	652	1,160	2,392	5,073
69	834	1,556	3,334	6,113
1970	650	1,300	2,700	4,550
Accumulated catch	398,232	414,050	314,752	296,178

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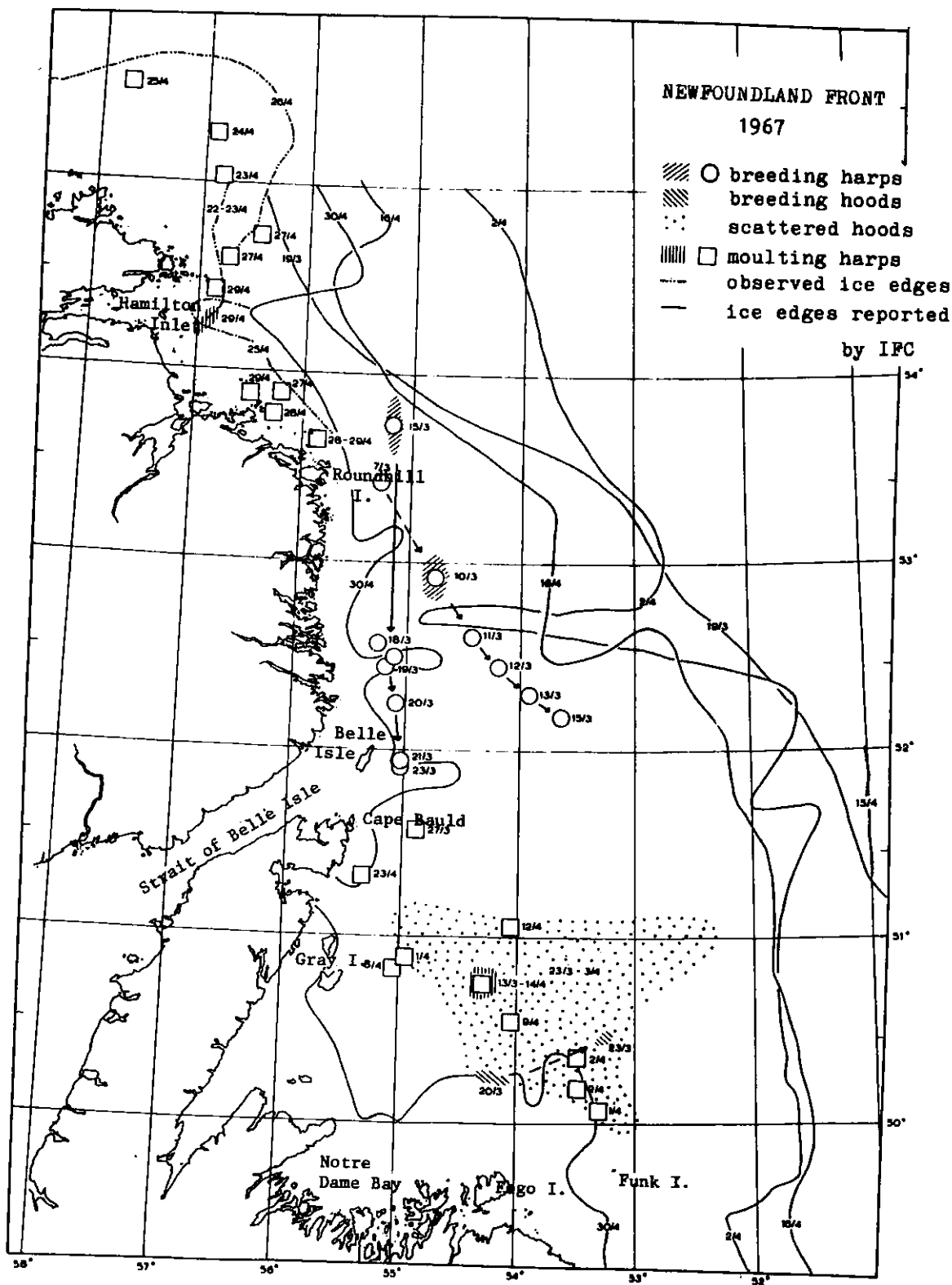
NEWFOUNDLAND FRONT

1965

Hamilton Inlet

Cape Porcupine

Gannet Islands

South Wolf I.

21/3

Cape Bluff 21/3

19-30/4

15/3

Breeding harps
scattered bedlamers
scattered young
scattered bedlamers and saddlers
breeding hoods
scattered breeding hoods
ice edge 9-13 March
"   20 March
"   24-30 March
"   2 April

Belle Isle

54°

Strait of Belle Isle

52°

Cape Bauld

2-13/4

Gray I.

51°

21/3

50°

Notre Dame Bay

Fogo I.

49°

20/3-1/4

Bonavista

57°   56°   55°   54°   53°

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

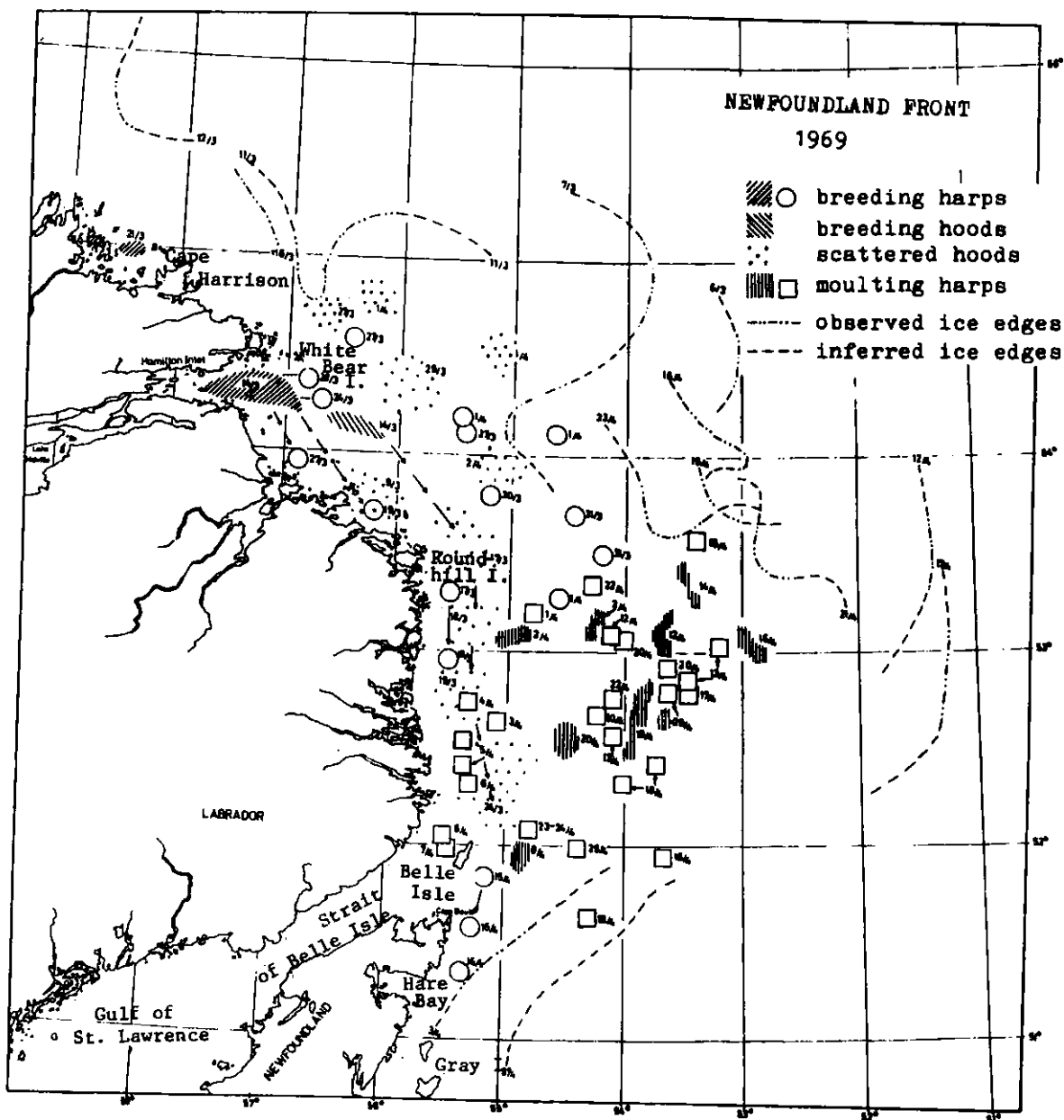**NEWFOUNDLAND FRONT**
1971

Breeding harps
Moulting harps
Observed ice edges
Inferred ice edges
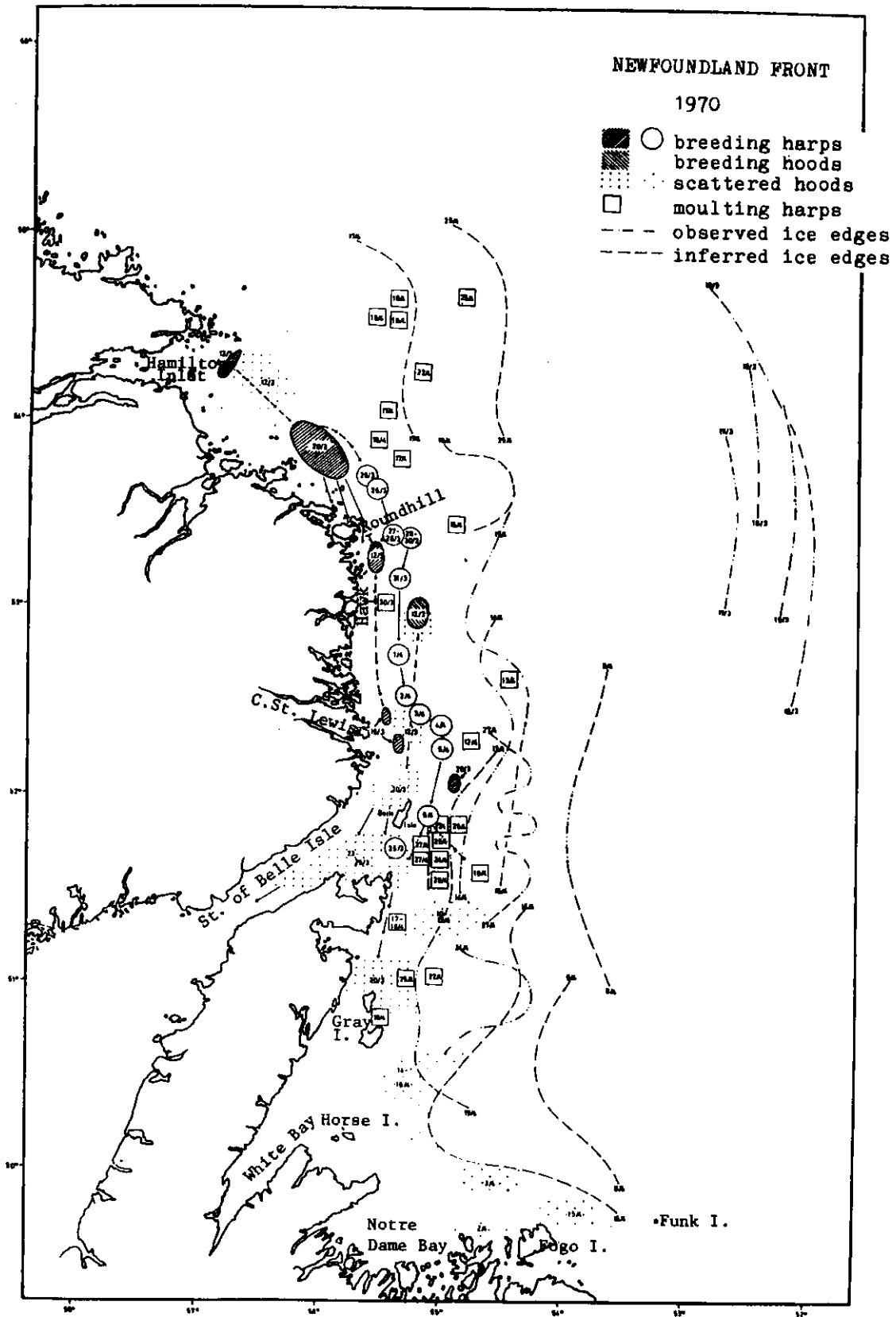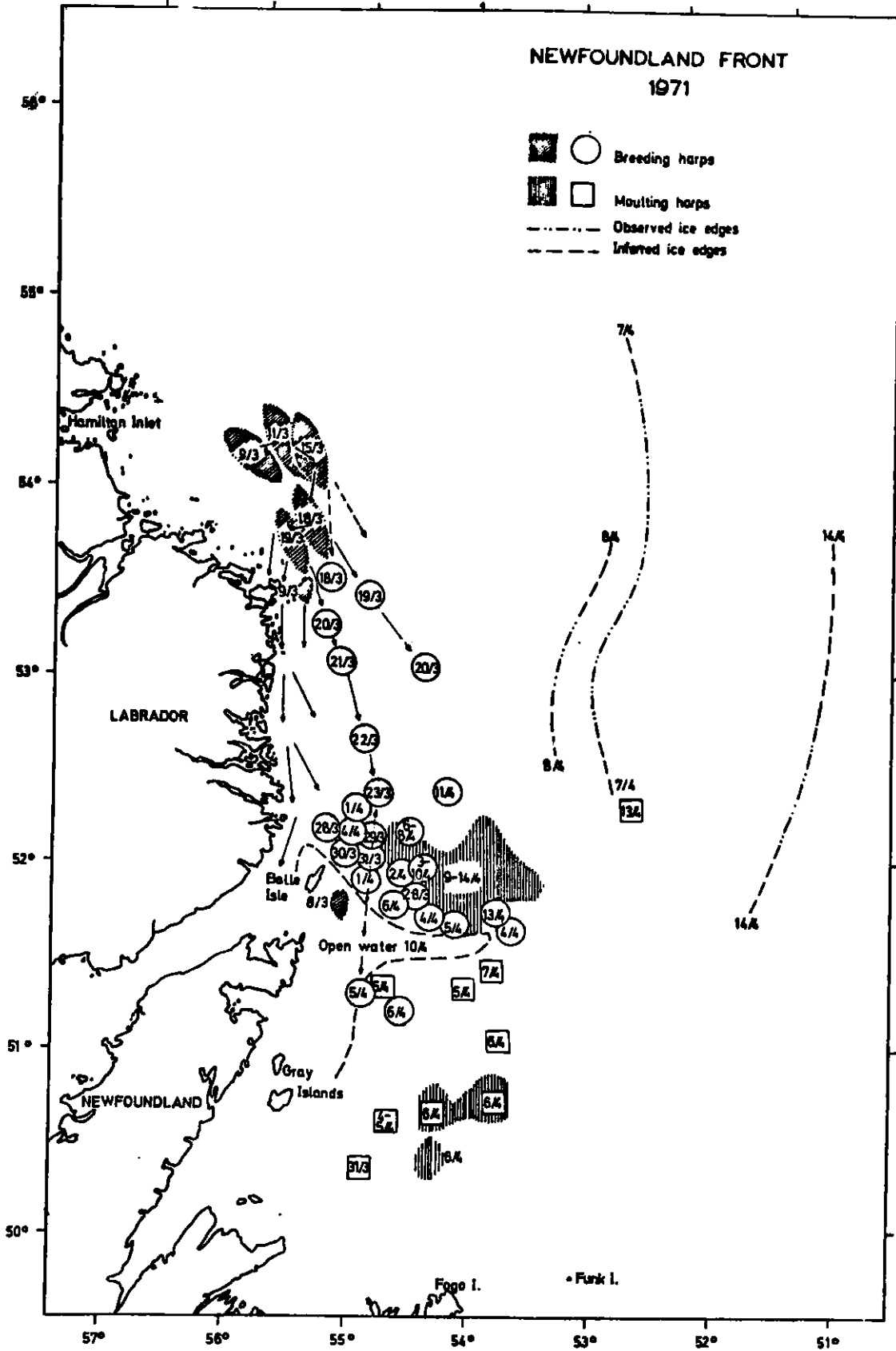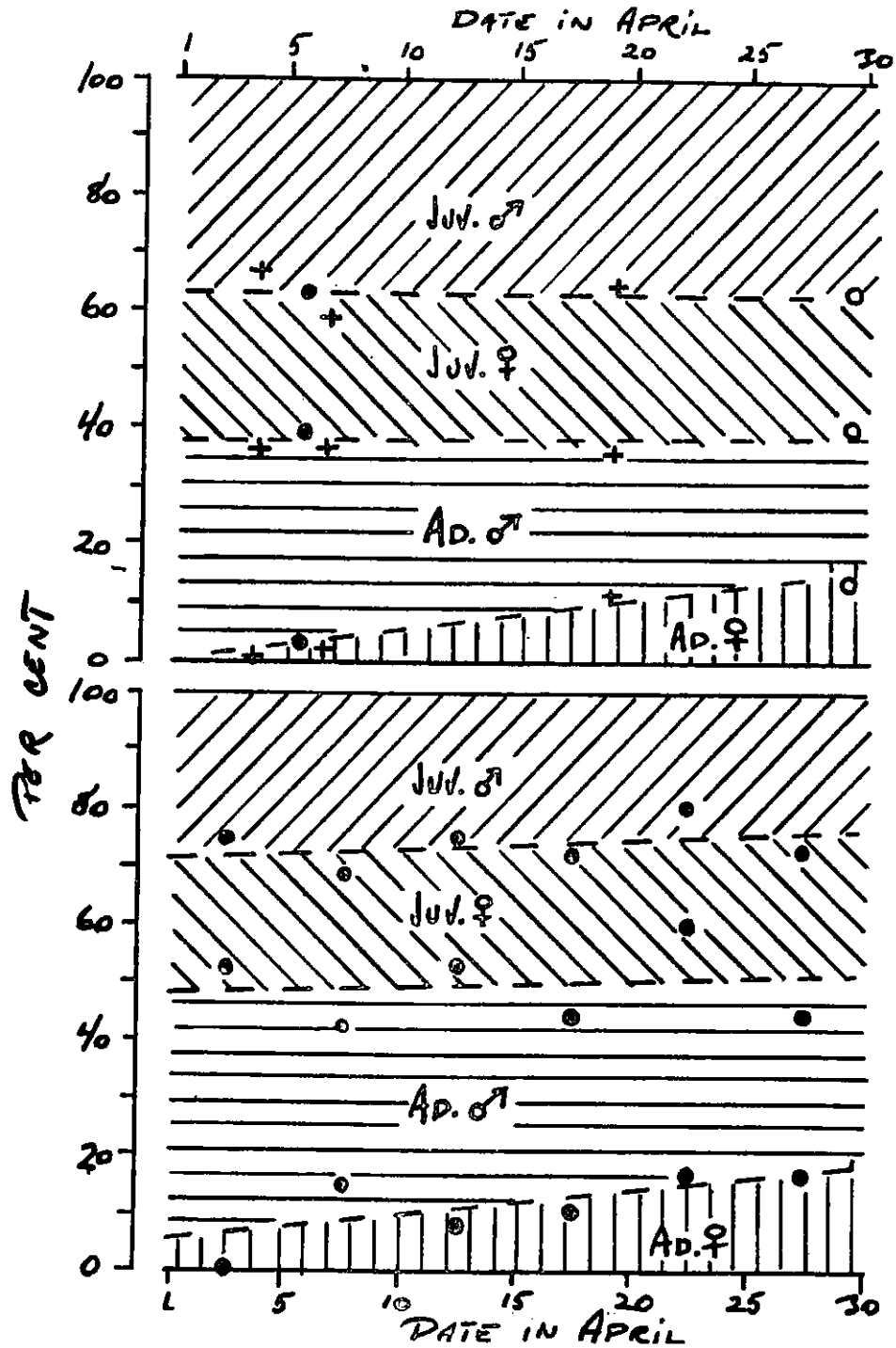
Fig. 5.

Fig. 6. Age and sex composition of catches of moulting Harp seals in
Front area, Newfoundland, through April.
A) From age samples (Tab. 4), ● 1967, + 1969, o 1970.
B) From counts of pelts (Tab. 3).
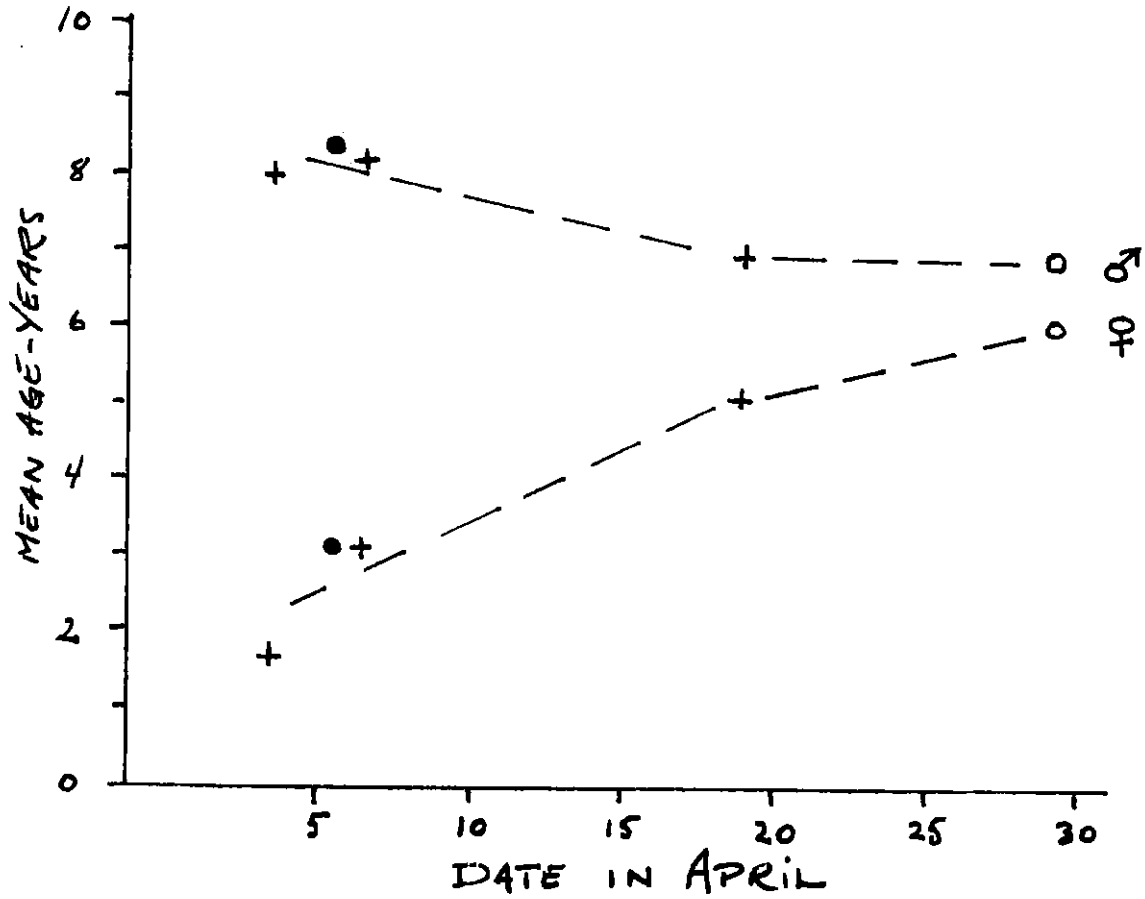
Fig. 7. Mean age of males and females in catches of moulting Harp seals
in Front area, Newfoundland, through April (Tab. 5).
● 1967, + 1969, o 1970.
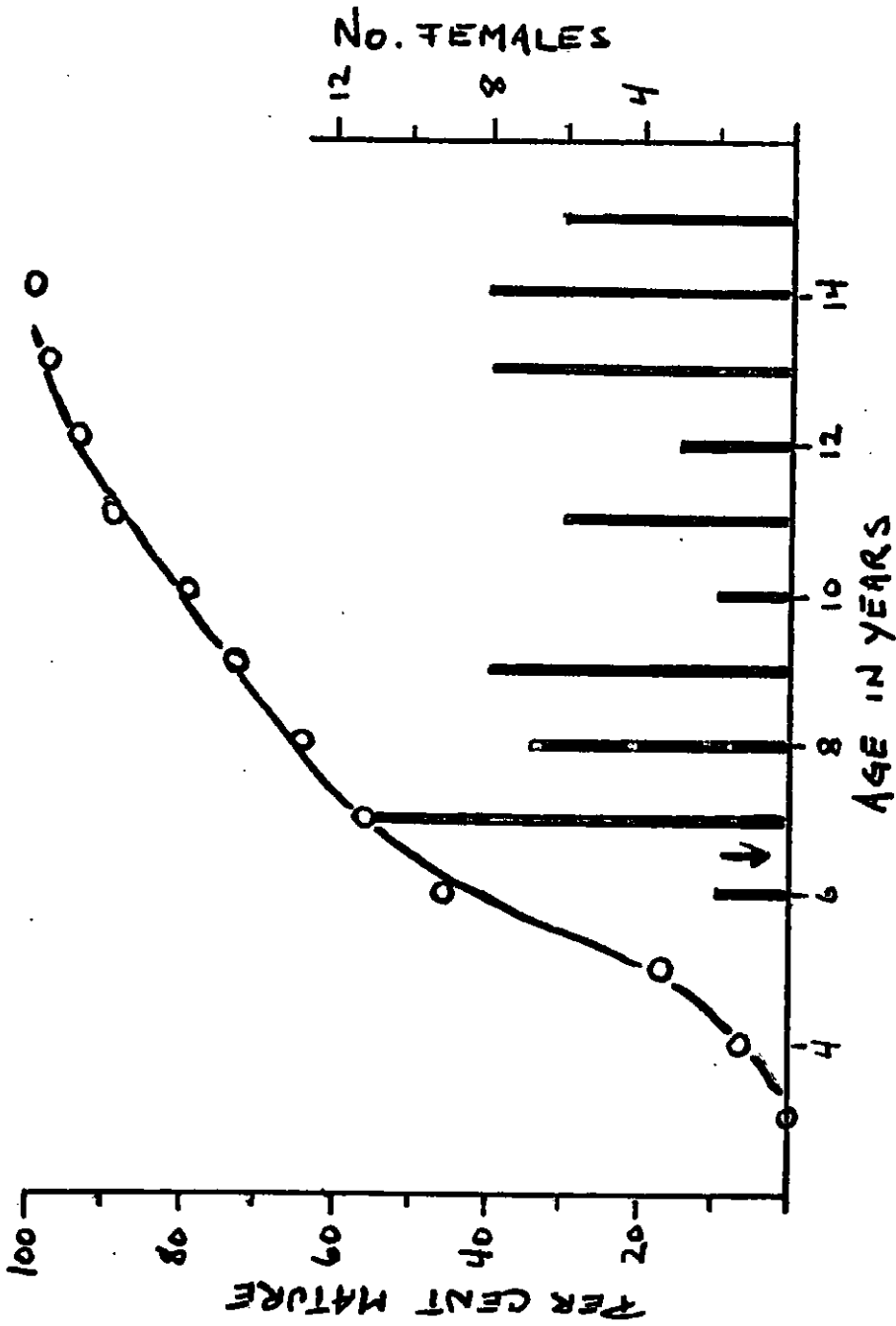
Fig. 8. Sexual maturity of female harp seals, Newfoundland Front, from data on breeding females 1964 and 1967 (Table 7), and age frequencies of breeding females in 1964 and 1967.
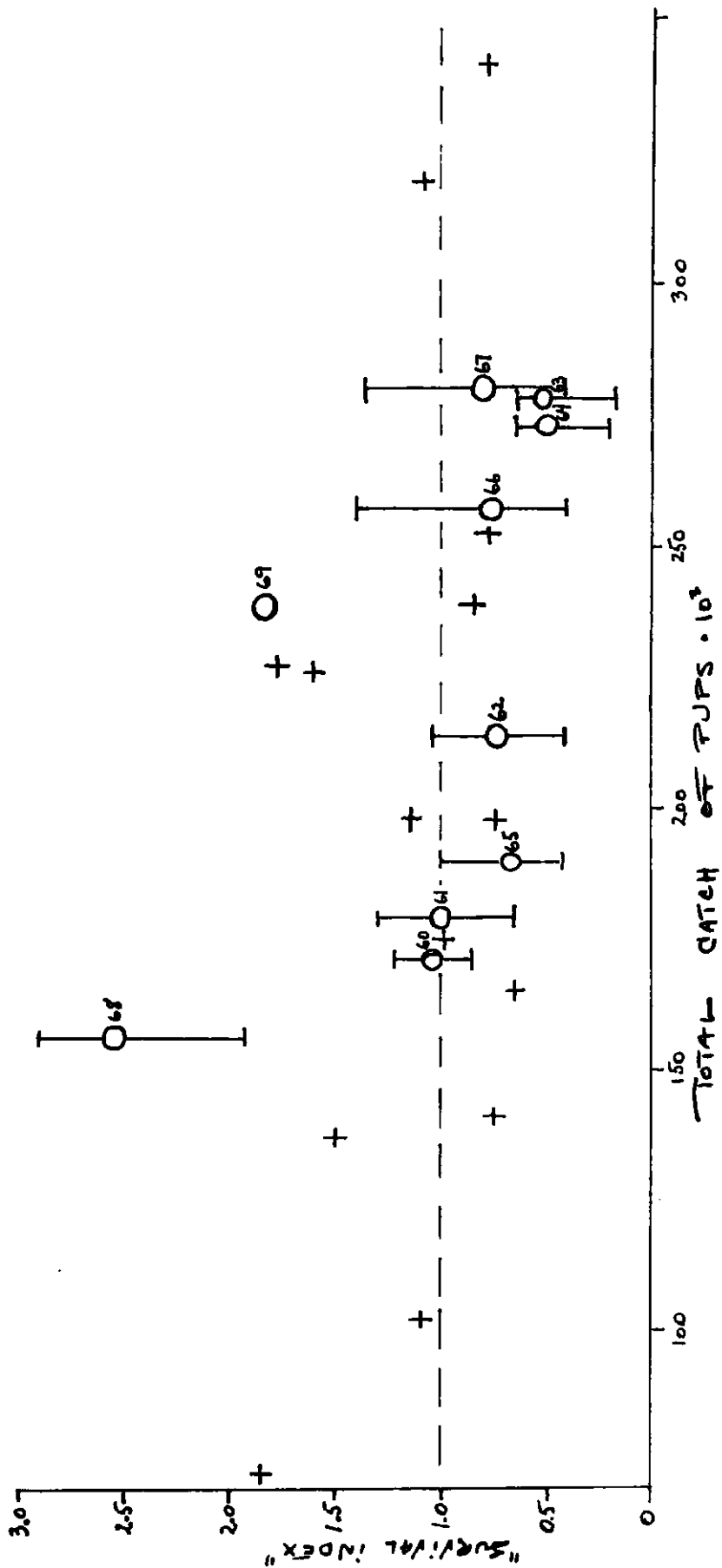
Fig. 9. Total catch of harp seal pups at Newfoundland and survival of corresponding year-classes as indicated by "survival index" (Table 10).
+ : weighted mean for year-classes 1946-1959.
O : weighted mean for year-classes 1960-1969 (with range).
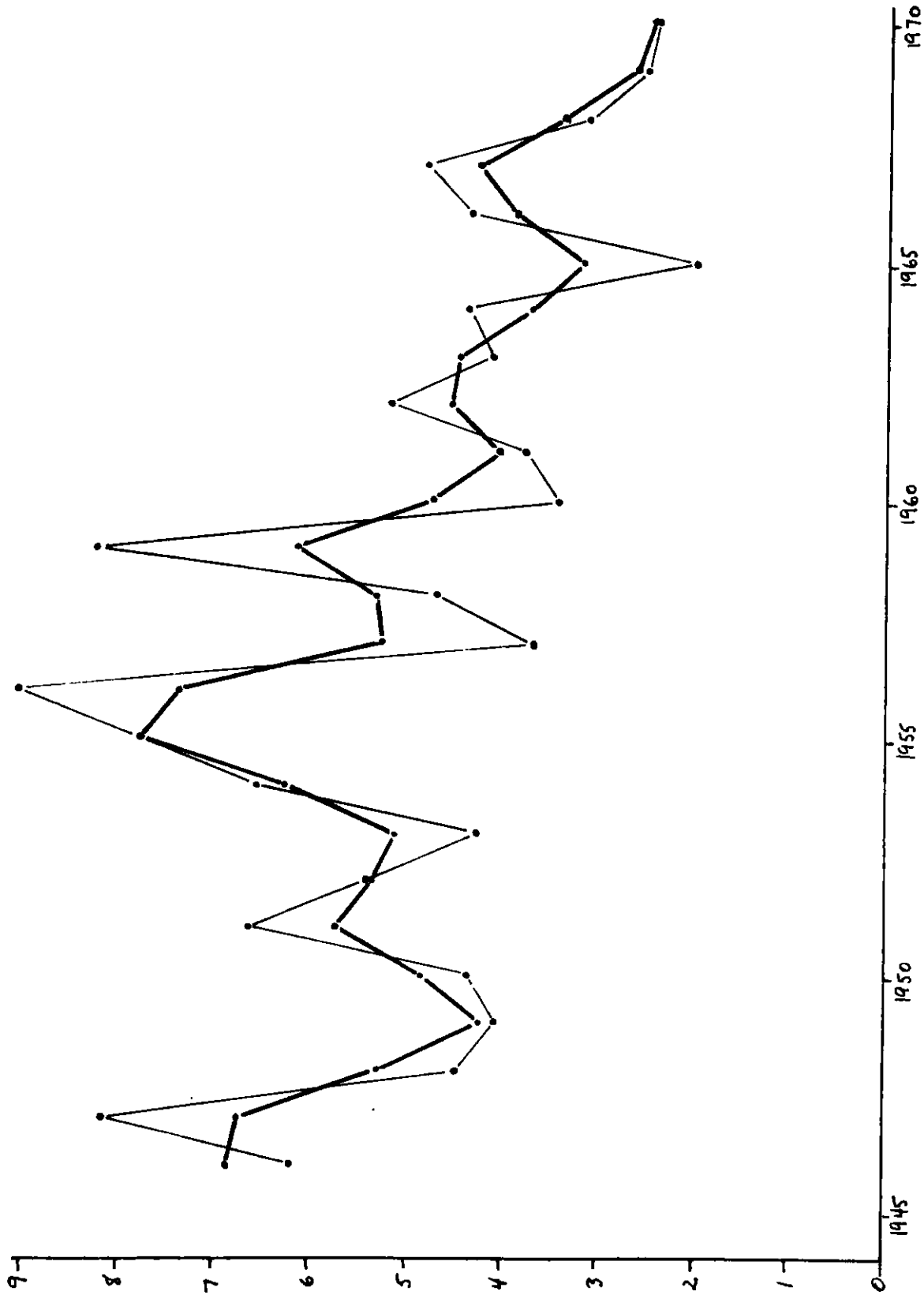
Fig. 10. Harp seals in Front area, Newfoundland. Total Norwegian catches per unit of hunting activity
(C / n $\frac{P}{T}$), direct plot and values smoothed by a three-year moving average.
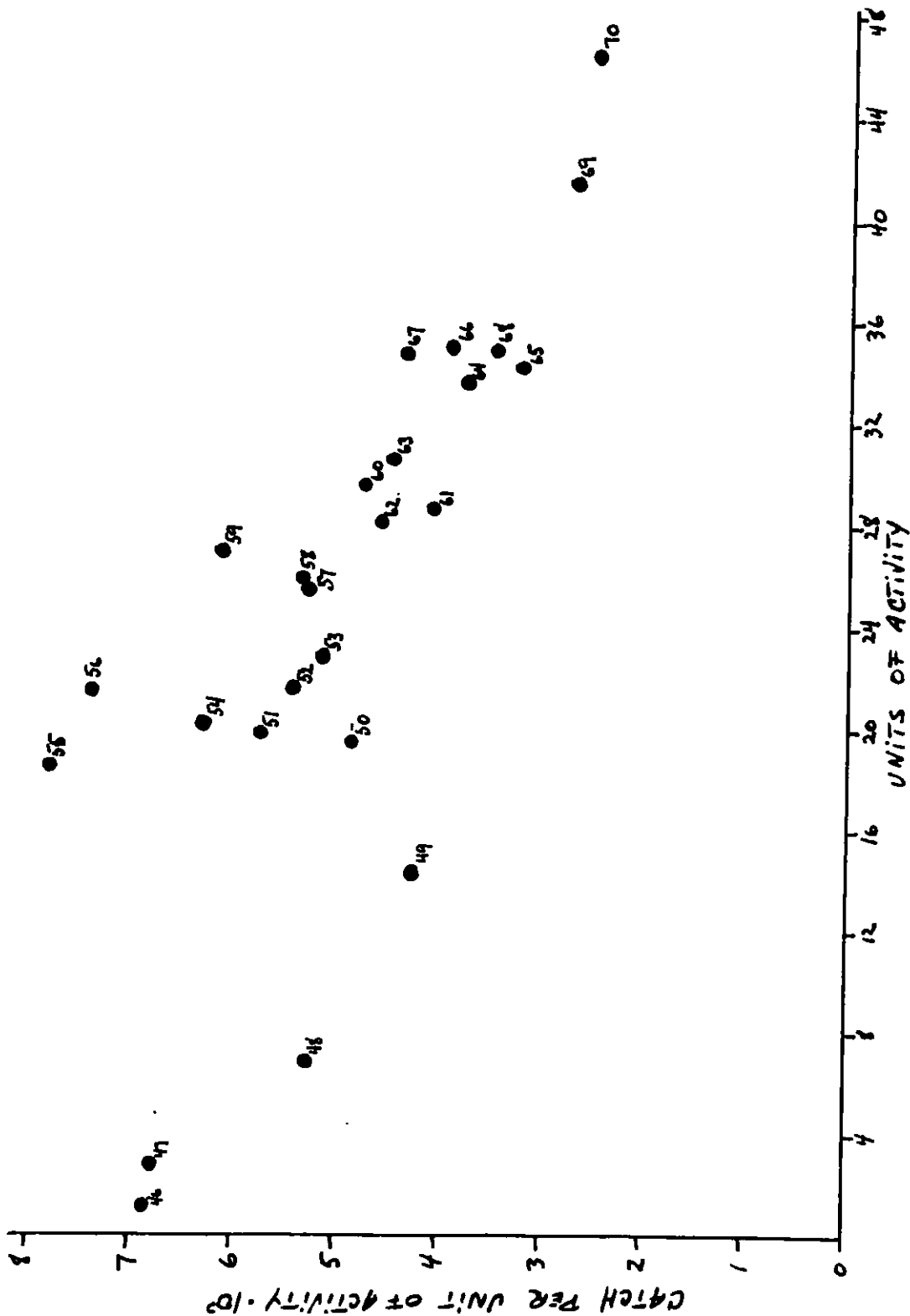
Fig. 11. Harp seals in Front area, Newfoundland. Total Norwegian catches per unit of hunting activity $(C / n \frac{P}{T})$, in relation to the hunting activity. Values smoothed by a three-year moving average.

