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FOR THE

NORTHWEST ATLANTIC FISHERIES



REDBOOK 1973, PART III

**SELECTED PAPERS
FROM THE
1973 ANNUAL MEETING**

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PART III. SELECTED PAPERS FROM THE 1973 ANNUAL MEETING

SECTION A. OCEANOGRAPHY

1. FURTAK, A. Environmental conditions in the region of Georges Bank, Gulf of Maine, Nantucket Shoal and western part of the Nova Scotia Shelf, October 1972..... 5
2. BURMAKIN, V.V. Water temperatures in Labrador and Newfoundland areas at the end of 1971 and during 1972..... 13
3. TEMPLEMAN, W. Temperatures and salinities in the eastern Newfoundland area in 1972..... 19
4. HERMANN, F., W. LENZ, and R.W. BLACKER. Hydrographic conditions off West Greenland in 1972..... 27
5. LENZ, W. On the hydrography of the Southern Laurentian Channel (ICNAF Div. 3P, 4V) 33

SECTION B. COD

6. PINHORN, A.T. Comparison of mortalities calculated from virtual population assessments and from research vessel survey data for cod stocks in ICNAF Divisions 3NO and 3Ps..... 37
7. MEYER, A. Mean length and weight for various age-groups of cod in the northern and the southern divisions of West Greenland..... 41
8. PINHORN, A.T., and R. WELLS. Evaluation of research survey indices of abundance for cod stocks in ICNAF Subareas 2 and 3..... 45
9. SMIDT, E. Mean length of cod age-groups in northern and southern divisions of Subarea 1 (West Greenland)..... 51

SECTION C. REDFISH

10. NIKOLSKAYA, T.L. Distribution of beaked redbfish (*Sebastes mentella* Travin) by depth in areas off Newfoundland and South Labrador..... 53

SECTION D. FLOUNDERS

11. MINET, J.P. Food and feeding of the American plaice (*Hippoglossoides platessoides* F.) on St. Pierre Bank and on Cape Breton Shelf..... 59
12. PITT, T.K. Catch per unit effort relationship in Grand Bank American plaice (ICNAF Div. 3L and 3N)..... 71
13. EFANOV, V.N., and V.I. VINOGRADOV. Feeding patterns of yellowtail of two New England stocks..... 75
14. HALLIDAY, R.G. The flatfish fisheries of the Scotian Shelf..... 79

SECTION E. OTHER GROUND FISH

15. PETROV, V.N. Maturity, feeding and length and age composition of white hake, *Urophycis tenuis* (Mitch.), in ICNAF Subarea 3, 1969-72..... 101

SECTION F. HERRING

16. DRAGANIK, B. Estimates of fishing mortality and stock size for Georges Bank herring..... 105
17. DECAMPS, Ph., and D. BRIAND. Some biological data on the herring (*Clupea harengus harengus* L.) in the Gulf of St. Lawrence, southwestern Newfoundland and Banquereau areas in 1972..... 109
18. ILES, T.D., and D.S. MILLER. Length-weight relationships for the herring of the Bay of Fundy (ICNAF Division 4X)..... 119

SECTION G. OTHER FISH

19. KOVALYOV, S.M., and B.D. KUDRIN. Soviet investigations on capelin in the Northwest Atlantic in 1971 and 1972..... 121
20. DRAGESUND, O., and T. MONSTAD. Observations on capelin, *Mallotus villosus*, in Newfoundland waters..... 127
21. CAMPBELL, J.S., and G.H. WINTERS. Some biological characteristics of capelin, *Mallotus villosus*, in the Newfoundland area..... 137

SECTION H. SHELLFISH

22. IKEDA, I., and F. NAGASAKI. Stock assessment of common American squid in ICNAF Subarea 5 and Statistical Area 6..... 145
23. MERCER, M.C. Nominal catch of squid in Canadian Atlantic waters (Subareas 2-4), 1920 to 1968..... 153

SECTION I. SPECIES MIX AND FISHING EFFORT

24. GROSSLEIN, M.D. Mixture of species in Subareas 5 and 6.....	163
25. LENARZ, W.H., and B.E. BROWN. Factors affecting estimates of relative catch-abilities of fishing units in ICNAF Subarea 5 and Statistical Area 6.....	209
26. BROWN, B.E., J.A. BRENNAN, E.G. HEYERDAHL, and R.C. HENNEMUTH. Effect of by-catch on the management of mixed species fisheries in Subarea 5 and Statistical Area 6.....	217
27. TRESCHÉV, A.I. Fishing unit measures.....	233

SECTION J. DISCARDS

28. HODDER, V.M. (Assistant Executive Secretary, ICNAF). Summary of information on discards and industrial fish (ICNAF Statistics Form 4) for the year 1971.....	249
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NOTE

REDBOOK 1973 is in three parts: PART I contains 1973 Proceedings of the Standing Committee on Research and Statistics (STACRES); PART II contains Research Reports by Member Countries for the year 1972; and PART III (this volume) contains Selected Papers from the 1973 Annual Meeting.

This volume was produced in the Secretariat largely through the efforts of Mrs Vivian C. Kerr who did the typing and to Mr R.A. Myers who did the multigraphing.

14 December 1973

V.M. Hodder
Assistant Executive Secretary

**SECTION A
OCEANOGRAPHY**

1. Environmental conditions in the region of Georges Bank, Gulf of Maine, Nantucket Shoal and western part of the Nova Scotia Shelf, October 1972¹

by A. Furtak
Sea Fisheries Institute
Gdynia, Poland

INTRODUCTION

Environmental investigations in conjunction with the ICNAF Larval Herring Survey Program in the Georges Bank, Nantucket Shoal, Gulf of Maine and western Scotian Shelf areas were initiated in 1971 and continued in 1972. Polish investigations were carried out from the research vessel *Wieczno* of the Gdynia Sea Fisheries Institute during 2-28 October 1972 and consisted of water temperature measurements and collection of sea-water samples for determination of salinity, dissolved oxygen and phosphate content. In 1971 the areas were investigated during the same period (4-26 October).

METHODS

The distribution of hydrographic stations is shown in Fig. 1. Observations were made at so-called "full stations" pre-selected for constructive hydrological profiles of vertical distribution of temperature, salinity, oxygen and phosphate, and at intermediate stations where surface and bottom temperatures were taken and bathythermograph casts to 200 m were made to check on the results of the deep-sea reversible thermometers and complete the vertical profiles.

Sea-water samples were collected for determination of (a) salinity by means of salinometer (Mk III) with an accuracy of 0.001 ‰, (b) phosphate content by means of spectrophotometer (the samples were preserved by the addition of CHCl_3 and stored for later analysis in the laboratory), and (c) dissolved oxygen content by Winkler's method.

SUMMARY OF RESULTS

The results obtained in October 1972 (Fig. 2-7) indicate that the particular hydrological elements were much different from those found in October 1971, especially temperatures which in 1972 were lower than those of the previous year and indicated a strong transgression of cold water of Labrador Current origin. The surface water was colder than at the same time in the previous year, the main difference being as follows: temperatures were 1.0° to 2.5°C lower in the Gulf of Maine, 0.5° to 1.0°C lower on the central part of Georges Bank, 2.5°C lower on the western part of Georges Bank and 0.5° to 0.9°C lower on the western part of the Nova Scotia Shelf. Similar differences were observed in bottom temperatures between 1971 and 1972: 1.0° to 1.5°C lower on the western part of Georges Bank, 0.5° to 2.0°C lower on other parts of the Bank, as low as 2.5°C in the Gulf of Maine, and 1.0° to 1.4°C lower on the western Nova Scotia Shelf.

No very significant differences were found in salinity from 1971 to 1972. The western part of the Nova Scotia Shelf exhibited an increase of 0.6 ‰ in the surface water, and an appreciable increase in the extension of the 32 ‰ isohaline was noted to the east of Cape Cod. On the southern slope of Georges Bank the bottom salinity was higher by about 1 ‰, whereas it was lower by 0.5 to 1.5 ‰ on the western part of the Bank. A salinity decrease of 0.5 ‰ was also observed at the bottom on Browns Bank. In the Gulf of Maine no significant differences in bottom salinity were observed except for the 33.5 ‰ isohaline which in 1972 ran along the 69°30'W meridian, but which did not exist at all in October 1971.

The phosphate-phosphorus content of water at the bottom (Fig. 6) generally ranged from 1.25 to 1.50 $\mu\text{g atom P/l}$ in the Gulf of Maine, and 1.00 to 1.25 on the western part of the Nova Scotia Shelf. On the shallower parts of Georges Bank phosphate content was generally less than 1.00 $\mu\text{g atom P/l}$, but in the deeper parts of the Fundian Channel values up to 3.00 $\mu\text{g atom P/l}$ were found.

The distribution of dissolved oxygen in the bottom water (Fig. 7) generally ranged from about 4.0 ml/l in the deeper water on the slopes of the banks to 6.5 and 7.0 ml/l in the shallower water on the banks.

CONCLUSIONS

The whole area investigated was covered by colder water in 1972 than in 1971. This was associated with the stronger influx of transformed Labrador water. The temperatures were, on the average, about 1°C lower than in October 1971.

On the northwestern slope of Georges Bank, the hydrological front was steeper than in 1971 and the range of bottom temperatures therein was found to be from 6° to 16°C, whereas in 1971 the front was much less obvious. The range of values of the horizontal temperature gradient within the front zone on the

¹ Submitted to the 1973 Annual Meeting of ICNAF as ICNAF Res.Doc. 73/21.

northwest slope in 1972 was 0.69° to 1.00°C per sea-mile, whereas in 1971 the front gradient values ranged from 0.50° to 1.14°C per sea-mile.

The phosphate content of bottom water was generally less than $1.00\ \mu\text{g atom P/l}$ on the shallower parts of the banks and greater than $1.00\ \mu\text{g atom P/l}$ in the deeper areas of the slopes and channels.

The dissolved oxygen content of bottom water was lower (about $4\ \text{ml/l}$) in the deeper slope areas than in the shallower bank areas (up to $7\ \text{ml/l}$).

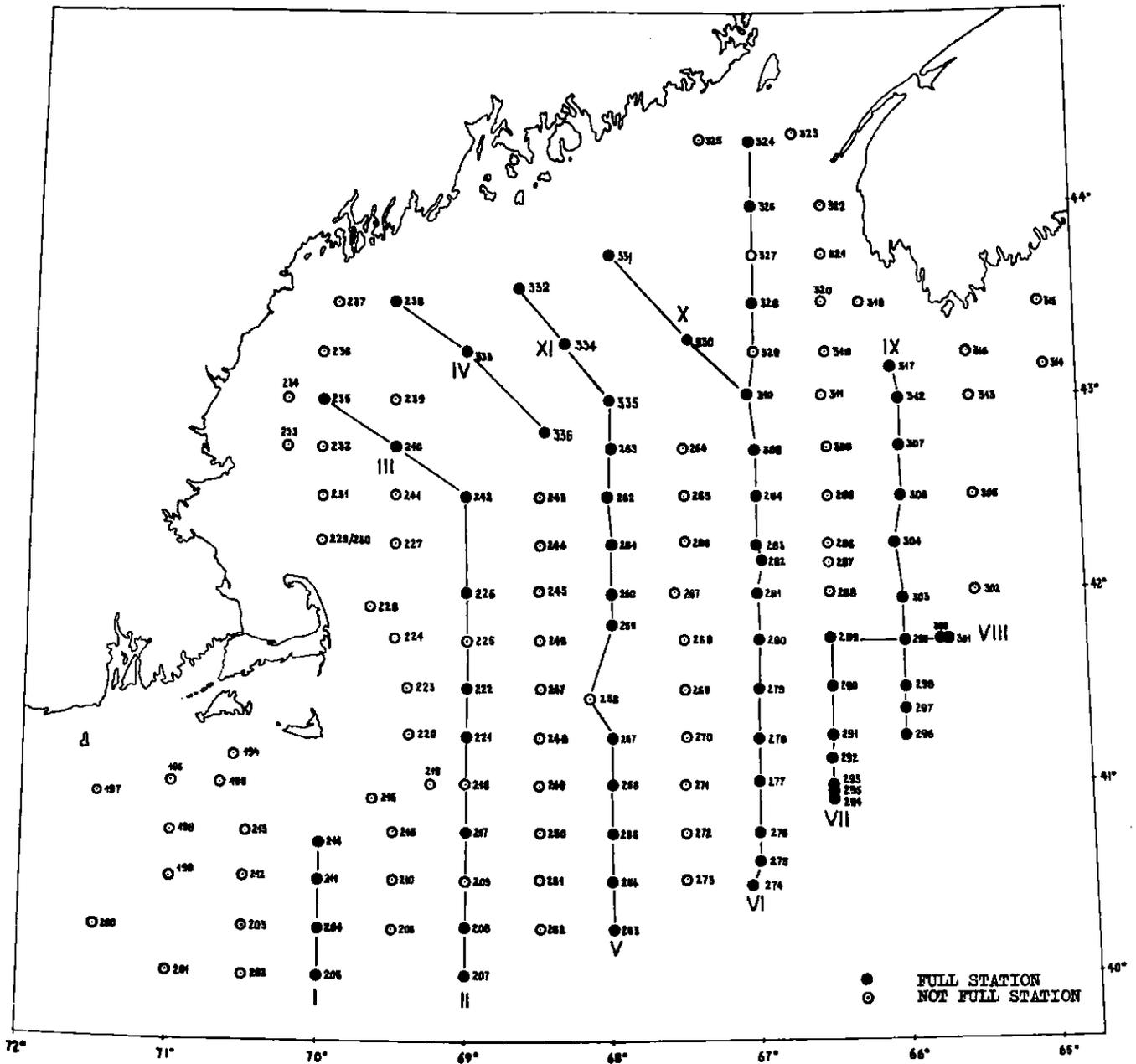


Fig. 1. Distribution of hydrological stations and profiles in the area of Georges Bank, Gulf of Maine, Nantucket Shoal and western part of the Nova Scotia Shelf, R/V *Wieczno*, 2-28 October 1972.

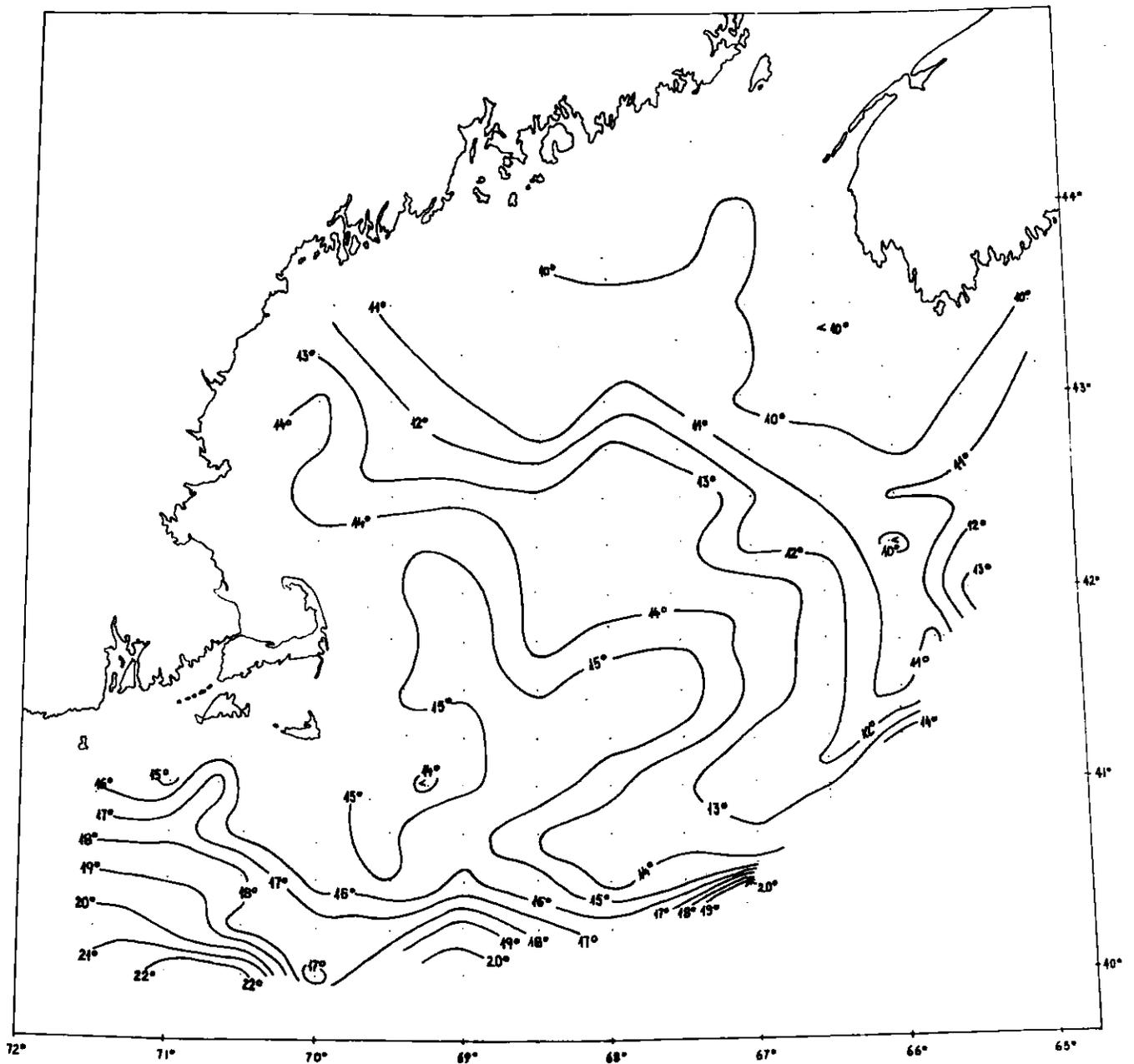


Fig. 2. Distribution of surface isotherms (°C) in the area of Georges Bank, Gulf of Maine, and western part of the Nova Scotia Shelf, R/V *Wicczno*, 2-28 October 1972.

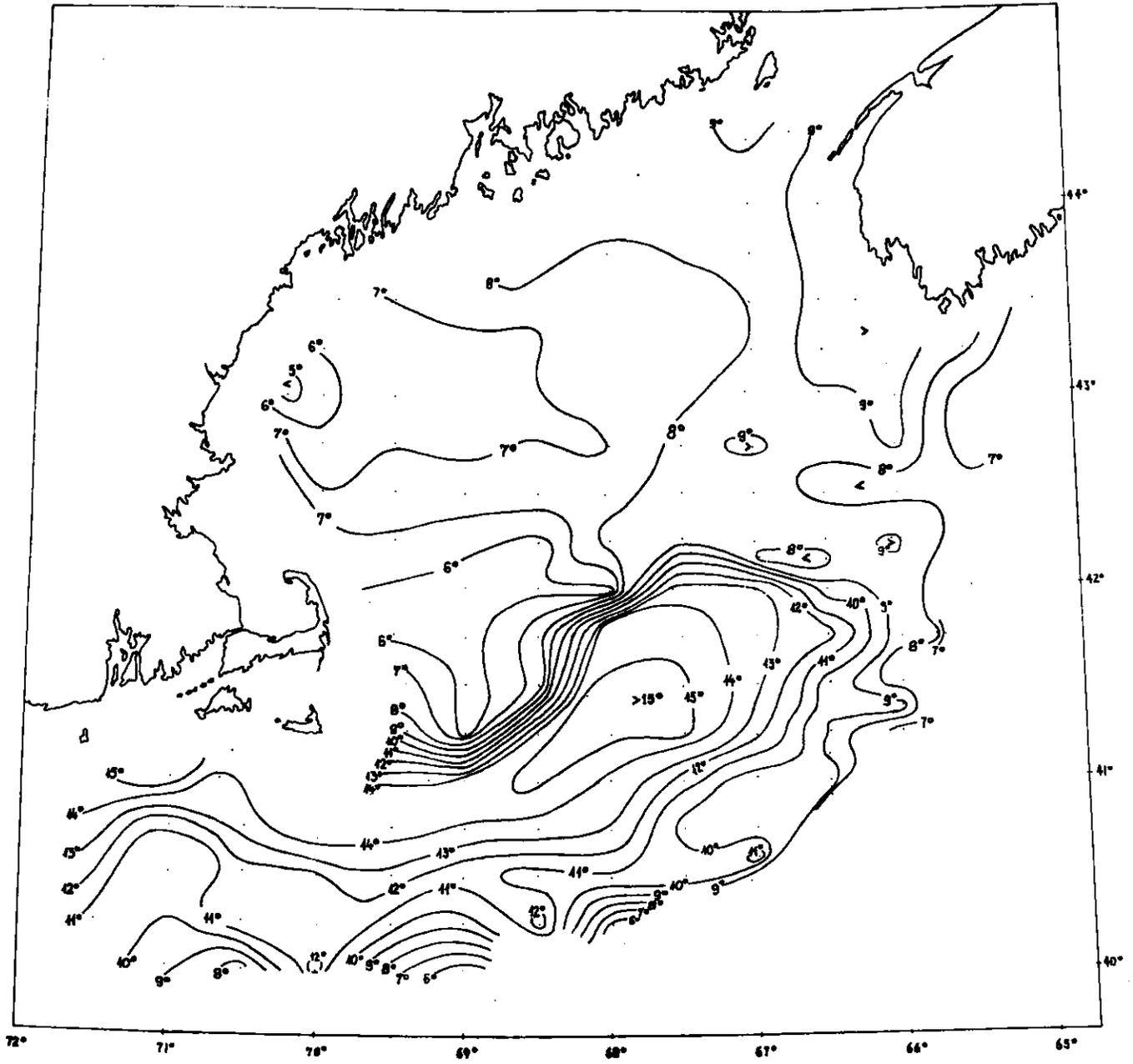


Fig. 3. Distribution of bottom isotherms ($^{\circ}\text{C}$) in the area of Georges Bank, Gulf of Maine, and western part of the Nova Scotia Shelf, R/V *Wicczno*, 2-28 October 1972.

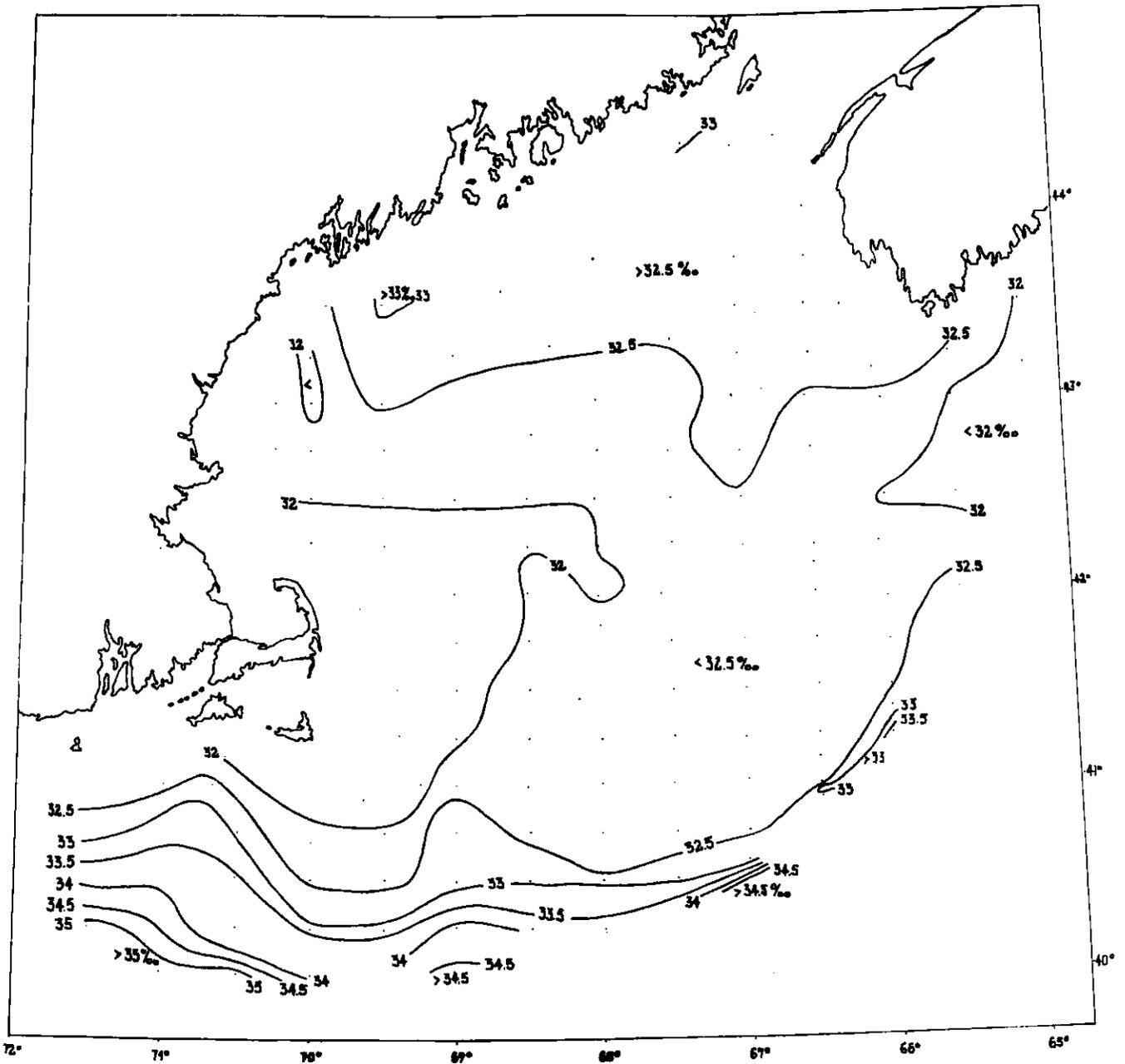


Fig. 4. Distribution of surface isohalines (‰) in the area of Georges Bank, Gulf of Maine, and western part of the Nova Scotia Shelf, R/V *Wisconsin*, 2-28 October 1972.

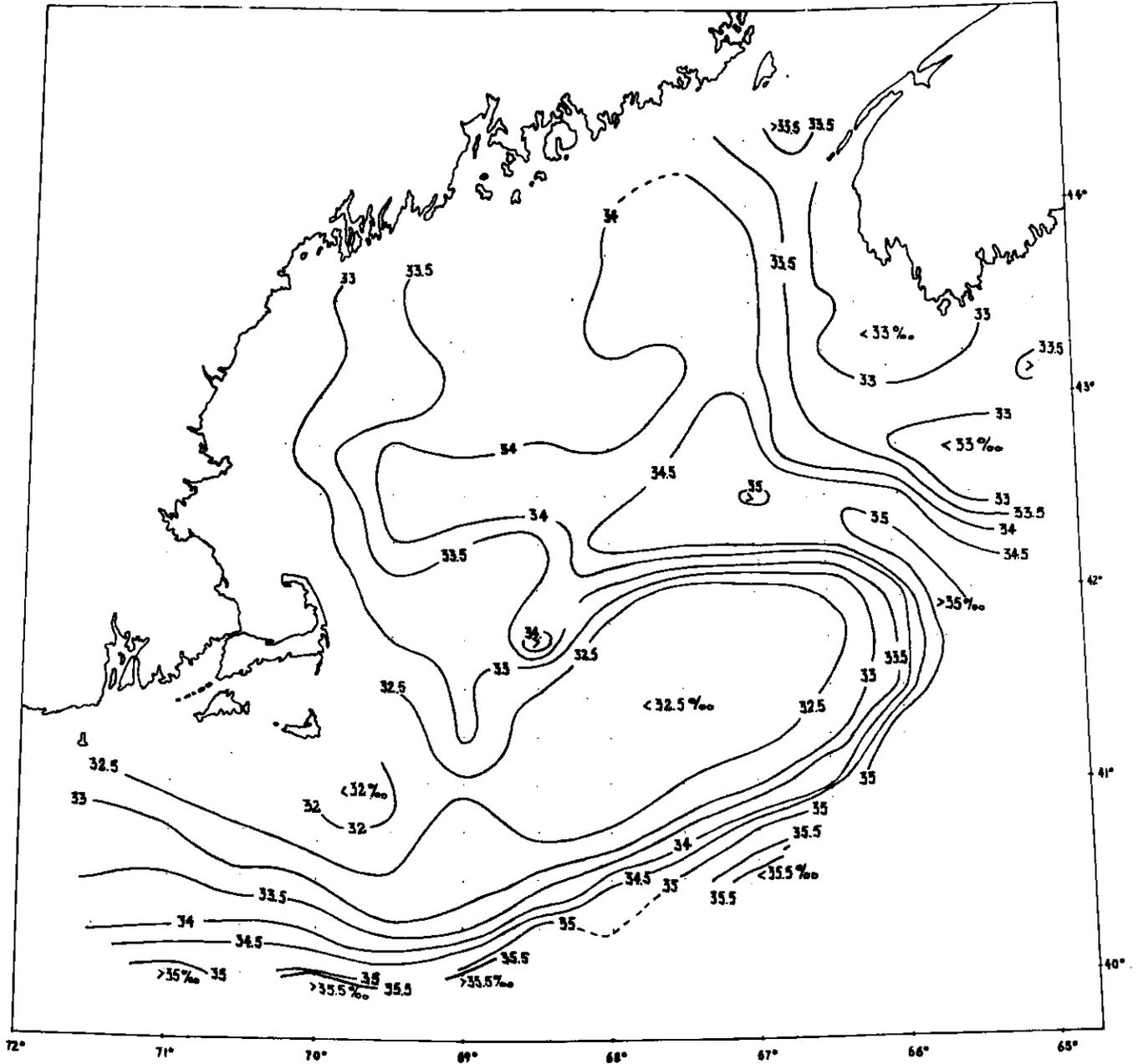


Fig. 5. Distribution of bottom isohalines (‰) in the area of Georges Bank, Gulf of Maine, and western part of the Nova Scotia Shelf, R/V *Wicazo*, 2-28 October 1972.