16. <u>Distribution and abundance of yellowtail flounder populations</u>
<u>on Georges Bank and off southern New England</u>
<u>according to trawl survey data</u>[1]

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Introduction

In 1970 the absolute abundance of yellowtail flounder populations on
Georges Bank and in southern New England was calculated by Brown (1970). He
described the abundance of the 1958-1961 year-classes at the age of 2 years and
older estimated by Gulland's model (1963) and also gave its evaluation for 1968
on the basis of the catch data. This paper calculates the abundance of two
yellowtail stocks in 1967-1970 from trawl survey data.

Materials and methods

This study is based upon material obtained during the joint USSR-US trawl
surveys conducted in the autumn of 1967-1970. Charts of distribution and
relative abundance were constructed as follows: the data on a trawl survey
were plotted on plane-tables and then interpolated, using zones of species
density of 1-10 specimens, 11-25 specimens, 26-100 specimens, 101-200 specimens,
201 and more specimens per 30-minute haul and treating each separately. The
areas inhabited by the species with a certain density were determined with the
help of a planimeter.

Mean individual weights by sample sizes for the populations were calcu-
lated by the formula:

$$P = \frac{\Sigma n1 P1}{N}$$

where P = mean individual weights by sample sizes,
$n1$ = number of specimens of a certain size,
$P1$ = mean individual weight by fish sizes,
N = total number of specimens in the size frequency.

Since the populations from Georges Bank and southern New England come in
contact in nature, calculation of the absolute abundance is made along the 70°
meridian which is used as a conventional boundary between the above populations
(Fig. 1). We have used the following formula:

$$No. = \frac{1}{K} \Sigma \frac{S_i \times n_i}{S}$$

where $No.$ = the abundance of the population in numbers,
S_i = the area of a certain density,
S^1 = the tow area (0.016 square miles),
n_i = average abundance within the layer of a certain density,
k^1 = general catchability coefficient by Edwards (1968) which is 0.39.

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[1] Submitted to the 1971 Annual Meeting of ICNAF as ICNAF Res.Doc. 71/87.

Distribution of yellowtail flounder

According to Scott (1954) there are three populations of yellowtail flounder in the area off New England: (1) the population inhabiting the Cape Cod area, (2) the Georges Bank population, and (3) the population off southern New England. Later, tagging experiments and morphometric studies by Lux (1963) confirmed this suggestion. The present paper deals with only two populations: one from southern New England and the other from Georges Bank.

The distribution of yellowtail flounder on Georges Bank is given in Figs. 3, 4, and 5. These figures show that no substantial changes in habitat were observed during the period of 1968-1970. However, some change of areas of different density took place within the habitat, e.g. in 1968 concentrations of yellowtail flounder with a density of 101-200 specimens per 30-min haul were observed over an area of 0.46 thousand square miles, the area decreased to 0.08 thousand square miles before 1970. The tendency to decrease is also observed over the areas with a density of 26-100 specimens; respectively, the areas with the least density of yellowtail flounder tended to increase (Table 1).

Table 1. Areas (in thousands of square miles) occupied by various densities of yellowtail flounder in the southern New England and Georges Bank populations, 1967-1970.

| Year | Areas of fish densities | | | | | Total area |
	1-10	11-25	26-100	101-200	201-max	
Southern New England						
1967	3.70	3.05	4.24	2.53	0.08	13.60
1968	3.91	2.24	4.96	2.41	0.51	14.03
1969	5.96	3.56	2.52	1.83	1.15	15.02
1970	5.18	2.36	2.98	0.95	0.49	11.96
Average	4.96	2.80	3.65	1.93	0.56	13.63
Georges Bank						
1968	3.79	2.49	3.61	0.46	–	10.35
1969	5.53	2.93	3.19	0.16	–	11.81
1970	7.07	2.07	2.09	0.08	–	11.31
Average	5.46	2.50	2.96	0.23	–	11.15

In southern New England (Figs. 2, 3, 4, and 5) an increase of the habitat areas due to the southerly extension of yellowtail flounder was noted up to 1970, e.g. in 1967 this species occurred over an area of 13.60 thousand square miles, while in 1968 it occupied 14.03 thousand square miles, and in 1969 - 15.02 thousand square miles (Table 1). In 1970 the habitat areas decreased abruptly and constituted only 11.96 thousand square miles. It should be noted that up to 1970, the areas with frequency of occurrence of 201 specimens and more increased substantially. In 1967 they occupied 0.08 thousand square miles, in 1968 - 0.51 thousand square miles, in 1969 - 1.15 thousand square miles, while in 1970 these areas decreased somewhat and were only 0.49 thousand square miles (0.6%, 4.3%, 7.6% and 4.0% of the total habitat area, respectively).

Size composition

The results of mass measurements of yellowtail flounder are given in Figs. 6 and 7. These figures show that the areas under study undergo some changes in size composition of the catches. A decrease in mean length is observed on Georges Bank. The population is characterized by an increase of the young size-groups and a decrease of the older ones. The reverse is recorded in southern New England where the mean length of yellowtail flounder increases: the proportion of the young size-groups decreases and that of the older ones increases from year to year. The percentage recruitment of 12-28-cm specimens decreases in both populations. This can be explained by a lower abundance of 1967, 1968 and 1969 year-classes as pointed out earlier by Brown (1970). The decrease in mean size of yellowtail flounder from Georges Bank results in a decrease in mean weight. Mean weight of yellowtail flounder in southern New England increases (Table 2).

Table 2. Mean weights (g) of yellowtail flounder populations in southern New England and Georges Bank, by sample sizes based on the trawl surveys, 1967-70.

Year	Southern New England	Georges Bank
1967	190	–
1968	211	304
1969	224	287
1970	253	291

Studies of the absolute abundance of the populations

The absolute abundance of the two populations was evaluated on the basis of the frequency of occurrence and the general catchability coefficient. In 1968-1970 the average absolute abundance on Georges Bank was 54.5×10^6 specimens, but the abundance decreases from year to year (Table 3). In 1968 it was 66.8×10^6 specimens, but before 1970 it decreased to 40.2×10^6 specimens. In the period 1967-1970 the average absolute abundance in southern New England was 140.8×10^6 specimens. Highest abundance was observed in 1968 (167.6×10^6 specimens). That year also had the highest catches per unit of effort (Graham, 1969). Later, the abundance began to decrease and by 1970, was 100.0×10^6 specimens (Table 3). After estimating mean individual weights of yellowtail flounder by sample sizes, and its absolute abundance, we calculated the biomass of the two populations (Table 4). Biomass in autumn 1968 was 55.7 thousand tons, in 1969 - 52.1 thousand tons, and in 1970 - 37.0 thousand tons. Thus, in 1971 the biomass of these two populations will be lower than in the previous years.

Conclusion

The following conclusion can be drawn from these investigations.

The habitat of the Georges Bank yellowtail flounder population showed no changes during the period of investigation, but showed some tendency toward a decrease in areas in which the maximum fish density was observed within the habitat.

Table 3. Absolute abundance (in pieces x 10⁶) of the southern
New England and Georges Bank populations by densities.

Year	Numbers of fish with densities					Total area
	1-10	11-25	26-100	101-200	201-max	
Southern New England						
1967	3.7	10.1	47.8	69.8	4.4	135.8
1968	3.9	7.4	57.3	66.3	32.7	167.6
1969	6.0	11.7	29.0	50.5	62.9	160.1
1970	5.2	7.8	34.4	26.1	26.5	100.0
Average	4.7	9.2	42.1	53.2	31.6	140.8
Georges Bank						
1968	3.8	8.2	42.1	12.7	–	66.8
1969	5.6	9.7	36.8	4.3	–	56.4
1970	7.1	6.9	24.1	2.1	–	40.2
Average	5.5	8.3	34.3	6.4	–	54.5

Table 4. Biomass (in thousand tons) of the southern New
England and Georges Bank yellowtail flounder
populations, 1967-70.

Year	Southern New England	Georges Bank
1967	25.8	–
1968	35.4	20.3
1969	35.9	16.2
1970	25.3	11.7
Average	30.6	16.1

The boundaries of the southern New England population expanded to 1970,
the habitat areas increased (by 1.5 thousand square miles) from 13.51 thousand
square miles in 1967 to 15.01 thousand square miles in 1969; in 1970 the area
decreased sharply to 11.95 thousand square miles.

Mean length of yellowtail flounder from Georges Bank decreased and in
southern New England tended to increase.

The absolute abundance of the Georges Bank population in 1968 was 66.8 x 10^6 specimens, in 1969 – 56.3 x 10^6 specimens, and in 1970 – 40.2 x 10^6 specimens. It decreased in 1970 by 26.6 x 10^6 specimens (40%), as compared with 1968. Average biomass was about 16.1 thousand tons.

In southern New England the maximum abundance was recorded in 1968 – 167.6 x 10^6 specimens, the minimum abundance in 1970 (100.0 x 10^6 specimens).

The average biomass during the period in studies was 30.6 thousand tons.

Discussion

Our results differ slightly from the abundance data given by Brown (1970) who estimated abundance at 105,297 x 10^3 specimens based on catch data, and the yield at 32.6 thousand tons with an F = 0.8, or 31.2 thousand tons with an F = 1.15. Richter and Vinogradov (1969) determined the absolute abundance of the Georges Bank population at 11.148 thousand tons from 1968 trawl survey data.

The data on the absolute abundance and biomass of the populations from Georges Bank and southern New England obtained by using the general catch-ability coefficient of 0.39 proposed by Edwards, reflecting the state of the populations and the tendency of the abundance and biomass to decrease, are doubtful as absolute; the biomass is practically equal to the catches. The general catchability coefficient is, evidently, somewhat overestimated and, hence, the values of the absolute abundance and biomass should be considered as relative.

Summary

1. The abundance of the Georges Bank population is considerably lower than that of the population in southern New England.

2. In recent years, these two populations have tended to decrease in abundance.

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Fig. 1. Areas occupied by the three populations of yellowtail flounder off New England.
(1) Cape Cod population
(2) Georges Bank population
(3) Southern New England population

Fig. 2. Distribution and abundance of the Georges Bank and southern New England yellowtail flounder populations in 1967.

Fig. 4. Distribution and abundance of the Georges Bank and southern New England yellowtail flounder populations in 1969.

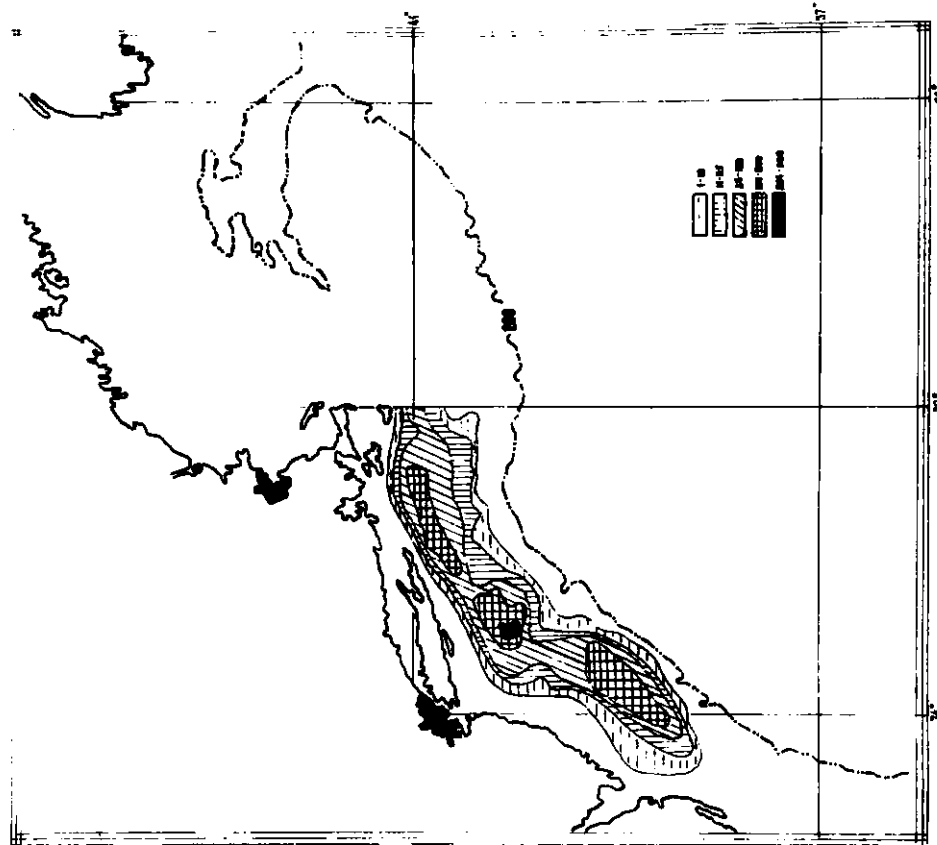Fig. 3. Distribution and abundance of the Georges Bank and southern New England yellowtail flounder populations in 1968.

Fig. 5. Distribution and abundance of the Georges Bank and southern
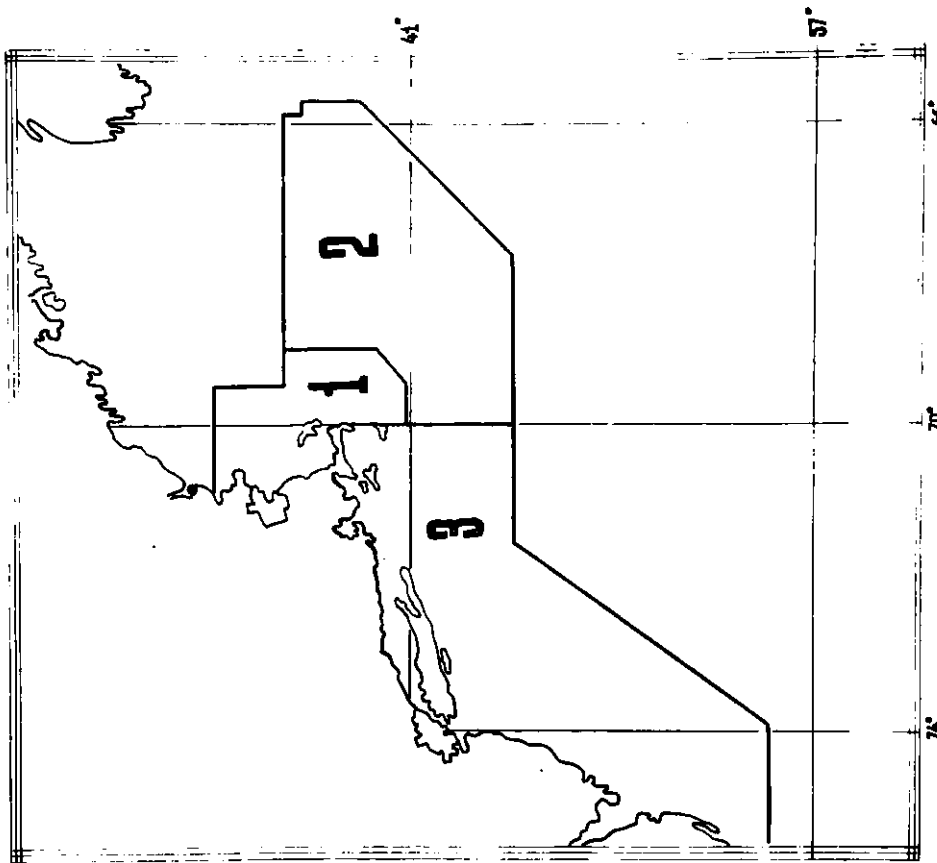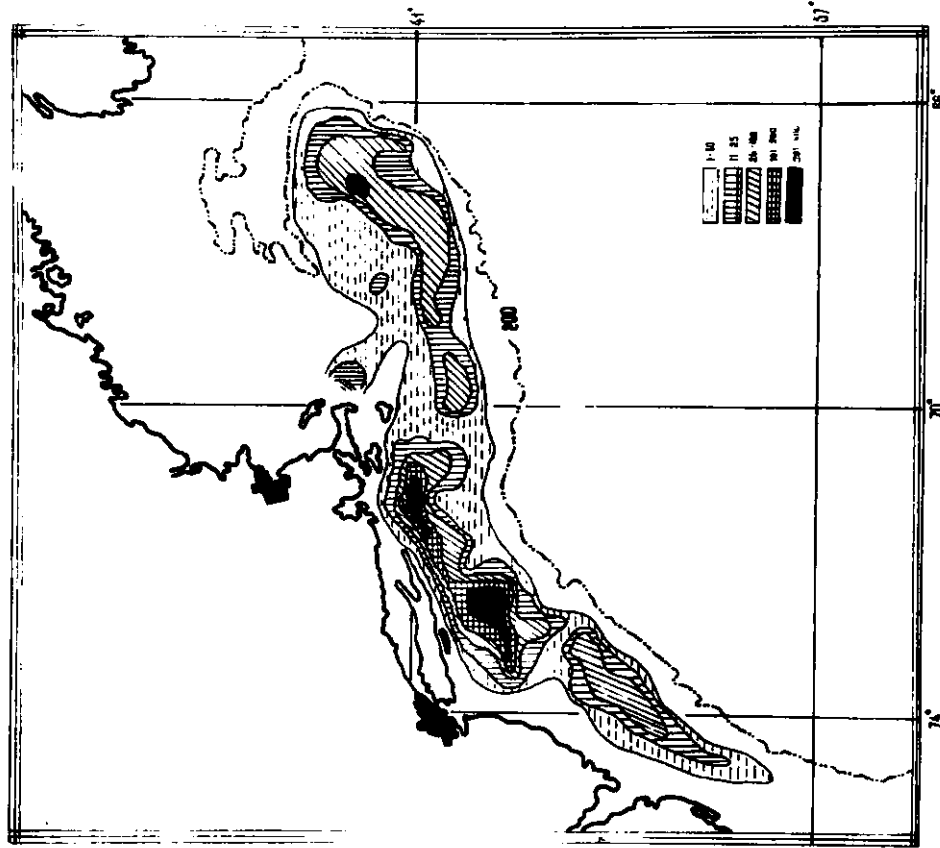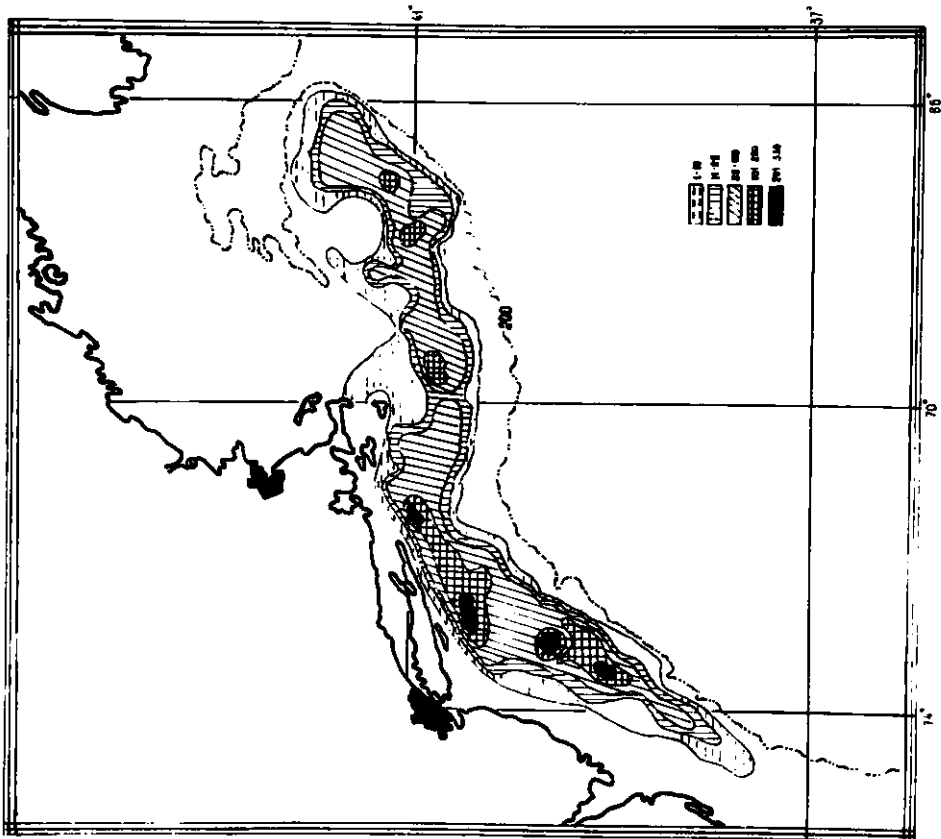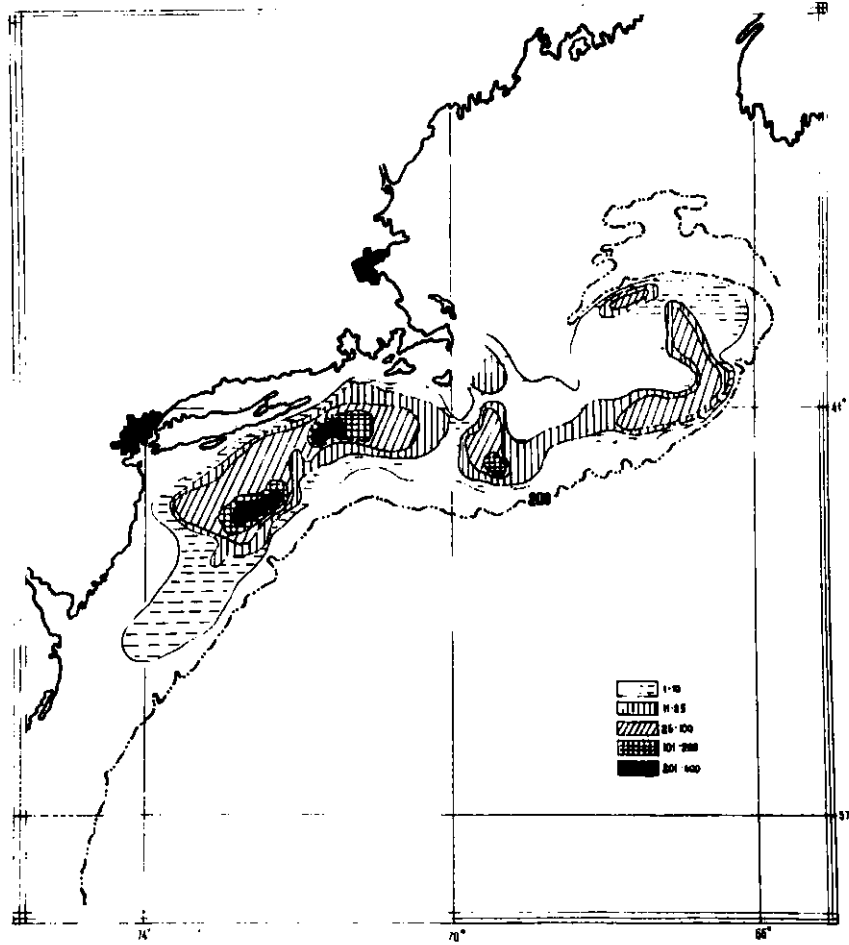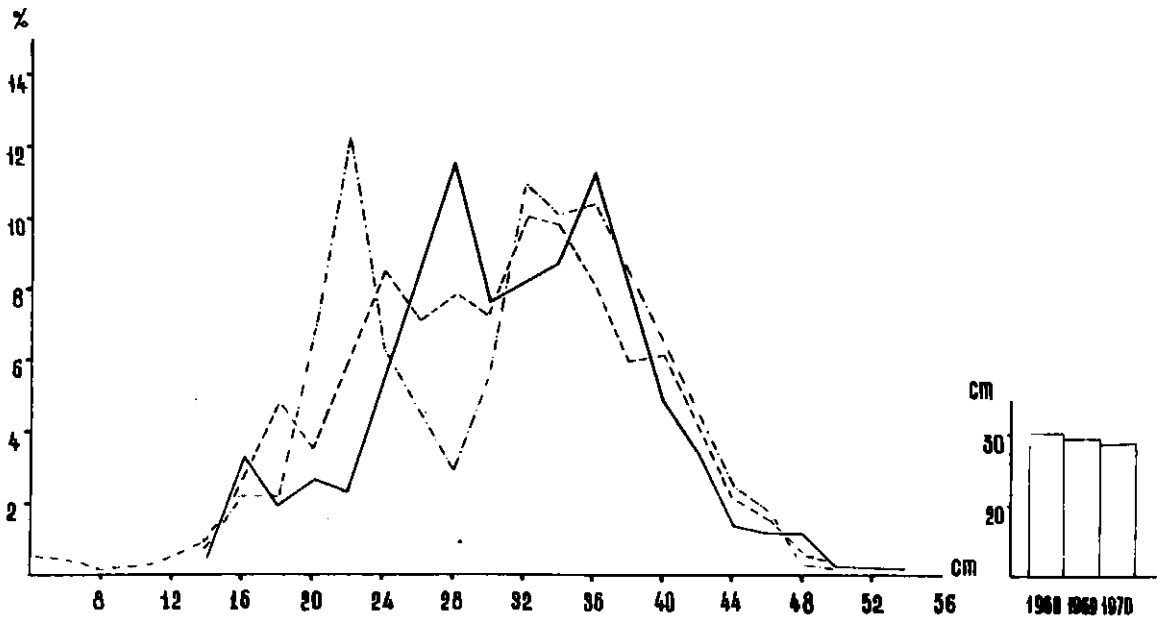New England yellowtail flounder populations in 1970.

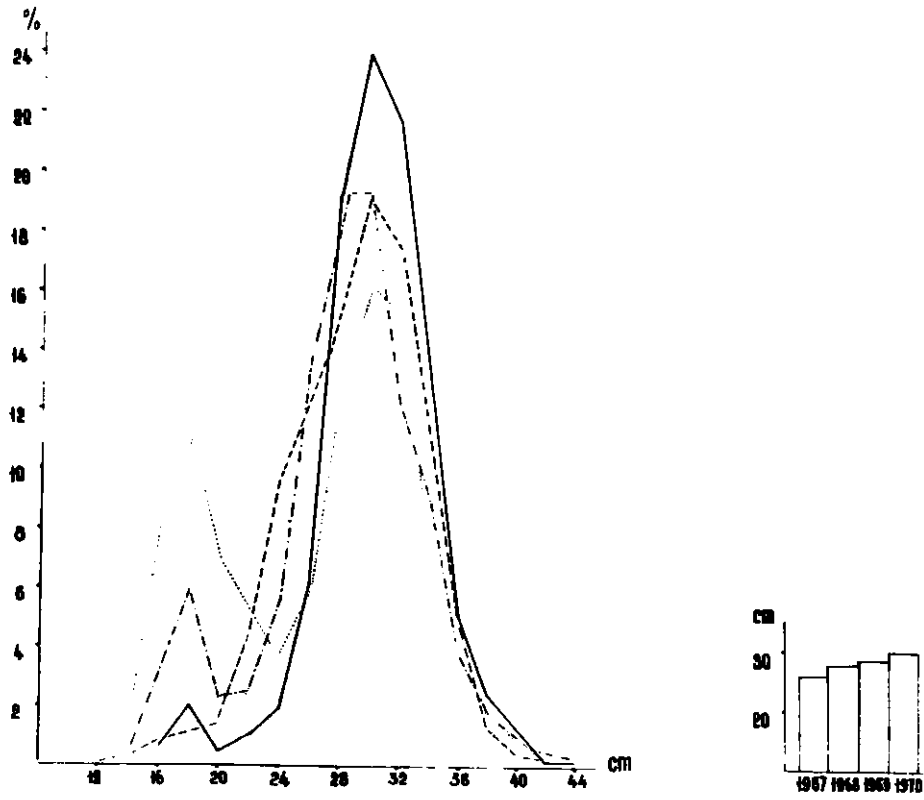Fig. 6. Length frequency of Georges Bank yellowtail flounder for 1968-70.

Fig. 7. Length frequency of southern New England yellowtail flounder for 1967-70.

17. Prediction of yellowtail flounder population size from pre-recruit catches[1]

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Introduction

Research vessel survey cruises (Grosslein, 1969) conducted each autumn since 1963 provide an estimate of relative abundance of pre-recruit yellowtail flounder. These values may be used to predict population size in following years assuming certain rates of mortality. The relationship between this prediction and actual catch can be utilized to establish a catch quota one year in advance that would provide for the desired fishing rate. This procedure has been used to estimate a 1972 quota for yellowtail flounder in the southern New England area - west of 69° and south of 41°15' within Subarea 5.

Methods

It was possible to identify the fish of age-group I with reasonable accuracy in the length frequencies of the autumn (October-November) *Albatross IV* survey cruises. These are the youngest fish which are consistently caught in sufficient quantity to provide an estimate of abundance with reasonable precision. The stratified mean numbers of yellowtail flounder in age-group I caught per tow in the autumn survey cruises was estimated for the southern New England strata (Fig. 1). These estimates (Table 1) were taken to represent the relative abundance of age-group II at the beginning of the year following that in which the cruise was made.

Table 1. Number of age I yellowtail flounder caught per tow in autumn survey cruises in the southern New England strata (see Fig. 1).

Year of cruise	1963	1964	1965	1966	1967	1968	1969	1970
Number per tow	16.3	18.5	11.7	34.4	19.9	9.0	7.0	8.3

At present yellowtail flounder first enter the US commercial fishery in significant numbers at age II. Fish are almost completely recruited by age III. Most of the commercial catch is represented by age-groups II through V (Brown and Hennemuth, 1971).

Let $n_{i,j}$ = relative abundance of age-group j in year i,

where $j = 0,3$; $i = 1,2, \ldots$

For our data, $n_{1,0}$ represents the relative abundance of age-group II at the

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[1] Submitted to the 1971 Annual Meeting of ICNAF as ICNAF Res.Doc. 71/115.

beginning of 1964, the initial observation. The $n_{i,o}$ are observed, and the $n_{i,j}$, $j = 1,3$ are calculated.

The relative abundance of the available total population at the beginning of any year is

$$N_i = n_{i,0} + e^{-Z_1}(n_{i-1,0} + n_{i-2,0}e^{-Z_2} + n_{i-3,0}e^{-2Z_2}). \tag{1}$$

Z_1 = total mortality during the first year in the fishery (age-group II).

Z_2 = total mortality during the second, third or fourth years in the fishery (age-groups III-V).

The numbers caught,

$$C(N)_i = n_{i,0}(1-e^{-Z})E_1 + (1-e^{-Z_2})E_2e^{-Z_1}(n_{i-1,0} + n_{i-2,0}e^{-Z_2} + n_{i-3,0}e^{-2Z_2}). \tag{2}$$

$E = F/Z$, the percent of total mortality due to fishing.

The same indices in terms of weight, W_j, and $C(W)_j$, may be obtained by multiplying the $n_{i,j}$ in (1) by the mean weight per fish, adding the instantaneous growth rate, G, in the exponential of the catch equation (2), *viz.* e^{-Z+G}, and expressing E as $\frac{F}{Z-G}$. The mean weight per fish at age was calculated from the growth equation estimated by Lux and Nichy (1969) and the length weight equation estimated by Lux (1969).

Results

The survey population index, N_i, and the survey catch index, $C(N)_i$, are tabulated in Table 2 and plotted in Fig. 2 (top line). The average fishing rate, $\Sigma C(N)_i / \Sigma N_i$, was 40 percent.

Table 2. Estimated population and catch indices for two fishing intensities, and the observed catch in numbers of fish.