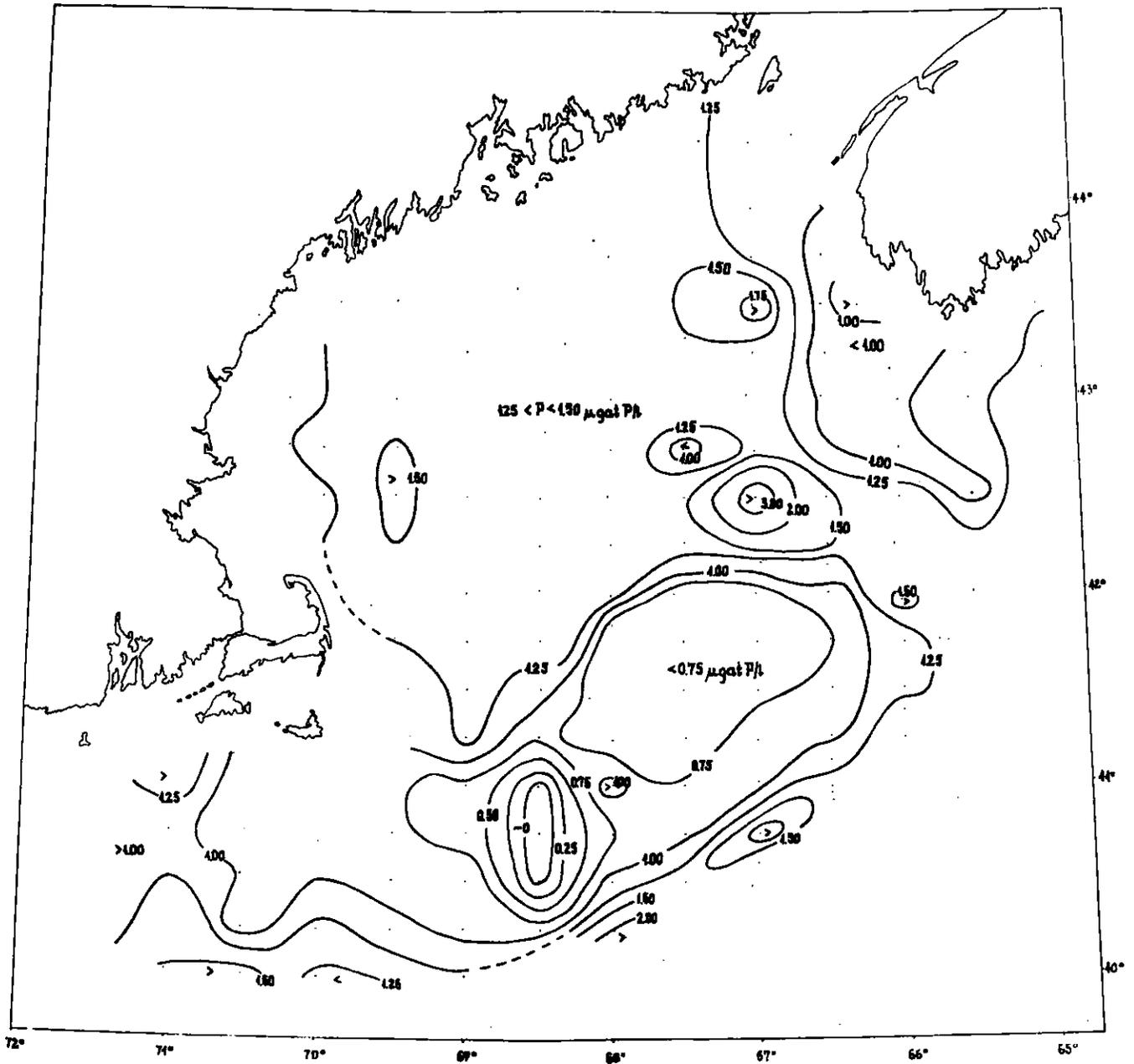


Fig. 6. Distribution of phosphate-phosphorus content ($\mu\text{g atom P/l}$) of bottom waters in the area of Georges Bank, Gulf of Maine, and western part of the Nova Scotia Shelf, R/V *Wicazo*, 2-28 October 1972.

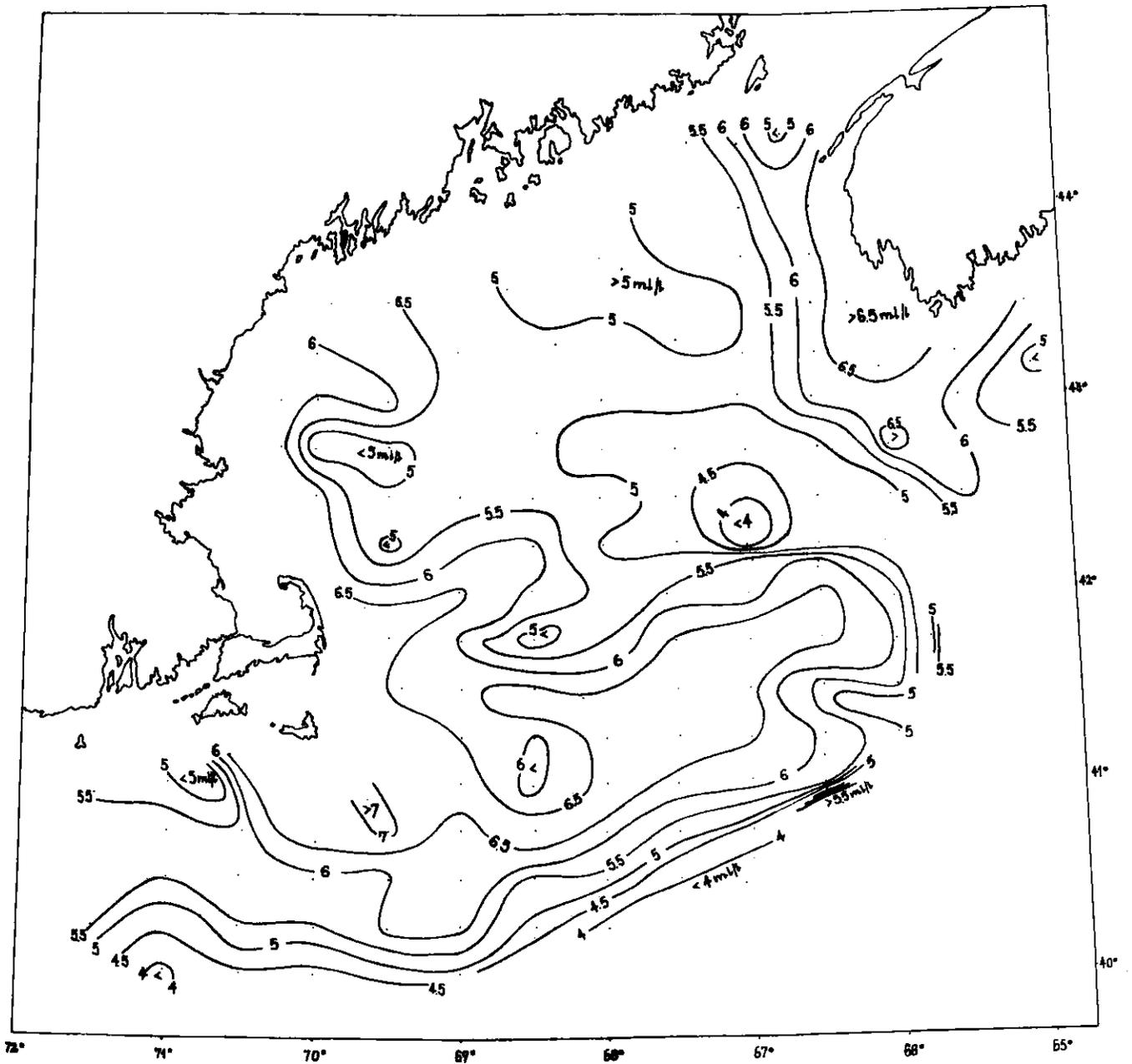


Fig. 7. Distribution of bottom oxygen (ml/l) in the area of Georges Bank, Gulf of Maine, and western part of the Nova Scotia Shelf, R/V *Wieczno*, 2-28 October 1972.

2. Water temperatures in Labrador and Newfoundland areas at the end of 1971 and during 1972¹

by V.V. Burmakin
PINRO, Murmansk, USSR

ABSTRACT

The paper describes average water temperatures on different standard hydrological sections in Labrador and Newfoundland areas in 1972. It was found that 1972 was a very cold year and temperature anomalies were the lowest over the whole period of observations since 1936. Maximum negative anomalies were recorded in the 0-50 m layer. Positive anomalies were observed in the 200-500 m layer of the southern slope of the Grand Bank.

INTRODUCTION

Hydrography observations in the Labrador and Newfoundland area were made at a total of 1,035 stations on a series of standard hydrological sections (Fig. 1). Temperatures were taken from the surface to bottom in the bank areas and down to 2,000 m on the slopes of the continental shelf. The research vessel *Protsion* carried out investigations in December 1971-February 1972 and in April-June 1972, and the *Perseus III* during April-July and in October 1972.

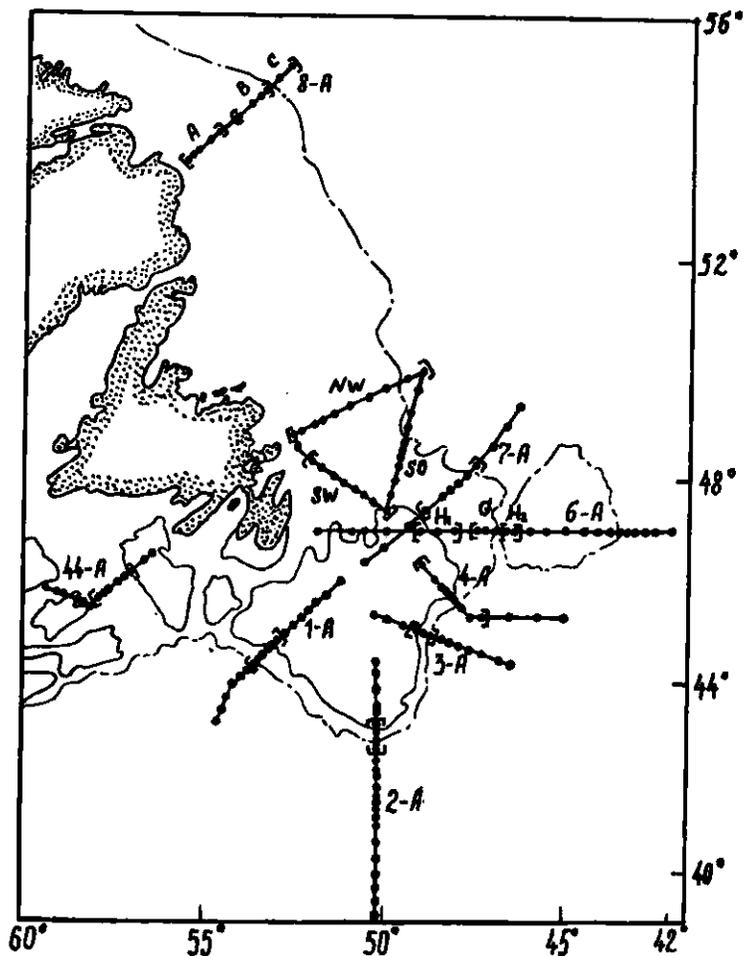


Fig. 1. Position of standard hydrological sections in Labrador and Newfoundland areas. Square brackets indicate sectors of sections where average temperature was calculated.

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METHODS

The temperature anomalies in the 0-200 m layer on the various sections are based on curves of the annual course of temperature by Burmakin (1972). The stations included in the square brackets in Fig. 1 indicate the boundaries of sections, suggested by Elizarov (1962), for which the average temperatures in the different layers were calculated.

RESULTS

As is evident from Table 1, considerable negative anomalies of temperature (-0.1° to -2.2°C) were found over the entire area observed in 1972, except for the southern and southwest slopes of the Grand Bank and St. Pierre Bank where positive anomalies from 0.3° to 2.2°C were observed (Sections 1A, 2A and 4A). The greatest negative anomalies were observed in the cold waters of the Labrador Current and the greatest positive anomalies on the southern slope of the Grand Bank.

Table 1. Temperature anomalies in the 0-200 m layer (°C) according to observations at the end of 1971 and during 1972.

Section	Dates	1971	1972					
		Dec	Jan	Feb	Apr	May	Jun	Oct
8A(B)	27 Oct	-	-	-	-	-	-	-1.4
7A	9 Dec, 7 Feb, 3 May	0.0	-	-0.8	-	-1.5	-	-
6A(G)	14 Dec, 10 Apr, 1 May, 26 May	-0.9	-	-	-2.2	-1.1 -1.9	-	-
4A	20 Dec, 25 Apr, 20 May	-1.3	-	-	-0.8	-0.9	-	-
3A	25 Dec, 18 Apr, 16 May	0.0	-	-	-1.3	-0.8	-	-
2A	27 Dec, 23 Apr, 5 Jun	+2.2	-	-	+0.5	-	+1.0	-
1A	8 Jan, 7 May, 19 Jun	-	-0.1	-	-	+0.3	+0.8	-
44A	20 Jan, 18 May, 27 Jun	-	-0.6	-	-	+1.2	-1.0	-

Table 2 gives the average temperatures in the 0-200 m layer and their anomalies relative to certain dates. This method of analysis of temperature conditions was used previously by Burmakin (1967, 1968, 1969, 1970, 1972) and by Burmakin and Kudlo (1971). As was indicated by Burmakin (1972), the inter-annual changes in average temperature in the Labrador Current usually have cycles of 3-4 years. The last cycle started in 1968 and probably ended in 1972. This cycle included two temperate warm years (1968 and 1969), one warm year (1970), and two cold years (1971 and 1972).

Table 2. Average temperatures in the 0-200 m layer (°C) which are relative to certain dates (and anomalies) in 1972.

Section	15 Apr	15 May	15 Jun	15 Nov
8A(AB)	-	-	-	-0.15 (-1.05)
7A	-	-0.52 (-1.36)	-	-
6A(G)	-	0.01 (-1.17)	-	-
4A	0.33 (-0.50)	1.04 (-0.22)	-	-
3A	-0.93 (-1.28)	-0.14 (-0.62)	-	-
2A	1.67 (+0.62)	2.39 (+1.01)	3.13 (+1.14)	-

In 1972 the water temperatures in Newfoundland-Labrador area were the lowest throughout the period of observations from 1936. The temperatures in the 0-200 m layer in 1972 on different sections were 0.55° to 1.17°C lower than the average values in the period 1968-72 (Table 3).

Evidence of the great cooling of the water in different layers between 1971 and 1972 is given in Table 4. Cooling was greatest in the surface layer (0-50 m) on the eastern slope of the Grand Bank in April and May (Sections 6A(H₁) and 4A) and in the near-bottom layer (200-500 m) on the southeast slope in April (Section 3A). In the core of the Labrador Current in the 50-200 m and 0-200 m layers, cooling was 0.5° to 1°C lower than in the 0-50 m layer.

Table 3. Average temperatures in the 0-200 m layer (°C) and their anomalies on Sections 8A on 1 November and on Sections 7A, 6A(G), 4A, 3A on 15 May, 1968-72.

Year	8A 1 Nov	7A 15 May	6A(G) 15 May	4A 15 May	3A 15 May
1968	0.50	1.25	1.48	2.25	1.85
1969	0.50	0.70	1.99	3.46	0.80
1970	0.60	0.87	1.95	2.05	0.44
1971	0.57	0.26	0.46	2.01	0.65
1972	-0.15	-0.52	0.01	1.04	-0.14
Average	0.40	0.51	1.18	2.16	0.72
Anomaly	-0.55	-1.03	-1.17	-1.12	-0.86

Table 4. Average temperatures in different water layers (°C) on Sections: "triangle", 7A, 6A, 4A, 3A in spring and summer, 1971-72.

Section	Date	Water layer (m)			
		0-50	0-200	50-200	200-500
Triangle (S side)	7 May 1971	0.83	0.23	-0.45	-
	14 May 1972	-0.64	-0.74	-0.84	-
Triangle (SW side)	7 May 1971	0.92	-0.04	-0.64	-
	14 May 1972	-0.63	-0.91	-1.08	-
	2 Jun 1971	2.29	0.44	-0.69	-
	28 May 1972	0.04	-0.56	-1.04	-
	10 Jul 1971	4.02	0.87	-0.82	-
	1 Jul 1972	3.34	0.66	-1.07	-
7A	3 May 1971	-0.05	0.07	0.07	2.84
	3 May 1972	-0.90	-0.70	-0.65	1.22
6A(H ₁)	1 May 1971	0.89	0.32	-0.38	-
	2 May 1972	-0.48	-0.76	-1.02	-
	25 May 1971	2.74	1.30	-0.25	-
	26 May 1972	0.44	0.04	-0.76	-
6A(G)	30 Apr 1971	0.25	0.65	0.74	3.29
	1 May 1972	-0.19	0.25	0.40	2.43
	24 May 1971	1.25	0.35	0.05	2.86
	26 May 1972	-0.35	-0.17	-0.20	2.82
6A(H ₂)	30 Apr 1971	1.35	2.84	3.34	4.48
	1 May 1972	1.91	2.71	2.97	4.18
	24 May 1971	2.46	2.74	2.84	4.56
	26 May 1972	1.72	2.26	2.43	3.68
4A	25 Apr 1971	2.72	2.25	1.63	4.48
	24 Apr 1972	0.40	0.57	0.57	3.54
	18 May 1971	2.60	2.07	1.20	4.28
	20 May 1972	1.16	1.16	0.94	3.68
3A	20 Apr 1971	0.62	0.32	-0.22	1.78
	23 Apr 1972	-0.88	-0.95	-1.02	-0.27
	15 May 1971	1.37	0.66	-0.16	2.68
	16 May 1972	0.38	-0.10	-0.57	1.00

On Section 1A across the southwest slope of the Grand Bank and on Section 44A across Cabot Strait (Table 5), the water temperature in the 0-50, 0-200, 50-200 and 50-100 m layers was lower in January, May and June 1972 than in 1967, 1970 and 1971, but in the near-bottom layer (100-200 m) and especially in the 200-500 m layer of these sections the temperatures were higher. Thus, during the last three years the heating effect of Gulf Stream water in near-bottom layers to the south of Grand Bank and St. Pierre Bank was the highest in 1972, and the phenomenon occurred simultaneously with the maximum winter cooling in the remainder of the Grand Bank to Labrador areas.

Table 5. Average temperatures in different water layers (°C) on Sections 2A, 1A and 44A in January, April-June 1972, and in 1966, 1967, 1970 and 1971.

Section	Date	Water Layer (m)					
		0-50	0-200	50-200	50-100	100-200	200-500
2A	3 Apr 1971	1.44	0.77	0.23	-0.11	0.99	2.94
	23 Apr 1972	2.33	1.86	1.53	2.18	2.98	3.41
	13 Jun 1966	3.66	2.77	2.26	1.95	2.56	3.30
	5 Jun 1972	3.86	2.89	1.62	0.45	4.16	4.84
1A	12 Jan 1970	6.89	6.39	5.51	5.82	7.22	5.94
	8 Jan 1972	3.51	4.47	4.86	4.49	8.72	7.68
	1 May 1967	2.98	2.62	2.45	2.45	2.70	3.37
	7 May 1972	2.70	2.80	2.60	2.34	5.87	6.84
	19 Jun 1971	8.11	6.86	4.96	4.98	7.09	5.29
	18 Jun 1972	6.16	5.01	3.66	2.82	6.44	7.02
44A	17 Jan 1970	3.90	3.92	3.93	2.65	4.57	4.96
	20 Jan 1972	1.43	2.04	2.25	1.39	2.67	5.33
	24 May 1971	3.18	3.28	3.59	2.07	3.78	5.18
	18 May 1972	2.04	3.08	3.43	1.29	4.52	6.57
	20 Jun 1970	6.35	4.08	3.32	1.95	4.00	5.36
	27 Jun 1972	5.19	3.60	3.07	1.96	3.62	5.80

CONCLUSIONS

In 1972 water temperatures in the Newfoundland and Labrador areas in the 0-500 m layer were below normal by 0.8° to 2.2°C and about 1°C lower than in the cold year of 1971. Such low temperatures were not observed throughout the period from 1936.

Compared with 1971, the surface (0-50 m) and near-bottom (200-500 m) layers in 1972 were subjected to the severest cooling, whereas cooling was not as great in the core of the Labrador Current (50-200 m).

On the southern and southwestern slopes of the Grand Bank and in Cabot Strait, positive temperature anomalies were observed in the 0-200 m layer. The temperature in the 200-500 m layer was also higher than normal.

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3. Temperatures and salinities in the eastern Newfoundland area in 1972¹

by W. Templeman
Fisheries and Marine Service, Environment Canada, Biological Station
and Memorial University of Newfoundland, St. John's, Newfoundland

INTRODUCTION

The six standard monitoring hydrographic sections across the Labrador Current east of Newfoundland were taken by the *Cape Freels* at approximately the usual dates in July and August. Station 27, off Cape Spear was occupied monthly or oftener during the year. The 1972 section temperatures are compared with the lowest, average, and highest temperatures at each station and depth in the period 1951-65 at approximately the same dates (unpublished), also with temperatures at the same time of year in these sections in 1969-71 (Templeman, 1970, 1971, 1972), and additionally for the Flemish Cap section in 1966-68 (Templeman, 1967, 1968, 1969). Salinities are also compared with those of some of the previous years. In the sections, apart from the surface temperatures and salinities, the position of the decimal point in an inserted temperature or salinity indicates its level and position.

SECTIONS ACROSS THE LABRADOR CURRENT IN JULY-AUGUST

Temperatures

In 1972, the intermediate cold water of the Labrador Current was colder than in any previous year of observation and more extensive horizontally and often vertically, whereas the deep slope water on the eastern slopes of the area, attributable to the influence of the West Greenland Current, possessed temperatures usually close to the highest of former years for which records are available.

In the southern Labrador section (Section A) from off Seal Island across Hamilton Inlet Bank (Fig. 1A), more cold water, at a lower temperature below 0°C and especially below -1.0° and -1.5°C, was present than in any year of the 1951-65, 1969-71 periods for which the section is available. Very cold water extended farther seaward than in any previous year of the period. In the intermediate cold water layer, throughout the whole extent of the section from Station 51 to Station 57, at each station almost all the temperatures were lower than previously recorded. The volume of water below -1.5°C was about seven times as great as in the previous coldest year. Temperatures from 0° to -1.5°C extended to record depths on the seaward side of Hamilton Inlet Bank and farther seaward than in any previous year, but over the bank there was a shallow layer of higher than average temperatures. Surface temperatures were below average and in the three seaward stations were the lowest of the observation period. On the seaward slope of the bank in the deep water derived from the West Greenland Current, temperatures at 400 m and deeper were almost as high as the highest temperatures of the above period.

In Section B, in the Cape Bonavista section between Stations 43 and 50 (Fig. 2A), temperatures at the core of the intermediate cold water were lower and temperatures below -1.5°C extended farther seaward than in any year of the 1951-65, 1969-71 period. Surface temperatures were below average, at the most seaward stations close to the lowest temperatures of the period and at Station 50 the lowest of the period. The near-bottom temperatures of the Northeast Newfoundland Shelf at the western Stations 45 and 46 were only a little below the average of the 1951-65 period and were lower than in 1970-71. Seaward on the shelf, near-bottom temperatures were above average, a little lower than the highest of the 1951-65 period and below those of 1970-71. In the deep water of the continental slope at Stations 49B and 50, temperatures were above average, higher than in 1971 and only a little below the highest of the period of observation.

In the part of Section B extending southwards from Station 50, through Stations 35F-35 to the northern part of the Grand Bank (Fig. 2A¹), which has only been done in recent years (but not in 1971), surface temperatures in the northern part of the section were much lower than those of 1969-70 but those of stations near the Grand Bank similar to those of 1969 and 1970. There was more water below -1°C and much more below -1.5°C than in these two years and the lowest temperatures were lower than those previously observed. Deep-water temperatures on the northern slope of the Grand Bank were lower than in 1970 and higher than in 1969.

In Section C from St. John's to Flemish Cap (Fig. 3A), surface temperatures were mostly close to the average of the 1951-65 period although a little lower than the average at some of the upwelling points east of the banks, and lower than in 1971. Temperatures in the coolest part of the Labrador Current were slightly lower in the Avalon Channel and especially east of the Grand Bank, than in any year 1951-71. For the first time in this period, water temperatures below 1°C (lowest -1.16°C) were present at Flemish Cap. Bottom temperatures in the Avalon Channel and especially at Station 28 were lower than any previously encountered in these sections. Bottom temperatures over the western part of the Grand Bank were below average but not as low as the lowest of earlier years, and bottom temperatures on the upper part of the eastern slope of

¹ Submitted to the 1973 Annual Meeting of ICNAF as ICNAF Res.Doc. 73/50.

the Grand Bank were lower than any previously found. Bottom temperatures on Flemish Cap were lower than any taken previously. In the deep water of Flemish Channel, temperatures on the western side were above average and on the eastern side mainly higher than any previously found. In the deep water east of Flemish Cap, temperatures were above average and generally close to the highest previously found.

In Section D from St. John's to the southeast slope of the Grand Bank (Fig. 4A), surface temperatures (except at Station 32) were a little below average and below those of 1971. Temperatures in the Avalon Channel and in the eastern branch of the cold water of the Labrador Current were slightly lower than any encountered in this section in 1951-65, 1969-71. Bottom temperatures over the Grand Bank were average and those of the Southeast Shoal, a little above average. The temperatures of the deep water on the eastern slope of the Grand Bank, derived from the West Greenland Current, were above average and a little below the highest temperatures which were found in 1970.