Year	Survey Population[1] Index N	Survey Catch[1] Index C(N)	Observed Catch Nos. x 10^{-6}
1967	45.8	14.6	77
1968	43.9	18.6	78
1969	28.0	13.0	87
1970	17.9	7.9	57
1971	15.2	5.8	—

[1] $Z_1 = 0.5$; $Z_2 = 1.2$; $M = 0.2$

The mortality rates given in Table 2 were derived from an analysis of the

US commercial fishery statistics for the years 1960-1968 (Brown and Hennemuth, 1971). This study also indicated that a reduction in fishing mortality (F) of at least 20% would be required to maximize sustainable yield. A 20% reduction in F corresponds to an average fishing rate, as defined above, of 35% (bottom line in Fig. 2).

The observed commercial catch in numbers of fish plotted against the survey catch index (Fig. 3) contains too few points to verify the accuracy of precision of the relationships. In comparison to Fig. 2 it does appear that the catches during 1969 and 1970 did produce higher fishing intensities than in 1967-1968, assuming that the survey indices are valid.

To be useful in determining the quota for 1972, the relation between the catch and the population index in terms of weight and also the age II index for 1972 are required. The latter is, of course, not available until autumn 1971, and we have used instead the average of the age II index for 1969-1971, which equals 8.1.

The indication, in Fig. 3, of an increased fishing rate in 1969 and 1970 requires an upward adjustment of the fishing mortality rate. The required increases were taken to be proportional to the increased fishing intensity, and the adjusted rates are listed in Table 3, along with the estimated population indices for each age-group. The resulting survey population weight index, W_i, and the observed catches are plotted in Fig. 4.

Table 3. Weight indices of yellowtail flounder abundance by age-group.

| Year-class | Age | | | |
	2	3	4	5
1962	25.9	32.0	15.3	6.1
1963	29.4	36.3	17.3	6.8
1964	18.6	23.0	10.7	4.1
1965	54.7	67.7	32.1	7.4
1966	31.6	39.2	15.3	4.8
1967	14.3	15.9	6.1	2.7
1968	11.1	12.3	5.6	2.0
1969	13.2	16.2	7.6	2.7
1970[1]	12.9	-	-	-

[1] Average of 1967-69 year-classes

$$M = .2$$
Age 2, F = .3, 1964-68, 1971
Age 2, F = .4, 1969, 1970
Age 3, F = 1.0, 1964-68, 1971-74
Age 3, F = 1.2, 1969, 1970

The points for 1967 and 1968 determine a line of yield corresponding to a fishing rate believed to be moderately higher than that corresponding to sustained yield under the conditions of high average recruitment which occurred during the period 1960-1968. The line through the 1969 and 1970 points indicates over-fishing. The point for 1971, assuming the entire catch quota of 13,000 metric tons is taken from the southern New England stock, falls between the two lines. Even if 2,000 metric tons of the quota is taken from the Cape
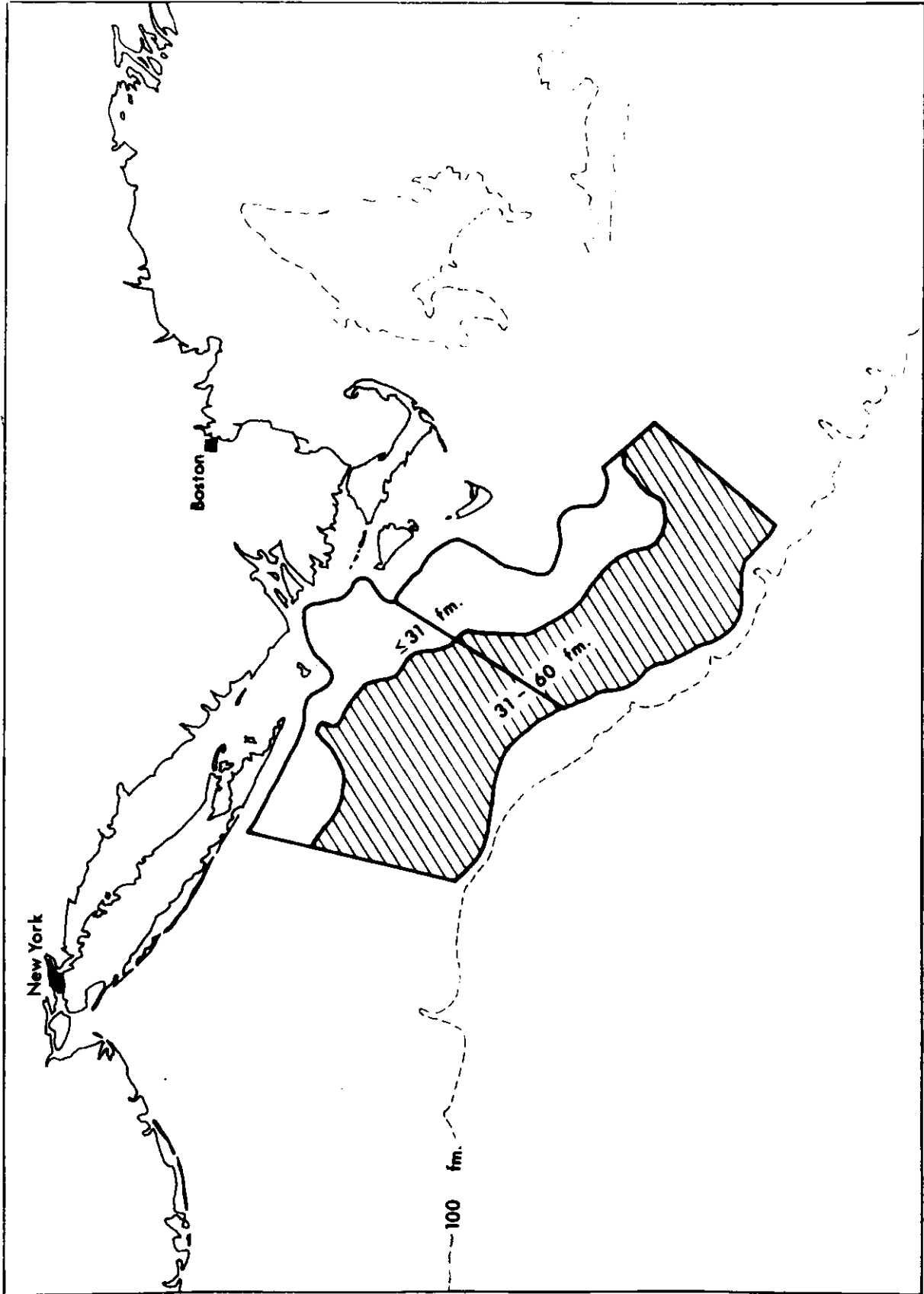
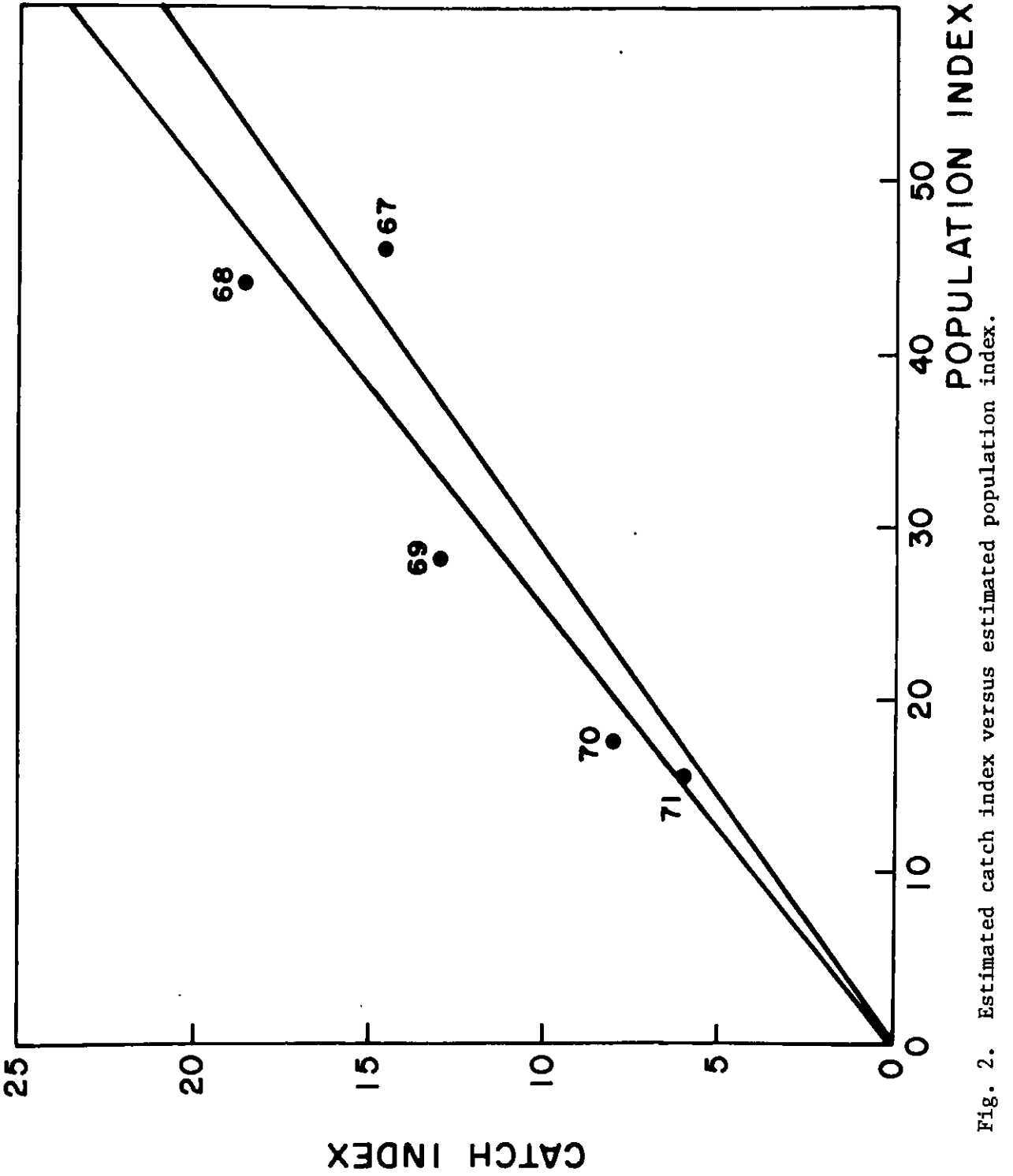Fig. 1. Southern New England survey strata.

Fig. 2. Estimated catch index versus estimated population index.
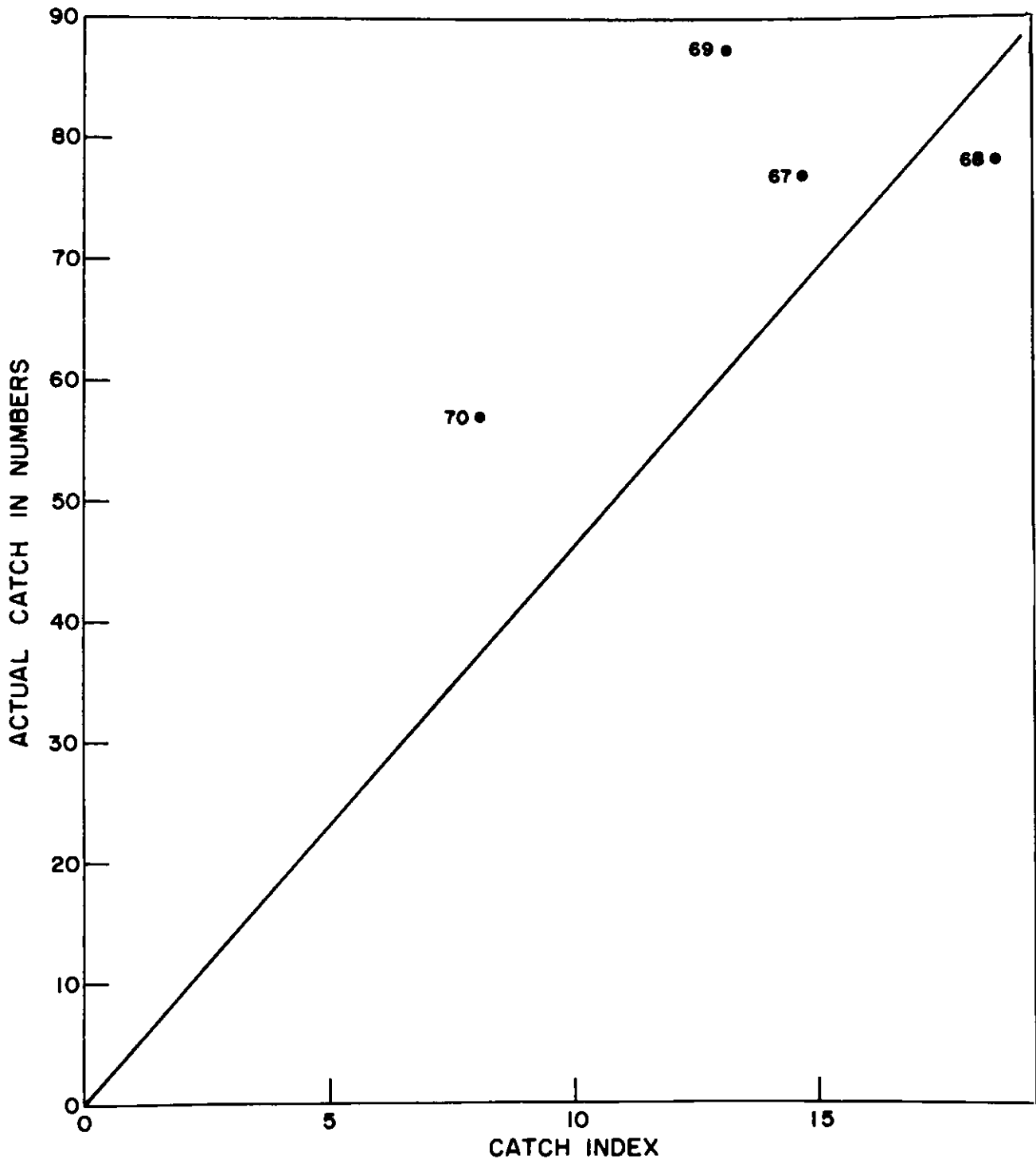
Fig. 3. Actual catch in numbers versus catch index.
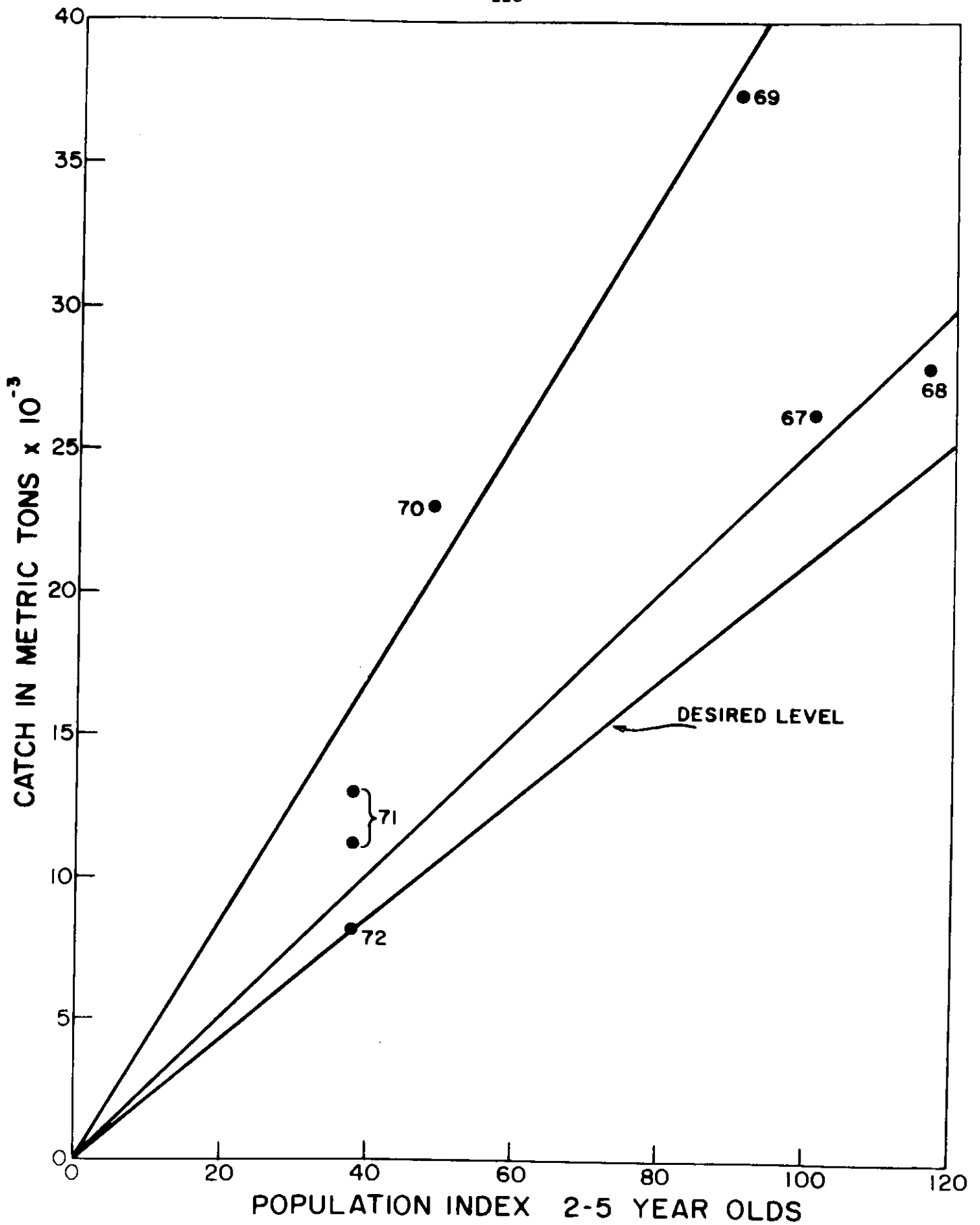
Fig. 4. Population weight index versus catch in weight.

18. Comparisons of abundance indices from research vessel surveys and
     commercial statistics for cod and haddock in ICNAF Subarea 4[1]

by

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Introduction

On recommending that an ICNAF Working Group on Coordinated Groundfish
Surveys be established, the Standing Committee on Research and Statistics
emphasized that determination of accuracy of abundance indices derived from
research vessel surveys should be one of its first tasks. Obviously, future
survey planning decisions should be based on a realistic assessment of the
ability of surveys to provide the type of information required.

To this end, a number of comparisons of survey and commercial abundance
indices for cod and haddock in ICNAF Subarea 4 are brought together here.
Complete analysis has not been possible on these data because of time limita-
tions and this report should be considered preliminary.

Div. 4X cod

The U.S. National Marine Fisheries Service has surveyed most of ICNAF
Div. 4X at least once a year since 1965. These surveys by the research vessel
Albatross IV, using a stratified random sampling design, extended as far as the
mouth of the Bay of Fundy and included LaHave and Roseway Banks. Stratified
mean catch of cod in pounds per tow, calculated after $\log_e$ transformation of
the data, is used here as an index of cod abundance (Table 1). Pre-recruits
are included in this index but they make a very small contribution to the
survey index on a total weight basis because of their relative unavailability
to the survey trawl. The strata considered (numbers 31-35, 41, 42 - see Lux
and Grosslein, MS 1970) cover most of Div. 4X but exclude the inner Bay of
Fundy, inshore southwestern Nova Scotia, and depths greater than 100 fathoms.
These indices are, therefore, estimates of abundance of the offshore cod stock
in Div. 4X.

Halliday (MS 1971) has taken the catch per hour of Canadian side otter
trawlers of 151-500 gross tons which caught predominantly cod in "unit areas"
N, O, P of Div. 4X as being the best available commercial index of abundance
of the offshore cod stock (Table 1). This area includes deep waters of the
Fundian Channel and eastern Gulf of Maine while excluding the region between
northern Brown's Bank and the Bay of Fundy. Thus, the areas from which survey
and commercial data come do not coincide exactly. However, both include the

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[1] Submitted to the 1971 Annual Meeting of ICNAF as Res.Doc. 71/37.

major areas of cod concentration on Brown's and LaHave Banks.

Table 1. ICNAF Div. 4X cod abundance indices from USA research
vessel *Albatross IV* and Canadian commercial otter trawlers.

Year	Quarter	Season	Survey index $\log_e$ (lb/tow)	Commercial index metric tons/hour Quarterly	Annual
1965	1	Winter	–	.307	
	2	Spring	–	.355	
	3	Summer	2.66	.376	
	4	Fall	3.25	.333	
					.343
1966	1	Winter	–	.362	
	2	Spring	3.28	.433	
	3	Summer	–	.263	
	4	Fall	2.71	.225	
					.321
1967	1	Winter	–	.362	
	2	Spring	–	.381	
	3	Summer	–	.273	
	4	Fall	2.16	.265	
					.320
1968	1	Winter	–	.332	
	2	Spring	2.47	.317	
	3	Summer	–	.270	
	4	Fall	1.86	.240	
					.290
1969	1	Winter	–	.302	
	2	Spring	1.86	.307	
	3	Summer	1.88	.192	
	4	Fall	1.74	.137	
					.235

Expressing the abundance estimates as percentages of the mean values
facilitates comparison of trends (Fig. 1). Both survey and commercial indices
show a pronounced downward trend in cod abundance during the period 1965-69.
A measure of the similarity in these trends is provided by the fact that the
correlation coefficient (r) of survey indices with their corresponding commer-
cial quarterly indices is quite high (r = .74), there being only a probability
of about .015 (with 8 degrees of freedom) of as high a value occurring by
chance. While this is encouraging, more precise comparisons require that we
take into account seasonal availability factors and related differences in the
accuracy of abundance indices for different seasons.

Obviously, there are large seasonal variations in availability of cod to

the commercial fishery with the maximum usually occurring in the winter and spring quarters (1st and 2nd) during the pre-spawning and spawning aggregations (Table 1, Fig. 1). The survey data at hand are insufficient to determine whether availability of cod to the survey trawl changes with the season, but it is reasonable to assume that it does. In general, however, differences in fishing practices between commercial and survey operations will result in larger seasonal availability changes in the commercial index because commercial vessels concentrate on fish aggregations, and thus, the relative differences between availability factors for the two types of index may be quite different in different seasons. Furthermore, in the case of the commercial fishery, the precision of the first and second quarter indices probably is greater than that for the third and fourth quarters because the volume of the fishery is much greater in the first two quarters.

For these reasons we should expect a higher correlation between survey and commercial indices taken one season at a time (or averages of season combinations) than if all seasons are included in the correlation; and furthermore, on the average, we might expect higher correlations of survey indices with winter or spring commercial indices than with summer or fall commercial indices. In fact, the data for 4X cod are consistent with such expectations.

The correlation of fall survey indices with fourth quarter commercial indices was higher (r = .77, P = .14) than the correlation based on all seasons represented by survey indices, and it was higher still for fall survey indices and annual commercial indices (r = .83, P = .08) even though these correlations each had only 3 degrees of freedom. Fall survey indices and the following winter (1st quarter) commercial indices have a still higher correlation of .91 (P = .09, df = 2).

Thus, in spite of the fact that there are so few comparisons available and that the survey indices are on a log scale (thereby not strictly comparable with the commercial indices on the linear scale), there is reasonably good agreement between the two data series for 4X cod.

Div. 4X haddock

Survey and commercial data on Div. 4X haddock abundance are available in an identical form to that described above for Div. 4X cod (Table 2). Both survey and commercial indices indicate that abundance was lower in the latter part of 1968 and in 1969 than in earlier years but the trend was less prominent than for cod (Fig. 2). In fact, abundance held steady or even increased in 1966 and 1967 due to recruitment of the strong 1963 year-class. However, abundance began dropping rapidly in 1968. The correlation between all haddock survey indices and their corresponding commercial quarterly indices is only 0.32 (P = .38, df = 8), which is not surprising in view of the non-linear trend over the entire period. However, fall indices for the two data sets give r = 0.76 (P = .14, df = 3); and fall survey vs. annual commercial indices give r = 0.70 (P = .19). Fall survey indices and the following winter (1st quarter) commercial indices have a correlation of 0.98 (P = .02). Thus, as for Div. 4X cod, the agreement between the two data series is encouraging even though the trend for haddock is not a simple linear one.

The inclusion of pre-recruits in the survey indices for haddock, does inflate the 1965 indices somewhat because large numbers of the 1963 year-class were present in 1965 survey catches. However, removal of haddock less than

40 cm from the survey indices (thus approximating commercial sizes) made only a minor change in the comparison. For example, the correlation between fall surveys and following first quarter commercial indices was reduced from .98 to .91.

Table 2. ICNAF Div. 4X haddock abundance indices from USA research
vessel *Albatross IV* and Canadian commercial otter trawlers.

Year	Quarter	Season	Survey index $\log_e$ (lb/tow)	Commercial index metric tons/hour	
				Quarterly	Annual
1965	1	Winter	–	.306	
	2	Spring	–	.400	
	3	Summer	2.78	.250	
	4	Fall	3.61	.237	
					.298
1966	1	Winter	–	.391	
	2	Spring	3.72	.390	
	3	Summer	–	.279	
	4	Fall	3.22	.228	
					.322
1967	1	Winter	–	.370	
	2	Spring	–	.397	
	3	Summer	–	.236	
	4	Fall	3.87	.212	
					.304
1968	1	Winter	–	.423	
	2	Spring	3.13	.296	
	3	Summer	–	.248	
	4	Fall	2.93	.148	
					.279
1969	1	Winter	–	.352	
	2	Spring	2.53	.286	
	3	Summer	2.96	.215	
	4	Fall	2.68	.162	
					.254

Div. 4T cod

The Groundfish Investigation of the St. Andrews Biological Station of the Fisheries Research Board of Canada has undertaken annual fall (September-October) cod surveys in the southern Gulf of St. Lawrence (ICNAF Div. 4T) since 1957. On these surveys, 13 fixed stations were normally occupied, two half-hour otter-trawl tows being made at each station, the station locations being originally chosen to coincide with popular areas for commercial fishing. Those surveys undertaken in 1957-65 have been analyzed to provide abundance

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the same stations were fished each year. An obvious requirement for this approach to be successful is that the density of fish in the selected habitats should remain in direct proportion to the total stock abundance from year to year. While this condition seems to have held in the case of 4T cod, it would be risky to assume that constant proportionality holds generally, particularly when large stock changes occur.

In the case of the U.S. surveys in 4X which employed stratified random sampling, the objective was to sample all trawlable habitats with probability proportional to their area, and to estimate abundance of all species. The random sampling design avoids the type of bias referred to above, but it does so at the expense of statistical precision. That is, sampling errors are almost certain to be larger than in cases where specific habitats are selected and then sampled each year. It is particularly encouraging then that the correspondence between commercial and survey indices in the 4X studies appeared to be reasonably good. Admittedly, we would be on firmer ground with a few more years' data.

The 4W haddock surveys represent a compromise between the 4T and 4X survey approaches, with sampling directed specifically toward haddock, but not confined to the same stations each year. Precision of the 4W haddock pre-recruit indices would appear adequate for assessment purposes.

In conclusion, the degree of correspondence between abundance indices from research vessel surveys and commercial statistics in Subarea 4 provides very encouraging evidence that surveys can produce accurate measures of groundfish abundance. If sampling is directed toward a single stock, then the relatively modest sampling intensity represented by the surveys in 4T and 4W appears sufficient to provide a level of accuracy required for certain assessment needs. If sampling is directed toward estimation of the total biomass of groundfish, then it would appear that the sampling intensity of the U.S. surveys in 4X is adequate to measure major stock changes. However, substantial increases in sampling intensity may be necessary in order to achieve the accuracy required for assessment of less drastic changes which nevertheless are significant from the standpoint of management.

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Fig. 1.

Fig. 2.

Fig. 3.

DIV. 4 W HADDOCK
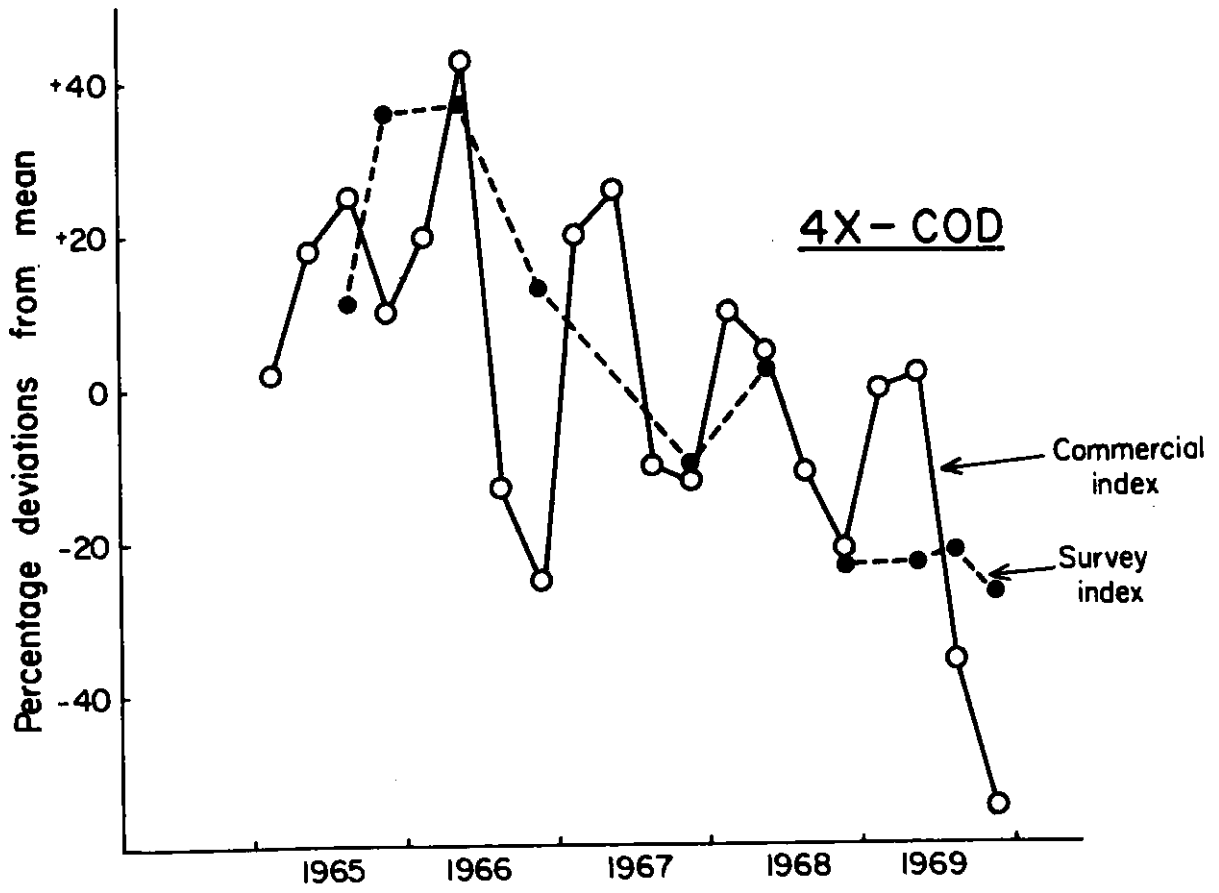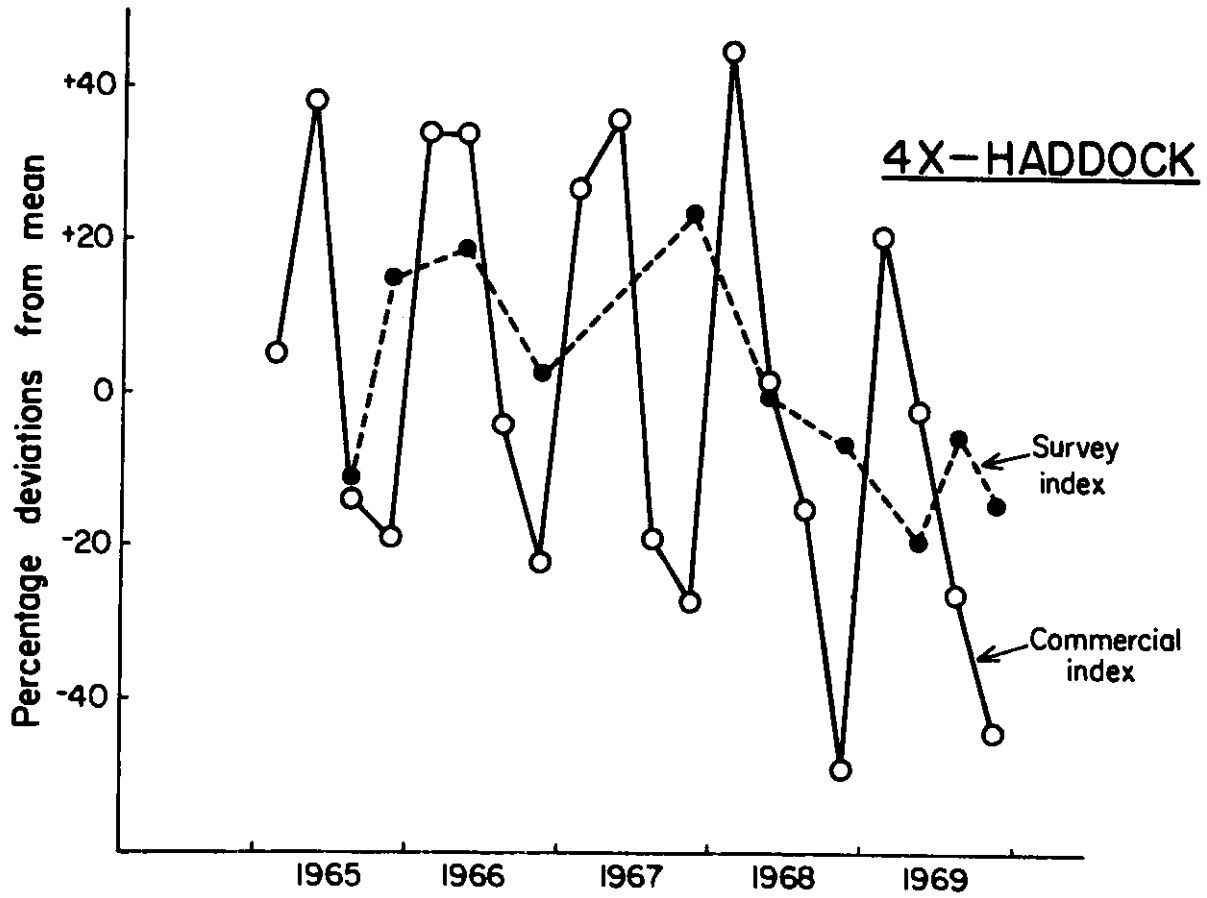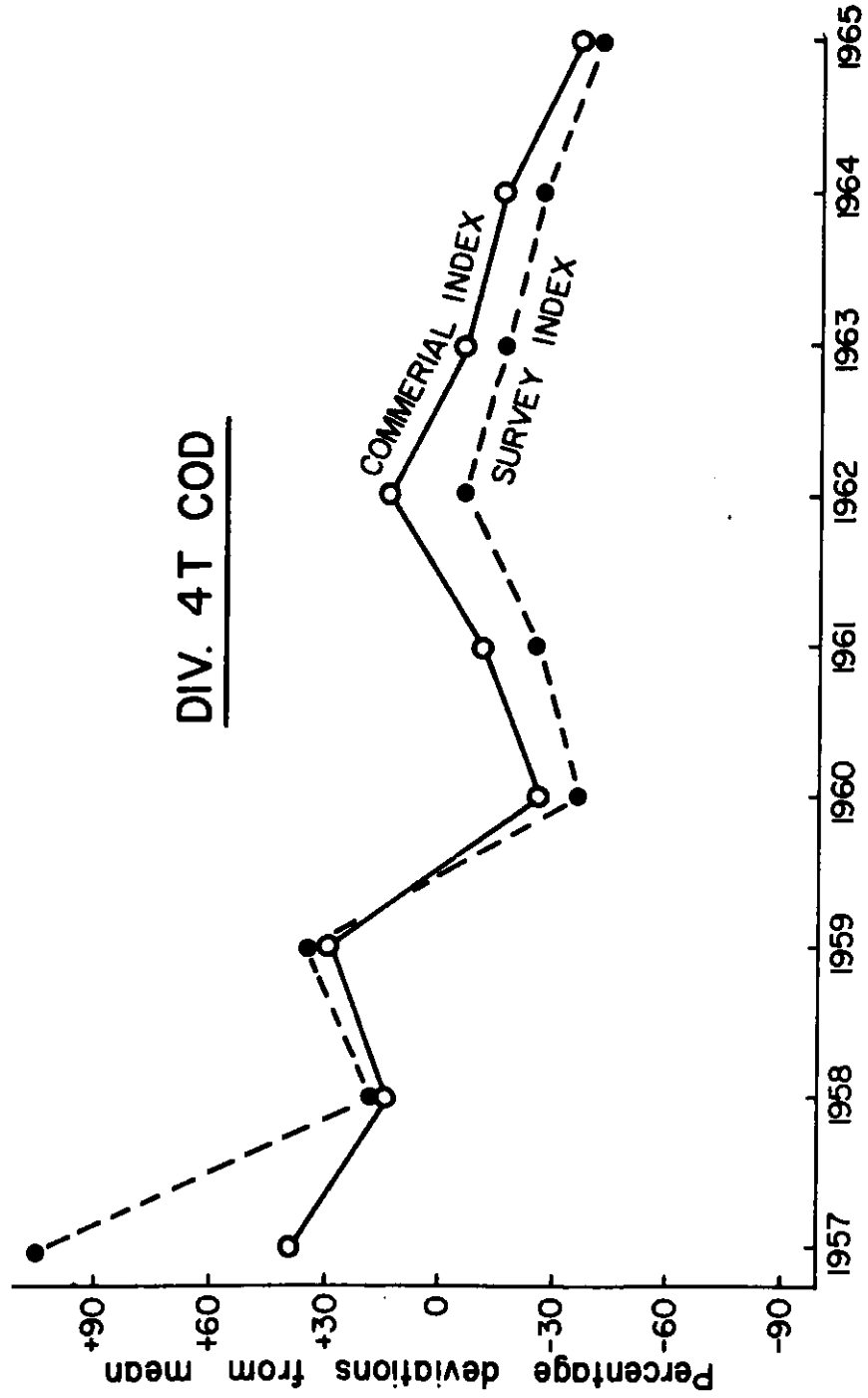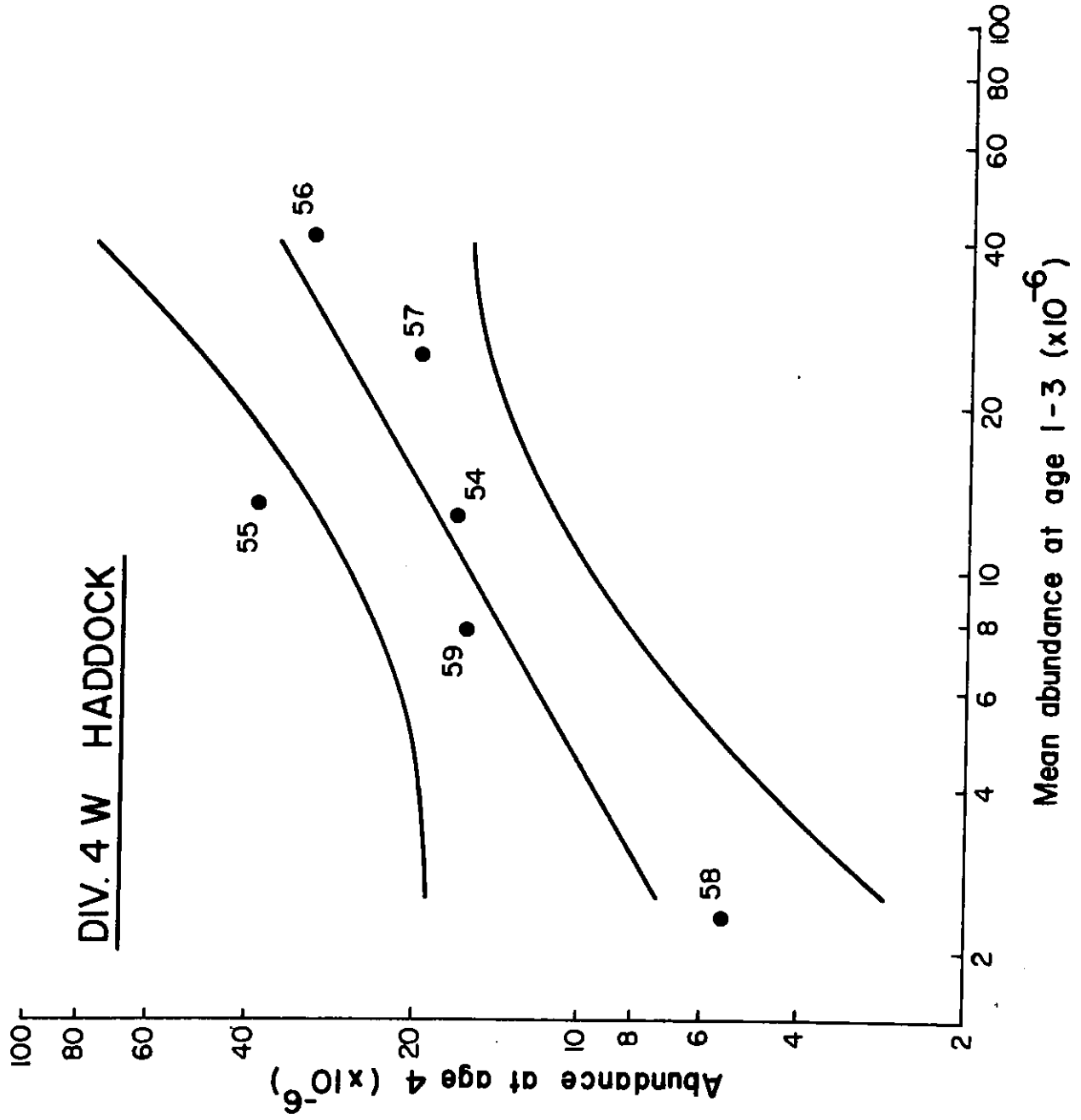
Fig. 4.