In Section E extending along the southwestern edge of the Grand Bank at about 75 m (Fig. 5A), surface temperatures were close to the average of the 1951-65 period, except east of the Grand Bank where they were higher than average. Over the bank they were a little lower than in 1971 and east of the bank a little higher. Temperatures in the Haddock Channel were slightly lower, and in the eastern branch of the Labrador Current distinctly lower than in any previous year. Bottom temperatures over the Grand Bank at Stations 22 and 23 were a little higher and those at Stations 25 and 26 lower than the average. On the eastern slope of the Grand Bank, water with temperatures below 0°C extended a little more deeply than in any previous observation year and temperatures at all levels in the cold water of the eastern division of the Labrador Current touching the upper slope of the bank were lower than any previously found. An eastern division of the eastern branch of the cold water was present in Station 26H, only noted previously in 1971 but still farther east and slightly lower in temperature in 1972. This eastern division was present also in Sections C and D. In the deep slope water east of the bank, at and below 400 m, temperatures were above average and close to the highest of previous years of observation.

In Section F at about 275 m along the southwestern slope of the Grand Bank to St. Pierre Bank (Fig. 6A), surface temperatures were a little above the average for the 1951-65 period and some a little higher and others a little lower than in 1971. The lowest temperatures of the western branch of the Labrador Current were below average, close to but slightly higher than the lowest previously found. Core temperatures in the eastern branch of the Labrador Current were lower than any obtained previously for this section. Remarks for the division of the cold water under Station 26H and for the deep water of the eastern slope are similar to those from Section E since slope data from the same stations are included in both sections. The temperatures of the warmer central water over the slope (Station 17), derived from the slope water of the southwestern Grand Bank, were above average but about 2°C lower than the highest level which was found in 1971. Bottom temperatures at about 275 m across the slope of the bank were on the average higher than any previously found.

Salinities

In the Seal Island Section A (Fig. 1B), lower salinities (33.5‰) extended much more deeply than usual on the eastern slope of Hamilton Inlet Bank but there was an isolated area of somewhat higher salinity (and higher temperature) on the crest of the bank. Salinities of the deeper water on the eastern slope of the bank were higher than in 1971 and at Station 57 at the same level as in 1969 and 1970.

In the Bonavista Section B (Fig. 2B), salinities of the deeper water of the Northeast Newfoundland Shelf and its seaward slopes were mostly slightly lower than in 1971 and lower than in 1970. The deep-water salinities on the northern slope of the Grand Bank (Fig. 2B¹) were considerably lower than in 1970 but considerably higher than in 1969.

In the St. John's-Flemish Cap Section C (Fig. 3B), salinities in the deepest part of the Avalon Channel were higher than in 1971 and lower than in 1970. Bottom salinities over the Grand Bank were slightly lower than in 1971 and still lower than in 1969-70. Salinities in the deeper part of the Flemish Channel were mostly little different from those of 1971 but considerably lower than those of 1970. Salinities over Flemish Cap and on its eastern slope were lower than in 1971 and much lower than in 1970.

In Section D from St. John's to the southeastern slope of the Grand Bank (Fig. 4B), salinities in the deeper water of the Avalon Channel were higher than in 1970, 1971 and a little lower than in 1969. Salinities in the deep water of 400 m and greater on the eastern slope of the Grand Bank were similar to or slightly lower than those of 1970 and slightly lower than those of 1969 and 1971.

In Section E at about 75 m along the southwestern slope of the Grand Bank (Fig. 5B), salinities in the deep water of 400 m and more to the east of the bank were only slightly lower than in 1969-71.

In Section F at 275 m along the southwestern slope of the Grand Bank to St. Pierre Bank (Fig. 6B), near-bottom salinities at the level surface were higher than in 1971.

STATION 27, 1972

At Station 27 off Cape Spear (Fig. 7), surface temperatures in winter-spring 1972 were considerably below the 1950-62 average (Templeman, 1965) and at this season also, temperatures were lower to a greater depth than the average from the above period and in recent years from 1969-71. Also, throughout the year lower temperatures than usual occurred in the deep water. Summer and autumn surface and upper layer temperatures were close to the 1950-62 average and lower than in 1972 from June to September. Salinities in the deeper water were a little higher than in 1971.

ACKNOWLEDGEMENTS

I am especially grateful to Mr A.G. Kelland, hydrographic technician at the St. John's Station, also to Mr A.M. Fleming, Acting Director of the St. John's Station and to Mr L.N. Cluett for their contributions toward this paper and also to the scientists and technicians of the St. John's Station who have taken hydrographic observations at Station 27 and in the various sections.

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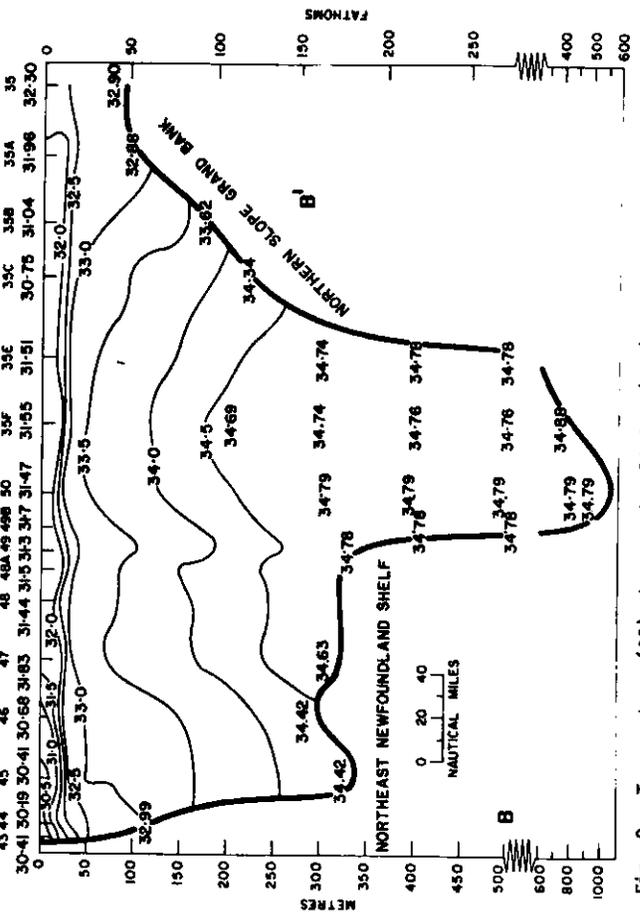
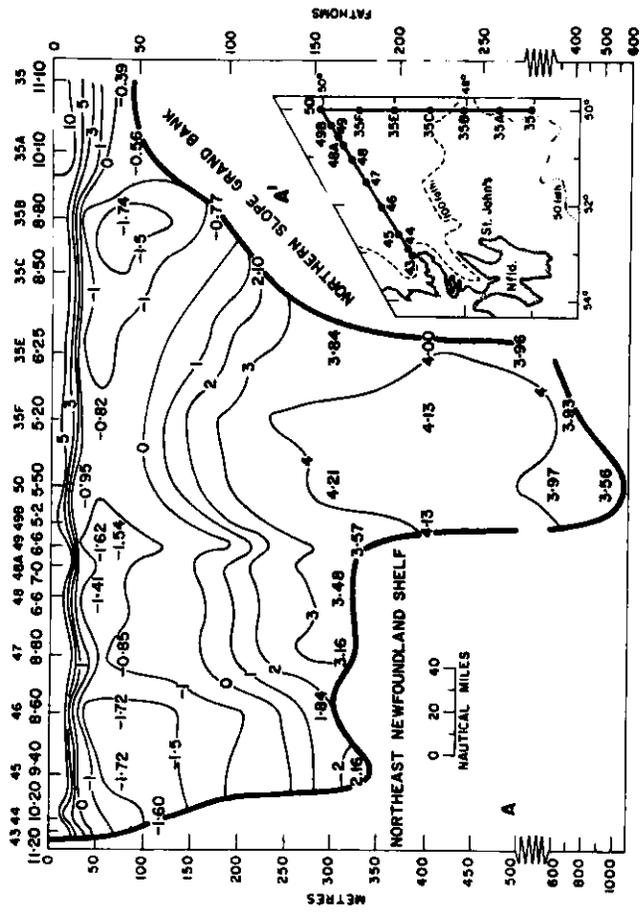


Fig. 1. Temperature ($^{\circ}\text{C}$) above and salinity (‰) below, Section A, Seal Island-Hamilton Inlet Bank, 1-2 August 1972.

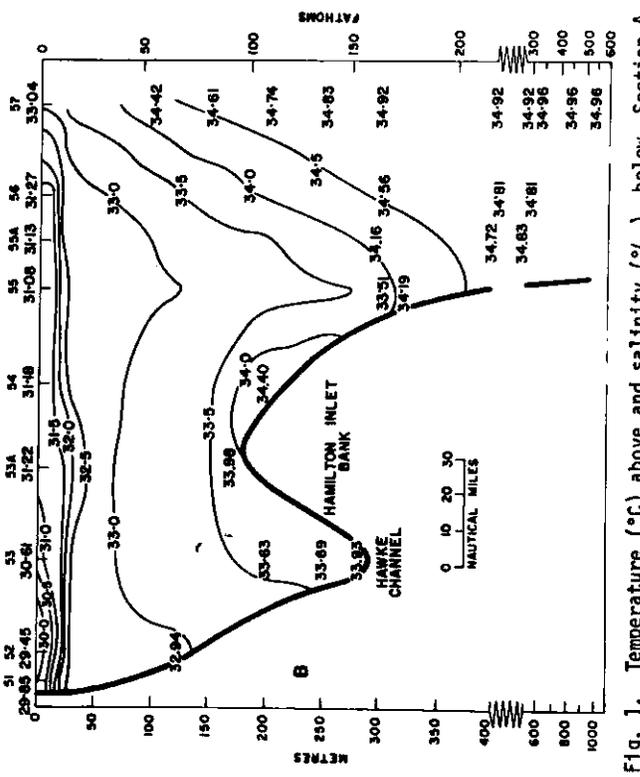
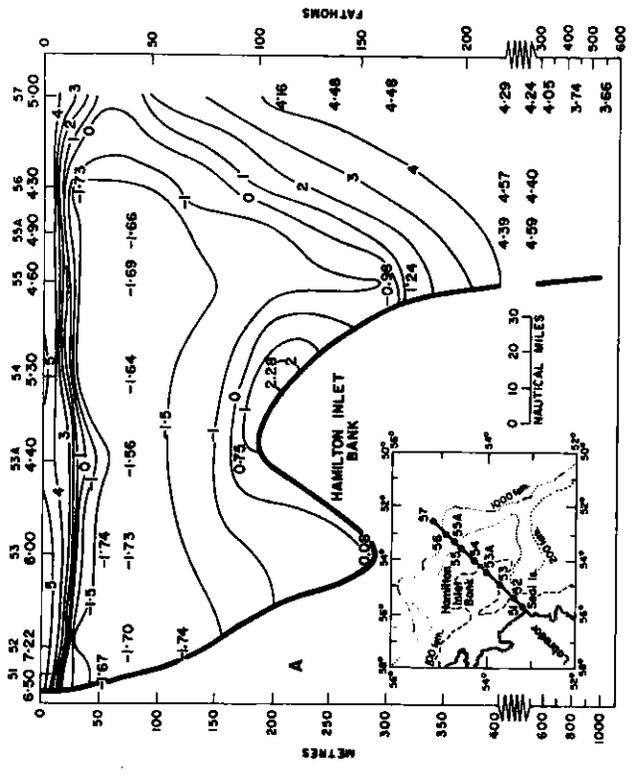


Fig. 2. Temperature ($^{\circ}\text{C}$) above and salinity (‰) below, Section B, off Cape Bonavista, and southward to northern Grand Bank, 26-28 July 1972.

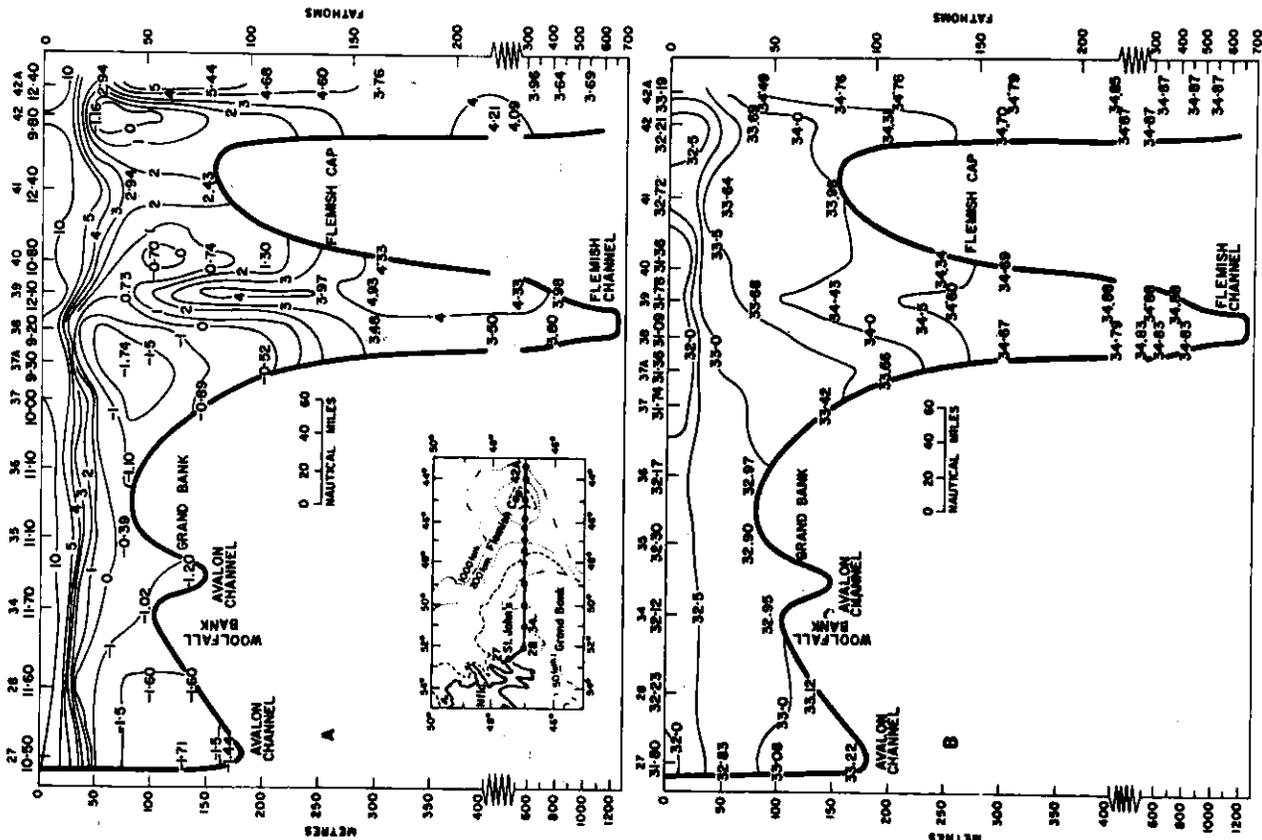


Fig. 3. Temperature (°C) above and salinity (‰) below, Section C, St. John's-Flemish Cap, 26-28 July 1972.

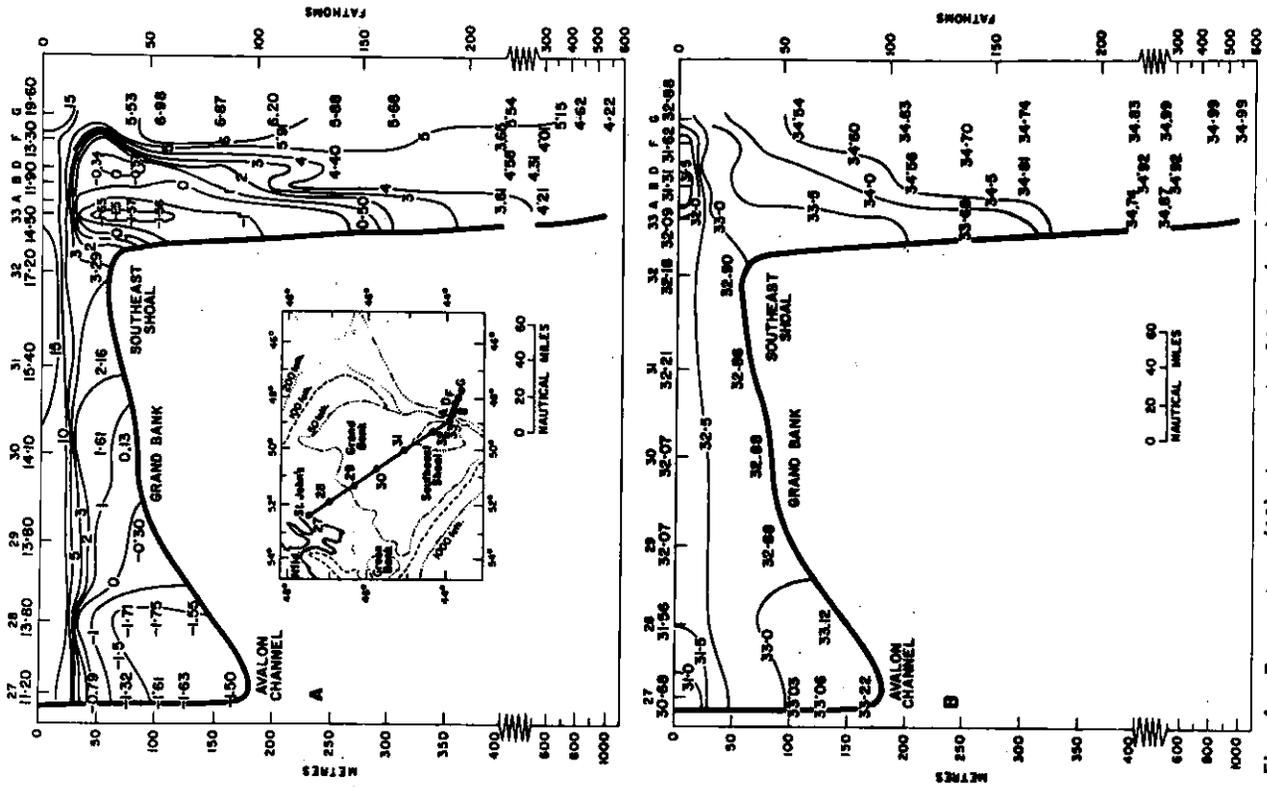


Fig. 4. Temperature (°C) above and salinity (‰) below, Section D, St. John's-southeast slope Grand Bank, 19-20 August 1972.

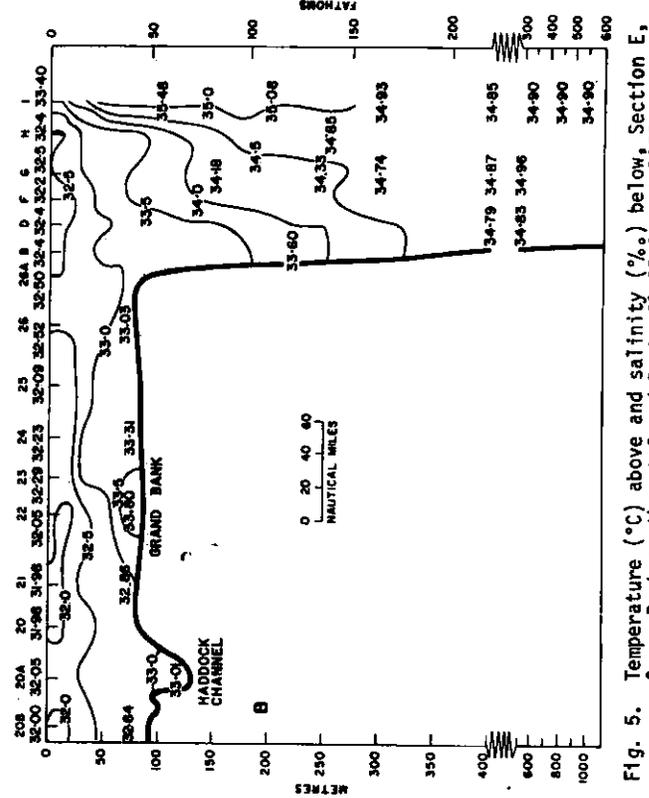
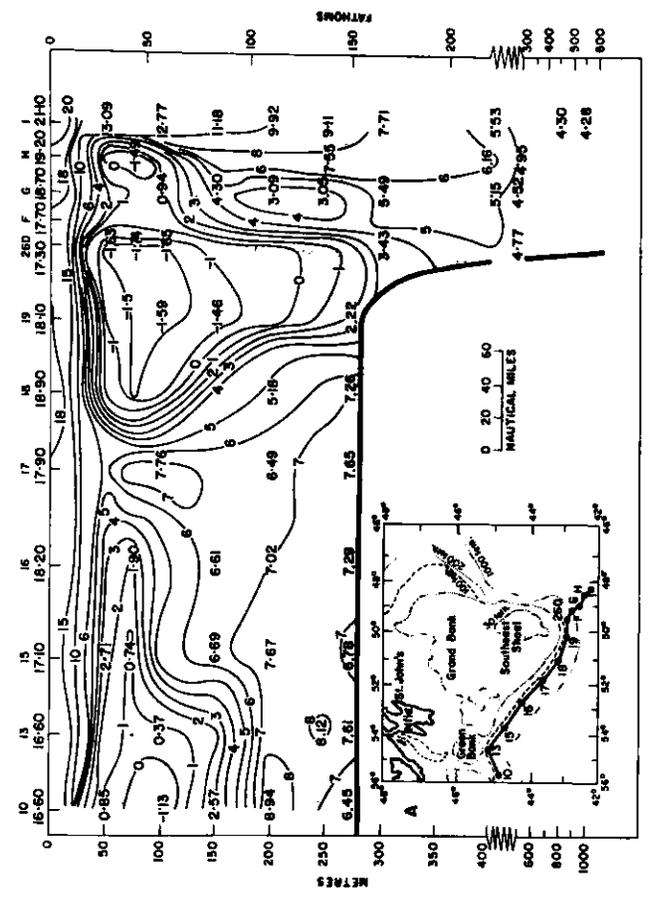


Fig. 5. Temperature ($^{\circ}\text{C}$) above and salinity (‰) below, Section E, Green Bank-southwest Grand Bank, 21-25 August 1972.

Fig. 6. Temperature ($^{\circ}\text{C}$) above and salinity (‰) below, Section F, south-west slope Grand Bank-St. Pierre Bank, 21-24 August 1972.

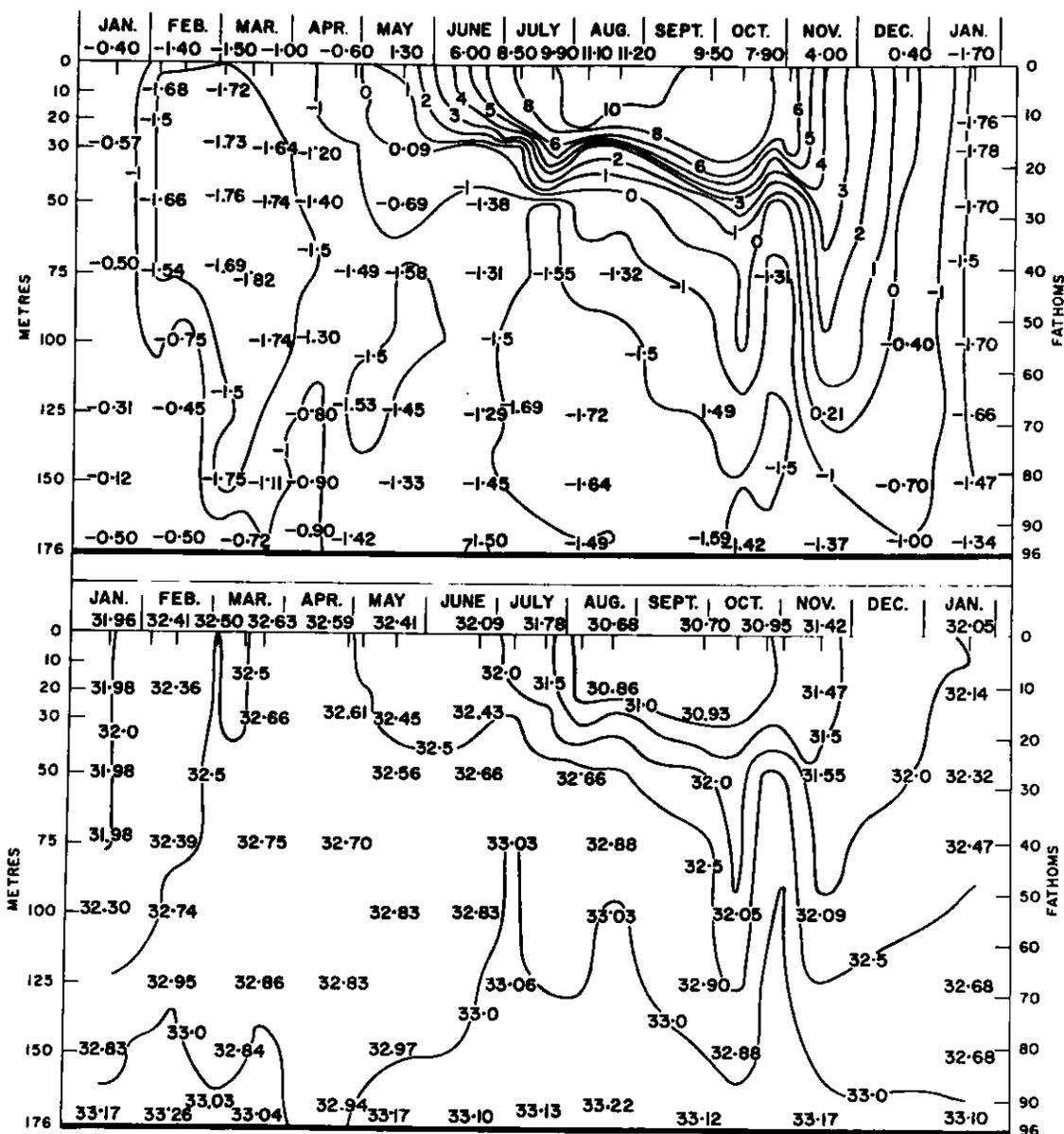


Fig. 7. Temperature ($^{\circ}\text{C}$) above and salinity (‰) below, January 1972 to January 1973, from surface to bottom at Station 27 (see Fig. 3, 4, inset), 2 nautical miles off Cape Spear near St. John's.

4. Hydrographic conditions off West Greenland in 1972¹

by F. Hermann
Danish Institute of Fisheries and Marine Researches
Charlottenlund, Denmark

and W. Lenz
Institut für Seefischerei
Hamburg, Fed. Rep. Germany

and R.W. Blacker
Sea Fisheries Laboratory
Lowestoft, Suffolk, England

INTRODUCTION

As the authors felt that a report based on the combined data from the research vessels of the three countries would give a better description of the hydrographic conditions off West Greenland than three separate reports, it was decided to present the observations in a combined paper prepared by the senior author.

The Danish research vessel *Adolf Jensen* worked Section I (see Fig. 1) in June and Section II in April, June and July. The FRG research vessel *Anton Dohrn* worked Sections III, IV and V in December. Section II was worked in December by *Anton Dohrn* and the English research vessel *Cirolana* together, and the sections over Dana Bank, Noname Bank and off Cape Desolation and Cape Farewell were worked by *Cirolana* in December.

SUMMARY OF RESULTS

Temperature conditions in the various sections are shown on Fig. 2-9 and 11-15. Very cold conditions were found on Fylla Bank in the upper 100 m in April, June and July as a result of strong winter cooling and inflow of cold polar water from the East Greenland Polar Current. The 1972 cod year-class will probably be small as the temperatures over the shallow part of Fylla Bank in June was less than 1°C, and earlier experience indicates that great year-classes can be expected only when the temperatures exceed 1°C.

Over Little Hellefiske Bank and Great Hellefiske Bank the temperatures were very low in the upper 100 m in July.

In December the winter cooling has caused negative temperatures in the upper layers, at Section III reaching to 50 m and at the northernmost Section V reaching to 100 m. From Section II and southwards the volume of water with negative temperatures was relatively small in December. At depths greater than 100 m relatively high temperatures were found in December. In the core of the Irminger component of the West Greenland Current the temperature exceeded 5°C as far north as Section IV.

Deviations of temperature and salinity from the mean values for the years 1950-66 (Hermann, 1967) for the station at 63°53'N and 53°22'W, west of the slope of Fylla Bank, in July are shown below:

Depth interval (m)	Mean temperature (°C)	Mean salinity (‰)	ΔT	ΔS
	1950-66	1950-66	July 1972	July 1972
0-50	2.07	33.29	-0.96	-0.14
50-100	1.33	33.65	-0.59	-0.29
100-200	1.85	34.00	-0.84	-0.30
200-300	2.88	34.39	-0.65	-0.23
300-400	3.79	34.67	-0.76	-0.20
400-500	4.22	34.81	-0.82	-0.17
0-500	2.89	34.27	-0.77	-0.22

Negative temperature and salinity anomalies are found in all water layers down to 500 m, indicating great inflow of polar water.

¹ Submitted to the 1973 Annual Meeting of ICNAF as ICNAF Res.Doc. 73/53.

Figure 10 shows the 5-year running mean of the surface temperature anomalies in the West Greenland area (A₁) and the South Greenland area (B) based on the surface anomalies for the years up to 1970 (Smed, up to 1970). The temperatures are now back at the level of the mean value for the years 1876-1915 and the climatic jump back to cold conditions has been just as sudden as the rise in temperatures in the twenties.

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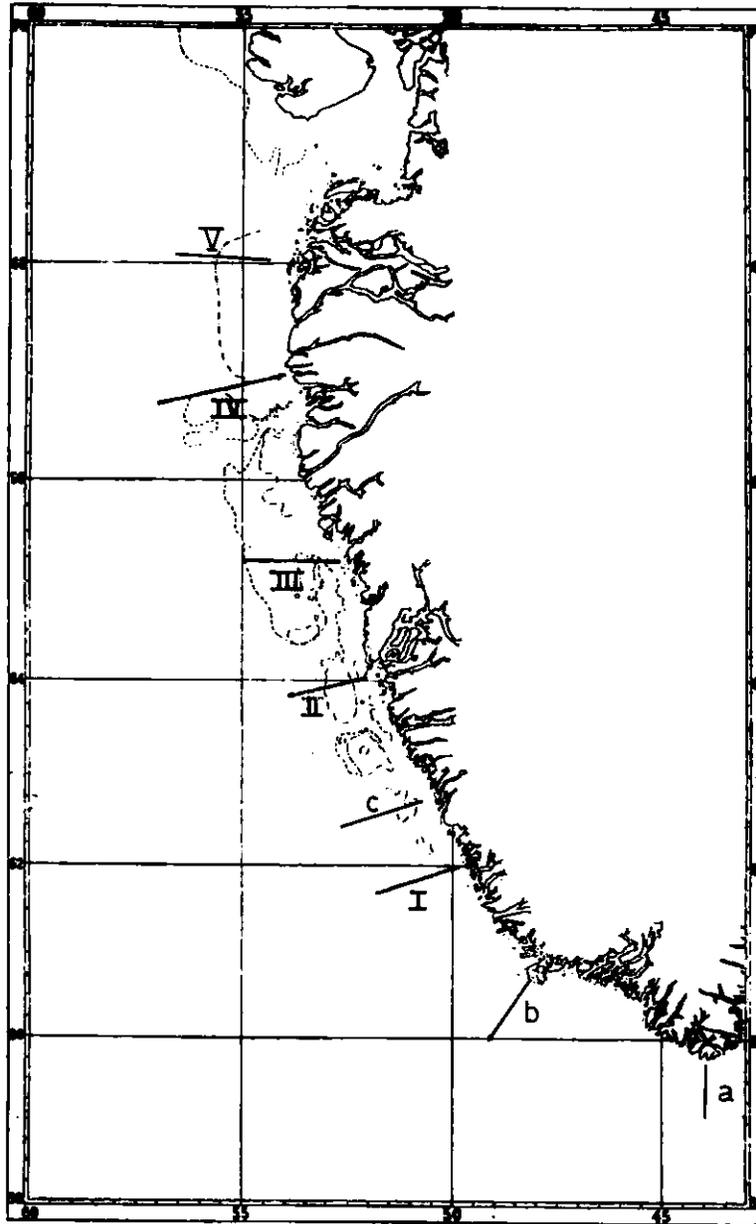


Fig. 1. Location of sections.

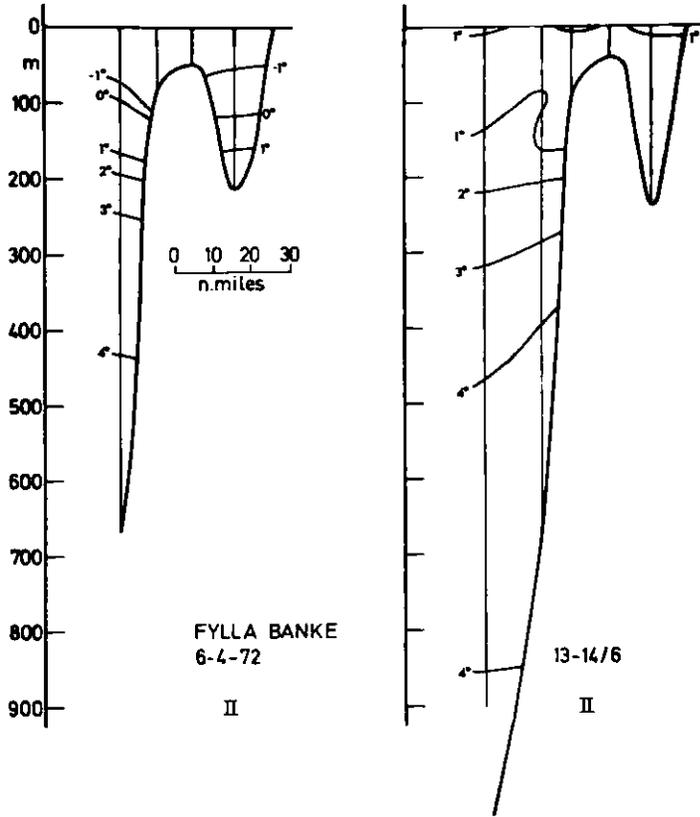


Fig. 2. Temperature distribution at Fylla Bank Section in April and June.

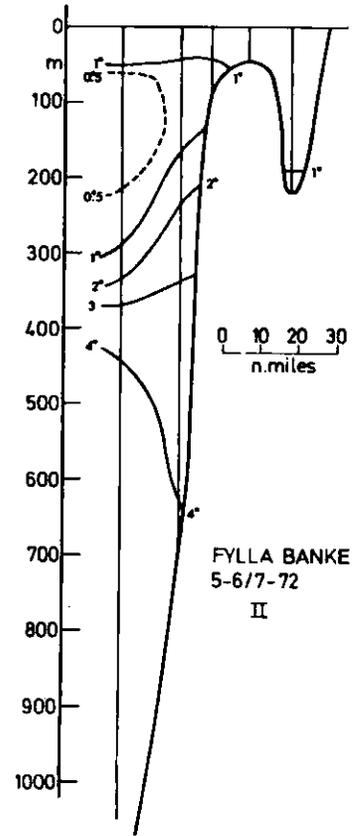


Fig. 3. Temperature distribution at Fylla Bank section in July.

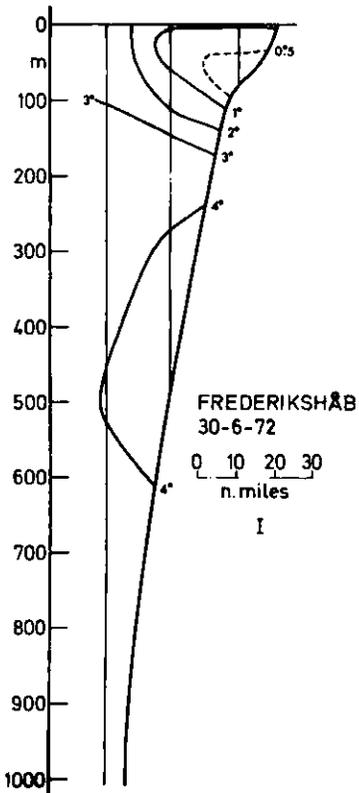


Fig. 4. Temperature distribution at Frederikshåb section in June.

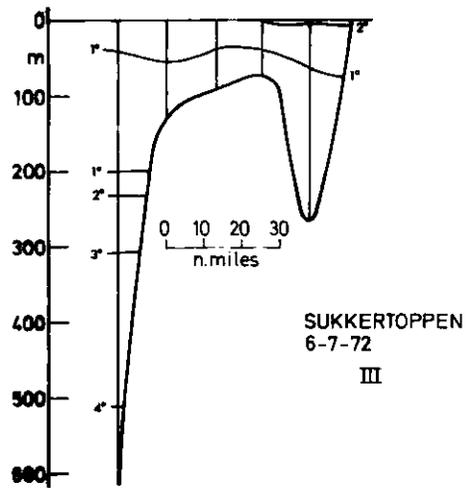


Fig. 5. Temperature distribution at section across Little Hellefiske Bank in July.

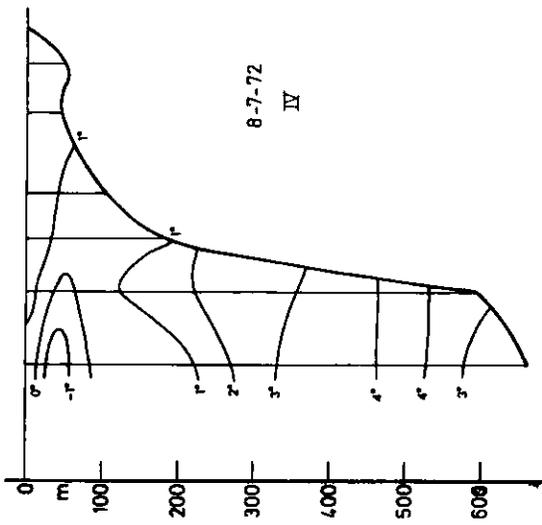


Fig. 6. Temperature distribution at section across Great Hellefiske Bank in July.

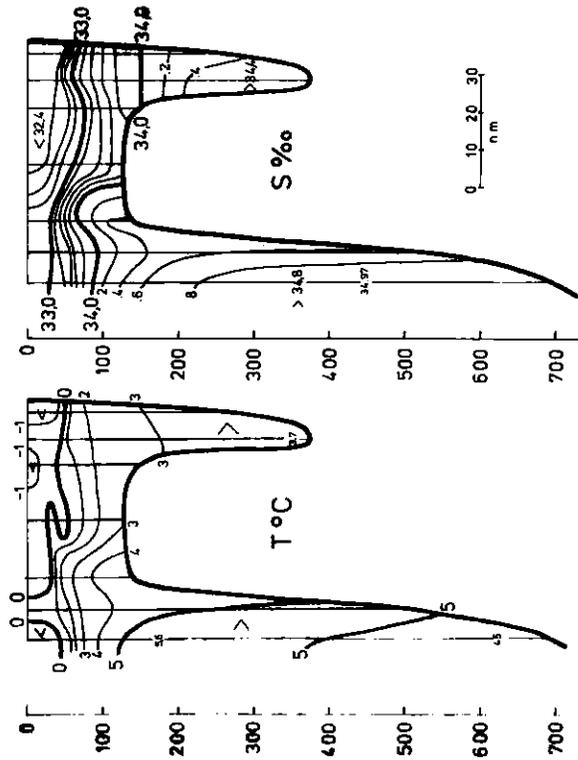


Fig. 7. Temperature and salinity distribution across Little Hellefiske Bank in December.

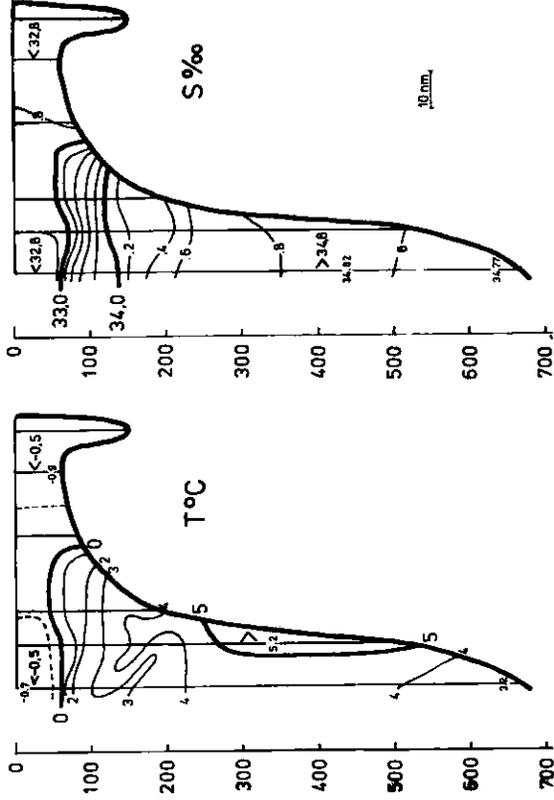


Fig. 8. Temperature and salinity distribution across Great Hellefiske Bank in December.

HOLSTEINSBORG, Section IV
2. 12. 72

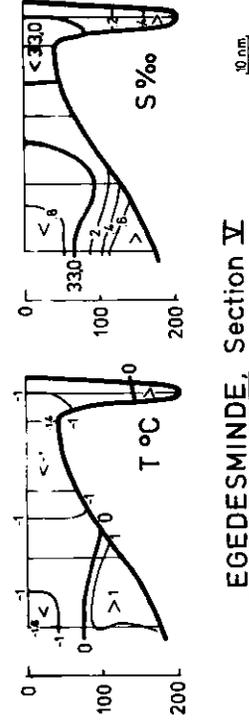


Fig. 9. Temperature and salinity distribution off Egedasminde.

EGEDESMINDE, Section V
1. 12. 72

SUKKERTOPPEN, Section III
3/4. 12. 72

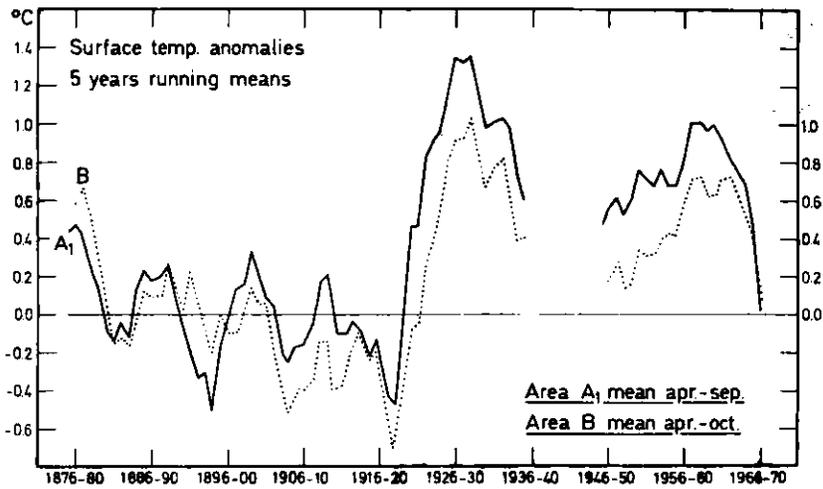
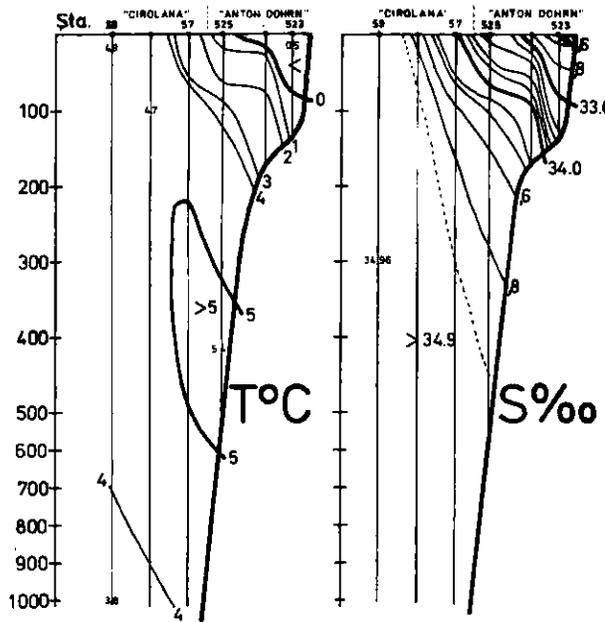


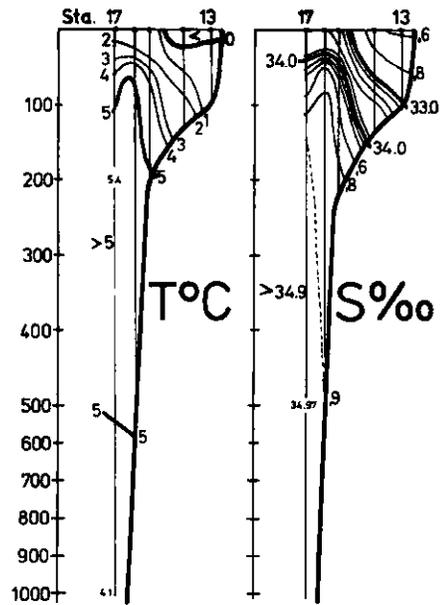
Fig. 10. Sea surface temperature anomalies, 5-year running mean.

A₁ (solid line): West Greenland area,
B (dotted line): South Greenland area.



Cape Farewell

10./11. 12. 72 a.

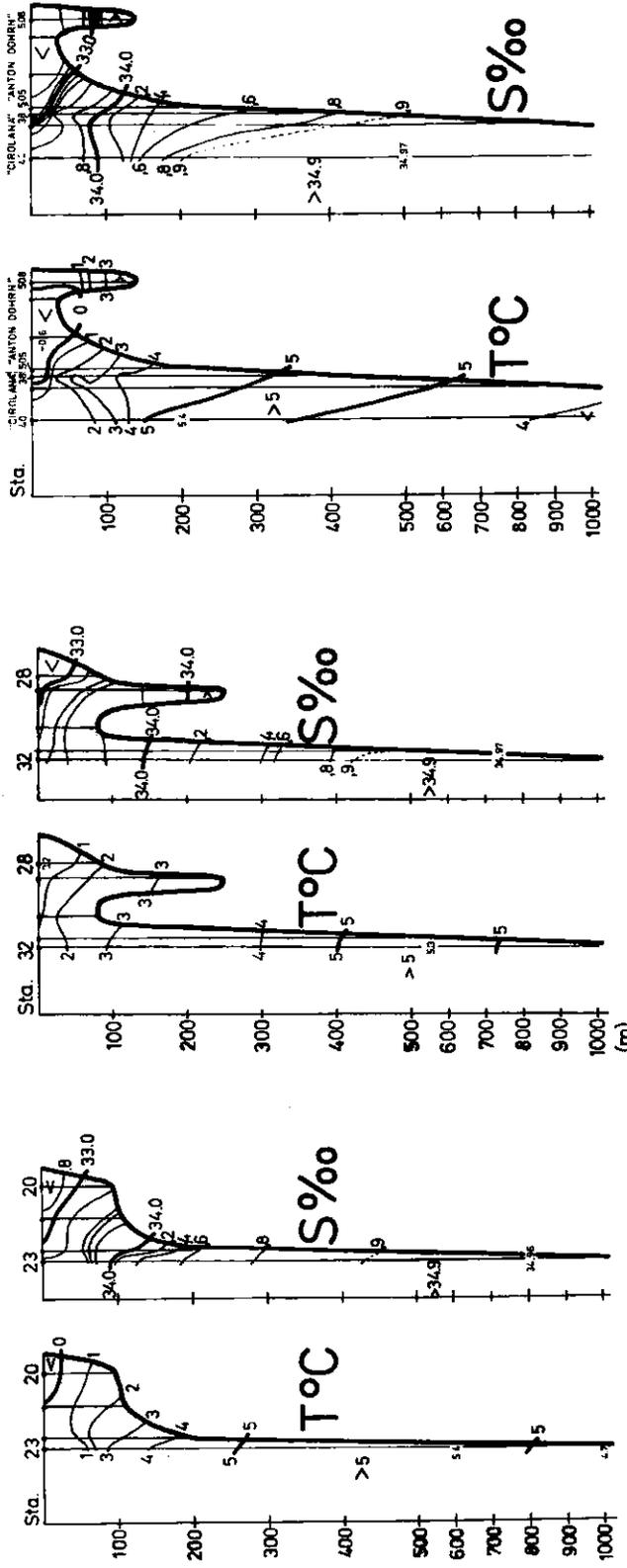


Cape Desolation

1./2. 12. 72 b.

Fig. 11. Temperature and salinity off Cape Farewell in December.

Fig. 12. Temperature and salinity off Cape Desolation in December.



Noname Bank

2.12.72

Fig. 13. Temperature and salinity over Noname Bank in December.

Danas Bank

3/4. 12. 73 c.

Fig. 14. Temperature and salinity over Danas Bank in December.

Fyllas Bank

4./5. 12. 72

II

Fig. 15. Temperature and salinity over Fyllas Bank in December.

5. On the hydrography of the southern Laurentian Channel (ICNAF Div. 3P, 4V)¹

by W. Lenz
Institut für Seefischerei
Hamburg, Fed. Rep. Germany

INTRODUCTION

The Laurentian Channel runs from the mouth of the St. Lawrence River into the Gulf of St. Lawrence through Cabot Strait in a southeasterly direction to the continental slope with an average depth of about 500 m. Although the hydrographic features within the Gulf of St. Lawrence are often observed and comprehensively described (Lauzier, Trites and Hachey, 1957; Lauzier and Bailey, 1957), those for the outer part of the Laurentian Channel have not been described to any significant extent, except for observations recently presented in ICNAF Research Reports, especially by Canada and USSR, and a contribution for the spring of 1970 by L'Herrou and Minet (1971). This paper is an attempt to generalize the view into the hydrographic characters of the water masses in this area.

DESCRIPTION OF WATER MASSES

Because of the U-shaped cross-section with smooth slopes throughout most of the 200-mile long channel, it should be possible to trace the movements of the waters within the channel by hydrographic sections perpendicular to the channel. In 1972 the FRG research vessel *Walther Herwig* worked the hydrographic section (Fig. 1) in late winter (15 March) and in fall (14 November). The measurements were done by Nansen casts and bathythermograph. Figure 2 shows the two sections drawn separately for temperature and salinity. A remarkable stratification is evident, caused by the interaction of different water masses. These water masses reveal fairly well their characteristics and origin on a T/S diagram (Fig. 3). Four different water masses can be identified as follows: (a) surface layer, (b) intermediate layer, (c) warm water body, and (d) bottom water.

The surface layer (shaded area on the left in Fig. 3) is exposed to the seasonal changes of the air temperature. The lowest salinity values are found on the western side of the channel during winter time, and this is a result of the outflow out of the Gulf of St. Lawrence (a feature so obvious on ice charts).

The intermediate layer has a complicated inner structure. In winter and spring it is like a thermocline but with a positive temperature gradient, whereas during the fall some cold water from the Labrador Current, which probably comes around Cape Race and around the Grand Bank (Sections C-E in Templeman, 1972; figure 13 in Hachey, Hermann, and Bailey, 1954) penetrates into this layer according to its density. This cold water is of Canadian Arctic origin ($T < 0^{\circ}\text{C}$, $S = 33\text{‰}$) and can be traced well in the T/S diagram. In November the intermediate layer was bordered by two thermoclines, the upper one with a negative and the lower one with a positive temperature gradient. The salinity distributions (Fig. 2) indicated that in November the isohalines were as much as 50 m shallower than in March.

The warm water body appeared in depths between 150 and 300 m. In the core the temperature exceeded 8°C in both March and November. In the T/S diagram this water can be identified as 'slope water' coming from the continental slope south of the channel. In the March section the core was leaning against the eastern wall of the trough, indicating a northward movement.

The bottom water (below 400 m) filled the channel with temperatures slightly below 5°C and salinities above 34.8‰ , as it is found in the western part of the North Atlantic at similar depths. Since the temperatures and salinities near the bottom in the section were the same in March and November, it may be assumed that no large-scale water movements occurred near the bottom.

Within the upper 200 m in both March and November sections, the isohalines on the eastern side of the Laurentian Channel tend to rise, which suggests an upwelling process in connection with the northward flow in the warm water body.

PERIODICAL AND IRREGULAR VARIATIONS

For these four water masses found in the southern Laurentian Channel the characteristics described above are for late winter (March) and the fall (November) in 1972. But examination of data available in the archives of oceanographic data centres reveals that values of depth, salinity and especially temperature within these water masses may vary irregularly, not only during a year but also from year to year. To give an idea about the amount of the variation and its irregularity, some values of maximum and minimum temperatures are given in Fig. 4 for the years 1967, 1968, and 1970. The values in the diagram are taken from USSR standard sections published by Sigaev (1969) and Konstantinov and Noskov (1971). The section used crosses the Laurentian Channel farther to the south than that in our investigations. The maximum temperature is chosen from the core of the warm water body, neglecting the case that during summer the highest

¹ Submitted to the 1973 Annual Meeting of ICNAF as ICNAF Res.Doc. 73/83.

temperature appears in the surface layer. The minimum temperature represents the lowest temperature between the surface and the bottom, which, however, can be only within the surface or intermediate layer. Corresponding values are also given from our investigations in 1972. The following features are evident: the temperature in the warm water body can be high throughout the year (or not), but, if not, then the highest values appear in the summer season; in the upper two layers the lowest temperature is found in summer and/or fall, but not always, *e.g.* in 1972. It is misleading to assume that there is a mutual dependence of the two extreme temperatures as they are the results from processes in quite different areas far away from the Laurentian Channel.

The irregular environmental variations, especially temperature, in the Laurentian Channel provides an opportunity to study the behaviour of fish in response to the irregularities.

ACKNOWLEDGEMENTS

I am grateful to B. Schillat, hydrographic technician, who was responsible for taking the data during the 1972 fall cruise.

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- WODC. World Oceanographic Data Center, Washington, D.C.

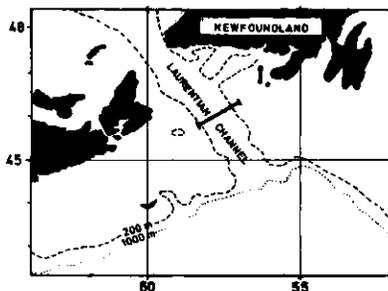
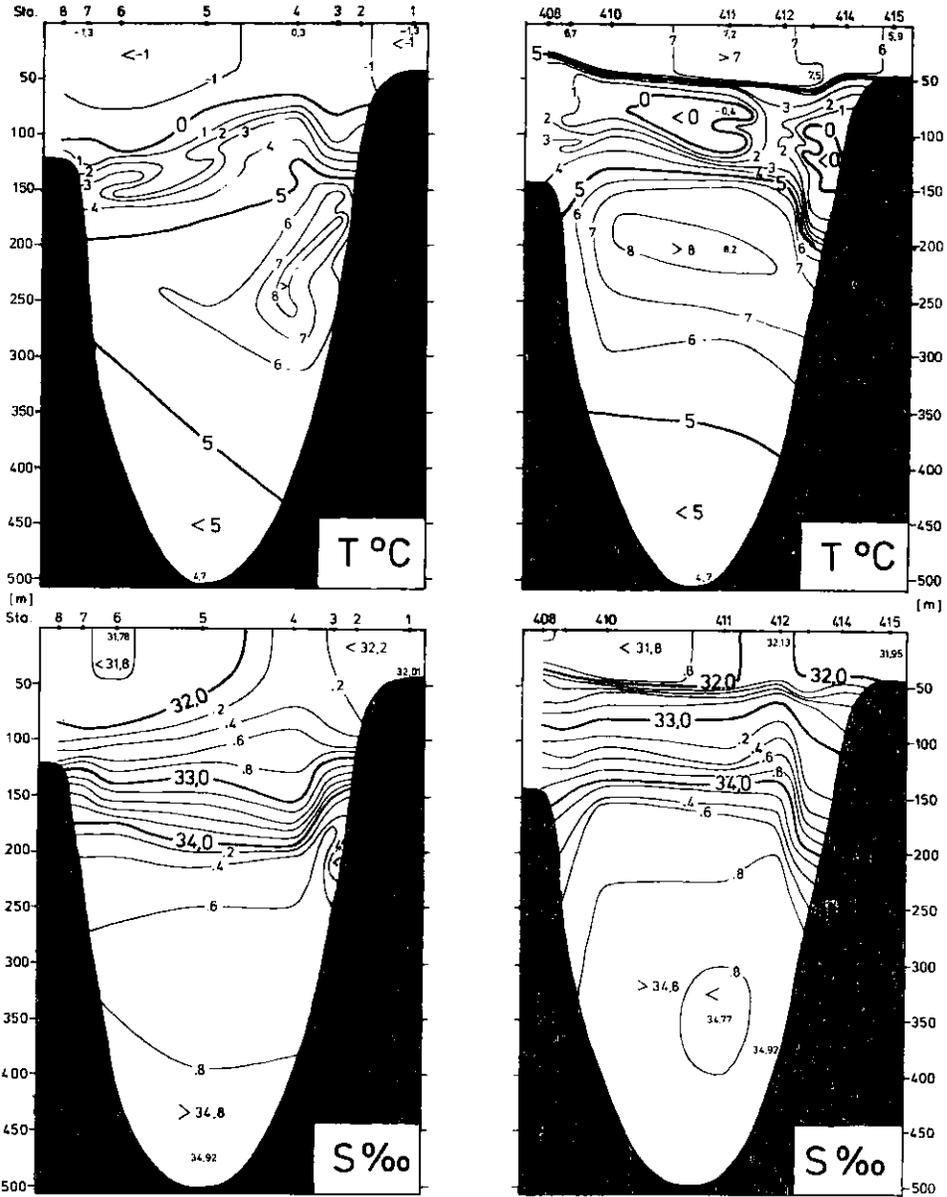


Fig. 1. Position of the section across the Laurentian Channel.