19. Accuracy of abundance indices for cod from St. Pierre Bank
(ICNAF Div. 3Ps) based on Canada (Newfoundland) research
vessel surveys in terms of comparisons
with commercial abundance indices[1]

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Introduction

One of the chief objectives of research vessel surveys is to estimate the absolute or relative abundance of year-classes of fish several years prior to their recruitment to the commercial fishery. The surveys conducted by the St. John's Biological Station have been no exception and the survival of year-classes of cod and haddock has been followed for many years, although no actual quantitative predictions have been made. The purpose of the present paper is to evaluate the survey data from St. Pierre Bank (ICNAF Div. 3Ps) and to correlate abundance estimates of year-classes of cod at the pre-recruit stage with abundance estimates of these same year-classes after recruitment to the commercial fishery.

Materials and methods

The sampling design traditionally used on groundfish cruises has been a standard line system. Lines and stations selected under this system are described by Pinhorn (1971) in a document presented to this meeting. Figure 1 shows the lines and stations fished on St. Pierre Bank during 1957-70, the period considered in the present paper.

Temperature conditions in this area vary with season and even from year to year within the same season (Templeman and Hodder, 1965). Also, primarily as a response to these changing temperature conditions, cod are known to migrate between depth zones from season to season (Templeman and May, 1965) and even to migrate to the Newfoundland coast in this area in the May-June period (Templeman, 1962). In view of these facts and since the survey cruises in 1957-65 were conducted during May-June but in 1967-70 were conducted during March-May (Fig. 2), the length compositions of the catches from each cruise were combined by depth zones of 0-50 fathoms, 51-100 fathoms and 101-150 fathoms. These were then converted to number per hour fished for each depth zone and the results are shown in Fig. 2. It became obvious that very few cod were caught deeper than 100 fathoms and this depth zone is omitted from Fig. 2. In fact, movements of cod occurred within depths less than 100 fathoms. It is further obvious that, except for occasional years of peculiar hydrographic conditions (*e.g.* 1958), the young cod of 2-3 years of age (< 37 cm) remained for the most part in the 51-100-fathom depth zone during the entire period from March to June, whereas the older cod were found in the 51-100-fathom depth zone during the early part of this period, but moved onto the top of the bank in depths less than 50 fathoms during the later part of this March-June period (Fig. 2).

To evaluate the similarity of abundance indices calculated from research vessel surveys in successive years, indices of abundance of 2- and 3-year-old cod of each year-class were compared with indices of abundance of 4- and 5-year-old cod of the same year-class in later cruises. In view of the facts outlined

[1] Submitted to the 1971 Annual Meeting of ICNAF as ICNAF Res.Doc. 71/38.

above, three separate methods of computing these indices were used as follows:

1. Numbers of cod caught per hour fished for each year-class at each age were computed by applying an age-length key to numbers per hour length compositions as shown in Fig. 2 from sets made in 51-100 fathoms only for each cruise.

2. Numbers of cod caught per hour fished for each year-class at each age were computed for 2- and 3-year-old cod by applying an age-length key to number per hour length compositions from sets made in 51-100 fathoms only and for 4- and 5-year-old cod from sets made in 0-50 fathoms for the 1957-65 late spring to early summer cruises and from sets made in 51-100 fathoms for 1967-70 late winter to early spring cruises.

3. Numbers of cod caught per hour fished for each year-class at each age were computed by weighting the number per hour length compositions in each depth zone by the area of the depth zone as shown in Fig. 1. These areas are as follows:

    0-50 fathoms - 5,749 square miles
    51-100 "   - 2,776   "   . "
    101-150 "   -   869   "   "

In the above computations, in years where no survey data were available (1961 and 1966) and for year-classes at the beginning and end of the period, numbers caught per hour for the missing ages were calculated by applying the average survival rates of the remaining year-classes between successive ages to the known number per hour at the age immediately before or after the missing ages.

In comparing indices of abundance of 2- and 3-year-old cod from the research cruises with indices of abundance of 4- and 5-year-old cod from the commercial fishery, the indices for 2- and 3-year-old cod calculated by Methods 1-3 above were used. The indices of abundance for 4- and 5-year-old cod from the commercial fishery were calculated in the following manner: Nominal catches and hours fished by Canada (Newfoundland) side trawlers of 151-500 tons were tabulated for the spring fishery for the 1959-68 period. Average weight caught per hour fished was then calculated for each year and average number caught per hour fished calculated from this figure by using average weight values as determined from the Sampling Yearbooks for the respective years. Per mille length frequencies of catches of Canada (Newfoundland) side trawlers of 151-500 tons, as well as length frequencies of other countries which appeared similar to Canada (Newfoundland) frequencies, where the latter were lacking or few in number, were averaged and the resulting per mille length frequency adjusted to number per hour caught by these Canada (Newfoundland) side trawlers in each year. Research age-length keys were applied to these length frequencies for each year and indices of abundance calculated for 4- and 5-year-old cod of each year-class. For 1961 and 1966, in which no age-length keys were available, keys from the adjacent years were averaged and applied to the length frequency in the particular year. Numbers of measurements used for each country are given below:

Year	Country	No. of Measurements
1959	Canada (Newfoundland)	2,047
1960	" "	520
	United Kingdom	2,013
1961	Canada (Newfoundland)	834
	Portugal	500
1962	United Kingdom	1,890
1963	-	-
1964	Canada (Newfoundland)	267
1965	" "	999
1966	" "	2,428
1967	" "	600
1968	" "	945

Results

Logarithmic transformations best described the relationships between abundance indices of 2- to 3-year-old cod and 4- to 5-year-old cod in successive research surveys. Correlation coefficients (r) were generally larger than with the arithmetic straight line fits and were significantly different from zero in all cases, except ages 2-3 versus age 5 calculated by Method 3 (Table 1 and Fig. 3). Only two r-values were significant using arithmetic straight lines, between ages 2-3 and age 5 and ages 2-3 and ages 4-5 as calculated by Method 1.

Table 1. Correlation coefficients and tests of significance between indices of abundance of 2- and 3-year-old cod and 4- and 5-year-old cod from Canada (Newfoundland) research surveys of St. Pierre Bank (ICNAF Div. 3Ps), 1957-70. Indices of abundance are computed by three different methods which are described in text.

Method	Ages compared	Arithmetic straight line			Log-log straight line		
		r	df	t	r	df	t
1	2-3 vs 4	0.52	10	1.91	0.64	10	2.64^{1}
	2-3 vs 5	0.83	10	4.73^{2}	0.74	10	3.45^{2}
	2-3 vs 4-5	0.72	10	3.20^{2}	0.72	10	3.26^{2}
2	2-3 vs 4	0.51	10	1.89	0.76	10	3.66^{2}
	2-3 vs 5	0.56	10	2.13	0.59	10	2.31^{1}
	2-3 vs 4-5	0.57	10	2.21	0.85	10	5.07^{2}
3	2-3 vs 4	0.40	10	1.40	0.59	10	2.32^{1}
	2-3 vs 5	0.42	10	1.45	0.50	10	1.84
	2-3 vs 4-5	0.45	10	1.60	0.59	10	2.31^{1}

[1] significant at the 5% level
[2] significant at the 1% level

On the other hand, arithmetic straight line fits best described the relationships between ages 2-3 in the research surveys and ages 4-5 in the commercial catches. Correlation coefficients were generally larger than with

the logarithmic transformation and were significant in all cases, except between ages 2-3 and age 5 calculated by Method 1 (Table 2 and Fig. 4). However, all r-values, except two, were still significant with the logarithmic transformation.

Table 2. Correlation coefficients and tests of significance between indices of abundance of 2- and 3-year-old cod from Canada (Newfoundland) survey catches and 4- and 5-year-old cod from Canada (Newfoundland) commercial catches of 151-500-ton side trawlers, St. Pierre Bank (ICNAF Div. 3Ps), 1959-68.

Method	Ages compared	Arithmetic straight line			Log-log straight line		
		r	df	t	r	df	t
1	2-3 vs 4	0.83	8	4.15[2]	0.79	8	3.59[2]
	2-3 vs 5	0.54	8	1.79	0.32	8	0.94
	2-3 vs 4-5	0.88	8	5.29[2]	0.67	8	2.57[1]
3	2-3 vs 4	0.82	8	3.99[2]	0.82	8	4.04[2]
	2-3 vs 5	0.63	8	2.29[1]	0.50	8	1.62
	2-3 vs 4-5	0.88	8	5.33[2]	0.76	8	3.29[1]

[1] significant at the 5% level
[2] significant at the 1% level

Except for the 1958 year-class, survival of the 1954-65 year-classes as determined from research vessel surveys fluctuated only moderately with the weakest year-classes being about 75% less than the long-term average and the strongest year-classes being about equal to the average (Fig. 5A). The 1958 year-class was represented in the 1960 research vessel catches in significant numbers but was only caught in small numbers in later research vessel cruises and in commercial catches. The catch of this year-class as 2-year-olds was not considered representative of its abundance and consequently, this year-class is omitted from the above correlations. The 1966 and 1968 year-classes appear to be considerably stronger than average, while the 1967 year-class was slightly below average.

Discussion

It appears from the results presented in this paper that indices of abundance as determined from survey cruises to St. Pierre Bank are accurate enough, or at least consistent enough from year to year, to allow for prediction of relative levels of recruitment to the commercial fishery, even with the present standard line system as used by the St. John's Biological Station. However, attempts at estimating absolute abundance levels of individual year-classes would be more difficult with this system, since it does not allow for random coverage of the entire habitat of the species and hence, any attempt at stratifying the area and using the stations fished on each line as random sets in the various strata would result in some strata having no sets at all and others with very few.

In considering the problem of stratifying the area according to the system of sampling described by Grosslein (1968), if only the pre-recruits of

age-groups 0-3 are being considered, then it appears that the problem may be simplified since in most years these age-groups are confined largely to the depth zone 51-100 fathoms and a stratification system within this zone may be sufficient. However, if older age-groups are considered, then the fact that these age-groups migrate to the top of the Bank and more important to the Newfoundland coast must be considered. Any survey then undertaken would have to be in winter or early spring before this migration takes place.

Comparison of year-class strengths with those given by Bulatova (1970) indicates some differences (Fig. 5C). Deviations from the long-term mean of the 1960-66 year-classes were similar in both sets of data for the 1960-63 year-classes, ranging from 25-75% below this mean. Also, the deviations for the 1965 year-class was reasonably similar in both cases, being equal to the mean for Canada (Newfoundland) and 25% above for Bulatova (1970). However, the strength of the 1964 year-class, while being 10% below the mean from Canada (Newfoundland) data, was 125% above the mean from Bulatova (1970). Also, the 1966 year-class, while being 200% above the mean from Canada (Newfoundland) data was only 60% above from Bulatova (1970) data. Bulatova (1970) also states that the 1967 year-class is probably not better than average, while the 1968 year-class was especially strong. This agrees favourably with the Canada (Newfoundland) data (Fig. 5A), from which the 1967 year-class was judged to be about 25% less than the long-term 1954-68 mean and the 1968 year-class about 150% greater than the mean.

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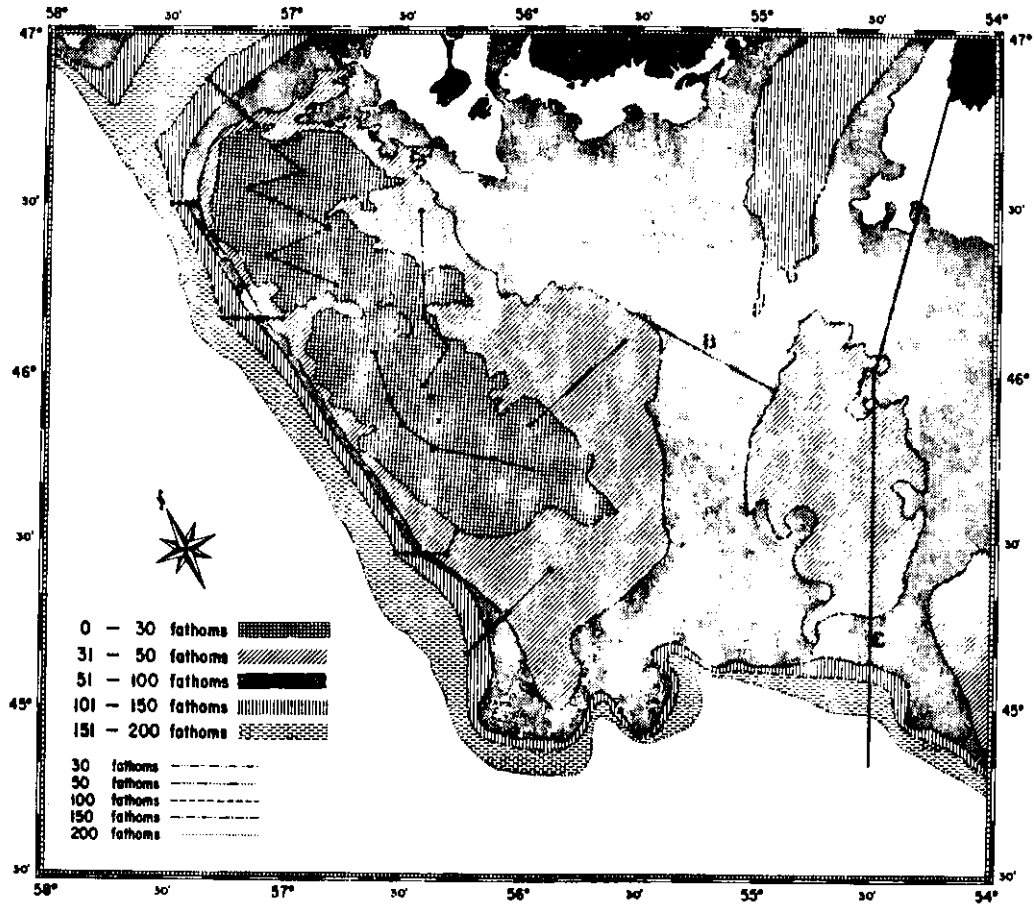
Fig. 1.   Chart of St. Pierre Bank showing depth zones used in
          calculation of indices of abundance of cod and lines
          and stations fished during the period considered.
          Solid lines marked A, B and C delineate sections used
          for determination of depth zone areas.
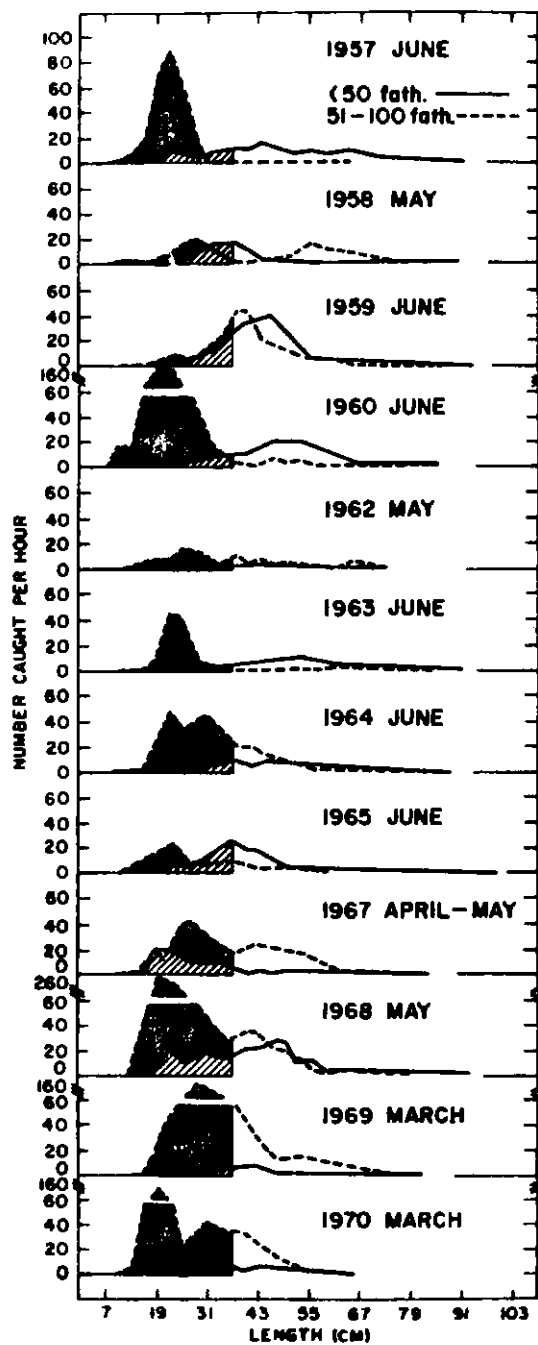
Fig. 2. Number caught per 1-hour trawling in each 3-cm length-group
in the two major depth zones from Canada (Newfoundland)
research vessel surveys, St. Pierre Bank (ICNAF Div. 3Ps).
Areas shaded and hatched to the left of vertical lines
indicate cod less than 4 years old.
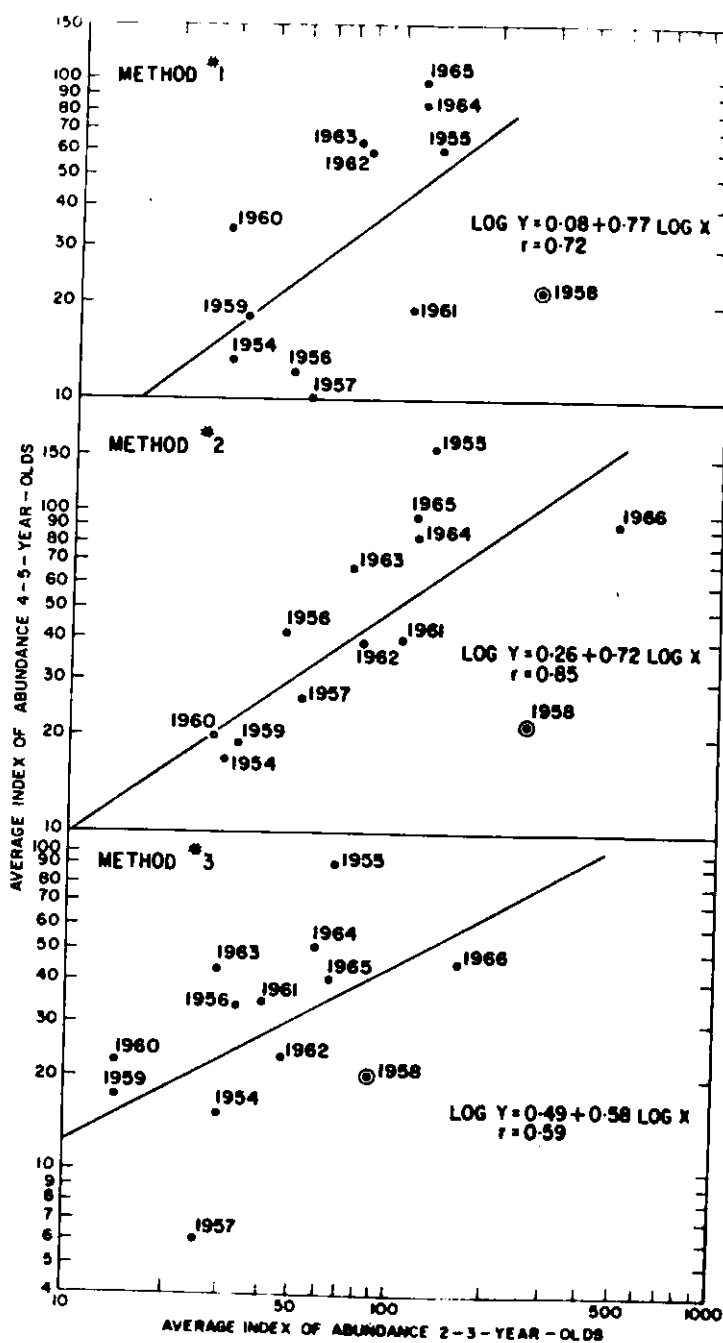
Fig. 3. Relationship between average indices of abundance of 2- to 3-year-old cod and 4- to 5-year-old cod of each year-class in successive research vessel surveys. See text for explanation of Methods 1-3 of calculating indices.
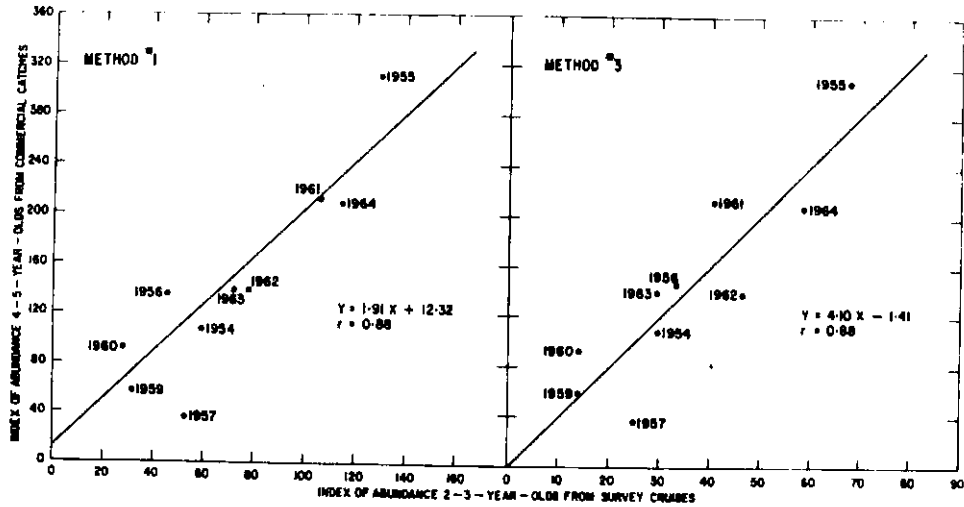
Fig. 4. Relationship between average indices of abundance of 2- to 3-year-old cod from research vessel surveys and 4- to 5-year-old cod from the commercial fishery by Canada (Newfoundland) side trawlers of 151-500 tons for each year-class.
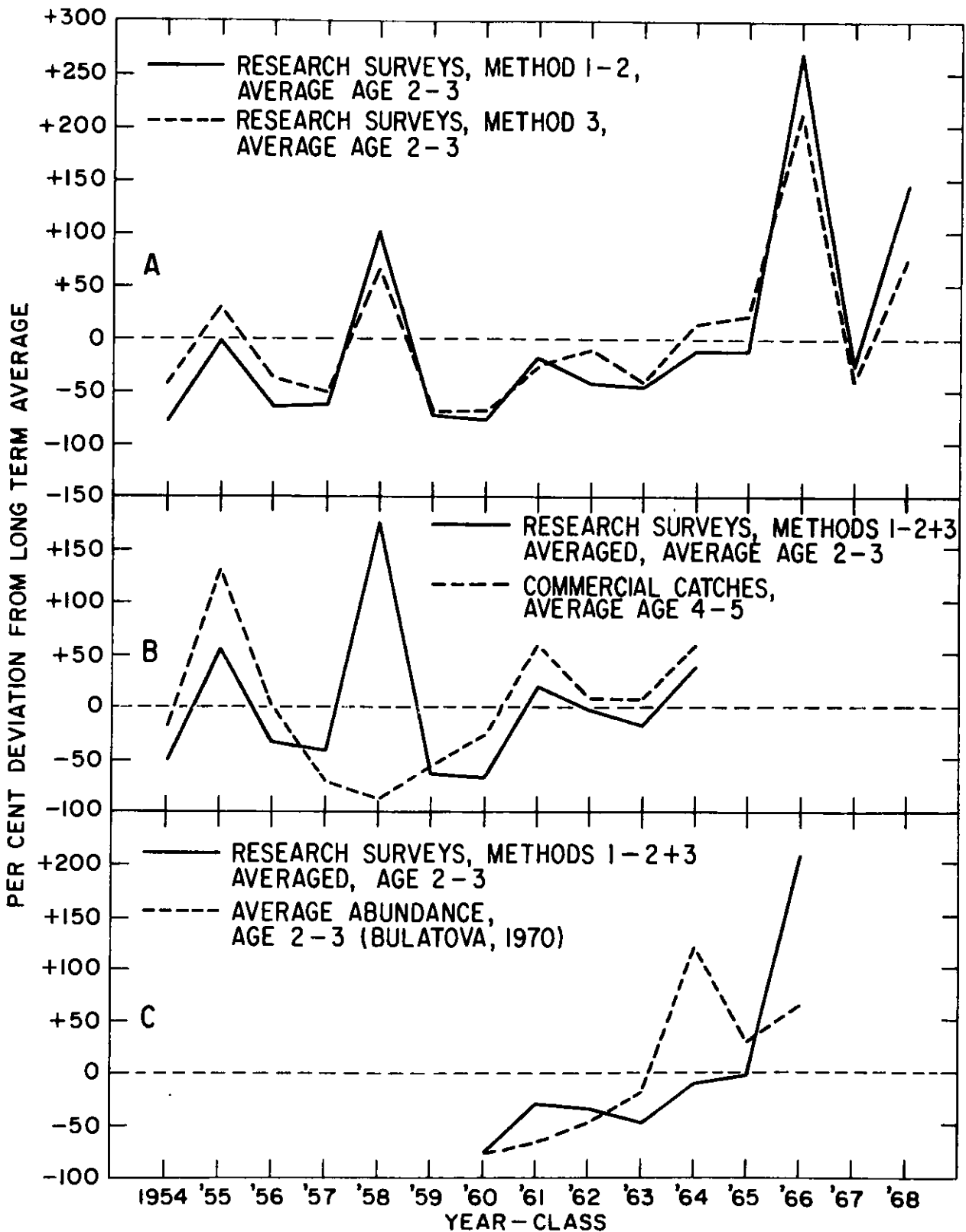
Fig. 5. Percent deviations by year-class of abundance indices of cod from
long-term average of: (A) 1954-68 year-classes from research data
alone; (B) 1954-64 year-classes from research data and commercial
data; (C) 1960-66 year-classes from Canada (Newfoundland) research
data and data of Bulatova (1970).

20. Some observations on accuracy of abundance indices derived from research vessel surveys[1]

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Introduction

In order to help evaluate the cost-benefit ratio of surveys it is necessary to have some idea of the magnitude of change in stock size that is considered significant, as well as the magnitude of change we are able to detect and with what probability. Clearly one of the most important questions is whether surveys can measure changes in abundance with sufficient accuracy to permit meaningful assessment of the short-term affects of fishing. However, it is important to remember that we are also concerned with long term changes involving not just a few priority species but the entire groundfish community. In general a lower level of accuracy probably would suffice for monitoring long term changes than in the case of assessment on a year-to-year basis. My principal aim here is to provide some information on what accuracy is possible with catch-per-haul statistics from research vessel surveys.

When considering accuracy of estimates, we must distinguish between statistical precision or sampling error (variance) and bias. That is, an estimate may be very precise in terms of a small variance but have a large bias, and therefore not be very accurate. In our problem we are concerned not only with precision but also with the possible biases in the survey abundance index (catch per standard haul) as a relative measure of absolute abundance. That is, we may consider our index unbiased if there is a constant proportionality (catchability coefficient) between the relative abundance index and the true absolute abundance of the stock. The next step is to estimate this coefficient so that we can estimate actual total numbers in the population.

Evidence to be presented later suggests that the assumption of constant proportionality is not unreasonable for certain species and observed stock changes in the case of joint US-USSR surveys. Consequently the following data on precision of abundance indices from these surveys probably reflects the general order of accuracy obtainable in measures of change in absolute stock size. Admittedly we will be on firmer ground when we can estimate variability of catchability coefficients, by utilizing direct (camera, acoustic) measures of abundance in conjunction with trawling.

Statistical characteristics of trawl catch data

As is well known trawl catches are highly variable even within relatively restricted areas because fish are not uniformly distributed; and random trawl hauls result in a frequency distribution of catches which is highly skewed. A major consequence of this skewness is that the variance is generally much larger than the mean resulting in very imprecise (although unbiased in the statistical sense) estimates of the mean, and even less reliable estimates of the variance

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[1] Revised version of paper submitted to 1971 Annual Meeting of ICNAF as ICNAF Res.Doc. 71/59.

itself, except with very large sample sizes. That is, the standard error associated with the variance is particularly susceptible to departures from normality, and without a reliable estimate of the variance of course it is not possible to calcualte meaningful confidence limits about the mean.