15. III. 72

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Fig. 2. Vertical temperature and salinity distribution across the Laurentian Channel in March and November 1972.

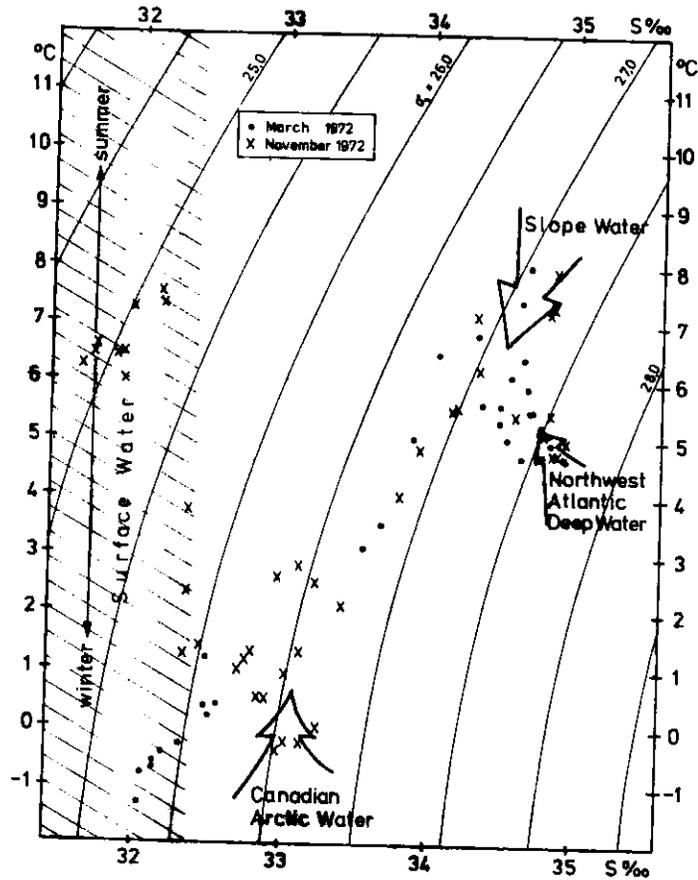


Fig. 3. T/S diagram from Nansen cast values out of the Laurentian Channel with indicated origins of different water masses.

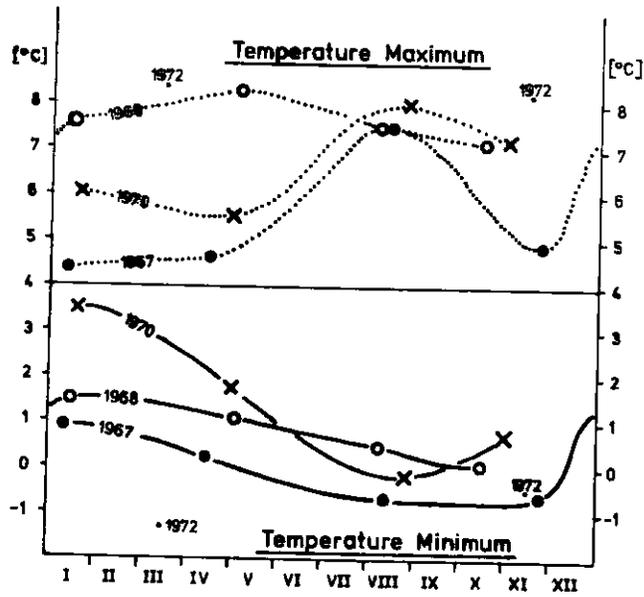


Fig. 4. Seasonal and annual variations of extreme temperatures found in the Laurentian Channel (after USSR standard section).

SECTION B
COD

6. Comparison of mortalities calculated from virtual population assessments and from research vessel survey data for cod stocks in ICNAF Divisions 3NO and 3Ps¹

by A.T. Pinhorn
Fisheries and Marine Service, Environment Canada
Biological Station, St. John's, Nfld.

INTRODUCTION

Mortality estimates at each age for a series of year-classes have been obtained for the major cod stocks in Subareas 2 and 3 by the virtual population technique. Survey data provide independent estimates of average mortality rates for the same year-classes over similar ages. Comparisons between these two sets of estimates are provided in this document for cod stocks in ICNAF Div. 3NO and Subdiv. 3Ps.

MATERIALS AND METHODS

Divisions 3NO

Canada (Nfld.) survey data for the years 1963-72 were utilized. The system of surveying for 1963-70 was the standard line survey as outlined by Pinhorn (1971) and the sets made during the cruises in each year were allocated to the strata designed by Pinhorn and Pitt and referred to in Grosslein and Pinhorn (1971). The surveys during 1971 and 1972 utilized the stratified-random system and no post-allocation was necessary. Numbers per standard haul at each age were then calculated as indicated by Grosslein (1971). Only the survey data for Div. 3N were complete enough to be used for mortality estimates since Div. 3O was not surveyed in 1967, 1969, 1970 and 1972 during the same period as the earlier surveys. \log_e of numbers per standard haul were then plotted for the year-classes 1959-64 (Fig. 1) and mortality estimates calculated in the usual manner. Mortality estimates from virtual population assessments were taken from Pinhorn and Wells (1973).

Subdivision 3Ps

Canada (Nfld.) survey data for the years 1957-72 were utilized. Surveys in 1957-70 were with the standard line system and in 1972 with the stratified-random system. No surveys were conducted in 1961, 1966 and 1971. For the years 1957-70 sets were allocated to strata outlined by Pinhorn (1972a) and numbers per standard haul at each age calculated. \log_e of numbers per standard haul were plotted for the year-classes 1952-63 (Fig. 2) and mortality estimates calculated in the usual manner. Mortality estimates from virtual population assessments were taken from Pinhorn (1972b).

RESULTS

Divisions 3NO cod

Comparisons between mortality estimates from surveys and virtual population assessments (Table 1 and Fig. 1) indicated general agreement with only the last two year-classes, 1963 and 1964, differing to any great degree (Z from surveys being 1.2 and from virtual population assessments being 0.8). The average for the six year-classes was 1.0 from survey data and 0.86 from virtual population data. The catch curve from surveys for all data combined (Fig. 1) resulted in $Z = 0.66$ and for a similar range of ages and year-classes the average Z was 0.77 from virtual population assessments. The differences in the averages from separate year-classes and those from all data combined are because of the greater ranges of ages and years possible with combined data.

Subdivision 3Ps cod

There was again general agreement between the two sets of estimates with only the 1962 and 1963 year-classes differing to any degree (Z from surveys being 0.76 and 0.82 and from virtual population data being 0.58 and 0.55, respectively). The average for the 12 year-classes was 0.69 from surveys and 0.63 from virtual population assessments. The catch curve from surveys for all data combined (Fig. 2) resulted in $Z = 0.57$ and for a similar range of ages and year-classes 0.61 from virtual population data. Again, the differences are as explained above.

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¹ Submitted to the 1973 Annual Meeting of ICNAF as ICNAF Res.Doc. 73/3.

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Pinhorn, A.T., and R. Wells. 1973. Virtual population assessment of the cod stock in ICNAF Divisions 3NO. *Annu. Meet. int. Comm. Northw. Atlant. Fish.*, Research Document 73/4, Serial No. 2904. (mimeographed).

Table 1. Comparison of mortality estimates for cod from survey data and virtual population assessments.

Div.	Year-class	Survey			Virtual population assessment		
		Z	Ages	Years	Z	Ages	Years
3NO	1959	0.86	6-12	1965-71	0.87	5-9	1964-68
	1960	0.85	5-12	1965-72	0.92	5-8	1965-68
	1961	1.09	4-11	1965-72	0.81	5-9	1966-70
	1962	0.93	3-10	1965-72	0.95	5-8	1967-70
	1963	1.20	4-9	1967-72	0.82	4-7	1967-70
	1964	1.20	4-8	1968-72	0.81	4-6	1968-70
	Average	1.02			0.86		
3Pa	1952	0.81	5-11	1957-63	0.59	7-11	1959-63
	1953	0.59	4-12	1957-65	0.71	6-11	1959-64
	1954	0.48	5-11	1959-65	0.49	5-11	1959-65
	1955	0.68	4-12	1959-67	0.74	4-11	1959-66
	1956	0.64	4-12	1960-68	0.62	4-11	1960-67
	1957	0.59	3-12	1960-69	0.54	4-11	1961-68
	1958	0.80	5-10	1963-68	0.70	4-10	1962-68
	1959	0.58	4-10	1963-69	0.61	4-10	1963-69
	1960	0.81	4-12	1964-72	0.69	4-10	1964-70
	1961	0.76	4-11	1965-72	0.70	4-10	1965-71
	1962	0.76	3-10	1965-72	0.58	4-9	1966-71
	1963	0.82	4-9	1967-72	0.55	4-8	1967-71
	Average	0.69			0.63		

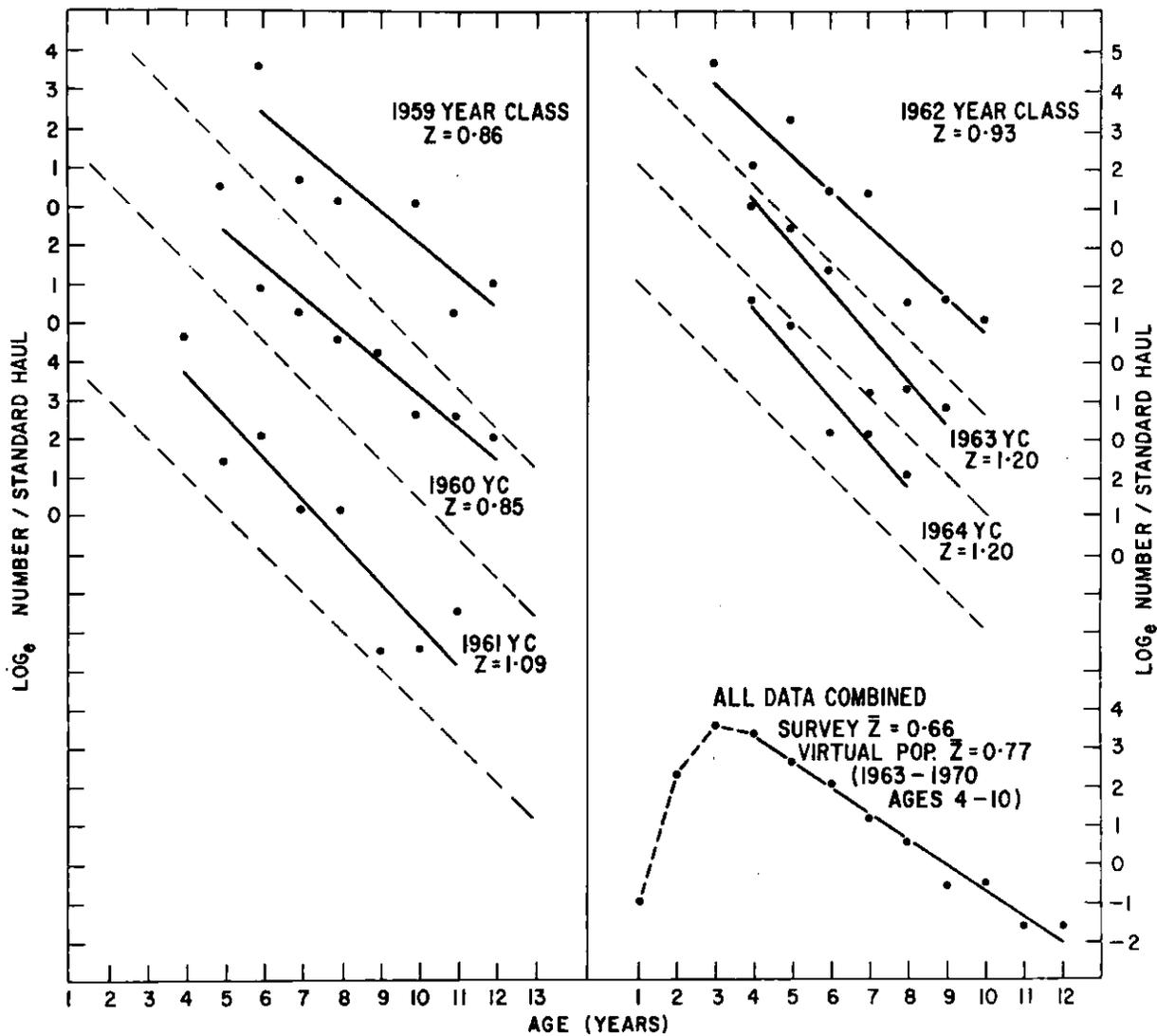


Fig. 1. Catch curves by year-class from survey data and resulting total mortality estimates, Div. 3NO cod.

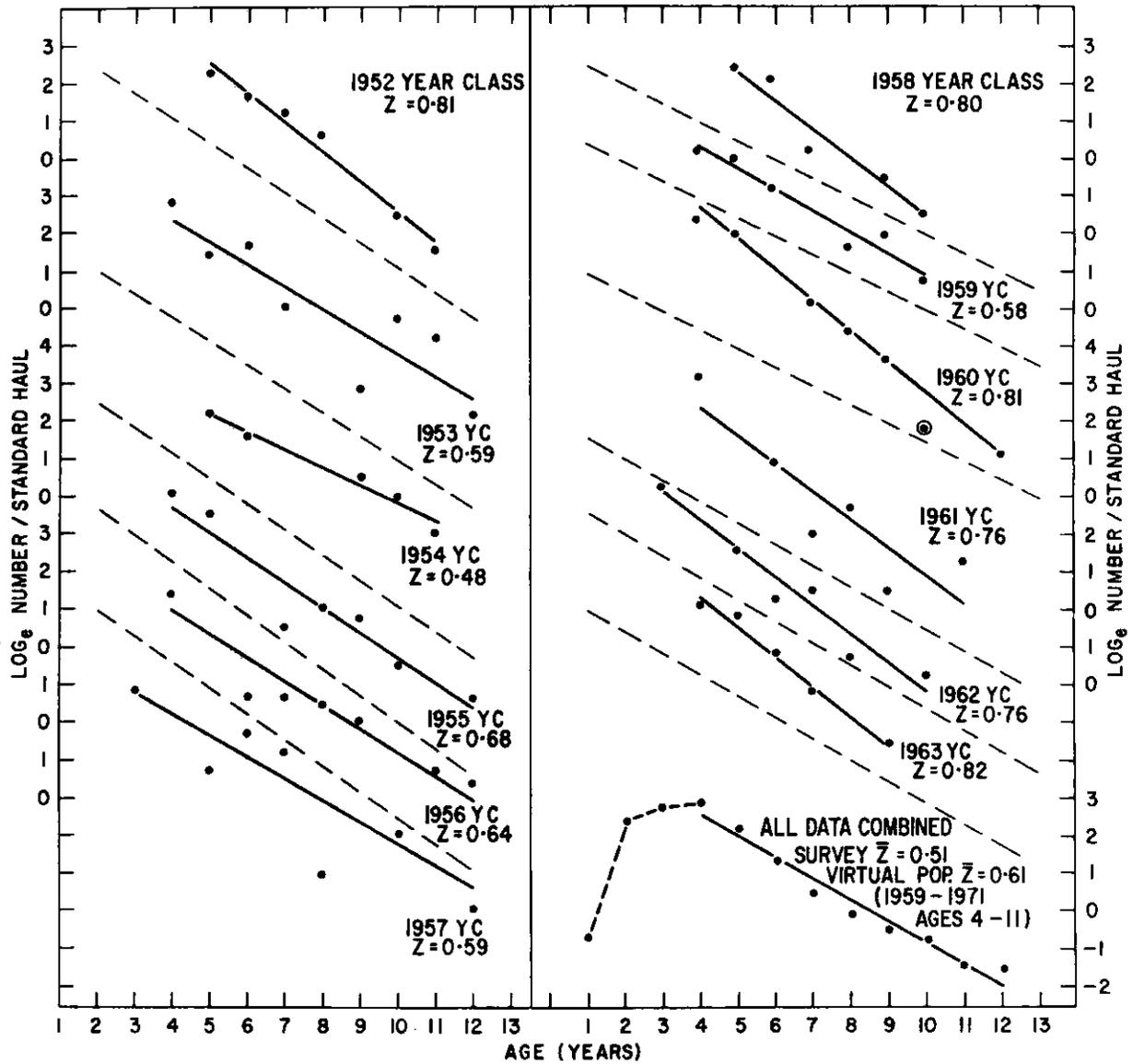


Fig. 2. Catch curves by year-class from survey data and resulting total mortality estimates, Subdiv. 3Ps cod.

7. Mean length and weight for various age-groups of cod in the northern and the southern divisions of West Greenland¹

by A. Meyer
Institut für Seefischerei
Hamburg, Fed.Rep. Germany

INTRODUCTION

In the 1972 Annual Meeting Report of the Assessments Subcommittee (ICNAF, 1972) stock assessments are reported for the first time for cod in ICNAF Div. 1A to 1D and in Div. 1E to 1F, separately. It was stated, however, that "the greatest uncertainty in the present calculation seems to be connected with mean weight at various ages". The following mean weights-at-age were used for the 1971 calculations:

Age	3	4	5	6	7	8	8+
Mean weight (kg)	0.62	1.18	2.1	2.7	3.0	3.0	5.5

In order to elucidate the problem of uncertainty, German (FRG) data from samples taken off West Greenland during the last 8 years have been summarized with respect to mean length and mean weight by age-groups, and are presented below.

MATERIALS AND METHODS

The study involves samples taken during 1965-72 from (a) research ships fishing with small-meshed trawls, (b) research ships using commercial trawls (110/130 mm), (c) commercial trawlers' catches before discarding, and (d) landings of commercial trawlers.

Samples from the first 3 categories only were used to calculate the mean lengths and weights for age-groups 3 to 6. For age-groups 7 and greater all samples were used. The fact that this procedure can be followed is indicated in Tables 1 and 2. The effect of the selectivity of different mesh sizes on the mean length is derived from extensive mesh selection experiments (Bohl, 1966) carried out in Div. 1B by the research vessel *Walther Herwig* in November 1965 (Table 1). The differences in mean lengths of cod caught with small-meshed nets and nets with 114.4 or 125.4 mm mesh size are 1.1-1.3 cm for age-group 3, and they gradually decrease to zero at age-group 6. This means that in November at the end of the seventh feeding period all 6-year-old cod are retained by commercial nets with a mesh size of at least 125.4 mm Perlon.

Table 1. Mean lengths of cod of age-groups 3 to 6 fished with four different trawl codends.

Codend size and type	Mean length (cm) by age-groups			
	3	4	5	6
114.4 mm polyethylene with cover (60 mm)	40.4	48.8	60.6	67.6
114.4 mm polyethylene without cover	41.7	49.4	60.7	67.6
125.4 mm Perlon with cover (60 mm)	40.5	50.0	60.5	67.7
125.4 mm Perlon without cover	41.6	50.4	60.7	67.7
Difference in mean length (cm)	1.1-1.3	0.4-0.6	0.2-0.1	0.0

The effect of discarding on the resulting mean length of the landed catch is considerably greater than the effect of selectivity of different mesh sizes, and this is especially true for the younger age-groups. Fishing with 125.4 mm Perlon nets and discarding up to 60 cm fish would change the mean lengths of the younger age-groups as shown in Table 2. This means that, if all fish of 60 cm and larger are retained, all 3-year-old cod are discarded, 97% of 4-year-olds are discarded with those retained having a mean length of 61.5 cm, 52% of 5-year-olds are discarded with the mean length of those retained being 63.5 cm, and no cod of 6 years and older are discarded.

¹ Submitted to the 1973 Annual Meeting of ICNAF as ICNAF Res.Doc. 73/38.

Table 2. Influence of discarding on resulting mean lengths (cm).

Discarding pattern	Mean length (cm) by age-groups			
	3	4	5	6
No discarding	41.6	50.4	60.7	67.7
Discarding 41 cm and smaller	44.6	50.7	60.7	67.7
Discarding 44 cm and smaller	46.6	51.5	60.7	67.7
Discarding 47 cm and smaller	-	52.5	60.7	67.7
Discarding 50 cm and smaller	-	54.7	60.8	67.7
Discarding 53 cm and smaller	-	57.7	61.1	67.7
Discarding 56 cm and smaller	-	59.4	61.7	67.7
Discarding 59 cm and smaller	-	61.5	63.5	67.7

The normal practice on fresh-fish trawlers (type (d) samples) was to retain only cod of at least 60 cm, but in recent years with smaller catches the discard limit is about 55 cm. Therefore, for the study of differences in cod growth between the northern and southern divisions of Subarea 1 (Div. 1A-1D and 1E-1F, respectively), only the mean lengths of cod aged 7 and older from the samples of the landings of fresh-fish trawlers were used in the comparisons.

RESULTS

The data of Table 3 are based on 159 samples from German (FRG) research ships and commercial vessels with 176,044 length measurements and 36,026 age determinations for cod in Div. 1B to 1F. To obtain the most realistic mean lengths of the international yearly catches, the average of month mean length values were weighted by the monthly international catches for the year 1970, the latest year for which monthly data were available and which represents best the recent seasonal distribution of the fishery. The mean weight values corresponding to the mean lengths were derived from a list of German length-weight data prepared for a meeting of the Greenland Cod Working Group in February 1966 (ICNAF, 1966).

Table 3. Mean length and mean weight by age-groups of cod in Div. 1A-1D and 1E-1F from German (FRG) sampling in 1965-72 and weighted to international monthly catches in 1970.

Division		Mean length (cm) and weight (kg) by age-groups								
		3	4	5	6	7	8	9	10	10+
1A-1D	\bar{L} (cm)	39.6	48.9	59.0	67.5	73.8	76.5	80.4	85.3	≈90.0
	\bar{W} (kg)	0.58	1.08	1.94	2.80	3.60	3.98	4.63	5.48	6.23
1E-1F	\bar{L} (cm)	35.5	44.5	51.3	58.3	66.4	71.1	75.9	82.6	≈90.0
	\bar{W} (kg)	0.41	0.82	1.27	1.88	2.68	3.25	3.90	5.02	6.23

Table 3 shows clearly that there is a considerable difference in growth between the faster-growing West Greenland stock, which lives mainly in Div. 1A-1D, and the slower-growing East Greenland stock, which in Subarea 1 inhabits Div. 1E-1F. The real difference in growth between the two stocks is, however, somewhat less because the mean length values in Table 3 resulted in weighting to the international catch and in the southern divisions the catch is taken about one month earlier than in the north. If the fishing pattern in the southern divisions had been the same as in the northern divisions, the mean lengths in the two areas would be as shown in Table 4.

Table 4. Mean length by age-groups with equal fishing pattern in Div. 1A-1D and Div. 1E-1F.

Division	Mean length (cm) by age-groups								
	3	4	5	6	7	8	9	10	10+
1A-1D	39.6	48.9	59.0	67.5	73.8	76.5	80.4	85.3	≈90.0
1E-1F	36.3	44.7	51.8	58.7	66.9	71.1	75.7	82.6	≈90.0
Difference	3.3	4.2	7.2	8.8	6.7	5.4	4.7	2.7	

The difference in growth between the two stocks is nearly 9 cm at age-group 6. This increase is more than the increase in length within one year, indicating that 5- and 6-year-old cod of the West Greenland stock reach their length more than a year earlier than the East Greenland cod. However, the difference in growth gradually decreases for the older age-groups to about a 3-cm difference in mean length at age 10. Also, the onset of maturity in East Greenland cod (7-9 years) is about 2 years later than in the West Greenland stock. Thus, because of the longer span of the immature phase (with higher yearly growth than during the mature phase) of East Greenland cod, older fish of both stocks (aged 10 and older) have nearly the same mean lengths.

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8. Evaluation of research survey indices of abundance
for cod stocks in ICNAF Subareas 2 and 3¹

by A.T. Pinhorn and R. Wells
Fisheries and Marine Service, Environment Canada
Biological Station, St. John's, Nfld.

INTRODUCTION

One of the most critical factors in the calculation of future total allowable catches at various levels of fishing is the prediction of the contribution of year-classes which have entered or will enter the fishery in years beyond the year of the last estimated stock size from virtual population analyses. These predicted contributions can only be calculated from known correlations between pre-recruit survey indices of abundance and stock sizes at first entry to the fishery. Such correlations are presented in this paper for cod stocks in ICNAF Div. 2J-3KL, 3NO and Subdiv. 3Ps.

MATERIALS AND METHODS

Divisions 2J-3KL

Pre-recruit indices of abundance for the stock complex in Div. 2J-3KL were derived from the USSR young fish surveys in Div. 3K and 3L (Bulatova, 1973). Stock size estimates at first entry to the fishery (age 4) were derived from updating the assessment by Pinhorn and Wells (1972).

Divisions 3NO

Pre-recruit indices of abundance for the stock in Div. 3NO were derived from USSR young fish surveys (Bulatova, 1973) and from Canada (Nfld.) surveys in Div. 3N. For the latter, the surveys were conducted using the standard line system up to 1970 as reported by Pinhorn (1971) and these were post-stratified by assigning sets to the strata in which the standard positions occurred. The strata used were those prepared by Pinhorn and Pitt and referred to in Grosslein and Pinhorn (1971). In 1971 and 1972 the surveys were conducted using the stratified-random survey method. Div. 3N rather than Div. 3O or 3NO was used in the correlations for two reasons: the best correlations between research indices of abundance and stock size were obtained for Div. 3N survey data and the Canada (Nfld.) surveys in 1967, 1969, 1970 and 1972 did not include Div. 3O.

Subdivision 3Ps

Pre-recruit indices of abundance for the stock in Subdiv. 3Ps were derived from USSR young fish surveys in Div. 3P (Bulatova, 1973) and from Canada (Nfld.) research surveys in Subdiv. 3Ps. For the latter, the surveys were conducted using the standard line system up to 1970 as reported by Pinhorn (1971) and these were post-stratified by assigning sets to the strata in which the standard positions occurred. The strata used were those shown by Pinhorn (1972a) for Subdiv. 3Ps. In 1972 the survey was conducted using the stratified-random survey method. In 1961, 1966 and 1971 no Canada (Nfld.) surveys were conducted in Subdiv. 3Ps and the numbers per standard set at each age for these years were estimated by applying average ratios to the numbers per standard set for the same year-classes in the adjacent years. Since only two strata on the seaward slope of St. Pierre Bank (Strata 311 and 317) contained most of the pre-recruit cod during the season of the survey (March-June), these two strata were selected for purposes of correlation with stock sizes. Stock size estimates at first entry to the fishery were derived from Pinhorn (1972b).