A standard approach to this general problem is to stratify the population to be sampled into high and low density units or strata, and then sample randomly within individual strata within each of which skewness is then reduced. Control of variability in this manner is one of the primary advantages to be gained from the technique of stratified random sampling. However in the case of trawl catches, considerable skewness remains even after stratification. For example the variability of variance estimates for haddock trawl catches on U.S. surveys, reflects the fact that catches within individual strata are still highly skewed (Table 1). Sampling strata used in the surveys discussed here are shown in Figures 1 and 2.

Another well known approach is to try to find a transformation which normalizes the frequency distribution of variables. We have found that on the average, stratum variances of trawl catches are approximately proportional to the square of the mean, $i.e.$ the standard deviation is proportional to the mean. This is true for haddock (Fig. 3) and for many other species as well. This relation indicates that a log transformation is appropriate, and such a transformation tends to normalize the data and stabilize the variance ($i.e.$ make means and variances independent). Also the log transformation converts multiplicative effects into linear additive effects. In terms of our problem of estimating proportional changes in abundance, this means that linear changes on a log scale represent estimates of multiple or factor changes on the original scale. That is, the anti-log of the difference between two log means represents the proportionality constant relating means on the linear scale. The estimates of proportional change on the original scale are believed to be essentially unbiased in the statistical sense, but it should be noted that the re-transformed mean is a biased estimate of the true mean on the linear scale (an unbiased estimate is theoretically possible).

Calculation of stratified mean and variance

The basic index of abundance dealt with here is the stratified mean catch per standard haul, calculated by weighting each stratum mean according to the proportional size (area) of the stratum relative to all strata in the set. The variance of a stratified mean is similarly derived by weighting each stratum variance in proportion to the stratum area and inversely according to the number of hauls in the stratum.

Table 1. Stratum means (catch/haul, pounds) and variances for haddock in three sampling strata on Georges Bank. *Albatross IV* surveys.

CRUISE	STRATUM 16				STRATUM 19				STRATUM 20			
	No. hauls	Mean	Variance	Std. deviation	No. hauls	Mean	Variance	Std. deviation	No. hauls	Mean	Variance	Std. deviation
63-05	7	41	2,740	52	4	126	22,442	150	3	7	52	7
63-07	7	101	4,330	66	4	291	66,992	259	4	115	33,379	183
64-01	10	41	857	29	7	147	37,875	194	5	37	1,322	36
64-210	8	300	338,823	582	5	364	209,248	457	5	356	70,072	264
64-13	7	148	31,926	179	6	168	26,652	163	5	335	155,074	394
65-2	6	73	6,309	80	6	392	243,932	494	5	21	338	18
65-510	8	405	682,555	826	6	800	2,019,784	1421	5	618	188,942	435
65-14	7	78	3,266	57	5	171	14,377	120	5	332	160,830	401
66-601	7	73	17,357	132	6	49	6,058	78	5	43	1,243	35
66-614	7	62	1,423	38	6	54	15,495	124	5	126	11,584	108
67-721	8	14	564	24	9	52	4,096	64	6	37	4,140	65
68-803	9	49	5,533	74	8	42	1,189	34	6	13	351	19
68-817	8	19	2,850	53	9	0	-	-	6	25	3,574	60
69-902	14	71	26,570	163	8	45	1,831	43	6	3	41	6
69-908	10	7	185	14	9	6	124	11	6	23	2,610	51
69-911	12	4	117	11	9	7	413	20	6	16	1,137	34
70-703	10	130	120,926	348	8	11	409	20	5	5	76	9

Computational formulae are:

$$\bar{y}_{st} = \frac{1}{N} \sum_{h} N_h \bar{y}_h$$

$$V(\bar{y}_{st}) = \frac{1}{N^2} \sum_{h} \frac{N_h^2 S_h^2}{n_h} ,$$

where $\bar{y}_{st}$ and $V(\bar{y}_{st})$ are the stratified mean catch per haul and its variance respectively, of some set of strata, and

N_h = area of the hth stratum

N = $\sum_{h} N_h$ = total area of all strata in the set

$\bar{y}_h$ = mean catch per haul in the hth stratum

n_h = number of standard hauls in h^{th} stratum

S_h^2 = variance of catches in the hth stratum

Examples of precision on linear scale

It is of interest to look at some examples of sampling errors of stratified means on a non-transformed scale before proceeding on to the log scale. Recall that in the examples of haddock data for individual strata, the standard deviation was on the average about equal to the mean (Fig. 3, Table 1). That is, coefficients of variation (ratio of standard deviation to the mean) were on the order of 100 percent with 5-7 hauls per sample. In the case of stratified means for haddock on Georges Bank (representing about 60 hauls in strata 13-25 combined) the average CV is only about 25 percent (Table 2). Similar values were obtained for cod.

In spite of the observed variability in estimates of individual stratum variances, we note that the CV's of the stratified means are reasonably consistent from year to year suggesting that the estimates of $V(\bar{y}_{st})$ may be approximately correct. Essentially we have computed a weighted mean of variances from 13 strata, and since most of these strata appear to have about the same variance this would account for the consistency among estimates of $V(\bar{y}_{st})$.

Stratified means for yellowtail on Georges Bank show CV's similar to those for cod and haddock (Table 3). Also shown in Table 3 are stratified means for the three principal strata for yellowtail, representing about half of the total area of the strata set, 13-25. The CV's are only slightly greater on average for this subset of strata than for the entire set, although there were less than half as many hauls in the subset. Very little information on yellowtail was gained by sampling outside these three principal strata.

Table 2. Stratified mean catch per haul (pounds, linear) of cod and haddock on Georges Bank, (strata 13-25), and estimates of precision. *Albatross IV* fall surveys.

Year	Mean	Variance	S.D.	S.D./Mean	Mean± 2 S.D.
COD					
1963	24.18	43.35	6.58	.27	11.0-37.3
1964	15.74	20.89	4.57	.29	6.6-24.9
1965	15.90	26.04	5.10	.32	5.7-26.1
1966	11.10	5.87	2.42	.22	6.3-15.9
1967	18.43	17.85	4.22	.23	10.0-26.9
1968	11.66	8.54	2.92	.25	5.8-17.5
1969	10.91	4.79	2.19	.20	6.5-15.3
HADDOCK					
1963	112.83	590.75	24.30	.22	64.2-161.4
1964	165.68	1032.11	32.13	.19	101.4-229.9
1965	123.66	411.58	20.29	.16	83.1-164.2
1966	47.22	99.39	9.97	.21	27.3-67.2
1967	44.05	103.86	10.19	.23	23.7-64.4
1968	20.53	52.18	7.22	.35	6.1-35.0
1969	12.70	16.62	4.08	.32	4.5-20.9

Table 3. Stratified mean catch per haul (pounds, linear) of
yellowtail on Georges Bank, and estimates of
precision. *Albatross IV* fall surveys.

Year	Mean	Variance	S.D.	S.D./Mean	Mean± 2 S.D.	No. Hauls
STRATA 13-25 (15,300 sq miles)						
1963	18.00	11.56	3.40	.19	11.2-24.8	57
1964	18.58	53.27	7.30	.39	4.0-33.2	63
1965	12.36	15.73	3.97	.32	4.4-20.3	66
1966	5.38	3.07	1.75	.32	2.1-8.6	67
1967	9.71	6.91	2.63	.27	4.4-15.0	65
1968	14.73	11.33	3.37	.23	8.0-21.5	62
1969	12.02	9.73	3.12	.26	5.8-18.3	66
1970	6.37	3.49	1.87	.29	2.6-10.1	70
STRATA 13, 16, 19 (7,800 sq miles)						
1963	23.10	33.19	5.76	.25	11.6-34.6	16
1964	32.10	194.97	13.96	.43	4.2-60.0	18
1965	18.48	56.99	7.55	.41	3.4-33.6	19
1966	8.71	11.35	3.37	.39	2.0-15.4	19
1967	16.58	25.96	5.10	.31	6.4-26.8	25
1968	24.50	40.78	6.38	.26	11.7-37.3	25
1969	21.44	36.96	6.08	.28	9.3-33.6	30
1970	10.69	12.44	3.53	.33	3.6-17.8	24

255 - 255 -

Table 4. Stratified mean catch per haul (lb, $\log_e$ scale) and measures of precision for selected species. *Albatross IV* fall surveys, Strata 13-25.

YELLOWTAIL

Year	Mean	Variance	S.D.	S.D./Mean	2 S.D.	Mean± 2 S.D.	Factor diff.
1963	1.97	.026805	.1637	.08	.33	1.64-2.30	1.9
1964	1.41	.037142	.1927	.14	.38	1.03-1.79	2.1
1965	1.32	.029119	.1706	.13	.34	.98-1.66	2.0
1966	0.96	.025860	.1608	.17	.32	.64-1.28	1.9
1967	1.32	.027724	.1665	.13	.33	.99-1.65	1.9
1968	1.40	.038260	.1956	.14	.39	1.01-1.79	2.2
1969	1.35	.025200	.1587	.12	.32	1.03-1.67	1.9
1970	0.96	.0204	.1428	.15	.28	.68-1.24	1.8

HADDOCK

Year	Mean	Variance	S.D.	S.D./Mean	2 S.D.	Mean± 2 S.D.	Factor diff.
1963	3.34	.052176	.2284	.07	.46	2.88-3.80	2.5
1964	3.86	.080315	.2834	.07	.57	3.29-4.43	3.1
1965	4.02	.042355	.2058	.05	.41	3.61-4.43	2.3
1966	2.43	.044512	.2110	.09	.42	2.01-2.85	2.3
1967	2.45	.052075	.2282	.09	.46	1.99-2.91	2.5
1968	1.15	.029587	.1720	.15	.34	0.81-1.49	2.0
1969	1.10	.021536	.1467	.13	.29	0.81-1.39	1.8
1970	1.35	.0345	.1857	.14	.37	0.98-1.72	2.1

COD

Year	Mean	Variance	S.D.	S.D./Mean	2 S.D.	Mean± 2 S.D.	Factor diff.
1963	1.75	.084829	.2912	.17	.58	1.17-2.33	3.2
1964	1.29	.056270	.2372	.18	.47	0.82-1.76	2.6
1965	1.32	.041737	.2043	.15	.41	0.91-1.73	2.2
1966	1.20	.040673	.2017	.17	.40	0.80-1.60	2.2
1967	1.74	.047301	.2175	.12	.44	1.30-2.18	2.4
1968	1.04	.031888	.1786	.17	.36	0.68-1.40	2.1
1969	1.32	.025381	.1593	.12	.32	1.00-1.64	1.9
1970	1.35	.0332	.1822	.13	.36	0.99-1.71	2.1

Examples of precision on log scale

On the log scale the variances are nearly stabilized and the CV's of stratified means are on the order of 10-15 percent for the same species and strata (Table 4). However note that now we are interested in the absolute rather than relative size of the standard deviation. For haddock ±2 S.D.'s (±.40) corresponds to ±50 percent on the linear scale. Thus there is no great improvement in the size of difference (proportional change on linear scale) we are able to detect as compared with the non-transformed scale, but we have more efficient estimates of those differences over the range of abundance levels, and the estimated confidence limits more closely approximate true 95 percent confidence intervals. Results of stratified estimates for cod and haddock off western Nova Scotia are comparable to those on Georges Bank (Table 5).

Table 5. Stratified mean catch per haul ($\log_e$ pounds) and variance estimates for cod and haddock off western Nova Scotia. *Albatross IV* autumn surveys in strata 31-35, 41, 42.

HADDOCK

Year	Mean	Variance	S.D.	S.D./mean	2 S.D.	95% CI	Factor difference
1965	3.61	.1918	.4379	.12	.88	2.73-4.49	5.8
1966	3.22	.1321	.3634	.11	.73	2.50-3.94	4.3
1967	3.87	.1073	.3276	.08	.66	3.21-4.53	3.7
1968	2.93	.0598	.2445	.08	.49	2.45-3.41	2.7
1969	2.68	.0593	.2435	.09	.49	2.20-3.16	2.7
1970	2.82	.0352	.1876	.07	.38	2.44-3.20	2.1

COD

Year	Mean	Variance	S.D.	S.D./mean	2 S.D.	95% CI	Factor difference
1965	3.25	.1492	.3863	.12	.77	2.47-4.03	4.7
1966	2.71	.1608	.4010	.15	.80	1.91-3.51	5.0
1967	2.16	.1051	.3242	.15	.65	1.52-2.80	3.7
1968	1.86	.0949	.3080	.16	.62	1.24-2.48	3.5
1969	1.74	.0887	.2978	.17	.60	1.14-2.34	3.3
1970	1.77	.0500	.2236	.13	.45	1.32-2.22	2.5

The most significant feature of these data is that they indicate the present survey cannot detect with high probability, proportional changes in abundance which are less than a factor of about 2. That is, the $\log_e$ difference between the lower and upper limits of the 95 percent C.I. is about 0.7 corresponding to a factor difference of 2 on the linear scale; and to be very sure that two means are significantly different there must be no overlap in the 95 percent confidence intervals.

<u>Sample size vs. precision</u>

Some first approximations have been made of the relation between precision of stratified means and sample size (total number of hauls). The calculations are based on the general formula for estimating required sample size in stratified random sampling:

$$n = \frac{\sum\limits_{h} \dfrac{W_h^2 S_h^2}{w_h}}{V + \dfrac{1}{N} \sum\limits_{h} W_h S_h^2}$$

and in terms of this problem,

W_h and S_h are as defined earlier,

$w_h = \dfrac{n_h}{n}$, the observed relative sampling effort in the

h^{th} stratum (the ratio of the number of hauls in

the hth stratum to the total number of hauls,

n, in all strata of the specified set)

V = desired variance of the stratified mean
N = total number of possible hauls in the area represented by strata in the set.

Since the number of hauls in our survey is very small relative to the total number possible (strata 13-25 cover roughly 15,000 square miles and each standard haul covers approximately .01 square mile), the second term in the denominator is extremely small compared with the first.

Thus,

$$n = \frac{1}{V} \sum\limits_{h} \frac{W_h^2 S_h^2}{w_h}$$

Using the above formula and average values of S_h^2 for haddock, and w_h based on eight *Albatross IV* fall surveys, estimates were made of the sample sizes required to achieve various levels of precision. For example, if we wanted to be able to detect proportional changes in abundances of ±20 percent with high probability, this would require an interval of ±2 S.D.'s = ±.18 on the natural log scale, and thus S.D. = .09 and V = .0081. Substituting this value of V in the above formula, n = 338 hauls. Results of calculations for levels of precision between 10-100 percent of the stratified mean for haddock are given in Table 6. The same computations for yellowtail in strata 13, 16, and 19 (representing about half of Georges Bank) are also shown in Table 6.

Table 6. First approximations to sample sizes (total number hauls) required for specified precision of stratified mean abundance indices ($\log_e$ catch/haul in pounds) from *Albatross IV* surveys on Georges Bank.[1]

LEVEL OF PRECISION		Total number hauls required, (approximately proportional allocation)	
Percentage change linear scale	2 standard deviations, $\log_e$ scale	Haddock (strata 13-25)	Yellowtail (strata 13, 16, 19)
± 10%	±.10	>500	>500
± 20%	±.18	338	253
± 30%	±.26	164	120
± 50%	±.40	70	51
±100%	±.69	23	17

[1] An empirical measure of the improvement in precision with increase in sample size was obtained on the 1971 spring groundfish survey by pooling results of two cruises on Georges Bank, one in March and one in May. The pooled data shown below represent an increase in numbers of hauls of about 50 percent over the standard sampling rate, and resulted in reductions in standard deviations of about the magnitude predicted by the analysis based on the 1963-70 series of cruises shown above.

--Spring 1971 groundfish survey.

	Cruise 1		Cruise 2		Cruises 1 & 2	
	2SD's	No. Hauls	2 SD's	No. Hauls	2 SD's	No. Hauls
Haddock (Strata 13-25)	.38	71	.53	37	.32	108
Yellowtail (Strata 13, 16, 19)	.52	30	.51	17	.37	47

These data suggest that the cost of detecting with high probability changes of stock size as small as ±10 percent would be extremely high. It is even doubtful that we could justify the cost of measuring changes within ±20 percent; to get to this level it would appear that for haddock we would need to make nearly 5 times as many hauls as in the current survey which employs about 65 hauls in strata 13-25 and achieves a precision of roughly ±50 percent (Table 6). In sampling for yellowtail it would appear that we would need almost as many hauls for strata 13, 16 and 19 alone, in order to obtain comparable levels of precision.

These results should be considered as first approximations since we have not fully investigated all of the characteristics of these data. For example it is possible that some improvement could be achieved with a modified log transformation which would further improve normalization of the data. Also it is possible that we could make a significant gain in precision by additional stratification according to time of day, for those species exhibiting strong

diurnal variations in availability. Additional stratification would cost something however, either in terms of fewer degrees of freedom for estimating stratum means and variances, or additional time at sea, or both. Thus there is no guarantee that additional stratification would achieve a net gain in information per unit cost. Further it is possible that the region could be more effectively stratified, for example by utilizing additional information on bottom sediments relative to groundfish distribution. However this too could only result in slight gains so long as we are interested in many species distributed over a wide area.

I think the most promising approach lies in controlling or at least monitoring the haul-to-haul performance of the trawl; for example we do not have a precise measure of groundspeed, nor do we know what variations occur in wingspread, headrope height or bottom contact. Even direction of tow relative to bottom currents may be important for some species.

Even after all such improvements are incorporated however, it seems clear to me that there cannot be any drastic change in the observed relation between precision and sample size. The hard fact is that in sampling organisms with highly contagious distributions, achieving high precision will require intensive sampling.

So far we have been considering the precision of a single mean. It is of course possible to combine seasonal means into a single annual index which would have a smaller variance. For example if the means of two surveys were averaged, the standard deviation of the resulting mean would be reduced by approximately a factor of 0.7 (assuming homogeneous variances for the original means). Thus if the separate standard deviations were on the order of .2 (corresponding to a ±50 percent level of precision), the standard deviation of the combined mean would be about .14, corresponding to a ±30 percent precision level. Essentially the same precision would have been achieved by simply doubling the sampling effort on one cruise, and in that sense there would be no gain in accuracy through combination of two cruises. However by combining results of more than one season within a given year, there is less likelihood of bias due to variation in seasonal availability factors.

Finally it should be noted that in most cases it usually takes at least several years for major changes in stock size to occur. Given annual surveys, we then have a number of points in a time series with which to test for a significant slope or trend, and precision of such a test would be greater than that indicated for a single survey.

Comparisons between research and commercial abundance indices

Returning now to the more general concept of accuracy, we need to consider further the problem of bias in conjunction with precision. In particular we are concerned about the possibility that the ratio of our relative abundance indices to the absolute (unknown) abundance may not be constant at difference levels of absolute abundance. We may gain some insight into this question by comparing abundance indices derived from both research and commercial catch data. However we must use care in making such comparisons because both types of data are subject to error. The commercial data are potentially more subject to serious bias, and research data are usually characterized by larger sampling errors.

The most serious biases in commercial abundance data arise from unknown
changes in the effective unit of effort usually related to economic or tech-
nological factors. Even with standard gear however, bias can result simply
from variations in avilability of fish. With proper sample design the research
vessel index is free of the first bias, but still may be subject to bias from
changes in availability. For example the catchability coefficient for a given
species and research trawl may change due to a change in vertical distribution
of the species, in response to some environmental factor or even as a function
of absolute abundance itself. The possibility of a significant bias of this
type intuitively would seem to be much greater for a species for which the
trawl has a very low efficiency. We shall return to this point later in
comparing joint US-USSR survey results.

From the standpoint of precision it is important to recognize that the
commercial abundance index nearly always will be more precise than a research
index simply becuase it is based on a very large number of hauls. However we
seldom obtain variance estimates for commercial indices since at best it is
a very complicated task involving many sources of error. It is a relatively
simple matter to obtain statistically valid estimates of sampling error from
surveys but unfortunately the errors are large.

With the above characteristics in mind we may now turn to some comparisons
of research and commercial indices. Fourth quarter U.S. landings/day figures
for cod, haddock, and yellowtail on Georges Bank, and U.S. fall survey abundance
indices for strata 13-25, are tabulated for the period 1963-1969 in Table 7.
The percentage deviations of each index from the '63-'69 mean are plotted in
Figure 4, and it is clear that the two indices are correlated for haddock and
yellowtail.

For yellowtail the commercial and research indices show quite similar trends
in relative abundance; and the magnitude of changes indicated by the research
indices was not much greater than that indicated by the commercial indices
(Fig. 4). Correlation coefficients were .95 (linear scale, survey) and .81
(log scale, survey), and both are significant at the 95 percent probability
level.

The correspondence is perhaps almost too good in this case. That is, if
the research index is accurate to within only ±50 percent changes in abundance,
then one might not expect such close correspondence from year to year when the
actual yellowtail abundance (based on fairly reliable commercial indices)
appeared to vary by no more than about 30 percent from the mean. In other
words there may be some indication here that variance estimates may be inflated.
More detailed study will be required to clarify this notion.

For Georges Bank haddock correlation coefficients are also significant at
the 95 percent level - .74 and .84 for linear and log scales respectively.
Corresponding trends in abundance are indicated but the research indices show
a much greater magnitude of change in stock size than is indicated by the U.S.
commercial index. In this case however the commercial indices are believed
to have been negatively biased particularly in the mid-1960's as has been
described by Hennemuth (1968). Another feature is that the efficiency of
vessels remaining in the fishery after 1967 probably was above average, which
might be the explanation for the apparent discrepancy in trend between the two
sets of indices in the late 1960's. It should be emphasized that changes in
efficiency of commercial fleets are quite likely when stock levels change
drastically.

There is less consistency between commercial and research indices for Georges Bank cod than for yellowtail and haddock. Up to 1967 there was a rough similarity in trends, but thereafter the correspondence is poor (Fig. 4). Correlation coefficients do not differ significantly from zero. In the later years it is possible that the scarcity of haddock may have resulted in a partial shift of effort toward cod, in which case the commercial index would have a positive bias. This too will require more detailed study.

Another set of comparisons is provided by U.S. commercial and research indices for haddock off western Nova Scotia (Table 8). The best comparison is afforded by the first quarter commercial indices vs. the spring research indices and these show quite a consistent picture both with respect to trend and magnitude of change (Fig. 5). Trends are basically similar between fall surveys and annual commercial indices, but an unusually large discrepancy occurred in 1967. Sampling error was not particularly high in that year (see Table 5) and so far I have no explanation for the apparent discrepancy.

Still another set of comparisons is available for red hake in southern New England. During the period 1965-1968 there was a rapid steady decline in abundance shown by both the catch per haul statistics of the USSR fleet and the U.S. survey (Table 9, Fig. 6). The commercial data suggest that by 1968 abundance had dropped to about one-quarter the 1965 level, and the survey data imply a decline to about one-third the 1965 level. Abundance appeared to increase again in 1969 as indicated by both commercial and research indices. In contrast to southern New England, comparisons for Georges Bank show poor correspondence between the commercial and research data for red hake (Table 9, Fig. 7). This may be partly due to the fact that after 1965 the principal fishing effort by the Soviet fleet on red hake occurred in southern New England, and Georges Bank effort was not directed specifically toward red hake.

To summarize briefly the comparisons among commercial and research indices, it appears that survey indices more often than not provide about the same trends and relative changes in stock size as do commercial indices. This I think is basically encouraging. The problem now is how to improve precision.

Table 7. Fourth quarter U.S. commercial abundance indices and *Albatross IV* fall survey indices for cod, haddock and yellowtail on Georges Bank. Commercial index: Landings/day (lb x 10^{-3}) 5Z east. Survey index: stratified mean catch/haul (lb, linear and log_e) strata 13-25.

	COD			HADDOCK			YELLOWTAIL		
		Survey			Survey			Survey	
Year	Comm.	lb	log_e lb	Comm.	lb	log_e lb	Comm.	lb	log_e lb
1963	2.1	25.1	1.8	8.2	118.6	3.3	8.7	21.6	2.0
1964	1.4	15.6	1.3	10.8	193.6	3.9	8.0	22.3	1.4
1965	0.8	7.5	1.3	14.9	131.0	4.0	7.3	14.7	1.3
1966	1.8	8.8	1.2	9.4	51.4	2.4	4.5	6.5	1.0
1967	2.5	20.0	1.7	5.7	43.1	2.4	6.1	11.7	1.3
1968	2.8	10.8	1.0	6.1	19.2	1.2	7.7	17.7	1.4
1969	5.1	7.5	1.3	4.8	5.6	1.1	6.1	14.4	1.4

Table 8. Haddock abundance indices for 4X based on U.S. commercial data and *Albatross IV* surveys. Commercial index: U.S. landings per day, metric tons rd. fresh, Browns Bank survey: stratified mean catch per haul ($\log_e$ pounds), strata 31-35, 41, 42.

| Year | Commercial | | Survey | |
	Annual	1st Qtr.	Fall	Spring
1963		6.9		
1964	7.5	6.9	-	-
1965	6.5	5.3	3.61	-
1966	4.7	6.8	3.22	3.72
1967	5.4	3.4	3.87	-
1968	4.5	3.3	2.93	3.13
1969	3.4	3.2	2.68	2.53
1970			2.82	2.99

Table 9. Abundance indices for red hake in New England waters based on catch per haul statistics from USSR fleet[1], and joint USA-USSR groundfish surveys[2].

	RED HAKE					
	So. New England (strata 1-12)			Georges Bank (strata 13-25)		
	Fleet	Survey		Fleet	Survey	
Year	USSR	USSR	USA	USSR	USSR	USA
1965	2.44		1.85	1.32		0.78
1966	1.69		1.48	2.39		0.72
1967	0.96	2.07	1.05	0.96	0.84	0.46
1968	0.56	1.88	0.79	0.62	1.79	0.64
1969	1.75[3]	2.20	1.18	-	1.03	0.85
1970	-	2.36	1.35	-		0.44

[1] Catch per haul hour for red hake from ICNAF research document 70/39 by Richter, for "stocks I and II" which correspond approximately to strata sets 13-25 and 1-12 respectively.

[2] Stratified mean catch per haul (pounds, natural log scale).

[3] Estimate provided on graph by Dr. Noskov at Working Group in Copenhagen, January 1971.

Table 10. Stratified mean catch per haul ($\log_e$ pounds) of selected species in southern New England (strata 1-12). USA and USSR joint surveys.

RED HAKE

Year	Strat. mean		Variance		S.D.		S.D./mean		No. hauls	
	U.S.	USSR	U.S.	USSR	U.S.	USSR	U.S.	USSR	U.S.	USSR
1967[1]	1.05	2.07	.0229	.0554	.1513	.2354	.14	.11	65	40
1968	0.79	1.88	.0238	.0421	.1543	.2052	.20	.11	62	46
1969[2]	1.18	2.20	.0236	.0760	.1536	.2757	.13	.12	66	42
1970	1.35	2.36	.0199	.0314	.1411	.1772	.10	.08	64	56

SILVER HAKE

	U.S.	USSR	U.S.	USSR	U.S.	USSR	U.S.	USSR
1967	1.63	2.64	.0202	.0579	.1421	.2406	.09	.09
1968	1.80	3.62	.0155	.0404	.1245	.2010	.07	.06
1969	1.20	3.38	.0142	.0676	.1192	.2600	.10	.08
1970	1.35	3.71	.0125	.0273	.1118	.1652	.08	.04

YELLOWTAIL

	U.S.	USSR	U.S.	USSR	U.S.	USSR	U.S.	USSR
1967	2.25	1.70	.0270	.0514	.1643	.2267	.07	.13
1968	2.03	1.78	.0380	.0592	.1949	.2433	.10	.14
1969	2.00	1.75	.0361	.0708	.1900	.2661	.10	.15
1970	2.12	1.50	.0420	.0657	.2049	.2563	.10	.17

[1] No. hauls in stratum 10; sampling in strata 9, 11, 12 restricted to area west of 70°W.

[2] 24.6 m trawl used by USSR vessel in 1969; 27.1 m trawl used by USSR vessels in all other surveys.

Comparisons between USA and USSR survey indices

The larger USSR trawls appear to have up to 5 times the fishing power of the USA survey trawl for some species, as indicated by trawl comparison experiments and joint surveys since 1967 (Hennemuth, 1968; Grosslein and Sauskan, 1970). The question arises whether there is any significant relation between fishing power and accuracy of the abundance indices. We have been particularly concerned about the possibility that in the case of species for which our U.S. gear has relatively low fishing power (*e.g.* silver hake), relatively minor changes in behavior and especially vertical distribution might change avilability enough to obscure real changes in abundance. So far there is no clear evidence of any such disadvantage with the smaller trawl from the standpoint of accuracy.

Table 11. Stratified mean catch per haul ($\log_e$ pounds) of selected species in Georges Bank (strata 13-25). USA and USSR joint surveys.

COD

YEAR	Mean		Variance		S. D.		S.D./mean		No. hauls	
	USA	USSR	USA	USSR	USA	USSR	USA	USSR	USA	USSR
1967	1.74	–	.0473	–	.2175	–	.12	–	67	–
1968[1]	1.04	1.19	.0319	.0400	.1786	.2000	.17	.17	69	49
1969[2]	1.32	1.59	.0254	.0178	.1594	.1334	.12	.08	73	37
1970[3]	1.35	0.87	.0332	.0367	.1822	.1916	.13	.22	70	31

HADDOCK

	USA	USSR	USA	USSR	USA	USSR	USA	USSR
1967	2.45	1.07	.0521	–	.2282	–	.09	–
1968	1.15	1.07	.0296	.0248	.1720	.1667	.15	.16
1969	1.10	1.65	.0215	.0649	.1466	.2548	.13	.15
1970	1.35	0.57	.0345	.0285	.1857	.1688	.14	.30

YELLOWTAIL

	USA	USSR	USA	USSR	USA	USSR	USA	USSR
1967	1.32	–	.0277	–	.1664	–	.13	–
1968	1.40	1.01	.0382	.0340	.1954	.1844	.14	.18
1969	1.35	1.91	.0252	.0615	.1587	.2480	.12	.13
1970	0.96	1.80	.0204	.0878	.1428	.2963	.15	.16

[1] No hauls by USSR vessel in 1968 in stratum 25 and only one haul each in strata 15, 17 and 22.

[2] 24.6 m trawl used by USSR vessel in 1969; 27.1 m trawl used by USSR vessels in all other surveys.

[3] No hauls in strata 23-25 by USSR vessel in 1970.

With respect to sampling errors we find that variances of stratified means are fairly comparable for the two sizes of gear, and they appear to be rather independent of fishing power differentials. For example the fishing power differential is large for red hake but quite small for cod, haddock and yellow-tail, and yet variances are quite similar for all these species and both types of trawl in New England waters (Tables 10, 11). Generally similar results were obtained in the 1970 surveys off Nova Scotia (Table 12).

Table 12. Stratified means (catch per haul, $\log_e$ pounds) and measures of precision for selected species in 1970 surveys in Division 4X (sampling strata 31, 32, 41-49); USSR (34 hauls), USA (45 hauls).

Species	Stratified mean		Variance		S.D.		Mean ± 2 S.D.		Factor difference	
	USA	USSR	USA	USSR	USA	USSR	USA	USSR	USA	USSR
Cod	1.20	0.55	.0690	.0416	.2627	.2040	.68-1.72	.15-.95	2.9	2.2
Haddock	2.05	1.81	.0231	.0574	.1520	.2396	1.75-2.35	1.33-2.29	1.8	2.6
Am. Dab	0.83	0.21	.0214	.0041	.1463	.0640	.53-1.13	.09-.33	1.8	1.3
Yellowtail	0.35	0.11	.0227	.0041	.1507	.0640	.05-.65	0-.23	1.8	1.3
Silver hake	0.85	1.02	.0216	.0941	.1470	.3068	.55-1.15	.40-1.64	1.8	3.4

With respect to comparability of trends we find very close correspondence between the indices for red hake in southern New England, in both direction and magnitude (Fig. 6). The correspondence is not as good for silver hake in the southern New England area but the direction of change is the same from year to year (Fig. 7). More variability between the two indices was encountered for both red and silver hake on Georges Bank, where they were less abundant, but again the correspondence was better for red hake (Figs. 6, 7). These data are difficult to interpret because the USSR trawl used in 1969 was not the same as that used in 1967 and 1968; the 1969 gear obviously had greater fishing power. Furthermore sampling with the USSR trawls on Georges Bank was less intensive (and not consistent in the sense that all areas were not fished each year) because of more frequent tear-ups and necissity of avoiding rough bottom.

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21. Commercial fishes taken on the shrimp grounds of the Northwest Atlantic[1]

by B. Fontaine
ISTPM, St. Pierre et Miquelon

Introduction

Whether they are in coastal or open waters, shrimp grounds rarely provide exclusive catches of shrimp. Fish which appear in trawl hauls made on such grounds, at least those which are of commercial value, are among the species common to the whole Northwest Atlantic.

This paper attempts to show the importance and species composition in trawl hauls made by research vessels which provide a good yield of deep shrimp, *Pandalus borealis*.

The grounds described here are divided into different sections, starting from Georges Bank to the West Greenland coast; either coastal, such as the Burgeo trench or Esquiman Channel or offshore grounds as for all other sections.

Fishing areas

To simplify matters, the grounds which provided a good shrimp yield are designated by the name of the most general area where they are located. The position and characteristics of these grounds for each section are specified below.

1. Georges Bank section

The deep shrimp was taken in the deep located to the west of Georges Bank; this deep is indicated on the charts as Georges Basin.

In May and June 1969, seven trawl hauls, made between 145 and 195 m, provided an average shrimp yield of 38 kg/hr of trawling.

2. Nova Scotia section

The shrimp grounds are located in certain trenches dividing the banks, *i.e.*, the trench of the LaHave Bank, that of Emerald Bank, of Canso Bank, *etc.*

In March and April 1967, eight trawl hauls, spread over these deeps between 170 and 250 m, gave an average shrimp yield of 40 kg/hr of fishing.

3. South Newfoundland section

This region comprises the complex formed by the Laurentian Channel, its slopes and canyons, *i.e.*, the deeps located between the banks of the northeast region of Nova Scotia Shelf. The Burgeo Trench is dealt with separately.

Eight hauls, made in May 1970 at 190-320 m, provided an average shrimp yield of 22.5 kg/hr of fishing.

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[1] Submitted to the 1971 Annual Meeting of ICNAF as ICNAF Res.Doc. 71/62.

4. Burgeo Trench

This well-defined trench has been fished as a typical coastal grounds, as is the Esquiman Channel. It extends along the south Newfoundland coast, from La Poile Bay to Ramea Islands, inside Rose Blanche and Burgeo Banks. The soundings are in the order of 220-250 m.

Ten hauls, made in December 1970, gave average shrimp yields of 42 kg/hr of fishing.

5. Esquiman Channel

This deep is located in the Gulf of St. Lawrence, along the west coast of Newfoundland; it is about 43 miles wide at the level of Anticosti Island and gradually decreases, disappearing near the Newfoundland coast opposite Port-au-Choix.

Six hauls in December 1970, at depths of 225-250 m, yielded shrimp at an average of 83 kg/hr of fishing.

6. Labrador section

The important grounds are located off the Labrador coast and the east-northeast coast of Newfoundland, particularly northeast of Hopedale and off Bonavista Bay.

For eleven trawl hauls made at 350-400 m, shrimp catches averaged about 30 kg/hr of fishing.