RESULTS

Divisions 2J-3KL

Three sets of pre-recruit data at age 3 were correlated with stock sizes at age 4: Div. 3K, Div. 3L and Div. 3K + 3L (Fig. 1). The arithmetic correlation was highest with survey indices of abundance in Div. 3K ($r = 0.80$) and Div. 3K + 3L ($r = 0.82$) and lowest in Div. 3L, the latter not being significant.

Table 1 shows the basic data used in the correlation and indicates the variation in predicted stock sizes of year-classes beyond those estimated from the virtual population analyses.

Divisions 3NO

The arithmetic correlation between numbers of 3-year-old cod per standard haul from Canada (Nfld.) surveys and per hour from USSR surveys was significant with correlation coefficient ($r = 0.85$) (Fig. 2). Of the 11 year-classes correlated, only the 1962 year-class was obviously far outside the range of the

¹ Submitted to the 1973 Annual Meeting of ICNAF as ICNAF Res.Doc. 73/60.

correlation, the number per standard set from the Canada (Nfld.) survey being overestimated.

There was a significant log-log correlation ($r = 0.71$) between age 3 from Canada (Nfld.) surveys and stock size at age 4 from the virtual population assessments (Fig. 2). Again, the 1962 year-class was outside the range of the correlation.

Comparisons between USSR survey data and stock size could be made for 7 year-classes. For these the log-log correlation coefficient ($r = 0.86$) was significant. In both of the latter two cases, the log-log correlation coefficient was somewhat higher than the arithmetic correlation.

Table 1 shows the basic data used in the correlation and indicates the variation in year-class predictions for the 1966-68 year-classes from the two sets of survey data. Agreement is excellent for the 1966 and 1968 year-classes but the USSR estimates are considerably higher for the 1967 and 1969 year-classes.

Subdivision 3Ps

The arithmetic correlation between the numbers of 2 + 3-year-old cod per standard set from USSR surveys and Canada (Nfld.) surveys was significantly high with correlation coefficient ($r = 0.93$) (Fig. 3). Of the 9 year-classes compared, only the 1966 year-class was obviously far outside the range of the correlation. The Canada (Nfld.) survey in 1968 greatly overestimated the 1966 year-class because the cruise was of very short duration and only lines of known abundance of young cod were fished. Therefore, the number per hour for this year-class from Canada (Nfld.) surveys was not considered representative of the abundance of this year-class in relation to the others.

There was also a high log-log correlation ($r = 0.91$) between age 2 + 3 cod from Canada (Nfld.) surveys and stock size at age 4 from virtual population assessments (Fig. 3). Again, one year-class (1958) was obviously outside the range of the correlation, being overestimated in the Canada (Nfld.) survey cruises.

Comparisons between USSR survey data and stock sizes could only be made for 6 year-classes where overlap between the two sets of data occurred. For these 6 year-classes the log-log correlation coefficient ($r = 0.89$) was significant.

Table 1 shows the basic data used in the correlation and indicates the variation in year-class predictions for the 1966-68 year-classes by the different methods. The figures in the third column represent the USSR index of abundance converted to Canada (Nfld.) index of abundance and the latter used to predict year-class contributions using the correlations in Fig. 3.

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Table 1. Research indices of abundance and predicted stock sizes of year-classes later than those estimated from the virtual population analyses. Those underlined were used in calculation of total allowable catch for 1974.

Division	Year-class	No./hr. USSR surveys (age 3)			Stock size from virtual population assessment (age 4)	Predicted stock size from surveys in:		
		Div. 3K	Div. 3L	Div. 3K + 3L		Div. 3K	Div. 3L	Div. 3K + 3L
2J-3KL	1959	21	21	42	612			
	1960	11	8	19	506			
	1961	20	28	48	629			
	1962	15	40	55	762			
	1963	36	31	67	908			
	1964	8	48	56	581			
	1965	15	12	27	543			
	1966	27	43	70		758	720	820
	1967	34	26	60		844	645	752
	1968	40	84	124		918	904	1,189
	1969	13	43	56		587	721	725
1970					(800) ¹	(750) ¹	(900) ¹	
		Surveys (age 3)		Stock size from virtual population assessment (age 4)	Predicted stock size from surveys by:			
		Can (N)	USSR		Can (N)	USSR		
3NO	1955	7		92				
	1956	8		42				
	1957	4		40				
	1958	14		62				
	1959	12	8	94				
	1960	7	1	71				
	1961	11	5	85				
	1962	125	18	115				
	1963	14	30	171				
	1964	45	73	160				
	1965	25	23	94				
	1966	32	37		134	134		
	1967	7	32		64	130		
	1968	42	91		153	160		
1969	9	26		72	125			
1970		(25) ²		(110) ¹	(125) ²			
		Surveys (ages 2 + 3)		Stock size from virtual population assessment (age 4)	Predicted stock size from surveys by:			
		Can (N)	USSR		Can (N)	USSR	USSR+Can (N)	
3Ps	1955	131		104				
	1956	40		47				
	1957	49		47				
	1958	(261)		40				
	1959	36		37				
	1960	32	8	31				
	1961	115	12	56				
	1962	92	19	68				
	1963	83	30	79				
	1964	145	80	94				
	1965	110	46	69				
	1966	(418)	60		(179)	89	94	
	1967	91	30		68	68	70	
	1968	276	130		137	120	130	
1969	(144) ³	75		(91) ³	97	103		
1970	(117) ³	(19) ²		(80) ³	(60) ²	(63) ²		

¹ Stock size estimated as average of 1966-69 year-classes.

² No./hr. 3-year-olds estimated from No./hr. 2-year-olds reported in Res.Doc. 73/22 and average ratio 3-year-olds to 2-year-olds for 1959-69 year-classes.

³ Adjusted for stratified-random versus line surveys.

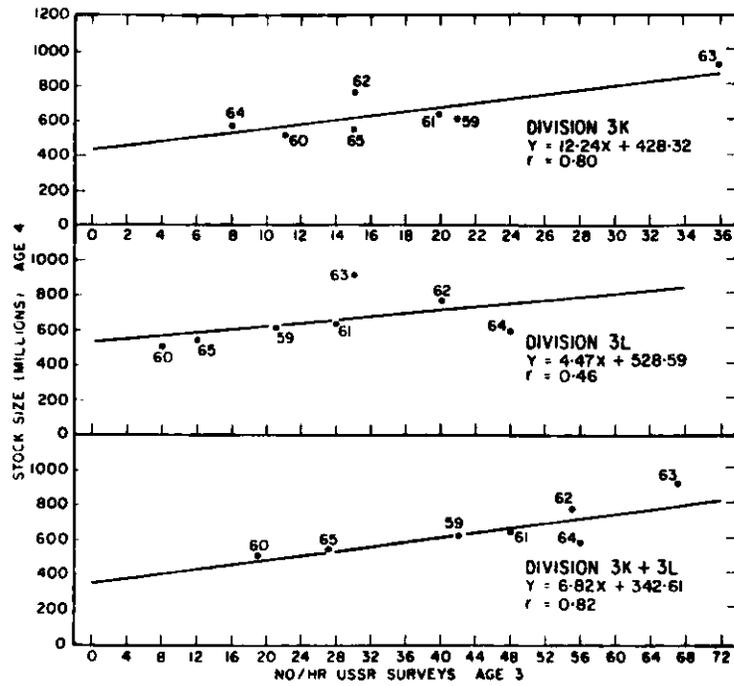


Fig. 1. Correlation of indices of abundance of pre-recruit year-classes of cod at age 3 from research surveys and stock sizes of same year-classes at age 4 from virtual population analyses. Div. 2J-3KL cod stock complex.

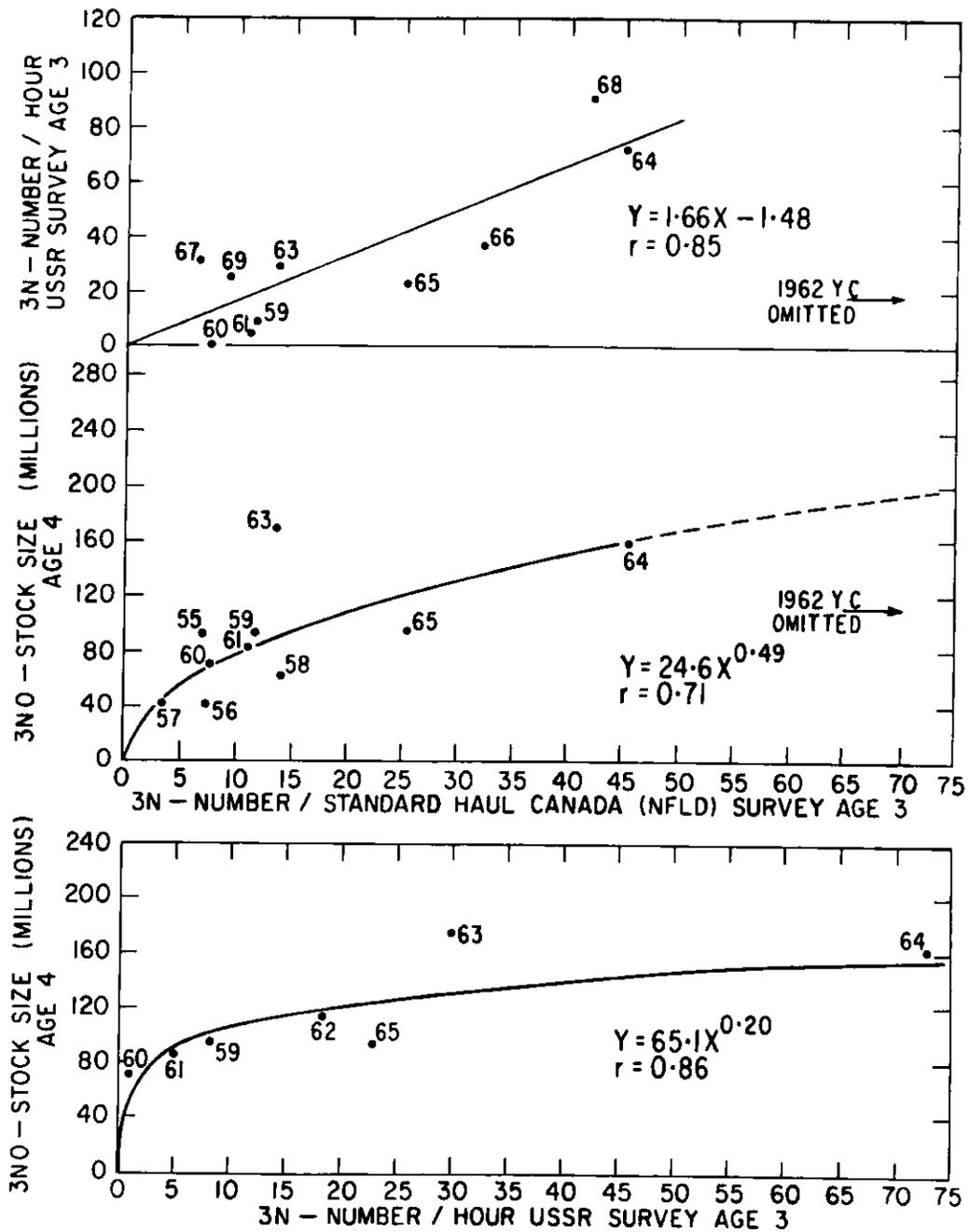


Fig. 2. Correlation of indices of abundance of pre-recruit year-classes at age 3 from research surveys and stock sizes of same year-classes at age 4 from virtual population analyses. Div. 3NO cod stock.

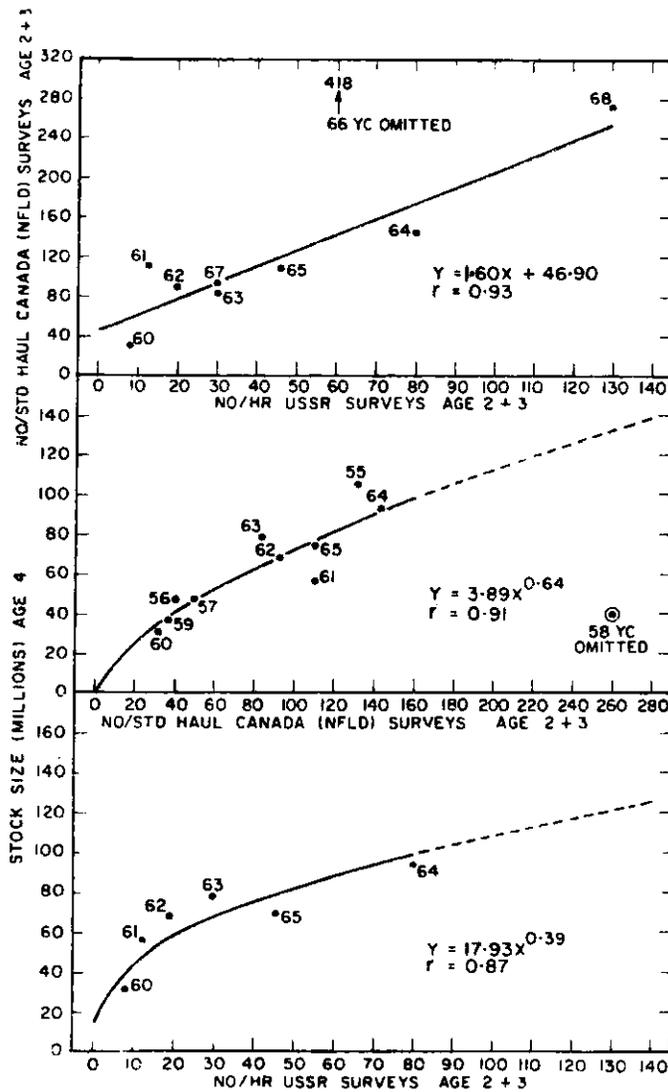


Fig. 3. Correlation of indices of abundance of pre-recruit year-classes at age 2 + 3 from research surveys and stock sizes of same year-classes at age 4 from virtual population analyses. Subdiv. 3Ps cod stock.

9. Mean length of cod age-groups in northern and southern divisions of Subarea 1 (West Greenland)¹

by E. Smidt
Grønlands Fiskeriundersøgelser
Charlottenlund, Denmark

In the Danish Research Report, 1971 (Horsted and Smidt, 1972), it was noted that cod in the southern part of Subarea 1 seemed to have a slower growth rate than cod in the northern divisions, and the same observations were evident in 1972. In order to see whether the differences in growth may have been the result of environmental conditions in the most recent years since 1969 (more cold water and ice from East Greenland to southwestern Greenland), length and age data collected in 1965 to 1971 have been summarized by age-groups and divisions and the results are given in Table 1. Age-groups with less than 30 fish are excluded, and the comparisons are made only between offshore samples mutually or inshore samples mutually. Data for 1972 are not given in the Table as samples from the northern divisions were taken offshore and those from the southern divisions were obtained inshore (see Horsted, 1973).

Examination of Table 1 indicates that, although the figures are not absolutely unambiguous, some tendencies are outstanding. No remarkable differences in mean lengths of cod from the southern (Div. 1E-1F) and northern (especially Div. 1C-1D) divisions are apparent for the years 1965-68. However, in the third quarter of 1969 the growth of cod in the southern divisions seems to have been slower than in the northern divisions, and this tendency is outstanding in most of the 1970 and 1971 samples, apart from those in the second quarter of 1970. There also seems to be a general tendency toward slower growth in Div. 1B than in Div. 1C and 1D.

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Table 1. Mean lengths of cod age-groups in Div. 1B-1F by years and quarters of years for 1965-71 with data from offshore and inshore zones listed separately. (1 = mean total length (cm below); 2 = standard deviation; 3 = number of individuals in sample.)

Year	1965				1966				1966		1968			1969				
Quarter	II				II				III		II			III				
Zone	offshore				offshore				offshore		offshore			offshore				
Division	1B	1C	1D	1E	1B	1C	1D	1E	1B	1C	1C	1D	1E	1C+1D	1D	1E		
Age-group																		
III											38.1	35.6						
1											3.18	3.97						
2											134	180						
3																		
IV	1	51.6	51.5	49.4	51.4							49.1	44.8	45.8				
2	2	3.16	3.13	4.71	3.78							3.91	3.69	3.95				
3	3	106	144	183	117							174	371	53				
V	1	57.9	58.6	60.3	59.9	57.4	58.5	57.2	57.6	56.5	57.9	57.1	54.7	53.2				
2	2	4.70	4.94	5.62	4.15	3.69	4.71	5.25	4.95	4.77	5.38	4.15	4.74	4.83				
3	3	546	268	204	88	1158	965	356	2785	204	65	1005	1655	1856				
VI	1	66.4		68.4	67.3	64.3	65.4	65.0	67.9	65.4	66.6	63.1	61.2	60.6	68.0	65.8	60.1	
2	2	5.52		6.16	5.04	4.93	5.49	7.93	5.30	5.22	5.02	4.79	5.13	6.27	5.05	5.58	5.79	
3	3	47		55	73	864	592	258	1514	282	39	564	816	1773	320	181	185	
VII	1			74.2	72.7	69.0	67.1	72.6	75.9			67.7	69.7	70.1	73.7	73.4	64.8	
2	2			5.73	5.55	4.66	7.02	3.64	5.30			4.33	5.32	7.01	4.96	6.24	6.92	
3	3			52	100	133	57	60	364			185	563	1976	217	149	142	
VIII	1	77.9		79.7	79.0		80.2	77.0	79.8			62.7	73.6	75.8	78.0	79.0	75.0	
2	2	5.36		5.70	5.75		7.59	6.78	5.71			9.55	5.10	7.78	6.37	6.69	5.64	
3	3	32		167	184		39	74	477			32	205	92	239	164	189	
IX	1					76.5	83.2	83.7	82.2						84.1	82.1	80.1	
2	2					5.70	5.63	6.18	7.00						5.35	7.93	7.97	
3	3					108	45	67	626						76	78	57	

Year	1970			1970			1970				1971			1971			
Quarter	II			III			III				II			III			
Zone	offshore			offshore			inshore				offshore			offshore			
Division	1C+1D	1D	1E	1C	1D	1E	1B	1C	1D	1F	1C	1D	1F	1C	1E	1F	
Age-group																	
IV	1	47.1	42.9		49.8	51.0		45.7	48.8			47.9	41.5				
2	2	2.60	5.61		4.22	5.46		3.14	4.34			3.36	4.16				
3	3	76	138		35	44		388	142			140	618				
V	1	55.8	58.5	56.5	60.3	59.0	57.5	55.6	61.5		51.0				58.5	52.3	48.4
2	2	4.22	4.72	6.39	5.96	4.95	4.86	5.16	5.05		5.90				5.23	4.46	2.29
3	3	404	170	72	56	154	91	460	133		50				178	44	47
VI	1	58.8	56.5	59.0		65.1	58.2	62.7	68.8	58.2	55.5	68.9	66.5	61.8			
2	2	5.37	7.60	5.69		5.28	4.95	7.05	6.30	4.96	4.55	4.58	5.94	5.28			
3	3	217	87	114		84	127	72	34	35	243	547	271	47			
VII	1	66.0	63.4	66.8	73.0	71.7	65.5	73.0	74.9	63.8	61.1	70.3	67.0	61.8			
2	2	5.73	7.16	7.06	6.02	6.77	7.16	6.02	6.04	5.22	5.18	7.22	5.92	4.96			
3	3	198	175	306	107	250	315	107	49	213	980	60	110	522			
VIII	1		70.0	71.8		77.3	72.7	78.9		66.8	63.8	74.4	72.6	66.6			
2	2		9.17	7.15		7.47	6.23	6.72		5.13	4.99	5.87	5.79	5.15			
3	3		56	110		75	103	37		48	230	71	141	750			
IX	1		80.8	80.1		83.2	79.7	82.0			69.2		78.6	70.1			
2	2		7.28	6.67		6.62	7.50	6.76			5.65		7.19	5.61			
3	3		102	52		59	46	122			72		38	137			
X	1		87.4	81.8								84.4	83.2	74.2			
2	2		7.24	7.75								4.65	8.42	5.07			
3	3		135	34								39	48	35			

SECTION C
REDFISH

10. Distribution of beaked redfish (*Sebastes mentella* Travin) by depth in areas off Newfoundland and South Labrador¹

by T.L. Nikolskaya
PINRO, Murmansk, USSR

ABSTRACT

Data on size and age composition of 'beaked' redfish in the areas off Newfoundland and South Labrador, collected in 1963-71, are compared by 100-m interval depth ranges for characteristics of redfish distribution. In all areas sampled the mean size and age of redfish increases with increasing depth, with females being, on the average, somewhat larger than males. Variation in the sex ratio of males and females by both depth and season was noted on the northeast slope of the Grand Bank, particularly in autumn and winter, when males dominated in the catches at the shallowest depths investigated (201-300 m) with a gradual transition to female domination at the largest depth range (501-600 m). During the period of larval extrusion in March-June, the sex ratio was almost the same at all depths with females slightly more abundant than males.

INTRODUCTION

Investigations on redfish distribution by depth in the Northwest Atlantic have been reported by scientists of the USSR and other countries (Templeman, 1959, 1962; Lundbek, 1961; Magnusson, 1962; Savvatimsky, 1963; Tokareva, 1966; Savvatimsky and Sidorenko, 1966; Sidorenko, 1967; Chekhova, 1970). It was observed that usually the size of redfish increases with depth. The purpose of this paper is to show the differences in size and age composition of redfish by depth and season in areas off Newfoundland and South Labrador.

The data, summarized for the years 1963-71, were collected aboard scouting and research vessels on the concentrations fished by the fishing fleet and grouped into 201-300, 301-400, 401-500 and 601-700 m depth intervals for comparisons. It was assumed that all redfish specimens examined were of the same species, *Sebastes mentella* Travin (beaked redfish). However, according to Barsukov (1968) and Barsukov and Zakharov (1972), in addition to the 'beaked' (*S. mentella*) and 'golden' (*S. marinus*) redfish occurring in the areas off South Labrador and Newfoundland, a third species, *S. fasciatus*, occurs at considerably shallower depths (70-350 m) than the other species. The existence of this species has not yet been acknowledged by all ichthyologists. It should be noted that the conclusions on redfish distribution in the area will not be invalidated for the trawl fishery, even if the presence of *S. fasciatus* is verified in the future.

RESULTS

Size composition

In the St. Pierre Bank area (ICNAF Div. 3P) the size compositions of redfish for the 201-300 and 301-400 m depth ranges are similar (Fig. 1). The peaks of the size frequencies are 30 and 35 cm for males and females, respectively. At the 401-500 m depth range, there are more 35-37 cm males than at shallower depths, but the mode for females remains at 35 cm although there are more fish over 40 cm in length than at 201-400 m depths.

On the southwest slope of the Grand Bank (Div. 3O) in 201-300 m, males 25-26 cm long represent the largest length groups, while 25-28 cm and 32-35 cm females dominate. At 301-400 m the relative numbers of larger males (26-30 cm) and females (32-35 cm) increase. At 401-500 m the length frequency peaks for males and females coincide (35 cm). Deeper than 500 m the proportion of large females (35-38 cm) increases, but the peaks for males at 401-500 and 501-600 m depths are similar.

On the southeast slope of the Grand Bank (Div. 3N) at 201-300 and 301-400 m depth ranges, the size frequency peaks for males are the same (28 cm), but at 401-500 m the peak shifts to 36 cm. With increasing depth from 201-300 m to 401-500 m, the peak for females shifts from 32 cm to 40 cm.

On the northeast slope of the Grand Bank (Div. 3L) at both the 201-300 and 301-400 m depth ranges, the modal size for males and females are 35 and 40 cm, respectively. Deeper than 400 m there is a gradual increase in size with depth. The modal lengths for males and females at 401-500 m are 36 cm and 40-43 cm, respectively, and at 501-600 m are 38 cm and 45 cm.

On the slope off southern Labrador (Div. 2J) the size differences between males and females are less apparent than in the more southerly areas, the length frequency curves being similar with their peaks almost coinciding. For males the modal sizes at all depth ranges are similar (35 cm), but the relative number of large males (40-42 cm) is greater at 601-700 m depth than at shallower depths. Except at 501-600 m, the relative number of large females increases with depth so that 40-42 cm fish are dominant among the large size groups.

¹ Submitted to the 1973 Annual Meeting of ICNAF as ICNAF Res.Doc. 73/41.

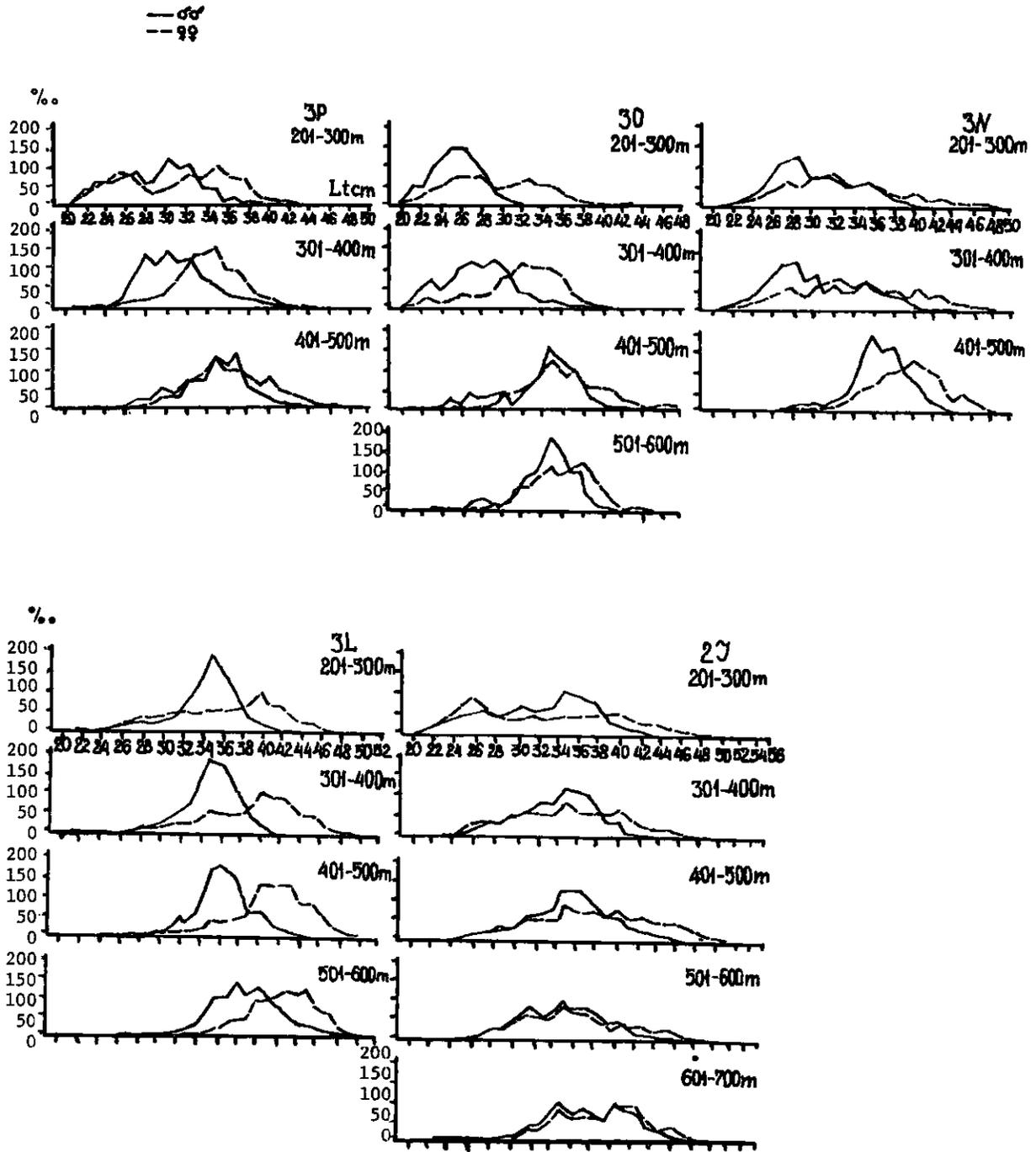


Fig. 1. Size composition of the beaked redfish by sex at different depths in the St. Pierre Bank (Div. 3P) to South Labrador (Div. 2J) areas.