7. West Greenland section

In July and August 1970, R/V *Thalassa* made good catches in different areas of the west coast of Greenland. These consisted of deeps located on the eastern edge of Fyllas Bank off Godthaab, east-southeast of Banana Bank, south-southeast and north of Lille Hellefiske Bank.

Depths varied according to zone, from 250-550 m; for 17 trawl hauls the average deep shrimp yield was 40-80 kg/hr of fishing.

Method of capture

Two types of gear were used during the different cruises. For the south of Newfoundland, Burgeo Trench and Esquiman Channel sections, a shrimp trawl "balloon type", with a 60-mm mesh in the wing, back and belly, and 40 mm in the "amorce" and codend (stretch mesh) was used. For all other sections, a bottom trawl of the "Lofoten" type, with a bobbin groundrope, 140-mm mesh in the wings, back and belly and 50 mm in the codend was used. In the study of the Greenland section, this codend was lined wth a 30-mm mesh net.

Results

The results are given in three tables. Table 1 gives the number of hauls per 100 trawl hauls on the shrimp beds, in which each fish species of commer- cial value was observed. This table shows the rate of occurrence of a species and not the quantity of animals caught; the crosses indicate rates lower than

Table 1. Abundance index (percentage of hauls containing each fish species) of commercial species taken on the shrimp beds. Crosses (+) indicate an index less than 30.

Species \ Fishing areas	Georges Bank	Nova Scotia	South of Newfoundland	Burgeo Trench	Esquiman Channel	Labrador	Greenland
Squalus acanthias	57	+	+	–	–	–	–
Raia radiata	100	75	88	100	100	90	+
Raia senta	71	75	75	100	83	–	–
Raia spinicauda	–	–	–	–	–	+	–
Raia laevis	+	–	+	–	–	–	–
Raia erinacea	–	–	+	–	–	–	70
Clupea harengus harengus	85	+	75	100	100	–	–
Mallotus villosus villosus	–	50	+	+	+	30	+
Argentina silus	+	37	37	60	–	+	–
Merluccius bilinearis	100	37	62	+	–	–	–
Brosme brosme	42	–	–	–	–	–	–
Urophycis tenuis	71	75	88	100	+	–	–
Urophycis chesteri	–	37	62	–	–	–	–
Gadus morhua morhua	85	100	37	100	100	100	65
Gadus morhua ogac	–	–	–	–	–	–	+
Boreogadus saida	–	–	–	–	–	–	+
Melanogrammus aeglefinus	85	87	+	+	+	–	–
Pollachius virens	57	87	–	40	–	–	–
Molva dipterygia	–	–	–	–	–	–	+
Macrurus sp.	+	35	50	–	–	70	30
Anarhichas lupus	–	+	+	–	+	80	40
Anarhichas minor	–	+	–	–	–	90	30
Sebastes sp.	100	100	100	100	100	100	85
Hippoglossoides platessoides	100	100	100	100	100	80	95
Hippoglossus hippoglossus	–	50	–	–	66	–	–
Reinhardtius hippoglossoides	+	87	62	100	100	90	95
Glyptocephalus cynoglossus	100	100	100	100	100	80	–
Lophius americanus	57	50	88	80	+	–	–

30 which, according to us, represented an accidental occurrence. Table 2 gives the average weight in kg of different commercial fish caught with 100 kg of deep shrimp. Table 3 indicates the size composition of catches for the five most important commercial species. These tables require, however, explanation which will be given when the different species considered are reviewed.

Sharks appeared in some hauls in the Georges Bank section in very small numbers, or as isolated individuals. Rays are almost always present on shrimp

Table 2. Weight (in kilos) of the different commercial fishes taken with 100 kg of deep shrimp.

Fishing areas and dates / Vernacular names	Georges Bank May–June 1969	Nova Scotia March–April 1967	South of Newfoundland May 1970	Burgeo Trench December 1970	Esquiman Channel December 1970	Labrador August–September 1966	Greenland July–August 1970
Dogfish (Chien de mer)	14	-	-	-	-	-	-
Rays (Raies)	154	87	103	45	37	67	12
Herring (Hareng)	31	-	30	58	56	-	-
Argentine	-	-	62	32	-	-	-
Silver hake (Merlu)	41	28	36	1	-	-	-
Cusk (Brosme)	15	-	-	-	-	-	-
Red hake (Morue barbue)	88	110	154	165	1	-	-
Cod (Morue)	253	390	29	62	218	322	28
Haddock (Eglefin)	84	135	-	1	1	-	-
Pollock (Lieu noir)	54	53	-	2	-	-	-
Grenadiers (Rats)	-	-	-	-	-	200	-
Wolffish (Loups)	-	27	-	-	-	105	24
Redfish (Rougets)	175	867	940	2703	1044	939	21
American plaice (Balai)	131	208	62	15	24	59	125
Halibut (Flétan)	-	8	-	-	10	-	-
Greenland halibut (Flétan noir)	-	13	27	43	126	74	125
Witch (Sole grise)	32	272	83	272	72	54	-
Angler (Lotte)	19	5	35	21	-	-	-
Total	1091	2203	1561	3420	1589	1820	335

grounds; only the species *Raia radiata* is of some importance by weight, except in Greenland where it is replaced by *Raia erinacea*. *Raia senta* is often represented, but always by a very limited number of individuals.

Herring, even if not of great importance by weight, were caught more or less regularly in certain sections. In the Burgeo Trench, the maximum catch per hour was 86 kg. In the absence of pelagic detection, it is supposed they were dispersed on the bottom.

Table 3. Length composition of the catch of five of the most important commercial species.

Species	Fishing areas	Georges Bank	Nova Scotia	Labrador	Greenland	South of Newfoundland	Burgeo Trench	Esquiman Channel
Cod	range of lengths (cm)	53-132	39-92	19-128	35-99	20-95		
	less than 40 cm	0%	5%	31%	0%	20%		
	between 40 and 60 cm	10%	66%	55%	15%	67%		
Redfish	range of lengths (cm)	14-42	7-38	7-60	7-43	11-43	7-43	
	less than 25 cm	77%	51%	20%	70%	83%	87%	
	between 25 and 35 cm	18%	44%	26%	25%	15%	9%	
American plaice	range of lengths (cm)	13-68	10-52	13-56	11-50	15-57	14-66	10-63
	less than 30 cm	40%	61%	72%	48%	66%	79%	87%
	between 30 and 40 cm	46%	32%	20%	44%	19%	11%	7%
Greenland halibut	range of lengths (cm)	-	-	13-84	12-78		21-61	
	less than 40 cm	-	-	43%	79%		48%	
	between 40 and 60 cm	-	-	44%	10%		47%	
Witch	range of lengths (cm)	35-60	21-55	26-66	-		13-58	17-49
	less than 30 cm	0%	5%	13%	-		32%	42%
	between 30 and 40 cm	15%	76%	27%	-		41%	30%

Argentine were only caught on the shrimp grounds in the south of Newfoundland in May, and in the Burgeo Trench in December.

Silver hake were caught on Georges Bank. The catches consisted of specimens 12-52 cm in total length, and about 30% were less than 15 cm.

Cusk seem almost accidental on Georges Bank as they are represented only by isolated individuals.

Red hake, *Urophycis tenuis*, occur in catches from Georges Bank to the Burgeo Trench (Table 2). This species is represented by a limited number of individuals whose sizes vary from 22-98 cm, and only 31% are less than 40 cm total length.

Cod caught with the deep shrimp in the Burgeo Trench and Esquiman Channel were not measured; individuals of less than about 40 cm were weighted separately.

In the Burgeo Trench, the numbers of cod caught were very small but were always of a large size. Thus, one of the hauls provided two cod of 132 and 121 cm, weighing 19 and 17 kg respectively. The same observations are valid for the Georges Bank and Greenland sections.

In the Esquiman Channel, cod less than 40 cm formed 20% of total weight. This section can be compared with those of Nova Scotia, south of Newfoundland, and Labrador.

Redfish caught in Esquiman Channel were not measured; individuals less than 25 cm made up approximately 35-40% of total weight. Table 3 shows that the Labrador section and, to a lesser degree, the Nova Scotia section provided in association with the shrimp, good commercial catches of redfish. From Nova Scotia to Labrador, redfish in the catches constitutes a problem for the shrimp fishery by being a nuisance and by damaging the shrimp which are more fragile than the fish.

American plaice were present in nearly all hauls with smaller quantities being taken in coastal deeps. Approximately 90% of the individuals caught were less than 40 cm in length.

Greenland halibut were not measured in the areas south of Newfoundland, nor in Esquiman Channel or Greenland, where it has some importance in weight.

Witch, rare in Greenland where only one specimen was taken, are well represented in hauls from Nova Scotia and from the Burgeo Trench. Individuals of less than 30 cm are more numerous on coastal than offshore grounds. Catches from Newfoundland were not measured.

American angler were present fairly regularly in catches from Georges Bank to Burgeo Trench. However, the number of individuals caught by trawl was always small.

Conclusion

Shrimp grounds located off the west coast of Greenland are of particular interest as shown clearly in Table 2. For all other sections, fishing of deep

shrimp involves taking a large quantity of fish of commercial value. These catches are unfortunately made up of a large number of individuals of small non-commercial size. This fact is particularly clear in the case of American plaice and redfish. The minimum sizes of fish caught are identical so we use a trawl with codend of 50 or 30 mm (stretch mesh); however, using a shrimp trawl catches a greater proportion of fish of smaller size.

The coastal shrimp grounds and, to a lesser degree, those offshore in the Northwest Atlantic are the areas of concentration of the young of certain species.

Data on fish catches accompanying the shrimp catch are accurate but little information exists about the importance of the quantity of rejected fish. A study of the influence of small mesh trawls on fish populations encountered on offshore shrimp grounds will be made and it is hoped that the coastal shrimp grounds can also be investigated.

22. Summary report of the ICNAF NORWESTLANT surveys, 1963[1]

by E. Smidt
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The NORWESTLANT surveys was the first large scale international scheme
of environmental research sponsored by ICNAF. Not less than 8 member countries
took part with 10 research vessels during April-July 1963 in the northwestern
Atlantic. Three surveys were carried out, namely NORWESTLANT 1 in April, 2
in May-June, and 3 in July. The surveys were carefully planned during several
meetings and a detailed Guide Book was prepared. Mr Arthur Lee (Lowestoft)
was the enthusiastic and dynamic organizer.

The main aim of the surveys was to establish the distribution and drift
of the eggs and larvae of cod and of the larvae of redfish, in relation to
specific environmental factors in the area. Other fish species were also
included. In addition, observations were made on adult fish and marine mammals.

Figure 1 shows the NORWESTLANT survey area and the grid stations occupied
during NORWESTLANT 2. Much meteorological, hydrographical, and biological data
was collected by the research vessels, and also by weather ships. All material
collected was worked up by the institutions in the different collecting countries.
The results were then sent to scientific coordinators who prepared the various
reports.

This paper reviews the results which are relevant to the main aim of the
surveys, and which are especially important to Subarea 1. The results were
published in ICNAF Special Publication No. 7, Part I (Text) and II (Atlas) in
1968 and distributed in 1969. The original Oceanographical and Biological
Data were distributed as Parts III and IV respectively.

I. Meteorological conditions and physical and chemical oceanography

Weather conditions were abnormal in 1963 and the surveys were carried out
in particularly stormy weather which influenced the stability of the water
layers. Ice conditions, however, were nearly normal along both the east and
west coast of Greenland.

Surface water temperature anomalies were calculated in different areas
in the different months. In the area north of 55°N lat., positive anomalies
in April ranged from about 1°C off West Greenland to 0.4°C off East Greenland.
South of 55°N lat., anomalies were slightly negative. In the months following
the anomalies were generally decreasing, especially off West Greenland.

The stability of the surface water layers, which is important to primary
production, was determined by Mr Arthur Lee as density differences between the
surface and 50 m. During NORWESTLANT 1 (April) there was little stability over
the area as a whole, except in certain zones where cold, low salinity water
covered warmer, high salinity water. This was most extensive off West Green-
land where north to northeast winds had driven the low salinity coastal water
westwards over water of Irminger Current origin. During the months following
the zones of stability expanded until in July the whole area had a certain
amount of stability. However, off West Greenland, stability had decreased in
July.

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[1] For published details, see ICNAF *Special Publication*, No. 7, 1968.
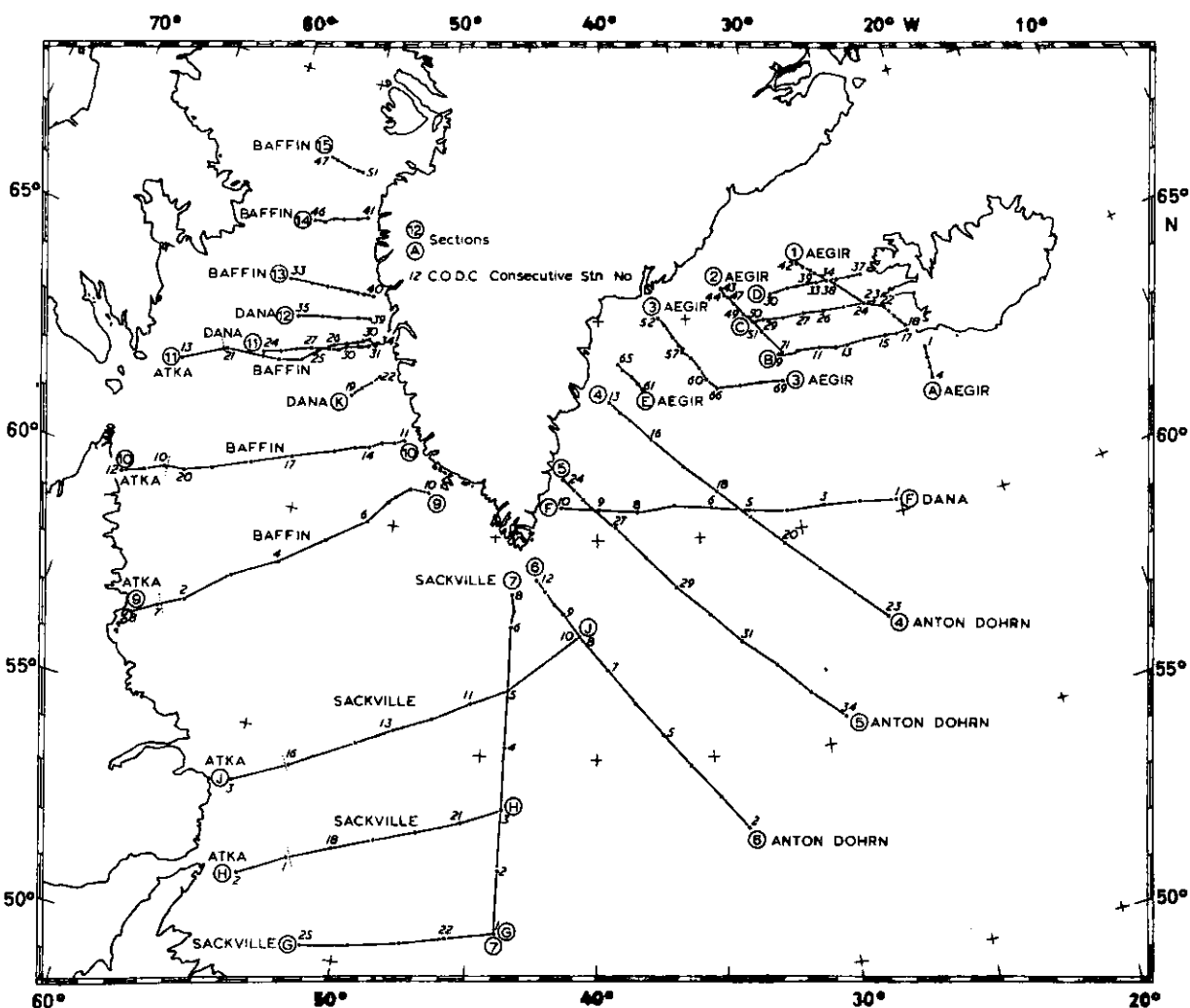
Fig. 1. NORWESTLANT 2., stations and sections. (Chart 32 in the NWL publication.

The distribution of phosphates, silicates, and dissolved oxygen from 0-100 m was in good agreement with the stability conditions. In April there was very little well-defined stratification of phosphates and silicates except in Davis Strait. Here, a high percentage of oxygen saturation was also found.

II. Phytoplankton production

Investigations on the phytoplankton were carried out using various methods of which the most comprehensive was to give a picture of the seasonal and geographical distribution of the total phytoplankton as micrograms of carbon per litre, μgC/ℓ. Phytoplankton from water samples taken at all stations from 10-m depth was treated by Dr M. Gillbricht (Hamburg). The main results are presented in charts showing the distribution during each survey.

During NORWESTLANT 1 (Fig. 2) phytoplankton was only abundant west of Greenland with a maximum of about 50 μgC/ℓ at 64°N lat. In almost all other areas production was less than 5 μgC/ℓ. This early (April) phytoplankton
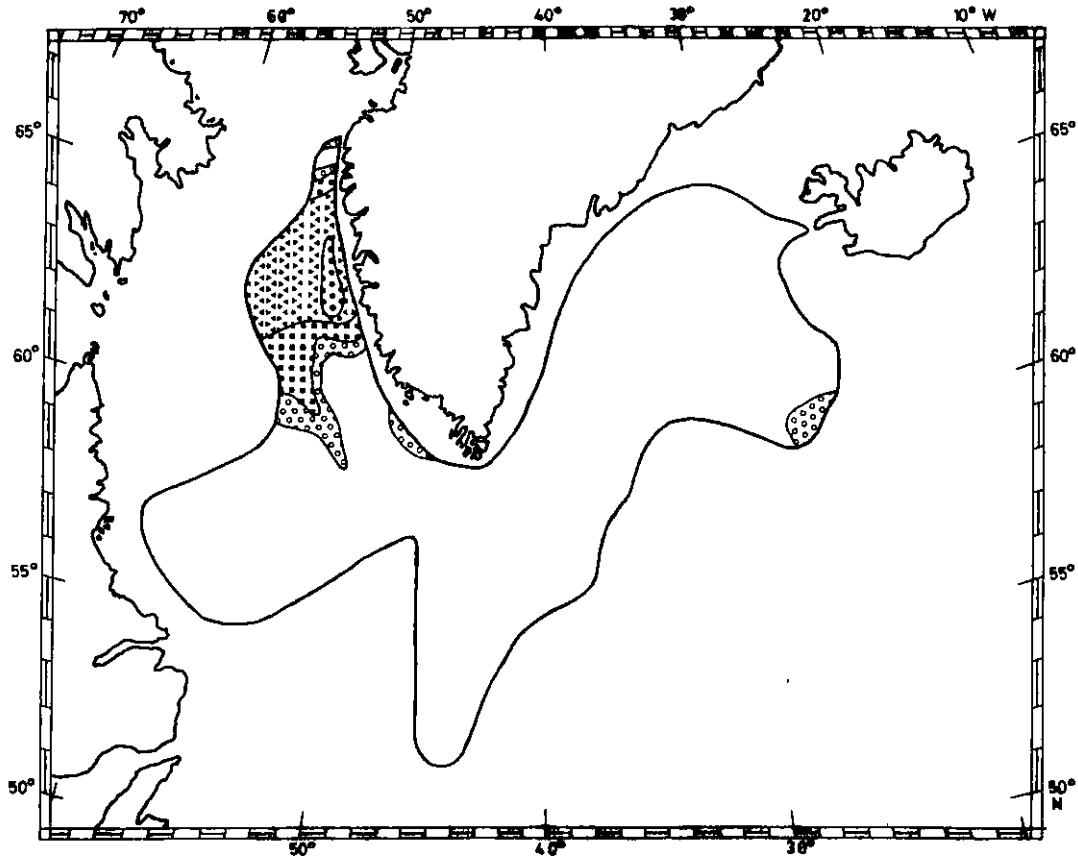
Fig. 2.   Phytoplankton at 10 m in μgC/ℓ during NORWESTLANT 1.
Contour levels at 5, 10, 20, 50, and 100 μgC/ℓ.   (Chart
180 in the NWL publication.)

maximum at West Greenland is in agreement with the early stability of the
water masses in the area.   During NORWESTLANT 2, the phytoplankton was at its
maximum in most of the area, as the water had now become generally stabilized.
During NORWESTLANT 3 there was an overall decline, especially at West Greenland.

Figure 3 shows the pattern of phytoplankton distribution during NORWESTLANT
3 (July), which is in good agreement with the distribution of the gross produc-
tion around Greenland in July-August of 1954, as measured by the carbon-14
technique during the cruise of *Dana*.   Figure 4 (after Steemann Nielsen, 1958)
shows a high rate of production where fronts between two current systems are
found and where deeper water ascends to the surface.   Such productive areas
were found: 1)   at the front between the Atlantic Current and the water from
the Irminger Sea;   2)   outside the East Greenland Current;   3)   at the front
between the Labrador Current and the oceanic water in the centre of Davis Strait;
and   4)   off the West Greenland coast.   An illustration of the hydrographic
mechanism is given in the NORWESTLANT Report by Mr F. Hermann.   The front area
between the light water component of the West Greenland Current and the heavy
Irminger water component is an area with horizontal turbulence causing vertical
water movements.   A section over Fyllas Bank (Fig. 5) in July shows the density
conditions, the current velocity with a maximum in the front over the western
slope of the Bank, and the upwelling of phosphate-rich and oxygen-poor water.
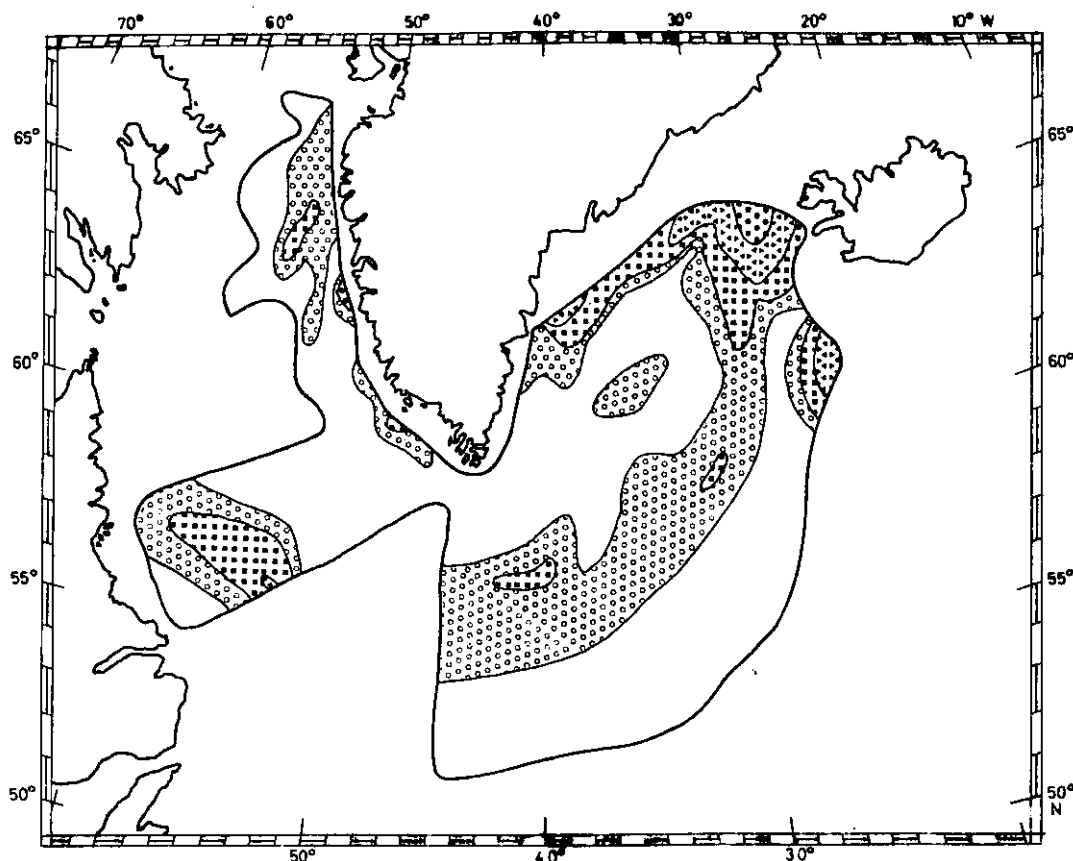
Fig. 3. Phytoplankton at 10 m in μgC/ℓ during NORWESTLANT 3.
Contour levels as in Fig. 2. (Chart 183 in the NWL
publication.

In addition to the above-mentioned investigations on the distribution of
phytoplankton in the whole area, less extensive research on the primary produc-
tion was made by chemical methods between southwestern Greenland and Labrador
from USSR vessels (M.V. Fedosov and I.A. Ermachenko). Phytoplankton abundance
was estimated from the silks of the continuous plankton recorder surveys (G.A.
Robinson). Estimates of chlorophyll-a concentration were made by 4 countries
(J.H. Steele). The results of these additional investigations seem to be in
agreement with those for the whole area. Further, the continuous plankton
records allowed comparison of conditions in 1963 to those of other years from
1958 to 1964 for all areas, except West Greenland. Production off West Green-
land was already abundant in May 1963, about a month earlier than in 1962, the
only year for.which data are available for comparison from that area. Else-
where, the production was relatively small, presumably due to the late stabi-
lizing of the water layers, but it was close to its normal timing.

III. The zooplankton

Much zooplankton material was collected during the surveys using the
different nets described in the Guide Book, namely, 1) Hensen net: diameter
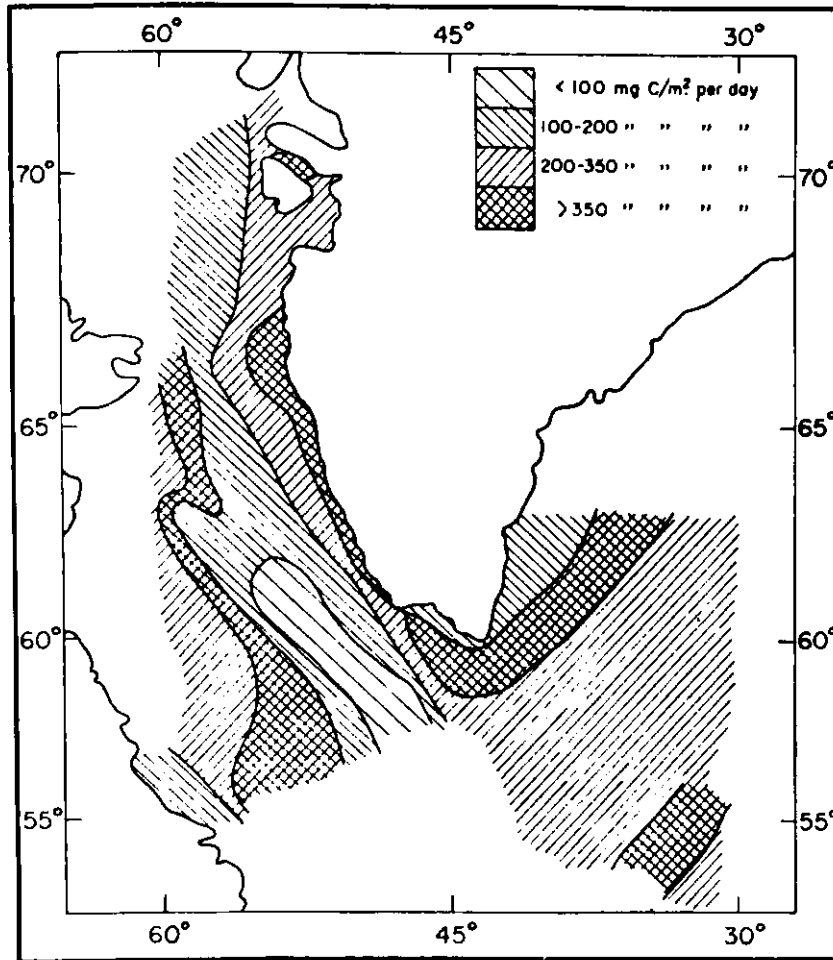
Fig. 4.   Gross production in the waters around Greenland in July-August 1954.
          The results from similar investigations in 1955, 1956, and 1957 agree
          in principle fully with those from 1954.   (After Steemann Nielsen, 1958).

72 cm, hauled vertically from 100 m to the surface, or from a few metres off
the bottom at stations less than 100 m in depth;   2)   stramin net: diameter
2 m, hauled obliquely from about 50 m to the surface at 1.5 knots, duration
about 30 min;   3)   Icelandic High Speed Sampler (IHSS):   an aluminum body 1 m
in length with a sampling aperture 90 mm in diameter, with a silk or nylon
gauze bag inside, hauled obliquely from about 50 m to the surface at 5 knots,
duration about 30 min.

The most complete coverage of the stations on all surveys was with the
Hensen net and the stramin net, while the IHSS was only used regularly by few
vessels.   In addition to these standard nets, the Nansen net and the Helgoland
larva net were used in some cases.

Displacement volumes were measured on board the vessels, while most of
the sorting and counting was done at the different laboratories.   At a meeting
in October 1963 it was agreed which species caught by stramin net and IHSS
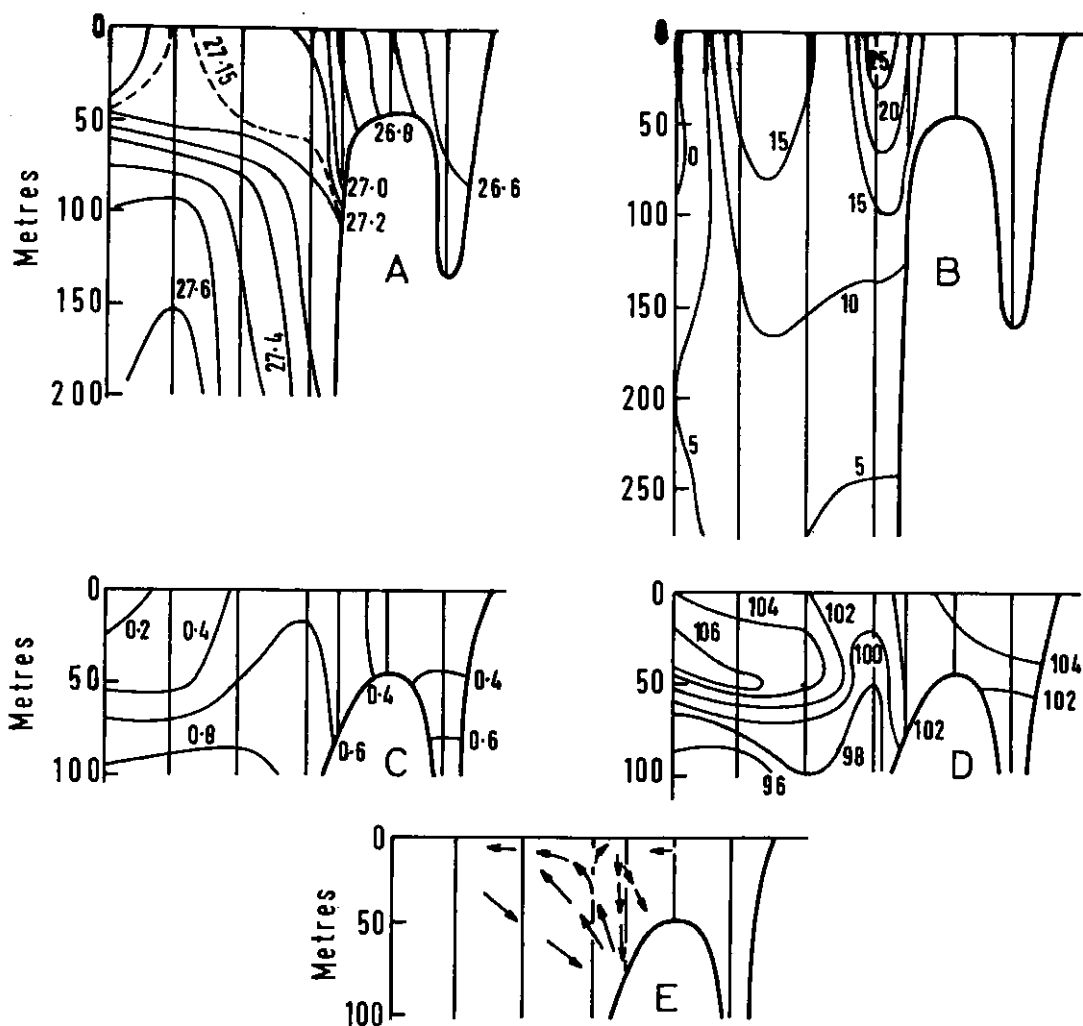
Fig. 5. Section over Fyllas Bank, 6-7 July 1963 (NORWESTLANT 3).
A - Sigma-t;   B - Currents (cm/sec) normal to the section, all
north-going;   C - PO₄-P (µg at/ℓ);   D - Dissolved oxygen content
(percent saturation);   E - Vertical water movements.
(Fig. 9 in the NWL publication.)

should be given priority for determining their total numbers. Animals in
samples from vertical hauls were recorded as numbers under 1 m² of the sea
surface within the top 100 m. The material was coordinated by Mr V. Bainbridge
(Edinburgh) and Mr J. Corlett (Lowestoft), who prepared distribution charts,
made figures, and prepared the reports. In addition, continuous plankton
records were published (Mr R.S. Glover and Mr G.A. Robinson, both Edinburgh).