Age composition

By analogy with the size composition the age composition varies with depth also. This can be readily demonstrated for the southern Labrador area where the data covers a wide range of depths (Fig. 2). In the 201-300 m depth range, males and females aged 8-10 years dominate in the catches. At 301-400 and 401-500 m fish of ages 12-15 years are the dominant groups, and there is a gradual increase in the number of older females (19-22 years) between 201-300 and 401-500 m. At 501-600 m there are fewer old females compared with 401-500 m depth range, and the prevailing groups are 14-16 years old. At the 601-700 m depth ranges the dominant ages for males are 18-19 years and for females, 21-22 years.

Distribution by depth and season

During the course of a year the size and age compositions of redfish vary with depth seasonally, and this may be explained by the seasonal migrations of the species. Three periods in the annual cycle of adult redfish distribution are apparent: (1) spring-summer (March-July) when the extrusion of larvae and also feeding occurs; (2) autumn (August-October) when feeding and copulation occurs; and (3) winter (November-February) during which the sexual glands mature.

On the northeast slope of the Grand Bank the data (Table 1) show considerable differences in the sex ratio both by depth and by season. During spring-summer females are somewhat more abundant than males at all depth ranges from 201-300 to 501-600 m. During the autumn and winter periods males are considerably more abundant than females at 201-300 m (68:32), but there is a gradual reversal of the situation with increasing depth (45:55 at 301-400 m, 32:68 at 401-500 m, and 20:80 at 501-600 m). During the winter the relative proportion change from an 83:17 ratio for males and females at 201-300 m to a 16:84 ratio at 501-600 m.

Larvae extrusion is observed at 301-500 m depths during the spring-summer period (March-June), when the sex ratio is close to 1:1. During the autumn and winter seasons there would appear to occur the migration of large females to deeper water, or the migration of males to shallower water, or the migration of both sexes but in opposite directions.

The data for mean length (Table 1) show a distinct increase in average size of both males and females with increasing depth, a fact noted above in comparing the size frequency distributions by depth.

CONCLUSIONS

1. Data for the years 1963-71, summarized by 100-m depth ranges, clearly indicate the increasing size and age composition of catches with increasing depth for all areas from off South Labrador to the southern Grand Bank and St. Pierre Bank.
2. Except in the South Labrador area, where males and females had similar length compositions at each depth range, the average size of females was larger than that of males at all depth ranges.
3. The distribution by sex not only varies with depth but also by season. The sex ratio in spring-summer is similar at all depths, with females slightly more abundant than males. In autumn and winter the male:female ratio varies from about 8:2 at 201-300 m to about 2:8 at 501-600 m.

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Table 1. Sex ratio (%), mean length of males and females (cm), and number of redfish examined by periods and depths on the northeastern slope of Grand Bank.

Period	Sex	201-300 m		301-400 m		401-500 m		501-600 m					
		%	Mean length	No. of specimens	%	Mean length	No. of specimens	%	Mean length	No. of specimens			
Spring-summer	Males	39	34.0	3,407	41	34.7	3,212	43	36.4	2,202	47	37.6	301
	Females	61	38.6	5,277	59	39.3	4,541	57	41.2	2,935	53	41.2	346
Autumn	Males	68	34.3	4,127	45	34.4	5,453	32	36.2	2,543	20	38.8	196
	Females	32	34.8	1,940	55	37.7	6,647	68	40.5	5,496	80	42.0	780
Winter	Males	83	35.6	6,477	47	35.8	3,842	24	36.9	441	16	40.5	356
	Females	17	38.3	1,297	53	38.5	4,422	76	39.9	1,387	84	42.4	1,842

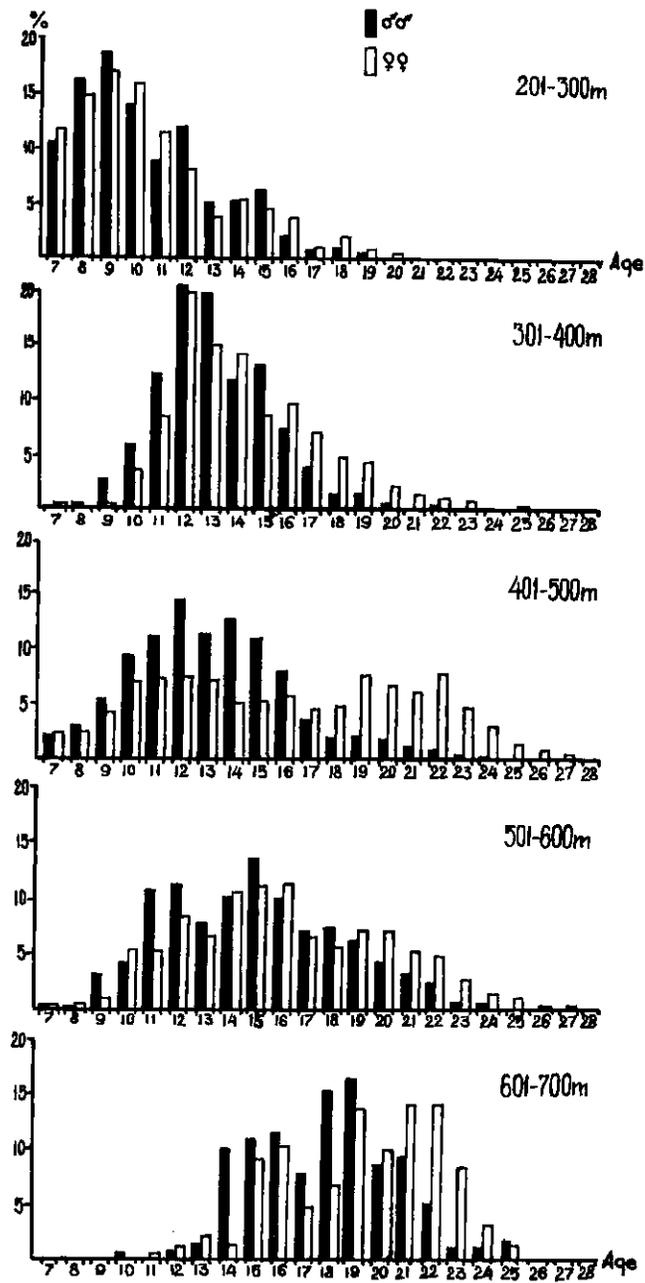


Fig. 2. Age composition of the beaked redfish by sex at different depths in the South Labrador area.

**SECTION D
FLOUNDERS**

11. Food and feeding of the American plaice (*Hippoglossoides platessoides* F.)
on St. Pierre Bank and on Cape Breton Shelf¹

by J.P. Minet

ISTPM, Saint-Pierre and Miquelon

ABSTRACT

This study contributes to the knowledge of food and feeding of the American plaice on St. Pierre Bank and off Cape Breton Island (ICNAF Subdiv. 3Ps and 4Vn). The foods principally consumed are echinoderms, molluscs, crustaceans, polychaetes and fish. The diet of St. Pierre Bank plaice is different from that of Cape Breton plaice. Small plaice feed mainly upon crustaceans, polychaetes, small brittle stars and bivalves. Adults eat more sea urchins, big bivalves, crabs, ascidians and fish. In the two regions studied, the diet of the plaice varies with the season and the temperature of water in which it lives. In the fall, and especially in the winter, a drastic reduction in feeding can be noted. Feeding intensity also varies throughout the day.

INTRODUCTION

There is little information on the food and feeding of the American plaice, *Hippoglossoides platessoides*, in the Newfoundland and Nova Scotia areas. However, attention must be drawn to studies by Huntsman (1918) and by Komarova on the food of the Barents Sea plaice (in Andriyatchev, 1954). More recently, research by Powles (1965) in the southwestern Gulf of St. Lawrence (ICNAF Div. 4T) has provided valuable data on the organisms consumed by the plaice, on the feeding intensity in relation to size and to the season, and on the feeding competition occurring between this species and cod.

As part of seasonal groundfish surveys, this study contributes to the knowledge of food and feeding of the American plaice on the St. Pierre Bank and off Cape Breton Island. It supplies further information on the effect that location, size, sex, bottom temperature, season and period of the day may have on the diet and feeding behaviour of the American plaice in these regions.

MATERIALS AND METHODS

The material used in this study was collected by the author in 1971 and 1972 during four seasonal cruises of the research vessel *Cryos* on St. Pierre Bank and the Cape Breton Shelf. The dates of the surveys were 11-25 July 1971 (summer), 9-14 November 1971 (fall), 7-22 February 1972 (winter), and 4-12 May 1972 (spring) in Subdiv. 3Ps, and 24-27 July 1971 (summer), 25-28 November 1971 (fall), and 18-24 May 1972 (spring) in Subdiv. 4Vn. Ice conditions in the latter region during the winter of 1971-72 prevented trawling.

The bottom trawl used had the following specifications: 31.20 m headline mounted on 30.80 m; 17.70 m groundrope with steel bobbins; 140-mm mesh in the wings and body and 50 mm in the codend. The positions of the trawl hauls are shown in Fig. 1.

On board, after each haul, the stomachs were immediately removed from a sample of males and females. Information recorded for each specimen was: sex, total length, weight of the fish, as well as the haul number, which provided details as to position, date, time of the catch, depth, nature of the ground and near-bottom temperature. The stomachs were quickly stored in jars containing 8% formalin in order to avoid deterioration of the stomach contents. The stage of repletion of each stomach was noted using the following criteria: 0 for empty stomach, 1 for stomach one-quarter full, 2 for stomach half-full, 3 for stomach three-quarters full, and 4 for stomach completely full.

In the laboratory, each stomach was drained and dissected and the organisms contained in it separated by species when possible or by systematic group (genus or family) when they were too far digested to make the distinction. The pebbles and shell debris and the vegetal or animal fragments were also grouped. Each species was weighed to the hundredth of a gram.

For each species or group, the stage of digestion was noted using four categories from the most recently ingested foods (stage A) to those having undergone the digestive process to a greater and greater degree (stages B, C and D). In this study only the data concerning the recently ingested food (stage A) are used for the main systematic groups as follows:

- Annelids - whole animal, with all its segments and appendices, and no signs of digestive attack;
- Molluscs - whole animal, adhering securely to the shell;
- Crustaceans - whole animal, without change in colour and with firm consistency;
- Brittle stars and sea stars - whole animal, with arms intact and plates rigidly locked together;
- Sea urchins - whole and full animal, with its test unbroken and with all its spines; and
- Fish - whole and fresh animal, with its scales, skin and colours and showing no signs of digestive attack.

¹ Submitted to the 1973 Annual Meeting of ICNAF as ICNAF Res.Doc. 73/34.

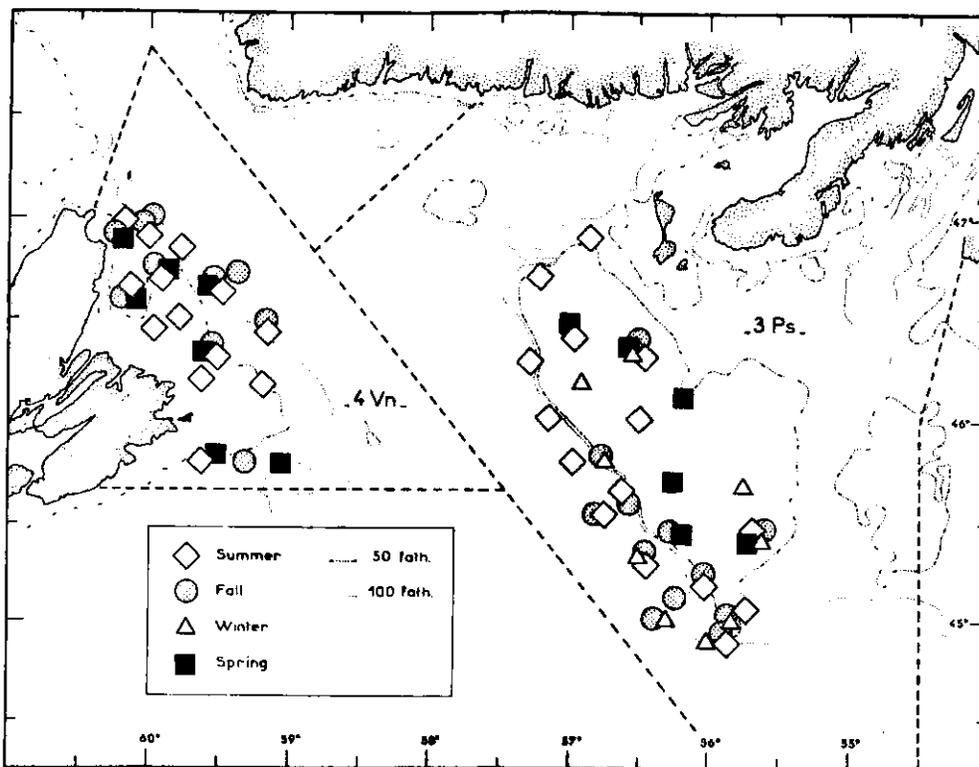


Fig. 1. Position of stomach sampling stations in ICNAF Subdiv. 3Ps and 4Vn, during the four seasonal cruises of the R/V *Cryos*, in 1971 and 1972.

In addition, a reference collection of the specimens in good condition was set up to help in determining the organisms too far digested for use. For each numbered stomach, an individual sheet was established reporting all the observations made on board and in the laboratory, as described above.

In all, 932 stomachs were sampled and examined for this study (564 from St. Pierre Bank during four seasonal cruises and 368 off Cape Breton Island during three cruises).

RESULTS

Food of the American plaice

In Table 1 are listed the main groups of organisms used as food by the American plaice in the two areas studied. It is necessary, nevertheless, to comment on and give further details about the data in this table.

Echinoderms are the group found most frequently in the stomachs examined. Among this phylum, few representatives of holoturians were found: genera *Cucumaria* and *Thyone*. As for sea stars, the only species found was *Ctenodiscus crispatus*. On the other hand, brittle stars were plentiful: *Ophiura sarsi*, *O. robusta* and *Ophiopholis aculeata*. The sea urchins are also important components of the food: a large proportion of *Strongylocentrotus droehbachiensis*, a little less of *Echinarachnius parma* and only one specimen of *Schizaster fragilis* in Subdiv. 3Ps.

Molluscs are the second most important food group for the plaice, due mainly to pelecypods found in large numbers: *Yoldia myalis* and *Y. thraciaeformis*. A few instances of *Y. sapotilla* and *Nuculana tenuisulcata* were found as further representatives of the Protobranchia. Among the Filibranchia, *Chlamys islandicus* were the most frequent. As for the Eulamellibranchia, we must note the presence of *Clinocardium ciliatum* and *Serripes groenlandicus* with lesser numbers of *Siliqua costata* and *Cyrtodaria siliqua* and a few specimens of the genera *Astarte*, *Tellina*, *Macoma* and *Spisula*. Gasteropods were quite scarce and small in size. *Margarites cinerea*, *M. helicina* and *M. groenlandica* accounted for two-thirds of this group, the remainder including *Turbonilla interrupta*, *Velutina laevigata*, *Natica clausa* and *Polinices groenlandica*. A single representative of the Polyplacophora (*Lepidochiton marmorea*) was found twice in Subdiv. 3Ps.

Crustaceans constitute the third food group, mainly because of numerous amphipod families (*Anonyx nugax*, *Euthemisto* sp., *Caprella* sp., *Stegocephalus* sp., *Ampelisca* sp., *Talorchestia* sp., etc.) and euphausiids (*Meganyctiphanes norvegica*). *Mysis mixta* of the mysids, *Diastylis polita* of cumaceans and *Idotea phosphorea* of isopods were also found. Among decapods were *Macrura* (*Pandalus borealis*, *Sabinea sarsi* and *Spirontocaris* sp.), *Anomura* (*Pagurus* sp.) and *Brachyura* (*Hyas coarctatus* and *H. araneus*).

Annelids were represented mainly by polychaetes in the stomach contents: *Aphrodite aculeata*, *Nereis* sp., *Nephtys* sp. and mainly *Onuphis conchilega* for Errantia; and *Pectinaria granulata*, *Amphitrite* sp. and mostly *Potamilla* sp. for Sedentaria. *Phascolosoma* sp. represented the sipunculids order.

Teleosts are also consumed as food by plaice: the most abundant was the sand lance (*Ammodytes americanus*) and small *Sebastes mentella* and *Glyptocephalus cynoglossus*, and rarer fish such as *Antimora rostrata* or non-identified *Myctophidae*, *Paralepididae* and *Zoaridae*.

Cnidaria were represented by *Antennularia* sp., *Pennatula borealis*, *Renilla reniformis* and especially *Bolocera tuediae*, *Lophophoroidea* by *Membranipora monostachys* and *Hemithyris psittacea*, and *Ascidians* by the *Styellidae* family.

Geographic variation in the diet of the American plaice

Certain differences in the diet of the plaice can be noticed on examining the relative importance of each food group contained in the stomachs sampled on St. Pierre Bank and on the Cape Breton banks (Table 1).

The American plaice off Cape Breton Island ate no ascidians and ate less fish (1.4%), cnidarians and molluscs (mainly Protobranchia) than the plaice of St. Pierre Bank. On the other hand, it consumes more polychaetes (23.3%), lophophoroidea, crustaceans (38.8%, especially amphipods and cumaceans) and echinoderms (9.4%, mainly a large quantity of brittle stars).

On St. Pierre Bank, echinoderms (mostly brittle stars) are also the most important food group, but their proportion is not as large. The diet in this region is, therefore, more varied and balanced.

Variation of the diet in relation to the size and sex of plaice

The diet of the plaice varies with its size. This variation has an effect on the diets of the two sexes, since the females reach greater sizes than the males. These differences are roughly the same in the two regions. Details are given in Tables 2A and 2B.

In general, brittle stars are consumed in equally large quantities by the small and large plaice. This is due to a change in species: *Ophiura robusta* and small *Ophiopholis aculeata* for the small fish and *Ophiura sarsi* and big *O. aculeata* for the large. As size increases, there is a greater percentage of sea urchins consumed.

The percentage of Protobranchia molluscs decreases with the size of fish. However, the small specimens eat more *Yoldia myalis* and the large ones, *Y. thraiciaeformis*. The percentage of Filibranchia (*Chlamys islandicus*) increases with the size and that of Eulamellibranchia is greatest at the medium sizes.

The percentages of crustaceans (isopods, amphipods, euphausiids and decapods *Macrura* (shrimps)) also diminish with the size of fish. It is clear that these small organisms constitute a choice food for the young plaice (20-35 cm). On the other hand, crabs (*Brachyura*) are ingested in greater quantity by the large fish (46-70 cm).

Fish are more frequently found in the stomachs of the larger plaice. However, the small plaice of St. Pierre Bank consume larvae and very young non-identified fish, as indicated by the relatively large percentage of the latter.

The consumption of polychaetes diminishes as the size of the plaice increases; this is true both for Errantia and Sedentaria. The percentage of ascidians (on St. Pierre Bank only) increases with the size of fish.

The changes in diet described above (which are due to varying capacities for ingestion of food of a given size) mean that the females, which are on the average larger than males, consume a somewhat different type of food. Therefore, the females eat less crustaceans (especially less isopods, amphipods and euphausiids), less polychaetes, but more echinoderms (large brittle stars and sea urchins) and more molluscs (Protobranchia).

Seasonal variation in diet on St. Pierre and Cape Breton banks

The diet of the plaice varies with the season, depending on the type and quantity of food available. In order to make this phenomenon clear, we have noted the relative quantity of each food group in the non-empty stomachs expressed as percentages (Table 3).

Table 1. Geographic variation in the diet of the American plaice, measured by frequency of occurrence of organisms in the stomachs. (N = number of stomachs examined; n = number of stomachs with food.)

Stomach contents	Subdiv. 3Ps			Subdiv. 4Vn		
	No. of stomachs	%N	%n	No. of stomachs	%N	%n
Cnidaria	35	6.2	7.9	16	4.3	5.9
Boloceridae	31	5.5	7.0	16	4.3	5.9
Others	4	0.7	0.9	0	0	0
Annelida	67	11.9	15.2	86	23.3	31.6
Polychaeta errantia	6	1.1	1.4	18	4.9	6.6
Polychaeta sedentaria	58	10.3	13.1	62	16.8	22.8
Sipunculida	3	0.5	0.7	6	1.6	2.2
Lophophoroidea	4	0.8	0.9	8	2.2	2.9
Bryozoa	1	0.2	0.2	8	2.2	2.9
Brachiopoda	2	0.4	0.5	0	0	0
Priapulioidea	1	0.2	0.2	0	0	0
Mollusca	208	36.9	47.0	120	32.7	44.1
Polyplacophora	2	0.4	0.5	0	0	0
Gasteropoda	12	2.1	2.7	15	4.1	5.5
Pelecypoda Protobranchia	127	22.5	28.7	36	9.8	13.2
Filibranchia	17	3.0	3.8	22	6.0	8.1
Eulamellibranchia	48	8.5	10.8	47	12.8	17.3
Not identified	2	0.4	0.5	0	0	0
Crustacea	178	31.6	40.3	143	38.8	52.4
Mysidacea	2	0.4	0.5	8	2.2	2.9
Cumacea	2	0.4	0.5	24	6.5	8.8
Isopoda	21	3.7	4.7	6	1.5	2.2
Amphipoda	73	12.9	16.5	63	17.1	23.2
Euphausiacea	42	7.5	9.5	14	3.8	5.1
Decapoda Macrura	7	1.2	1.6	15	4.1	5.5
Anomura	5	0.9	1.1	2	0.5	0.7
Brachyura	20	3.5	4.5	8	2.2	2.9
Not identified	6	1.1	1.4	3	0.8	1.1
Echinodermata	382	67.8	86.3	346	94.0	127.2
Holoturidea	2	0.4	0.5	1	0.3	0.4
Asteroidea	2	0.4	0.5	2	0.5	0.7
Ophiuroidea	229	40.6	51.7	247	57.1	90.8
Echinoidea	149	26.4	33.6	96	26.1	35.3
Ascidiacea	36	6.4	8.1	0	0	0
Teleostei	36	6.4	8.1	5	1.4	1.9
Paralepididae	1	0.2	0.2	0	0	0
Myctophidae	2	0.4	0.5	0	0	0
Moridae	0	0	0	1	0.3	0.4
Zoarcidae	3	0.5	0.7	0	0	0
Ammodytidae	13	2.3	2.9	1	0.3	0.4
Scorpaenidae	3	0.5	0.7	0	0	0
Pleuronectidae	4	0.7	0.9	0	0	0
Not identified	10	1.8	2.3	3	0.8	1.1
Pebbles and shell fragments	78	13.8	17.6	56	15.2	20.6
Vegetal fragments	3	0.5	0.7	5	1.4	1.9
Animal fragments not identified or identified but not separated	43	7.6	9.7	7	1.9	2.6
Number of stomachs examined (N)	564			368		
Number of stomachs with food (n)	443			272		

Table 2A. Variation in the diet of the American plaice in Subdiv. 3Ps, according to length and sex (%). (* = traces).

Stomach contents	Males					Females					
	<25 cm	25-35 cm	36-45 cm	>45 cm	Total	<25 cm	25-35 cm	36-45 cm	46-55 cm	>55 cm	Total
Cnidaria					0.9						0.6
Boloceridae			1.1	1.6	0.9			0.6	0.2	1.4	0.6
Others		0.1		0.2	*		*		*	*	*
Annelida					7.2						5.1
Polychaeta errantia		2.5	1.7		1.3		2.9	0.9	0.5	0.1	0.8
Polychaeta sedentaria	28.5	9.8	3.6	*	5.2	25.0	15.4	1.9	1.6	1.0	4.3
Sipunculida			0.8	1.3	0.7						0
Lophophoroidea					*						*
Bryozoa			*		*				*		*
Brachiopoda				0.1	*			0.1			*
Priapulidae		0.2			*						0
Mollusca					20.2						28.5
Polyplacophora					0				0.1		*
Gasteropoda		1.3	0.2	0.9	0.8			3.6	0.3		1.0
Pelecypoda Protobranchia		27.3	18.5	3.2	15.4		14.0	43.5	23.1	8.2	22.0
Filibranchia		*	0.4	0.8	0.4				0.2	0.9	0.3
Eulamellibranchia		2.0	7.8	1.2	3.6	0.1	0.7	3.4	7.8	5.9	4.8
Not identified		*			*		2.4				0.4
Crustacea					17.7						11.6
Mysidacea			0.2		*	2.3					0.1
Cumacea					0		1.3		*		0.2
Isopoda		0.9	1.9	1.7	1.5		2.0	1.1	0.2	0.1	0.7
Amphipoda	23.3	5.1	8.2	1.1	5.5	21.4	4.3	1.0	1.7	*	2.0
Euphausiacea	15.9	18.1	4.0	0.3	7.5		13.9	6.9	1.6	*	4.3
Decapoda Macrura		3.4	0.1	*	1.1		1.7	0.2	*		0.3
Anomura			1.2	0.4	0.5		0	0.5	0	0.1	0.1
Brachyura			2.2	2.0	1.4		2.1	0.8	5.2	4.9	3.4
Not identified		0.4	0.2		0.2		1.1	1.2		*	0.5
Echinodermata					41.4						41.9
Holoturidae			0.1		*				0.6		0.2
Asteroidea					0			*	*		*
Ophiuroidea	23.4	14.6	21.2	34.6	23.8	35.4	23.5	15.5	22.9	36.7	25.4
Echinoidea		2.7	15.1	35.3	17.6	11.8	2.6	7.7	18.4	29.5	16.3
Ascidiacea	0.3	3.3	5.4	6.6	5.0			6.0	6.7	2.9	4.2
Teleostei					3.8						3.4
Paralepididae					0	4.0					0.1
Myctophidae		1.4			0.4					0.2	0.1
Moridae					0						0
Zoaridae		0.2			*		3.2				0.5
Ammodytidae			3.5	1.9	1.8			0.9	2.5	1.4	1.3
Scorpaenidae				0.8	0.3			0.6			0.1
Pleuronectidae				0.3	0.1			*	0.6		0.2
Not identified	8.6	2.9	*		1.2		7.0		0.3	*	1.1
Pebbles and shell fragments		1.5	0.9	1.3	1.2		*	1.5	2.9	3.6	2.2
Vegetal fragments				1.6	0.5						0
Animal fragments not identified or identified but not separated		2.2	1.6	2.6	2.1		1.9	2.0	2.6	3.1	2.4
Total %	100.0	99.9	99.9	99.8	100.0	100.0	100.0	99.9	100.0	100.0	99.9
Number of stomachs examined	7	56	62	62	187	8	38	66	71	73	256

Table 2B. Variation in the diet of the American plaice in Subdiv. 4Vn, according to length and sex (%).
(* = traces).