In the Irminger and Labrador Seas the species composition showed consider-
able uniformity with *Calanus finmarchicus* as the dominant member of the zoo-
plankton, followed by *Euchaeta norvegica*, *Thysanoessa longicaudata*, *Conchoecia
obtusata*, *Spiratella retroversa*, *Aglantha digitale* and *Eukrohnia hamata*. In
the central part of Davis Strait, the plankton was somewhat the same but, in
addition to *Calanus finmarchicus*, there were substantial numbers of *C. glacialis*
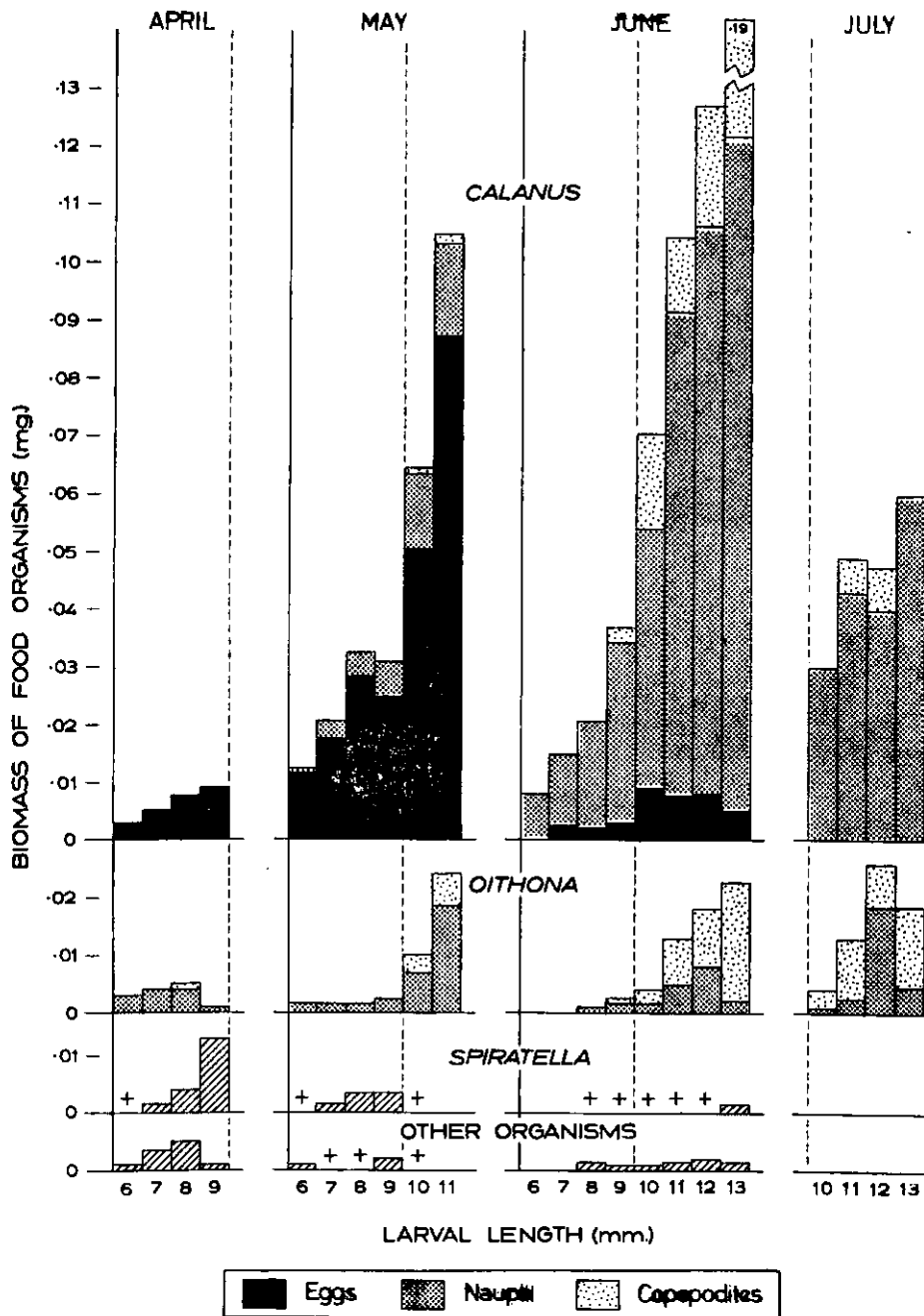
Fig. 6. The mean biomass of various food organisms in redfish
larvae of all length-groups from 6 to 13 mm during
NORWESTLANT 1-3 (April-July). (Fig. 52 in the NWL
publication.)

and *C. hyperboreus*. In the Icelandic coastal waters there was a greater divers-
ity of species. Quantities of zooplankton were lowest in the cold waters of
the East and West Greenland Currents.

In this brief review it is impossible to go into detail about all the
selected species. Only animals important to the feeding and predation of fish
larvae are mentioned hereafter.
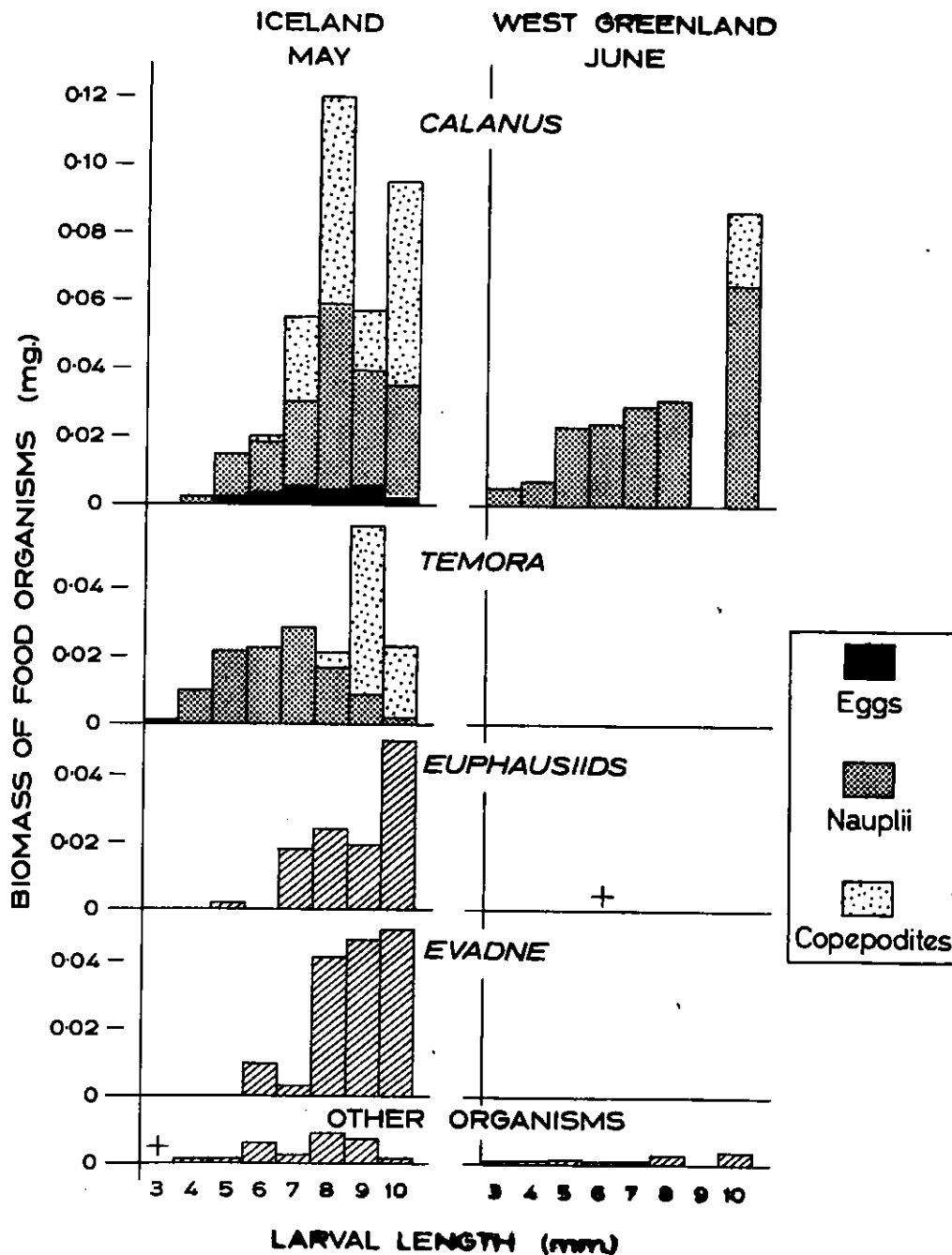
Fig. 7. The mean biomass of various food organisms in cod larvae of all
length-groups from 3 to 10 mm during NORWESTLANT 2 (May-June)
at Iceland and at West Greenland. (Fig. 53 in the NWL publication.)

1. The feeding of cod and redfish larvae

An important part of the NORWESTLANT surveys was an excellent comparative
study of the food of redfish and cod larvae by Mr V. Bainbridge and Mr B.J.
McKay (both Edinburgh) over a wide area.

It was shown that *Calanus finmarchicus* is by far the most important food organism for both redfish and cod larvae.

Recently extruded redfish larvae in the Irminger Sea are principally feeding on *Calanus* eggs in April and May, while older larvae taken in June and July in the Irminger Sea and Davis Strait were eating mainly nauphlii and copepodites of *Calanus* (Fig. 6).

The food of cod larvae is shown in Fig. 7. At West Greenland the larvae feed almost exclusively on different stages of *Calanus*, while in the Icelandic area the diet is more varied consisting also of other copepods, euphausids, *Evadne*, and some other organisms. The differences in the diet of cod larvae from the two areas reflect the diversity of the neritic zooplankton off Iceland compared with the more restricted species composition of the zooplankton in the West Greenland waters. It is also noted that cod larvae from the Icelandic area contained about twice the amount of food found in larvae from West Greenland waters, a difference which seems to be correlated with the availability of food in the plankton. Further in this connection, it should be noted that cod larvae off Iceland and in Denmark Strait seem to have a higher growth rate than at West Greenland.

Larvae of both redfish and cod showed a similar diurnal feeding pattern. The amount of food found in the gut decreased throughout the night to a minimum about sunrise.

In addition to the NORWESTLANT samples, a large number of cod larvae collected off West Greenland in 1950, 1957, 1958, and 1961 were also examined. In all but one of 18 samples, various stages of *Calanus* constituted more than 95% by weight of the food of the larvae.

2. *Calanus finmarchicus*

"Since *Calanus* is both the dominant herbivore and the principal food consumed by cod and redfish larvae in the seas around Greenland, the seasonal development of this species will be considered in detail. Average numbers of each copepodite stage per m^2 of sea surface have been calculated for each survey in seven standard areas using data from the Hensen-net samples." The standard areas are shown in Fig. 8, and averages obtained are shown as histograms in Fig. 9.

It is known (Marshall and Orr, 1955; Østved, 1955) that *Calanus* overwinters in deep water as late copepodite stages, and in cold waters there is only one generation per year. During spring, the copepodites ascend towards the surface, moult to become adults, spawn, and die soon afterwards.

Figure 9 shows that during April the *Calanus* population in the top 100 m was represented mainly by adults, while early copepodites were scarce. In June all three western areas had high numbers of early copepodites, but in the eastern oceanic areas, the Irminger Sea, there was a scarcity of young stages, and a persistence of adults in the northern Irminger Sea, which indicates that the main spring spawning had been delayed in these areas. In July early copepodites were reduced in numbers in the western areas, while they had become numerous in the eastern areas. In the western, as well as the eastern, areas, the stage composition in July indicates that the rate of development must have
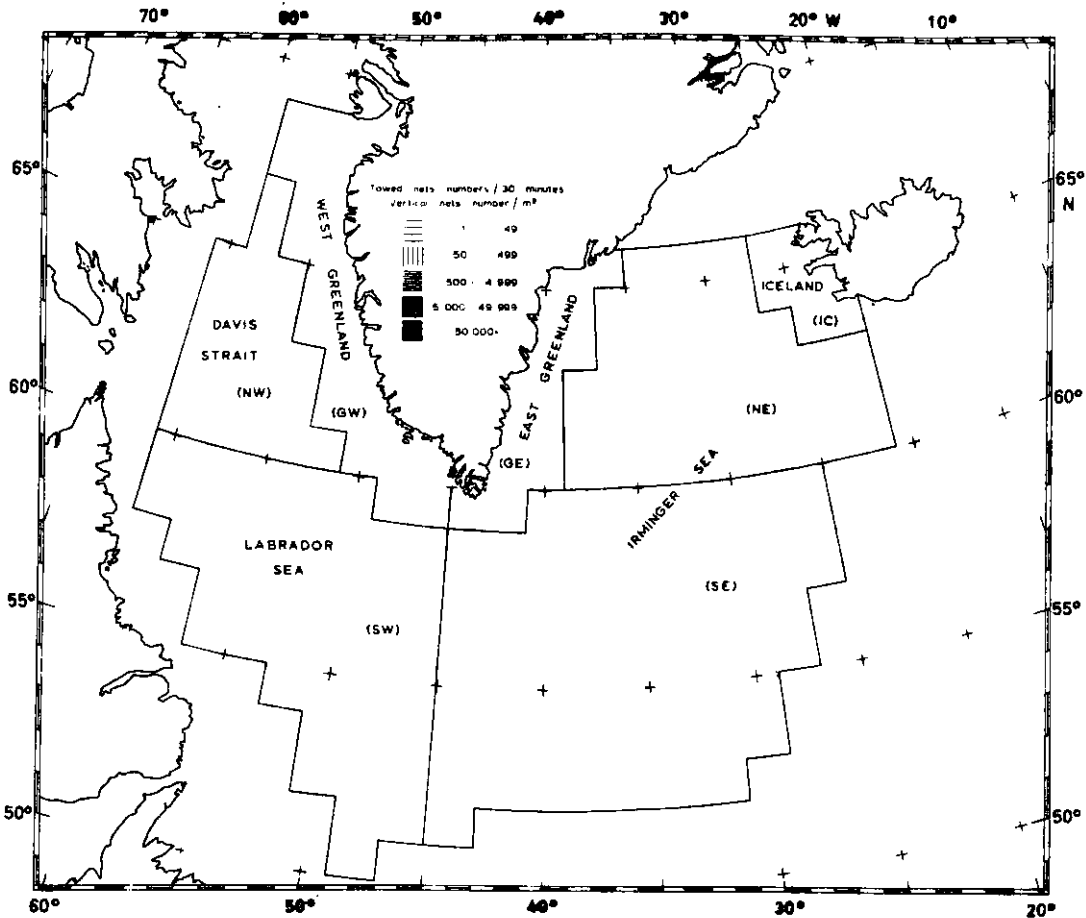
Fig. 8. Standard areas for the zooplankton surveys. (Chart 192
in the NWL publication.)

varied throughout the survey areas from north to south with younger stages
predominant in the north and older stages predominant in the south, possibly
due to temperature conditions.

The late spawning of *Calanus* in the Irminger Sea may be explained by the
late outburst of phytoplankton caused by the late stabilization of the surface
water in the area. It is known that the reproduction of *Calanus* depends very
closely on the food available (Marshall and Orr, 1964).

Seasonal and geographical variation in the development of other plankton
animals, namely euphausiacea, *Spiratelle retroversa*, certain medusae, and
chaetognatha, was studied, but it is not possible to go into detail here.

3. Potential predators of cod eggs and larvae

"It is generally accepted that the larval phase in the life history of
the fish is critical and two of the main causes of larval mortality are thought
to be starvation and predation, both of which will be directly influenced by
the abundance and composition of the zooplankton.

- 285 -
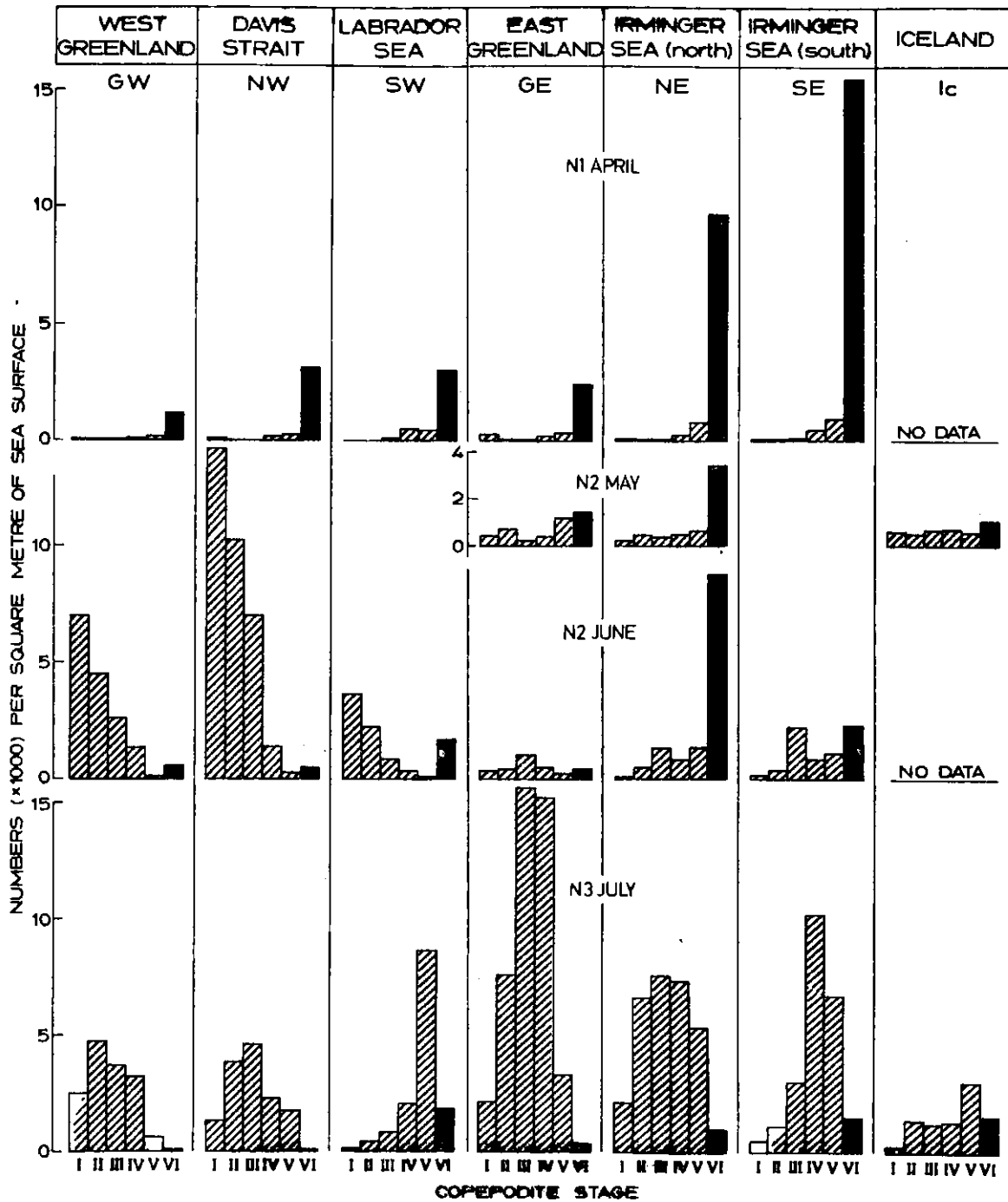
Fig. 9. Average numbers of the adult and copepodite stages of *Calanus*
under 1 m² in the standard areas shown in Fig. 8, during
NORWESTLANT 1-3. (Fig. 26 in the NWL publication.)
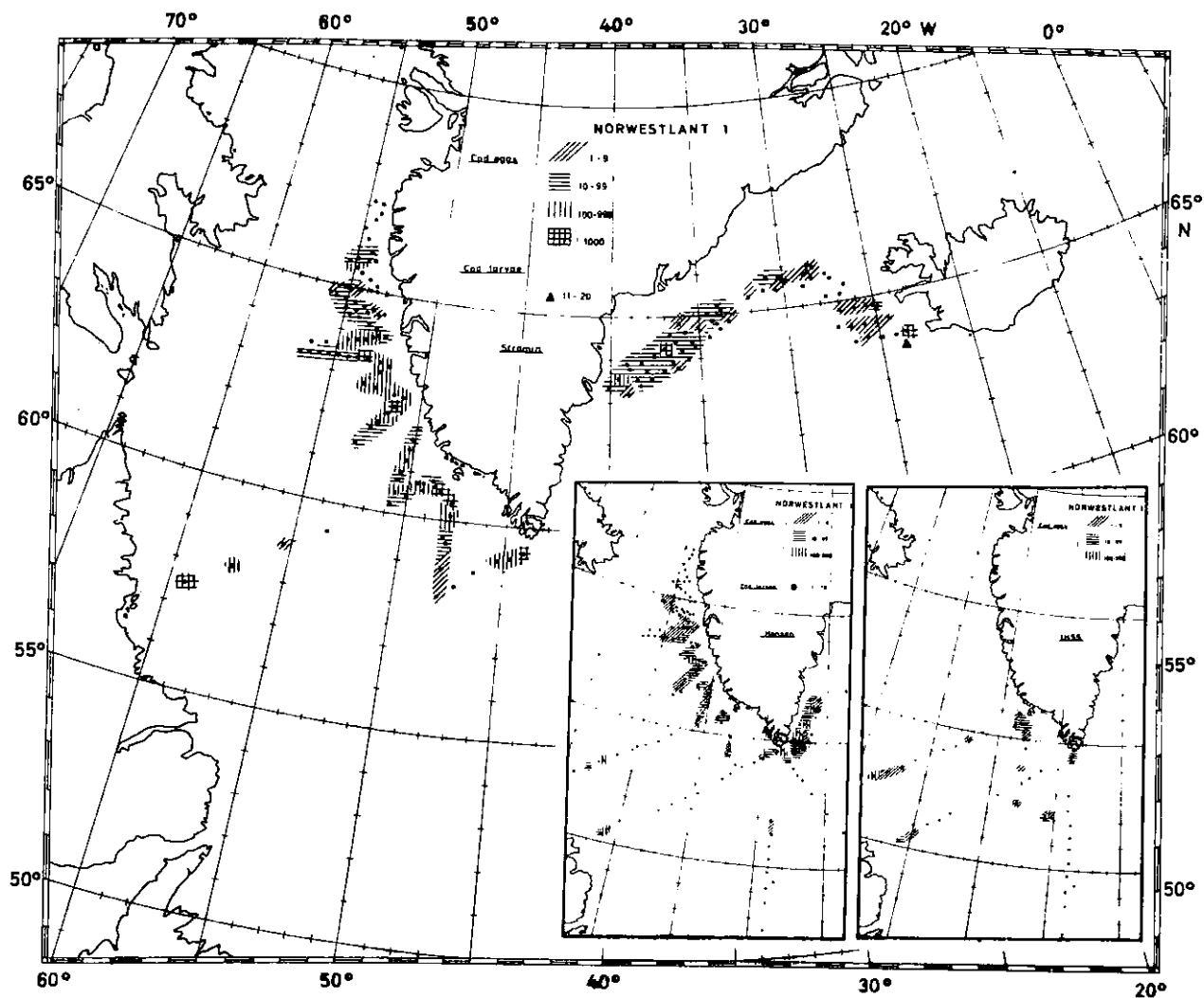
Fig. 11. Distribution and abundance of cod eggs and larvae during
NORWESTLANT 3 (July). Numbers per 30-min stramin-net haul.
(Chart 236 in the NWL publication.)

That means that cod larvae drifting northwards over the West Greenland fishing
banks are less exposed to predation than larvae drifting westwards over deep
water in Davis Strait.

IV. Fish eggs and larvae

1. Cod eggs and larvae (Coordinator, Mr P. Hansen, Denmark)

During April cod eggs were distributed in a continuous zone from Iceland
to East Greenland, around southern Greenland and along West Greenland as far
north as the Arctic Circle, with some concentrations off Labrador. Figure 10
shows cod eggs taken with different nets, a gap in the grid of stramin-net
stations being filled by Hensen-net stations. A special report on Labrador
cod was presented by Mr A.I. Postilaky (USSR).

Figure 11 shows the distribution of cod eggs and larvae during July.
Larvae were concentrated at West Greenland and at East Greenland-Iceland and

Average number

10

5

0

64

1950 52 53 54 55 56 57 58 59 61 63

$y - 60.2 = 45.4 (t-2.14)$

Year-class strength

%

140

120

100

80

60

40

20

0

0 1 2 3 4°C

Fig. 12.   Average numbers of cod larvae
per 30-min stramin-net haul
off West Greenland in dif-
ferent years from 1950 to
1963.   (Fig. 35 in the NWL
publication.)
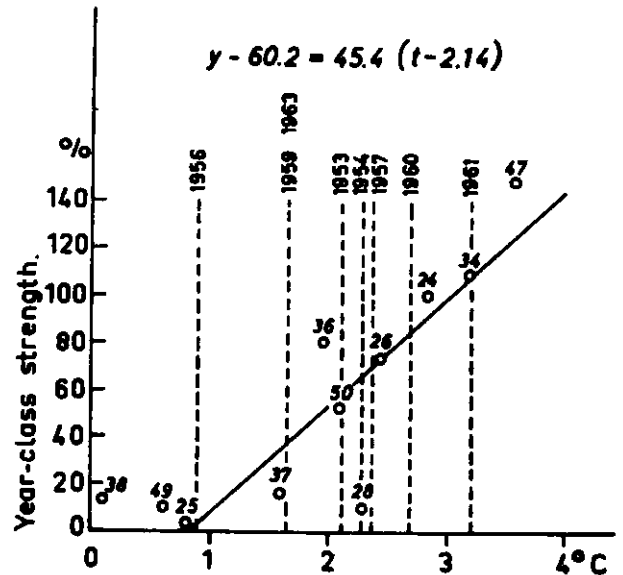
Fig. 13.   Year-class strength (calcu-
lated as percentage of the
1924 year-class) plotted
against mean temperature,
surface to 45 m over Fyllas
Bank in June. (After Hermann,
Hansen, and Horsted, 1965)

were absent around southern Greenland. There is some evidence that, during
the critical period when eggs and larvae were drifting around southern Green-
land, they were in lower temperatures and that food was scarce.

The occurrence of cod larvae in April and cod eggs in July in the East
Greenland-Iceland area is remarkable and indicates a longer spawning period
in the area compared with the West Greenland area, and consequently, a possibly
higher production of larvae.

Figure 12 shows average numbers of cod larvae taken per 30-min stramin-net
hauls off West Greenland annually from 1950 to 1963. To judge from the quantity
of larvae, as well as from the temperature conditions, the 1963 year-class was
expected to be poor. Hermann, Hansen, and Horsted (1965) have shown a close
relationship between variations in year-class strength of the West Greenland
cod and the mean temperature in the 0-45-m layer over Fyllas Bank in June,
good year-classes being associated with water warmer than 2°C (Fig. 13).
Temperatures in 1963 indicated a relatively poor year-class. Nevertheless,
some years later it became apparent that it was relatively good, as shown by
Horsted in an Annex to the NORWESTLANT Report. In 1966 the 1963 year-class
was numerous in the southernmost part of West Greenland inshore waters. From
here it spread northwards in the following years. A suggested explanation for
this is its transport by the currents from the East Greenland-Iceland larval
area. In previous years, the good 1956 year-class and, partly, the 1961 year-
class occurred similarly and were also suggested to be of East Greenland-Iceland
origin.
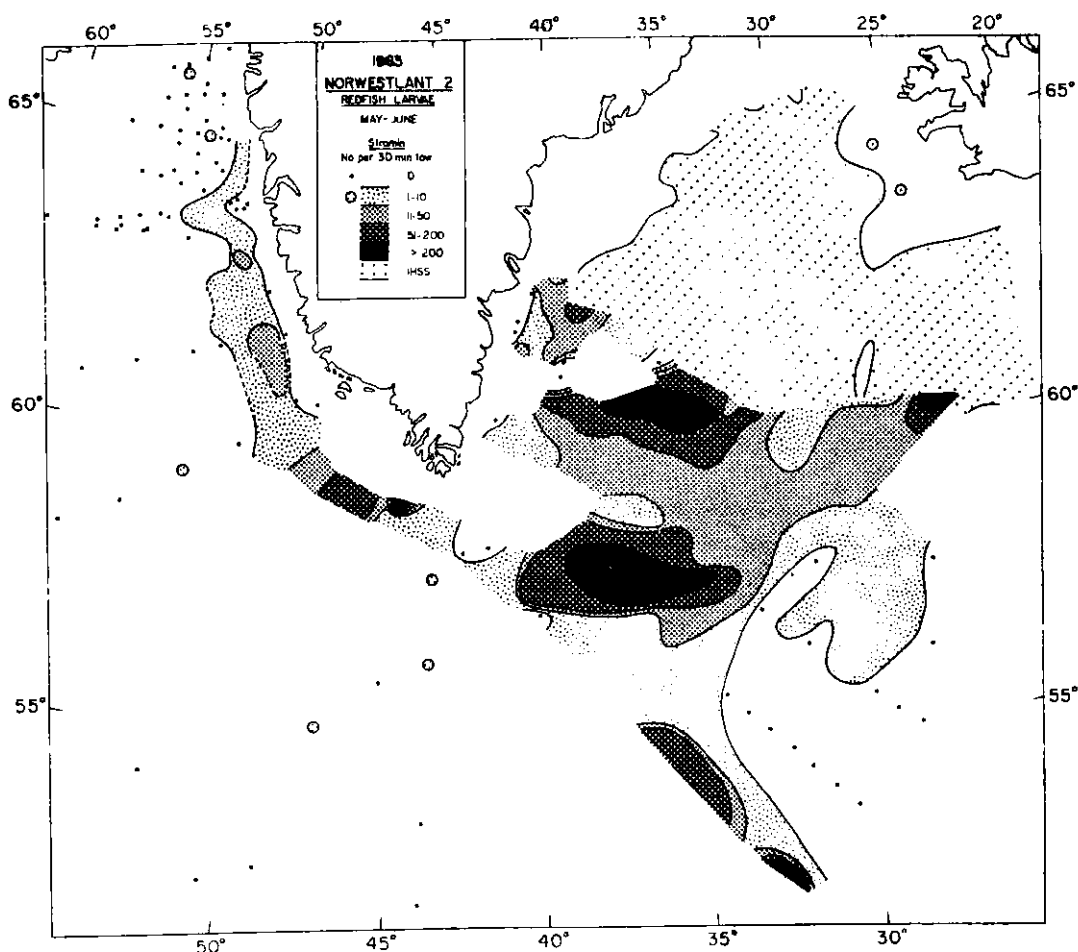
Fig. 14. Distribution and abundance of redfish larvae during
NORWESTLANT 2 (May-June). Numbers per 30-min stramin-
net haul. (Chart 238 in the NWL publication.)

2. Redfish larvae (Coordinator, Mr Jakob Magnusson, Iceland)

The widest distribution of redfish larvae was during NORWESTLANT 2 (May-
June), when they were reported from almost the entire Irminger Sea and were
found in a zone along southwestern Greenland up to 65°N lat (Fig. 14).

Extrusion of larvae was at its peak in May in the Irminger Sea. From
here they drifted to East Greenland and around Cape Farewell to off southwestern
Greenland, where they mixed with those extruded locally.

Icelandic data showed that the larvae were less numerous in 1963 than in
1961 and 1962 and that in 1963 they were in deeper water than in 1961, possibly
due to the stormy weather.

The West Greenland redfish stocks are recruited from the southwestern and southeastern areas. The adults migrate to these areas as has been shown by tagging fish released from pound-net catches in Godthåb Fjord and recaptured off southwestern and southeastern Greenland.

Redfish larvae from Continuous Plankton Recorder samples were reported by Mr G.T.D. Henderson (Edinburgh).

3. <u>Greenland halibut</u> (Coordinator, Dr E. Smidt, Denmark)

Figure 15 shows larvae from stramin-net samples in July from both the NORWESTLANT survey and from all the Danish expeditions since 1908. The densest occurrence is in Davis Strait where investigations have been made for many years.
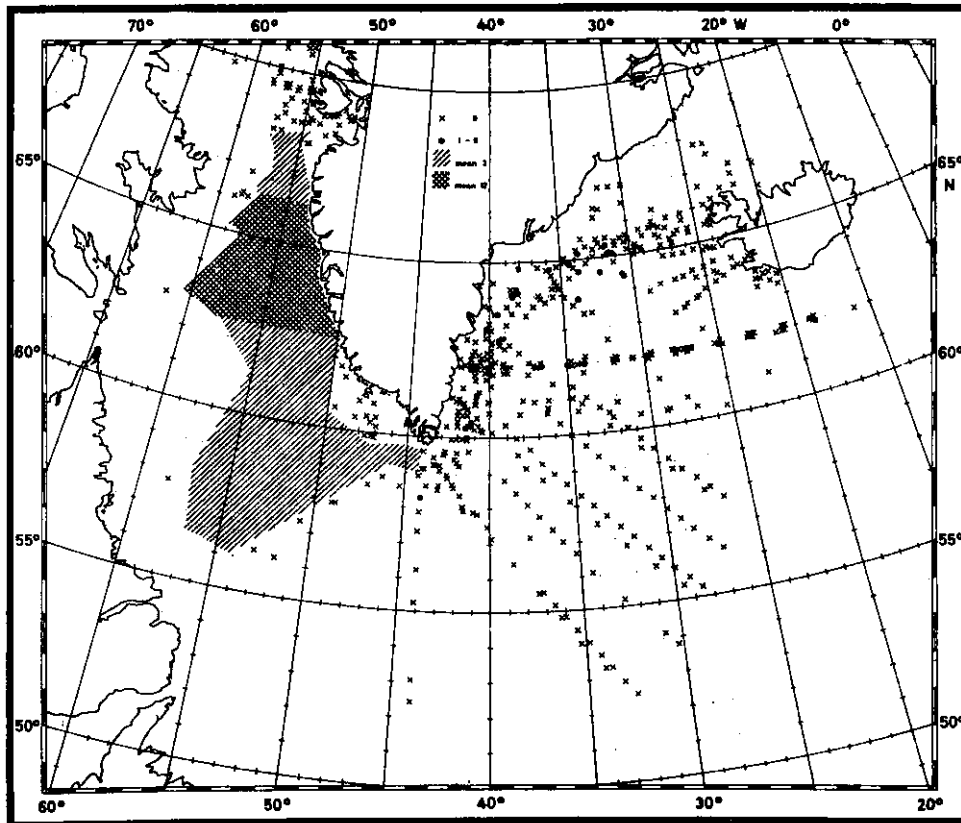
Fig. 15. Distribution and abundance of Greenland halibut larvae from all Danish expeditions since 1908 and from NORWESTLANT. Numbers per 30-min stramin-net haul in July. (Chart 250 in NWL publication.)

1950-52-53-54-55-56-57-58-59-61-63-64
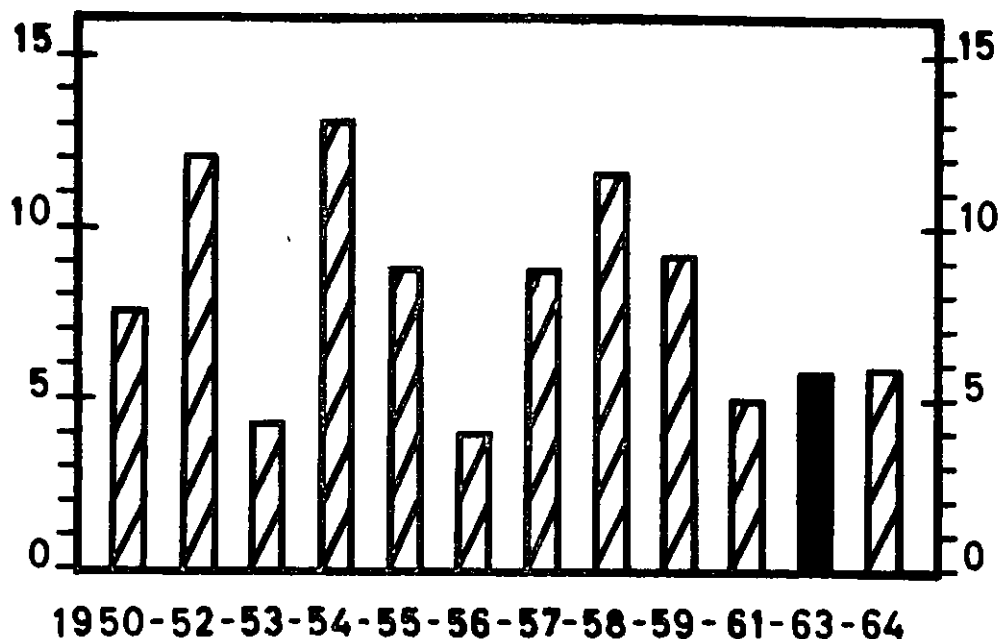
Fig. 16.   Average numbers of Greenland halibut larvae per
           30-min stramin-net haul off West Greenland in
           different years from 1950 to 1964. (Fig. 48 in
           the NWL publication.)

It has been known since 1908 that spawning takes place in Davis Strait
in deep water south of the submarine ridge between Greenland and Canada almost
along the Arctic Circle. The larvae drift north along West Greenland, but no
larvae have been taken north of 68°N lat. in spite of very rich populations
of adult fish in the northern inshore Greenland areas, where they are fished
by the Greenlanders, especially in the Disko Bay and in Umanak district. Also,
no larvae or eggs have been taken in the West Greenland fjords, where many
stramin-net hauls have been made over several years and where dense populations
of adult fish live. Figure 15 also shows that no larvae have been taken in
the Polar Current zone near the coast of southeastern Greenland and the southern-
most coast of West Greenland. In the East Greenland-Iceland area, the larvae
are scarce.

Figure 16 shows average numbers of larvae per 30-min stramin-net haul in
different years in Davis Strait (ICNAF Div. 1B-1E) in July. Annual variations
are slight, and no relation to hydrographic variations could be shown. The
number of larvae was almost normal in 1963.

4.   American plaice (Coordinator, Mr E. Wells, Canada)

Pelagic eggs and larvae were very numerous at West Greenland, the eggs
mostly during NORWESTLANT 1-2, the larvae mostly during NORWESTLANT 3 (July).
In other areas the eggs and larvae were scarce. Figure 17 shows numbers of
pelagic eggs per 30-min stramin-net haul during NORWESTLANT 1 (April).

The adult stock at West Greenland is very rich but it has not yet been
fished commercially. In 1970, limited experimental fishing was carried out
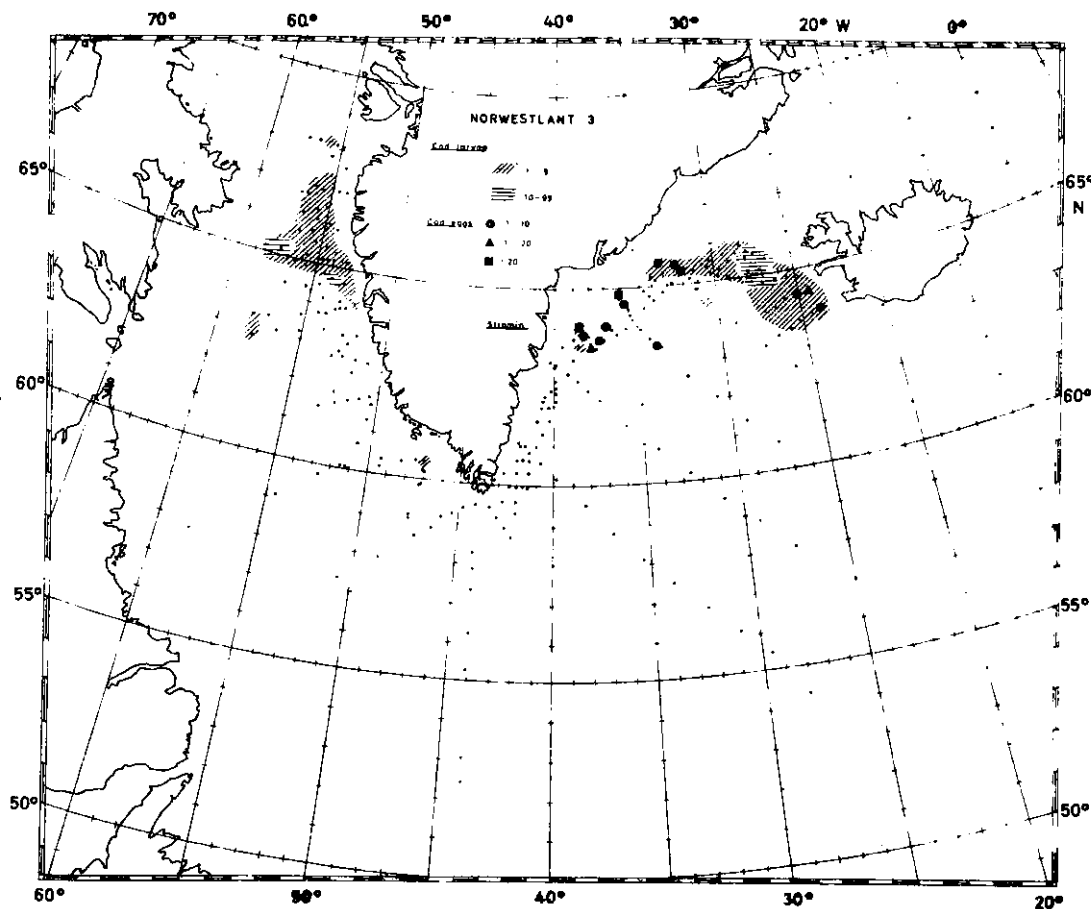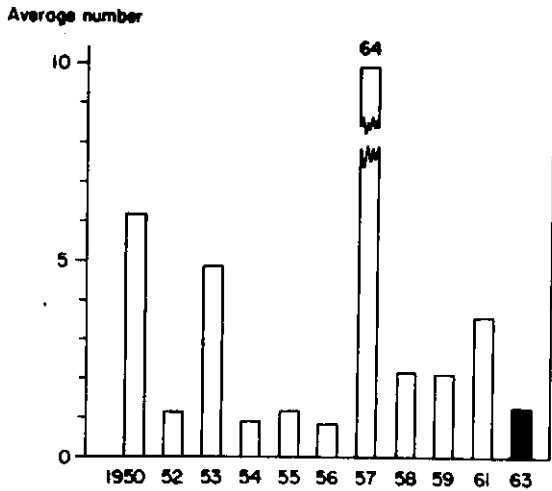for industrial purposes.
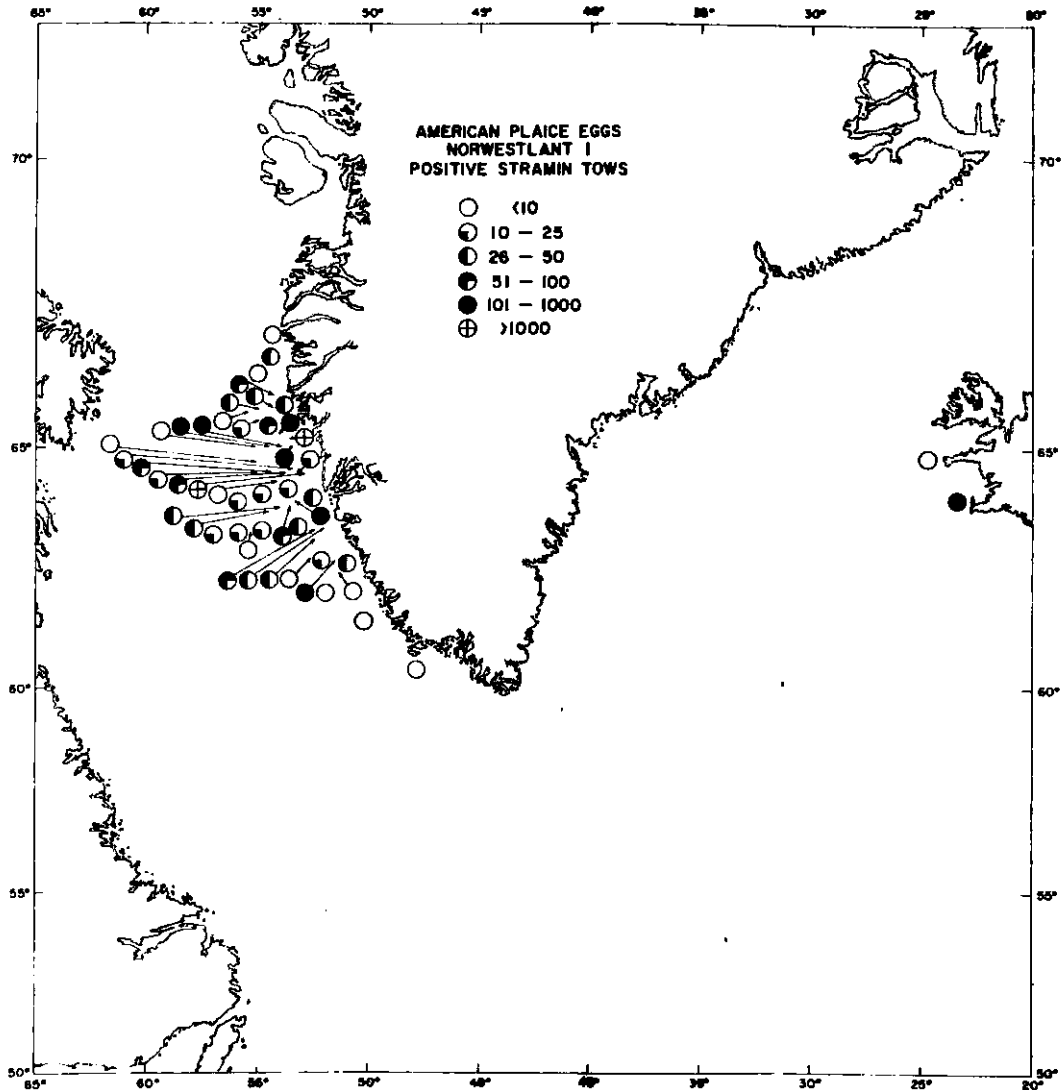
Fig. 17. Distribution and abundance of American plaice eggs during
NORWESTLANT 1 (April). Numbers per 30-min stramin-net
haul. (Chart 251 in the NWL publication.)

5. Capelin (Coordinator, Mr Jutta Magnusson, Iceland)

Figure 18 shows numbers of larvae per m^3 of water taken by IHSS during May-
June in the eastern area. Most larvae were caught in the Icelandic Shelf
region. This is in agreement with earlier observations, which showed that
capelin larvae are the most common of the fish larvae west of Iceland in the
spring and early summer.

No larvae were observed in offshore samples from West Greenland in spite
of the fact that adults are very numerous in the coastal area. However, in
the fjords where spawning takes place in May-June, mainly in the tidal zone,
the larvae were very numerous in the plankton samples, but all the NORWESTLANT
samples were from the offshore region.
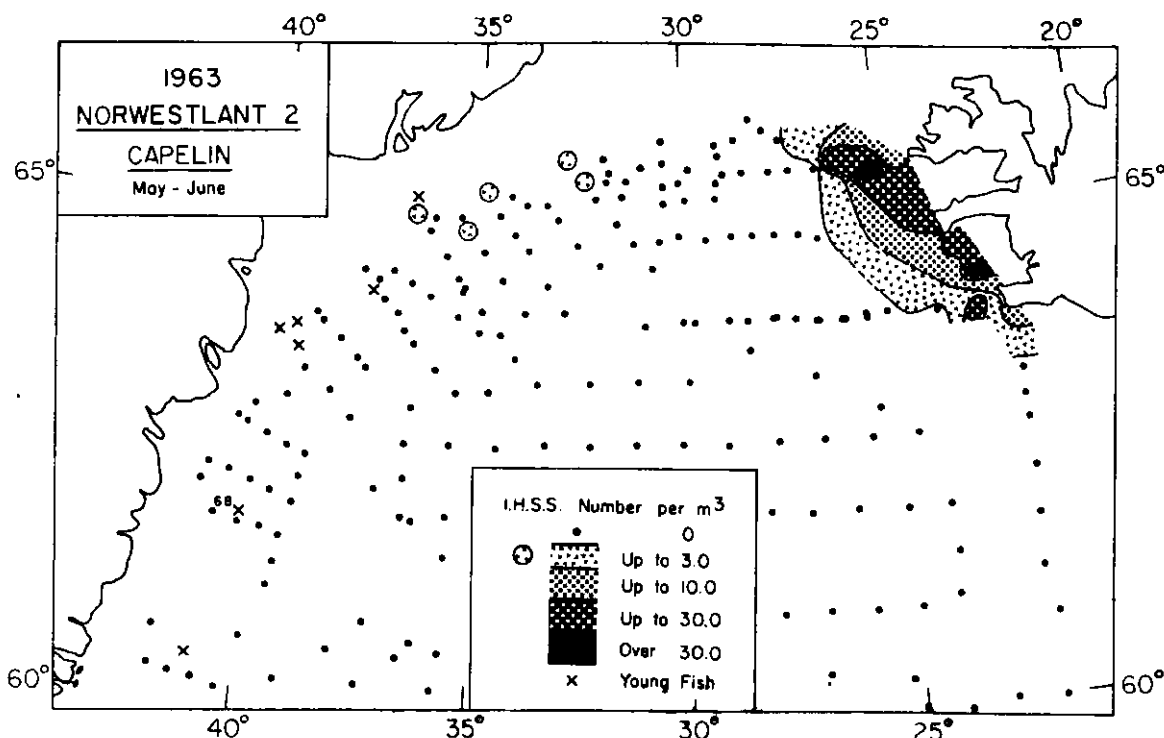
Fig. 18.   Distribution and abundance of capelin larvae during NORWESTLANT
2 (May-June).   Numbers per m^3 by IHSS.   (Chart 245 in the NWL
publication.)

At West Greenland the species is very important as a food for cod, Green-
land halibut, salmon, *etc*.   For the Greenlanders, it is important for local
consumption.

6.   Other fish larvae

Larvae of halibut and wolffish species were also included in the surveys.
Unfortunately, one very important fish species, the sandeel, was not included.
This fish is a most important food-chain link over the offshore fishing banks
at West Greenland, where it plays the same role as the capelin in the inshore
area.   It is an important food, especially for cod and salmon.   The larva is
one of the most common fish larvae over the northern West Greenland fishing
banks.

Figure 19 is a reminder that most of us are still zoologists.   In the
middle of the figure is a cod larva, in the upper row some herbivores the
early stages of which are eaten by fish larvae, in the bottom row some of the
predators of fish larvae.

V.   Concluding remarks

The NORWESTLANT surveys have provided much experience and valuable infor-
mation, but it has also left several open questions.   In his Conclusion of the
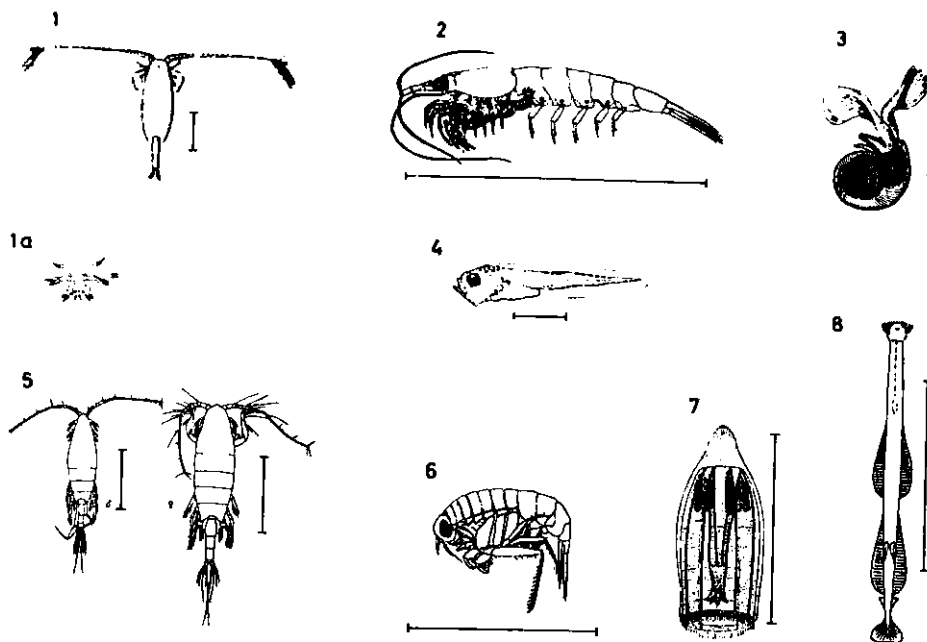
Fig. 19. Some important North Atlantic plankton animals. 1. *Calanus finmarchicus*; 2. *Meganyctiphanes norvegica*; 3. *Spiratella retroversa*; 4. cod larva; 5. *Euchaeta norvegica*; 6. *Themisto libellula*; 7. *Aglantha digitale*; 8. *Sagitta elegans*. (From various authors).

Report Mr Lee says, "before any further ICNAF cooperative work is carried out in the NORWESTLANT area, this Report will be studied by its Research and Statistics Committee. The question will no doubt arise as to whether it is possible to carry out surveys which are much more sophisticated than those of the reconnoitering type which formed NORWESTLANT 1-3."

Several technical problems arose during the surveys. Considerable difficulty was met in comparing samples from the different types of plankton nets used and points to the need to use standard nets.

Indeed, I am not an expert in this matter, but I feel it would be useful to consider carefully what kind and amount of research should possibly be carried out in the future, for instance, surveys on phytoplankton production, on occurrences and quantities of fish larvae, *etc.*

References

References given in this report are found in the NORWESTLANT publication (*Spec. Publ. int. Comm. Northw. Atlant. Fish.*, No. 7, Part I, 1968).

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23. Summary of statistics on discards, 1969[1]

by J.S. Beckett
ICNAF Secretariat

At their 1969 meeting, the Subcommittee on Statistics and the Standing Committee on Research and Statistics recommended

"that the discard portion of the summary document on discards and industrial fish continued to be published annually in Redbook, Pt. III ...." (Redbook 1969, Pt. 1, p. 48)

Statistics on species and nominal catch discarded at sea for 1969 have been prepared from data submitted on ICNAF Statistics Form 4 by Canada (M), Canada (N), France (M), Germany (Fed. Rep.), Poland, Portugal, Spain and the USA.

Some discrepancies between STANA 1W and Statistics Form 4 submissions have been noted but where these appear to be obvious errors, the corrected information has been incorporated into the summaries. However, there are cases where no nominal catch can be assigned to a particular vessel class for which discard and industrial fish information is available.

Canada (M) notes that "it remains normal practice to discard 100% of all silver hake, argentines, sculpins, lumpfish, sea robins, anglers, eelpouts and dogfish". However, these are species not sought for and, in general, are too small to be retained by a 4 1/2 inch mesh. Skates are landed occasionally but are normally discarded. Discards of commercial species of groundfish by longliners and gill netters are negligible due to the selective properties of the gear. Discards of pollock, hake and cusk by otter trawlers are also low.

Abbreviations and Symbols Used
(as in latest Statistical Bulletin)

Species:

Had	- haddock
Red	- redfish
Flo	- flounders
Pol	- pollock
Her	- herring
Wol	- wolffish
Mix	- mixed
NK	- not known

Gear:

OT	- otter trawl
OT.Si	- otter trawl, side
OT.St	- otter trawl, stern
PT	- pair trawl
DS	- Danish seine

Tonnage Class:

1	0 - 50 GRT
1b	26 - 50 GRT
2	51 - 150 GRT .
3	151 - 500 GRT
4	501 - 900 GRT
5	901 - 1800 GRT
6	over 1800 GRT

Country:

Can (M)	- Canada (Maritime and Quebec)
Can (N)	- Canada (Newfoundland)
Fr (M)	- France (Metropolitan)
Ger	- Germany
Pol	- Poland
Por	- Portugal
Spa	- Spain

Source of information:

Log	- logbook
Int	- dockside interview
Rep	- reports by captain

Symbols:

...	- not available or not reported
0	- magnitude known to be nil or zero
-	- magnitude known to be more than zero but less than half the unit

SUMMARY OF STATISTICS ON DISCARDS, 1969

Division	Main Species	Gear and Tonnage Class	Country	COD Nominal Catch	COD Dis-posed	COD Rate (%)	HADDOCK Nominal Catch	HADDOCK Dis-posed	HADDOCK Rate (%)	REDFISH Nominal Catch	REDFISH Dis-posed	REDFISH Rate (%)	FLOUNDERS Nominal Catch	FLOUNDERS Dis-posed	FLOUNDERS Rate (%)	OTHER Main Species	OTHER Nominal Catch	OTHER Dis-posed	OTHER Rate (%)	Source of Information	Sampling Rate (%)
1B	Cod	OTSi5	Fr(M)	110	-	-				0	-	100					0			Rep	100
	"	PT 4	Spa	7088	6	-										NK	0	76	100	Log	95
1C	Cod	OTSi5	Fr(M)	7286	69	1				0	50	100	0	2	100	Mix	15	0	0	Rep	100
	"	OTSt5	Fr(M)	1774	0	0				1	-	33	2	0	0	NK	14	19	58	Rep	101
	"	OT4-6	Ger	12013	134	1				333	18	5	9	0	0	NK	0	6	100	Rep	100
	"	OTSi5	Por	791	-	-										NK	0	11	100	Log	100
	"	OT5	Spa	353	-	-										NK	0	30	100	Log	94
	"	PT3	Spa	1690	20	1														Log	95
1D	Cod	OTSi5	Fr(M)	8413	112	1				0	62	100	0	21	100	Mix	15	0	0	Rep	100
	"	OTSt5	Fr(M)	4222	5	1				5	3	38	3	-	3	Wol	56	34	36	Rep	100
	"	OT4-6	Ger	27904	191	1				1019	32	3	26	0	0	NK	0	3	100	Rep	100
	"	OTSi5	Por	1073	-	-										NK	0	19	100	Log	100
	"	OT5	Spa	843	-	-										NK	0	5	100	Log	94
	"	PT3	Spa	11566	2	-														Log	95
1E	Cod	OTSi5	Fr(M)	2273	26	1				0	10	100	0	-	100	NK	1	0	0	Rep	100
	"	OTSt5	Fr(M)	938	2	-				0	1	100				Wol	52	33	39	Rep	100
	"	OT4-6	Ger	28099	27	1				993	20	2	39	0	0	NK	0	20	100	Rep	100
	"	OT5	Spa	660	-	-										NK	0	5	100	Log	94
	"	PT3	Spa	1524	-	-														Log	95
1F	Cod	OT4-6	Ger	10322	3	-				1541	38	2				Wol	90	13	13	Rep	100
	"	PT3	Spa	15	-	-										NK	0	1	100	Log	95
Subarea 1 Total All Nations				128957 / 204790	597	-				3892 / 4252	234	6	79 / 1734	23	23		243 / 4578	275	53		
2H	Cod	OTSi5	Fr(M)	339	8	2				0	8	100				Wol	66	207	76	Rep	100
	"	OT5-6	Ger	11118	905	7				8	17	68	71	0	0					Rep	100
	"	OTSt6	Por	4843	18	1										NK	0	4	100	Log	100
	"	OTSi5	Por	1370	17	1										NK	0	26	100	Log	100
	"	OT5	Spa	143	2	1														Log	94
2J	Cod	OTSi5	Fr(M)	17719	846	5				2	46	96	4	-	6	NK	21	0	0	Rep	100
	"	OTSt5	Fr(M)	11405	32	-				0	-	100	1	0	0	NK	40	0	0	Rep	100
	"	OT5-6	Ger	59899	2362	4				137	40	23	133	0	0	NK	179	565	76	Rep	100
	"	OTSt6	Pol	46148	60	-				485	0	0	1665	0	0	NK	2	-	-	Int	33
	"	OFSi5	Por	11000	58	1										NK	0	311	100	Log	100
	"	OT5	Por	48869	398	1										NK	0	1134	100	Log	100
	"		Spa	33006	135	-														Log	94
Subarea 2 Total All Nations				245859 / 412293	4841	2				632 / 6098	111	15	1874 / 17372	0	0		308 / 1296	2247	88		

SUMMARY OF STATISTICS ON DISCARDS, 1969 - continued

Division	Main Species	Gear and Tonnage Class	Country	COD			HADDOCK			REDFISH			FLOUNDERS			OTHER				Source of Information	Sampling Rate (%)
				Nominal Catch	Dis-posed	Rate (%)	Nominal Catch	Dis-posed	Rate (%)	Nominal Catch	Dis-posed	Rate (%)	Nominal Catch	Dis-posed	Rate (%)	Main Species	Nominal Catch	Dis-posed	Rate (%)		
3K	Cod	OTS15	Fr(M)	7570	97	1				32	204	86	11	1	8	NK	10	3	23	Rep	100
	"	OTSt5	Fr(M)	2357	8	-				0	9	100	1	0	0	NK	69	0	0	Rep	100
	"	OT6	Ger	229	0	0				5194	0	0	4544	0	0					Rep	100
	"	OTSt6	Pol	13302	40	-										Cod	-	-	-	Int	33
	"	OTSi5	Por	12492	13	-										NK	0	172	100	Int	100
	"	OT5	Spa	11971	9	-										NK	0	450	100	Log	96
3L	Cod	OTSt4	Can(N)	5258	0	0	12	0	0				2328	172	9	Wol	93	0	0	Log	1
	"	OTSt13	Can(N)	1171	0	0	1	0	0				652	47	7	NK	13	23	46	Log	14
	"	OTSi5	Fr(M)	7756	247	3				12	0	0	4	0	0	NK	27	0	0	Rep	100
	"	OTSt5	Fr(M)	2994	1	-				8	0	0				NK	189	0	100	Rep	100
	"	OTSt6	Por	4328	3	-				3	197	98				NK	0	12	100	Log	100
	"	OTSi5	Por	36115	25	-				1	3	75				NK	0	253	100	Log	100
	"	OT5	Spa	16684	36	-										NK	0	748	100	Log	94
	"	PT3	Spa	40496	489	1	515	30	6							NK	139	911	87	Log	95
	Flo	OTSt4	Can(N)	8485	0	0	14	0	0	42	0	0	38345	4281	10	Wol	752	0	0	Log	2
	"	OTSt13	Can(N)	1131	0	0	1	0	0	14	0	0	4437	573	11	Wol	64	0	0	Log	5
3M	Cod	OTSi5	Fr(M)	11145	9	-				0	249	100								Rep	100
	"	OTSt5	Fr(M)	686	2	-				0	2	100								Rep	100
	"	OTSi5	Por	6652	6	-	0	-	-				0	-	100	NK	0	33	100	Log	100
	"	OT5	Spa	1932	1	-										NK	0	94	100	Log	94
	"	PT3	Spa	750	-	-										NK	0	5	100	Log	95
3N	Cod	OTSi5	Fr(M)	111	1	1										NK	42	0	0	Rep	100
	"	OTSt5	Fr(M)	493	0	0										NK	0	19	100	Rep	100
	"	OT5	Spa	404	-	-	389	22	5							Pol	130	672	84	Log	94
	"	PT3	Spa	31251	448	1	2	0	0							Wol	98	0	0	Log	95
	Flo	OTSt4	Can(N)	1146	0	0				36	0	0	1201	1818	60					Log	1
3O	Cod	OTSt4	Can(N)	1175	0	0	167	0	0	14	0	0	257			NK	27	0	0	Log	6
	"	PT3	Spa	39503	525	1	268	42	14	0	2	100				NK	43	757	95	Log	95
3Pn	Cod	OTSi5	Fr(M)	47	-	-										NK	0	-	100	Rep	100
	"	OT5	Spa	79	-	-				0	2	100				NK	0	1	100	Log	94
	"	PT3	Spa	24	-	-														Log	95
	Red	OTSt13	Can(N)	166	0	0				3137			45	0	0	Mlx	15	0	0	Log	14
3Ps	Cod	OTSi5	Fr(M)	15	2	12	11	0	0							NK	49	16	25	Rep	100
	"	OT5	Spa	238	1	-	559	95	15							NK	73	478	87	Log	94
	Red	PT3	Spa	27903	160	1	12	0	0	3518	0	0	98	0	0	Mlx	12	0	0	Log	95
	"	OTSi3	Can(N)	174	0	0				750	43	5	28	0	0					Log	11
	"	OTSi2	Can(N)	27	0	0				17	0	0								Log	29
	Flo	OTSt4	Can(N)	370	0	0	126	0	0				1909	269	12	Mlx	24	0	0	Log	
Subarea 3 Total				296630	2123	1	2080	189	8	12778	709	5	53860	7161	12		1869	4647	71		
All Nations				569087			5321			87032			141345				165029				

SUMMARY OF STATISTICS ON DISCARDS, 1969 – continued

Division	Main Species	Gear and Tonnage Class	Country	COD Nominal Catch	COD Dis-posed	COD Rate (%)	HADDOCK Nominal Catch	HADDOCK Dis-posed	HADDOCK Rate (%)	REDFISH Nominal Catch	REDFISH Dis-posed	REDFISH Rate (%)	FLOUNDERS Nominal Catch	FLOUNDERS Dis-posed	FLOUNDERS Rate (%)	OTHER Main Species	OTHER Nominal Catch	OTHER Dis-posed	OTHER Rate (%)	Source of Information	Sampling Rate (%)
4R	Cod	OTS13	Can(N)	2842	0	0	72	6	8	331	0	0	502	67	12	Mix	50	0	0	Log	1-
	"	OTS15	Fr(M)	16318	243	1				1	427	100	9	5	35	NK	7	4	36	Rep	100
	"	OTSt5	Fr(M)	906	0	0				0	3	100	3	0	0					Rep	100
	"	OTSi5	Por	1330	2	-										NK	0	4	100	Log	100
	"	OT5	Spa	2688	1	-										NK	0	63	100	Log	94
	Red	OTS13	Can(N)	782	0	0	6	0	0	14897	0	0	259	0	0	Mix	76	0	0	Log	11
	Flo	OTS13	Can(N)	50	0	0	1	0	0	43	0	0	61	0	0	Wol	1	0	0	Log	100
	Mix	OT3	Can(M)	525	160	23	15	0	0	7494	0	0	233	0	0	NK	327	0	0	Log	3
	Mix	OT2	Can(M)	119	19	14				2959	0	0	111	29	21	NK	35	0	0	Log	7
4S	Cod	OT5	Spa	42	-	-										NK	0	-	100	Log	94
	Red	OTS13	Can(N)	93	0	0				3901	0	0	13	0	0	NK	23	0	0	Log	4
	Mix	OT3	Can(M)	438	65	13				13559	0	0	132	0	0	NK	218	0	0	Log	5
4T	Cod	OTS15	Fr(M)	207	13	6	19	0	0	0	3	100	1127	519	32	NK	305	0	0	Rep	100
	Mix	OT3	Can(M)	3459	326	9	53	0	0	1466	0	0	4402	701	14	Hak	800	0	0	Log	9
	"	OT2	Can(M)	6338	887	12	43	0	0	7542	0	0	1113	356	24	NK	71	0	0	Log	3
	"	OT1b	Can(M)	7736	419	5	9	0	0	1327	0	0	1547	340	18	NK	28	0	0	Log	4
	"	DS1b	Can(M)	870	122	12														Log	9
4Vn	Cod	OTS15	Fr(M)	119	19	14										NK	0	1	100	Rep	100
	"	OTSi5	Por	307	1	-										NK	0	-	100	Log	100
	"	OT5	Spa	277	4	-										NK	0	21	100	Log	94
	"	PT3	Spa	1372	3	-										NK	3	0	0	Log	95
	Red	OTSi3	Can(N)	86	0	0	0	-	100	2017	0	0	44	0	0					Log	15
	Her	OT5-6	Ger				1	0	0	28	0	0				Her	8996	0	0	Log	100
	Mix	OT3	Can(M)	5658	792	12	28	0	0	2376	0	0	2173	0	0	NK	157	0	0	Log	4
4Vs	Cod	OT5	Spa	629	-	-	631	9	1							NK	0	1	100	Log	94
	"	PT3	Spa	17092	48	-										NK	144	348	71	Log	95
	Her	OT5-6	Ger							70	0	0				Her	13033	5	-	Rep	100
	Mix	OT3	Can(M)	1316	0	0	218	0	0	814	0	0	4299	688	14	NK	185	0	0	Log	1
4W	Cod	PT3	Spa	14584	98	1	863	32	4							NK	864	301	26	Log	95
	Flo	DS2	Can(M)	5	0	0	11	0	0				545	31	5	NK	52	0	0	Log	2
	Her	OT5-6	Ger													Her	156	0	0	Rep	100
4X	Cod	PT3	Spa	8217	3	-	473	26	5	100	0	0	435	127	23	NK	203	54	21	Log	95
	Mix	OT2	Can(M)	2409	81	3	4209	0	0							Pol	2872	0	0	Log	1
Subarea 4 Total				96814	3306	3	6652	73	1	58925	433	1	17008	2863	14		28606	808	3		
All Nations				206065			41884			110928			53204				521549				

SUMMARY OF STATISTICS ON DISCARDS, 1969 - continued

Division	Main Species	Gear and Tonnage Class	Country	COD Nominal Catch	COD Dis-posed	COD Rate (%)	HADDOCK Nominal Catch	HADDOCK Dis-posed	HADDOCK Rate (%)	REDFISH Nominal Catch	REDFISH Dis-posed	REDFISH Rate (%)	FLOUNDERS Nominal Catch	FLOUNDERS Dis-posed	FLOUNDERS Rate (%)	OTHER Main Species	OTHER Nominal Catch	OTHER Dis-posed	OTHER Rate (%)	Source of Information	Sampling Rate (%)
5Y	Cod	PT3	Spa	152	-	-	230	-	-							NK	120	2	2	Log	95
	Her	OT5-6	Ger													Her	8376	57	1	Rep	100
5Ze	Cod	PT3	Spa	13598	26	-	1201	65	5				1	0	0	NK	225	227	50	Log	95
	Her	OT5-6	Ger	3	0	0				8	0	0	0	3	100	Mix	60897	457	1	Rep	100
	"	OTS14[1]	Pol	113	3	3										Her	11307	7	-	Int	33
	"	OTS14[2]	Pol	21	0	0										Her	17552	400	2	Int	33
5Zw	Her	OT5-6	Ger	9	3	25										Her	1195	5	-	Rep	100
	"	OTS14[2]	Pol										0	2	100	Her	438	6	1	Int	33
5Z NK	Yel	OT1-3	USA	3990	0	0	2583	0	0				31443	5073	14	Mix	6310	0	0	Int	13
Subarea 5 Total All Nations				17886 / 45823	32	-	4014 / 24952	65	2	8 / 12830	0	0	31444 / 78224	5078	14		106420 / 532192	1161	1		1
6A	Yel	OT1-3	USA	16	0	0							564	200	26	Mix	345	0	0	Int	6
	Her	OTS14[2]	Pol	3	2	40							0	1	100	Her	2827	3	-	Int	33
6B	Her	OTS14[1]	Pol	102	0	0										Her	7636	300	4	Int	33
	Her	OTS14[2]	Pol	11	2	15										Her	2590	3	-	Int	33
6C	Her	OTS14[1]	Pol	0	1	100							0	2	100	Her	66	1	1	Int	33
Subarea 6 Total All Nations				132 / 584	5	4							564 / 8688	203	26		13464 / 230210	307	2		
All Subarea Totals All Nations				786278 / 1438642	10904	1	12746 / 72219	327	3	76235 / 220808	1487	2	104829 / 300597	15328	13		150910 / 1454922	9445	6		
1	All	All	All	128957	597	-				3892	234	6	79	23	23		243	275	53		
2	All	All	All	245859	4841	2				632	111	15	1874	0	0		308	2247	88		
3	All	All	All	296630	2123	1	2080	189	8	12778	709	5	53860	7161	12		1869	4647	71		
4	All	All	All	96814	3306	3	6652	73	1	58925	433	1	17008	2863	14		28606	808	3		
5	All	All	All	17886	32	-	4014	65	2	8	0	0	31444	5078	14		106420	1161	1		
6	All	All	All	132	5	4							564	203	26		13464	307	2		
All All Total Catch	All	All	All	786278 / 1438642	10904	1	12746 / 72219	327	3	76235 / 220808	1487	2	104829 / 300597	15328	13		150910 / 1454922	9445	6		

[1] Motor trawler
[2] Steam trawler