Stomach contents	Males					Females					Total
	<25 cm	25-35 cm	36-45 cm	>45 cm	Total	<25 cm	25-35 cm	36-45 cm	46-55 cm	>55 cm		Total
Cnidaria					2.1						0.5
Boloceridae		3.5			2.1		2.2	0.1	0.1	0.1	0.5
Others					0			*		0.2	*
Annelida					17.6						7.9
Polychaeta errantia		4.8	5.7		4.8		6.6	2.6	0.1		2.3
Polychaeta sedentaria	0.8	18.0	0.9	25.0	11.9	30.3	15.3	3.3	0.4	0.4	5.3
Sipunculida		1.5			0.9		0.9	0.3			0.3
Lophophoroidea					*						*
Bryozoa		*	0.1		*			*			*
Brachiopoda					0						0
Priapulioidea					0						0
Mollusca					9.6						8.2
Polyplacophora					0						0
Gasteropoda		1.7	1.4		1.5		0.1	4.1	*	0.7	1.5
Pelecypoda Protobranchia		5.5	3.2		4.3		5.9	4.6	0.6		3.0
Filibranchia			0.2	7.9	0.3		0.4	0.8	2.0	5.1	1.5
Eulamellibranchia	0.8	3.1	4.4	*	3.4	8.3	3.6	1.7	2.1		2.2
Not identified		0.2			0.1						0
Crustacea					7.5						4.0
Mysidacea		0.6			0.4		0.1	0.8			0.3
Cumacea	7.0	1.1			0.9	0.2	0.1				*
Isopoda		0.3			0.2		0.1				*
Amphipoda	2.3	2.3	2.8	*	2.4	7.0	0.5	0.2	*		0.4
Euphausiacea		1.8	*		1.1	16.7	2.7	2.0	0.4		1.8
Decapoda Macrura		2.2	0.1	0.2	1.4	7.1		2.0	0.1		0.9
Anomura			0.6		0.2		1.2				0.3
Brachyura		*	0.4		0.2		0.3	0.4	0.1		0.2
Not identified	27.6		*		0.7		0.6				0.1
Echinodermata					57.8						71.9
Holoturidea					0		2.2				0.5
Asteroidea		0.3			0.2			0.1			*
Ophiuroidea	51.5	42.1	52.1	15.6	44.8	30.4	30.7	54.7	49.9	42.8	46.2
Echinoidea		8.6	18.5	38.1	12.8		19.9	14.9	36.8	39.7	25.2
Ascidiacea					0						0
Teleostei					1.2						0.5
Paralepididae					0						0
Myctophidae					0						0
Moridae					0			1.6			0.5
Zoarcidae					0						0
Ammodytidae			1.9		0.7						0
Scorpaenidae					0						0
Pleuronectidae					0						0
Not identified			1.4		0.5						0
Pebbles and shell fragments		1.3	5.9	13.2	3.3		4.1	5.4	7.3	4.3	5.5
Vegetal fragments			*		*			*	*	0.1	*
Animal fragments not identified or identified but not separated	10.0	0.9	0.3		0.9		2.4	0.4	*	6.6	1.4
Total %	100.0	99.8	99.9	100.0	100.0	100.0	99.9	100.0	99.9	100.0	99.9
Number of stomachs examined	3	72	41	4	120	4	32	51	48	17	152

Table 3. Seasonal variation in the diet of the American plaice (%). (* = traces).

Stomach contents	Subdiv. 3Ps				Subdiv. 4Vn		
	Summer 11-23 Jul 1971	Fall 9-14 Nov 1971	Winter 7-22 Feb 1972	Spring 4-12 May 1972	Summer 24-27 Jul 1971	Fall 25-28 Nov 1971	Spring 18-24 May 1972
Cnidaria	0.2		2.2	1.5	*	0.1	4.5
Boloceridae	0.1		2.2	1.5	*	*	4.5
Others	0.1		*	*		0.1	
Annelida	9.7	5.4	12.6	0.7	16.2	13.4	4.5
Polychaeta errantia	0.3	2.0	3.1	0.4	2.8	4.8	3.0
Polychaeta sedentaria	8.5	3.4	9.5	0.3	13.3	7.5	0.7
Sipunculida	0.9				0.1	1.1	0.8
Lophophoroidea	0.2			*	*		*
Bryozoa	*			*	*		*
Brachiopoda	0.1						
Priapuloida	0.1						
Mollusca	29.6	37.5	21.4	10.9	5.9	9.2	13.3
Polyplacophora	*			*			
Gasteropoda	0.3	2.6		0.5	0.2	0.9	4.3
Pelecypoda Protobranchia	27.5	32.6	16.9		2.3	6.3	2.7
Filibranchia	0.7	*		0.5	1.1	1.1	0.6
Eulamelibranchia	0.5	2.3	4.5	9.9	2.2	0.9	5.7
Not identified	0.6				0.1		
Crustacea	8.0	24.7	16.4	10.9	8.3	2.8	4.0
Mysidacea		0.2		0.1	0.8		
Cumacea		0.4		*	0.5		0.7
Isopoda	0.7	1.1	*	1.5	0.2		
Amphipoda	4.9	0.7	12.3	1.7	2.5	0.2	0.4
Euphausiacea	0.6	20.7			2.6		1.4
Decapoda Macrura	0.8	0.1	3.5	*	0.8	1.3	1.4
Anomura	0.7		0.6	*	*	0.8	
Brachyura	0.2	0.3		7.6	0.2	0.2	0.1
Not identified	0.1	1.2		*	0.7	0.3	
Echinodermata	39.6	20.2	40.3	61.8	62.3	65.4	71.3
Holoturidea		0.1		0.3	0.6		
Asteroidea	*	*				0.1	0.3
Ophiuroidea	25.0	15.4	33.3	29.5	43.1	43.3	52.0
Echinoidea	14.6	4.7	7.0	32.0	18.6	22.0	19.0
Ascidiacea	2.9	4.5	1.2	7.2			
Teleostei	4.7	2.6		4.3		1.7	1.1
Paralepididae	0.2						
Myctophidae	0.7						
Moridae						1.0	
Zoaridae	0.9						
Ammodytidae		0.9		4.1			1.1
Scorpaenidae		0.7					
Pleuronectidae		0.5					
Not identified	2.9	0.5		0.2		0.7	*
Pebbles and shell fragments	2.1	2.0	2.4	1.0	6.1	5.8	0.3
Vegetal fragments			2.4		*	0.1	*
Animal fragments not identified or identified but not separated	2.7	3.0	0.9	1.6	1.1	1.5	0.9
Total %	99.7	99.9	99.8	99.9	99.9	100.0	99.9
Number of stomachs with food	146	116	41	140	119	80	73

On St. Pierre Bank Protobranchia are important molluscs (32.6%) in the fall, while in spring almost all the molluscs ingested are Eulamellibranchia (9.9%). For the crustaceans there is a significant change: abundance of euphausiids in the fall (20.7%), replaced by amphipods in the winter (12.3%) and by crabs (7.6%) in the spring. The sea urchins are ingested more often in the spring (32.0%), while the brittle stars are more frequent in the winter (33.3%). Almost all the fish ingested in the spring are sand launces (4.1%), while in the fall redfish and witch are more numerous (1.2%).

On the Cape Breton shelf, Protobranchia molluscs are also principally consumed in the fall (6.3%), while in the spring the Eulamellibranchia are again more frequent (5.7%). In this region amphipods and euphausiids are eaten mainly in the summer (2.5% and 2.6%). The brittle stars represent the greater majority (52.0%) of echinoderms eaten in the spring, while the sea urchins are most frequently found in the fall (22.0%). Sedentaria polychaetes seem to be more abundant in the summer (13.3%). Here again, the sand launces account for the fish consumption of the plaice in the spring.

Variation of the diet in relation to bottom temperatures

In each season, the temperature was taken at each sampling station in order to have information about the thermic environment of the American plaice. Apart from a few details, the variations of the diet are the same in the two regions studied (Table 4).

Echinoderms form the basis of the food (70-95%) in cold and temperate waters (-1° to 4°C). The brittle stars make up the majority of food (44-55%) between 0° and 4°C, while the sea urchins also contribute and are still abundant in waters colder than 0°C. In warmer waters the percentages decrease.

Protobranchia molluscs replace the former group in the warmer waters (>4°C) covering St. Pierre Bank (63-72%). The same group is found at similar temperatures in Subdiv. 4Vn but to a lesser degree, since here the maximum percentage lies between 0° and 2°C, where *Yoldia myalis* and *Naculana* sp. are more abundant than *Y. thraciaeformis*. Between 4° and 6°C the gastropods and Eulamellibranchia (*Clinocardium ciliatum*) are more abundant. Other Eulamellibranchia (*Serripes groenlandicus* and mostly *Cyrtodaria siliqua*) and Filibranchia (*Chlamys islandicus*) are also found in cold waters (from -1° to 2°C) in both regions.

The polychaetes are ingested at high temperatures (>4°C) but in greater quantity off Cape Breton Island (close to 50%), replacing the Protobranchia molluscs.

Crustaceans of small size (mysids, cumaceans, isopods, amphipods and euphausiids) and crabs are generally eaten in larger numbers in cold waters (-1° to 2°C).

On St. Pierre Bank ascidians are only eaten at low temperatures (-1° to 2°C).

As for the fish, a distinction must be made between the sand launces and *Myctophyidae* consumed in cold waters (-1° to 2°C) and the *Scorpaenidae* and *Pleuronectidae* in warmer waters (mainly between 4° and 6°C).

Variation of the feeding intensity of the American plaice

During the various cruises in 1971 and 1972, when sampling the material for this study of the American plaice, considerable variation in the repletion of the stomachs was noted. Firstly, on a given cruise, the majority of the fish were all fed to the same degree, which led us to wonder whether there really was a seasonal variation in feeding activity, and, if so, in what proportion. Secondly, it seemed that similar variations could exist at different times of the day. We thus tried to determine whether precise rules controlled feeding intensity during the day.

Seasonal variation in feeding intensity. In addition to the seasonal changes in the diet already mentioned for both regions, the American plaice undergoes considerable seasonal variations in the intensity of its feeding (Table 5). On St. Pierre Bank, as on the Cape Breton shelf, the feeding intensity of the plaice is drastically reduced during the winter (65% of the stomachs examined on St. Pierre Bank were empty). In the spring the plaice begins feeding once again, and the activity reaches its maximum in the summer and then decreases in the fall. It must be noted that, off Cape Breton Island, the percentage of empty stomachs is always greater than that observed on St. Pierre Bank, even in the spring and summer (7.0% instead of 0.7%). This divergence becomes still greater in the fall (percentage doubled) and probably in the winter as well. Such seasonal fluctuations in the feeding intensity of the American plaice, and especially its drastic reduction during the winter months, have also been reported for the plaice of the southwestern Gulf of St. Lawrence by Powles (1965).

From a study of the repletion of the non-empty stomachs examined on St. Pierre Bank (Table 5), it can be seen that the plaice feeds little when it resumes feeding in the spring (most of the stomachs are half-full); it feeds more in the summer when the percentage of full stomachs is almost doubled; and in the fall the quantity of food ingested diminishes again until they reach the winter situation described above. Off Cape Breton Island, the resumption of feeding also takes place progressively (majority of half-full stomachs in the spring) but, in contrast to what happens on St. Pierre Bank, the percentage of half-full stomachs becomes still greater in the summer (almost 84%).

Table 4. Variation in the diet of the American plaice in relation to bottom temperature (%). (No data for -1° to 0°C and >6°C in Subdiv. 4Vn.) (* = trace)

	Subdiv. 3Ps					Subdiv. 4Vn				
	-1 to 0°C	0 to 2°C	2 to 4°C	4 to 6°C	>6°C	0 to 2°C	2 to 4°C	4 to 6°C		
Cnidaria	0.7	1.3	0.8	0.1		2.9	0.8			
Annelida	Polychaeta Errantia	1.1	0.9	0.1	0.1	0.8	4.0	11.1		
	Polychaeta Sedentaria	0.6	*		17.9	16.9	2.3	38.4		
Mollusca	Gasteropoda	1.1	0.1		* 0.6	0.2	0.1	8.3		
	Pelecypoda	Protobranchia			63.2	72.0	1.8	2.4	1.5	
		Filibranchia		0.7	2.2		1.6	1.1		
		Eulamellibranchia	10.7	6.7	0.1		3.5	2.4	4.1	
Crustacea	Mysidacea-Cumacea-Isopoda	1.3	1.7			0.4	2.3	0.3	0.1	
	Amphipoda	7.4	6.6	0.4	0.3	2.7	3.4	0.3	0.7	
	Euphausiacea	0.3	0.7		*		2.3	1.9		
	Decapoda	Macrura		1.2		1.6		1.1	1.9	0.1
		Anomura	0.3	0.9	0.2				0.5	
		Brachyura	10.4	1.6	1.1			0.1	0.2	
Echinodermata	Ophiuroidea	16.4	43.7	56.1	3.8	5.8	54.9	54.3	26.7	
	Echinoidea	36.9	26.2	39.0	4.0	0.2	21.9	26.8	9.0	
Ascidiacea		9.4	4.9			*				
Pisces	Myctophidae	0.2								
	Zoarcidae				1.9					
	Ammodytidae	3.2	2.6				0.9			
	Others		0.2		7.1	1.4	*	0.5		
Total %	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0		
Number of stomachs with food (610)	91	132	16	73	43	90	126	39		

Table 5. Seasonal variation in the feeding intensity of the American plaice. Stomachs empty - stage of repletion 0; stomachs half-full - stages of repletion 1 and 2; stomachs full - stages of repletion 3 and 4.

	Subdiv. 3Ps				Subdiv. 4Vn		
	Spring 4-12 May 1972	Summer 11-23 July 1971	Fall 9-14 Nov 1971	Winter 7-22 Feb 1972	Spring 18-24 May 1972	Summer 24-27 July 1971	Fall 25-28 Nov 1971
No. stomachs examined	142	147	159	116	79	128	161
No. stomachs empty	2	1	43	75	6	9	81
% empty	1.4	0.7	27.0	64.7	7.6	7.0	50.3
% half-full	69.7	55.7	49.7	27.5	69.9	83.6	46.6
% full	28.9	43.6	23.3	7.8	22.8	9.4	3.1

Variation of the feeding intensity during the day. For all the cruises, a variation of the percentage of empty stomachs can be distinguished throughout the day (Table 6). The percentage of recently ingested food (stage of digestion A described above) also varies, but inversely. At the times when empty stomachs are very numerous, the other stomachs examined contain food ingested for some time (stages of digestion C and D). These periods of the day correspond to the moments of minimal feeding intensity. At the times when empty stomachs are few, the others are filled with freshly ingested food. Feeding intensity is, therefore, at its maximum at these times.

Figure 2 shows clearly this relationship between the percentage of fresh food and the percentage of empty stomachs in relation to the time of the day, on St. Pierre Bank and off Cape Breton Island. In both regions, our observations led us to believe that at sunrise (0500-0700 hours St. Pierre local time¹) and at sunset (1700-1900 hours), the feeding intensity of the plaice is greater. On the other hand, in the middle of the day (1100-1300 hours) the feeding intensity is great on St. Pierre Bank but very weak on the

¹ St. Pierre local time is GMT minus 3 hours.

Cape Breton banks. These geographic differences are difficult to explain.

Table 6. Variation in the feeding intensity of the American plaice throughout the day in Subdiv. 3Ps and 4Vn. (% fresh food = % food at stage of Digestion A).

Region		Time divisions							
		0500-0700 h	0701-0900 h	0901-1100 h	1101-1300 h	1301-1500 h	1501-1700 h	1701-1900 h	1901-2200 h
3Ps	No. stomachs examined	127	115	30	19	115	72	65	21
	No. stomachs empty	16	42	7	0	23	26	4	3
	% stomachs empty	12.6	36.5	23.3	0	20.0	36.1	6.2	14.3
	% fresh food	25.4	10.0	0	18.0	6.1	2.1	12.5	14.1
4Vn	No. stomachs examined	102	20	60	70	39	35	12	30
	No. stomachs empty	20	3	14	37	9	4	0	9
	% stomachs empty	19.7	15.0	23.3	52.9	23.1	11.4	0	30.0
	% fresh food	6.3	9.0	4.1	4.7	3.0	14.1	20.9	4.3

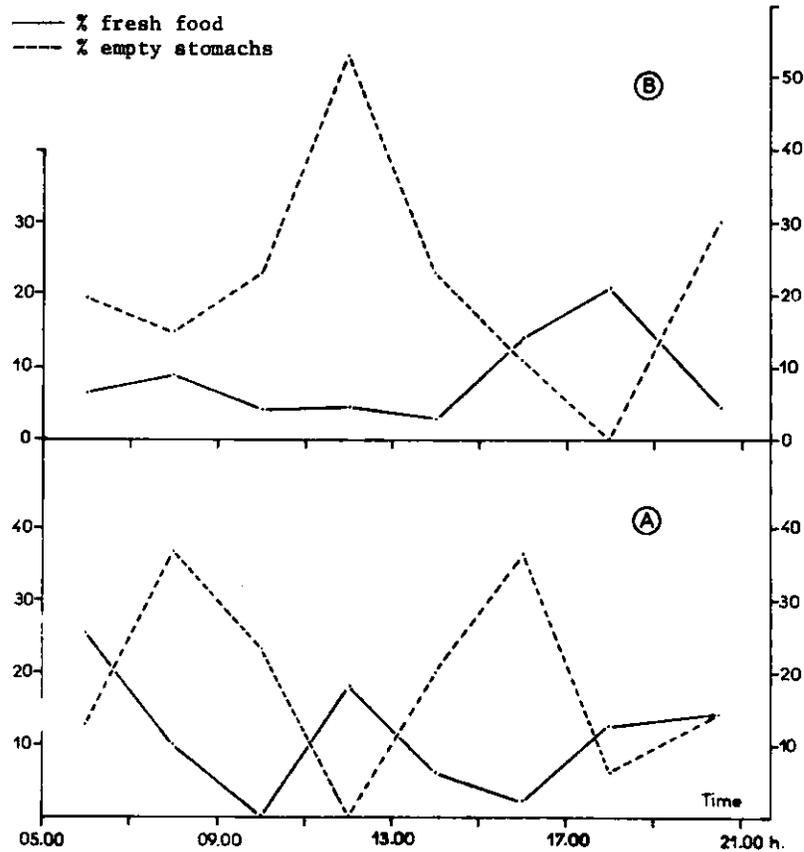


Fig. 2. Relationship between the percentage of empty stomachs and the percentage of recently ingested food throughout the day. (A - Subdiv. 3Ps; B - Subdiv. 4Vn)

CONCLUSIONS AND DISCUSSION

From this study on the feeding of the American plaice on St. Pierre Bank and the Cape Breton shelf, the following conclusions are evident:

1. The food of the plaice is made up principally of echinoderms (brittle stars and sea urchins), molluscs (pelecypods), crustaceans (amphipods, euphausiids and decapods), polychaetes and fish (sand lance). These foods seem to form the basis of the alimentation of the plaice in the area as a whole since they have also been found by Powles (1965) in the Gulf of St. Lawrence.

Therefore, the greater part of the food supply consists mainly of organisms living on the bottom (echinoderms, molluscs, Reptantia crustaceans, polychaetes, ascidians, cnidaria, etc.) but also of organisms living in free water and being more or less in contact with the bottom (Natantia crustaceans, fish, etc.).

2. The diet of the plaice in Subdiv. 3Ps is different from that of the plaice in Subdiv. 4Vn. In the latter area, plaice eat no ascidians, less fish, cnidaria and molluscs, but more annelids, lophophoroidea, crustaceans and echinoderms. In Subdiv. 3Ps the diet is more varied.

These differences must not be explained by plaice having a particular choice of food; they feed on what they find in the areas where they live. Explanation lies rather on the relative distribution and abundance, in each region, of the organisms used as food. A species or a group missing from certain seabeds will be replaced as food by others, thus modifying the diet of the plaice.

3. The diet of the plaice also varies with the size of the fish. Small plaice eat more crustaceans (isopods, amphipods, euphausiids and shrimp), polychaetes, small brittle stars and small pelecypods. The large fish ingest more sea urchins, big molluscs, crabs, ascidians and fish. These results correspond to the data given by Powles (1965).

The variations with size are obviously due to different capacities for ingestion, the criterion of choice being the size of the prey. These variations have indirect effects on the diet of the two sexes; the females, being larger, have a different diet than the males.

4. Seasonal variation of the diet is also evident from the data presented. The only point in common between the two regions is the ingestion of sand launces and Eulamellibranchia in the spring and of Protobranchia in the fall. Other than this, the variations are peculiar to each region and are clearly defined, especially for echinoderms and crustaceans.

These fluctuations with the seasons show that, at a certain time of the year when a prey become abundant, the plaice feeds upon it, not hesitating to leave the bottom if necessary (sand launces, amphipods, euphausiids).

5. The variations of the diet in relation to bottom temperature have also been shown. It is quite evident that they are connected to the ecology of the various food groups; an organism found in the stomach of a plaice living in water of 0°C will necessarily be an animal whose optimal, or at least vital, temperature is close to 0°C. Considering a given range of temperature, some organisms have become more abundant and others scarcer, and this is how the surrounding temperature influences the diet of the plaice.
6. The feeding intensity of the plaice varies with the season in both of the regions studied. A reduction in feeding can be observed in the fall and especially during the winter months. This reduction is more marked on the Cape Breton shelf than on St. Pierre Bank.

The degree of feeding activity during the spring and summer months depends on the abundance of certain organisms used as prey but also on the physiological cycle of the plaice. These months correspond to the period following reproduction during which the plaice store up energy for growth and also for the next maturation of its gonads.

The results of Powles (1965) show that this winter reduction in feeding intensity is still greater in the Magdalen Shallows (93.1%). These geographic differences may perhaps be explained by the peculiar thermic conditions which govern these three regions in the winter, or by the different benthic fauna.

7. The variation in the feeding intensity of the plaice throughout the day has been studied. In general, the plaice has a maximum feeding activity on the bottom during the daytime, and it leaves the bottom and swims freely at all depths during the night (de Groot, 1964).

The great feeding activity which we have observed at sunrise can be explained by the fact that this species seeks its food, using principally the sense of vision (highly developed optic lobes) as reported by de Groot (1969). In fact, as the intensity of the light increases and the plaice returns to the

bottom, it resumes the feeding activity that it had ceased during the night. For the other times of the day when this activity is just as great, we are obliged to acknowledge the influence of the digestive physiology of this species. Indeed, Barrington (1957) points out that although, in fish, complete digestion can last from 24 hours up to several days, the food remains in the stomach for only several hours. We may then suppose that, once the stomach is empty, the plaice resumes feeding.

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12. Catch per unit effort relationship in Grand Bank American plaice (ICNAF Div. 3L and 3N)¹

by T.K. Pitt
 Fisheries and Marine Service
 Biological Station, St. John's, Nfld.

INTRODUCTION

Previous assessments of American plaice for ICNAF Div. 3L and 3N (Pitt, 1970, 1971) were based on the virtual population model as modified by Gulland (1965) and Jones (1961, 1968). This model calculates fishing mortalities for fish of different year-classes and age-groups for the number of fish caught and does not require estimates of effort. This assessment is based on catch and effort data using the model developed by Schaefer (1954).

Commercial plaice fishery on the Grand Bank was to a considerable extent a Canadian fishery, since up to the mid-1960's, boats of the latter country landed 85-90% of the total catch from Div. 3L and 3N. During the mid-1960's, however, European trawlers began taking plaice almost exclusively in Div. 3N. Of the total landings Canada (N) has taken the greatest proportion (Table 1) and it is on these data that this document is based.

Table 1. Catch and effort data for ICNAF Div. 3L and 3N American plaice, 1956-71.

Year	Canada (N) catch (tons)	Total catch (tons)	Plaice as main species		Plaice in catch	
			Hours (¹ 000)	Catch/effort (kg)	Hours (¹ 000)	Catch/effort (kg)
1956	7,336	12,386	10.1	1,226	11.7	1,059
1957	6,477	11,664	10.6	1,100	12.6	926
1958	9,304	17,295	15.5	1,116	19.3	896
1959	11,688	17,208	16.6	1,037	19.5	882
1960	14,274	23,153	21.7	1,067	23.7	696
1961	11,166	15,970	16.9	945	19.2	831
1962	12,341	16,495	21.0	785	23.7	696
1963	15,392	23,993	26.2	916	28.7	836
1964	24,744	35,155	36.9	953	41.1	855
1965	35,550	50,342	54.7	920	58.9	854
1966	36,566	52,345	59.9	874	65.7	797
1967	43,290	61,435	73.3	838	82.2	747
1968	41,224	57,280	90.8	631	100.6	569
1969	57,843	64,217	117.8	545	126.3	508
1970	46,977	58,886	115.2	511	145.4	405
1971	42,668	60,115	127.0	473	167.5	359

MATERIALS AND METHODS

Most of the Newfoundland-based trawlers have recorded fairly accurate logsheets since the 1950's at the request of the St. John's Biological Station of the Fisheries and Marine Service, Environment Canada. These logs recorded fishing location, catch and duration of the actual fishing time in each statistical unit area. The Grand Bank fishery has been entirely by otter trawler, which up to 1965 were primarily side trawlers (ICNAF Tonnage Class 4); however, in recent years the latter type was gradually replaced by stern trawler (ICNAF Tonnage Class 5). Effort by the Newfoundland fleet was standardized by plotting catch per hour of side trawler on comparable monthly data for stern trawlers in the same statistical area. A line of best fit passing through the origin gave a slope of 0.8 (Fig. 1) which was used to convert Tonnage Class 4 to Class 5 effort.

¹ Submitted to the 1973 Annual Meeting of ICNAF as ICNAF Res.Doc. 73/87.

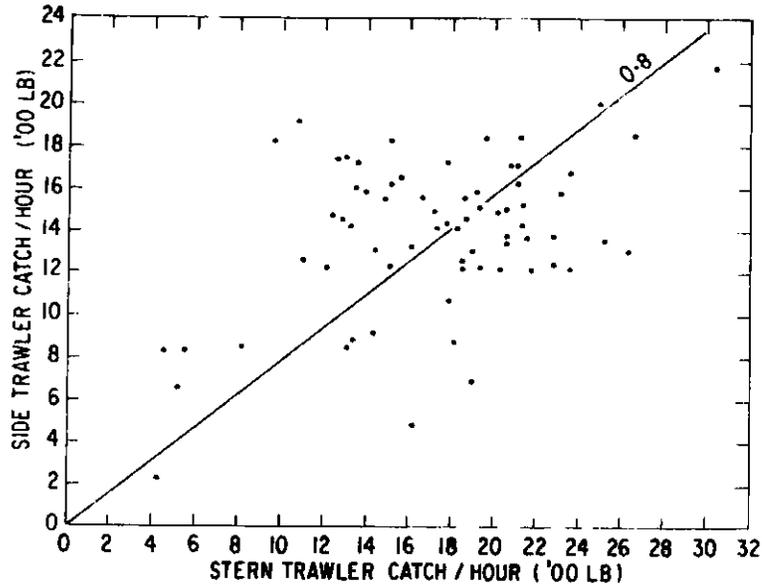


Fig. 1. Plot of catch/effort for Canada (N) OTSI 4 against catch/effort for Canada (N) OTST 5.

The total effort was determined by dividing total landings (Nominal Catch for ICNAF *Statistical Bulletin*) by the catch/effort of Canada (N) (Class 5 O.T.). Two categories of catch/effort were calculated: (1) main species plaice where plaice was the species taken in the greatest proportion in a statistical area for a particular trip, and (2) catch and effort where any plaice was recorded in the catch although not necessarily caught in the greatest proportion.

The regression of catch/hour against a 5-year running average of standardized effort was plotted: (1) for main species plaice, and (2) plaice recorded in the catch (Fig. 2B and Table 1); that is, catch/hour in year i on the average of the effort in year i and in the preceding four years.

The nominal catches of plaice by European countries, particularly the USSR and Poland which up to 1970 reported flatfish as unspecified flounder, were broken down on the basis of 1970 proportions (Pitt, 1972).

RESULTS AND DISCUSSION

The regression equation (Fig. 2B) for catch per hour with (1) plaice main species, and (2) plaice in catch were as follows:

	<u>Intercept</u>	<u>Slope</u>	<u>Correlation Coefficient</u>
(1)	1058.720	-5.856	-0.932
(2)	967.126	-5.075	-0.936

The equilibrium yield curves (Fig. 2A) derived from the catch per unit effort on effort relationships have a maximum between 45 and 50 thousand tons at 90 thousand standard hours. The plot of actual yields from the fishery for years 1956-71 corresponded to the equilibrium yield points up to 1964, but beyond this the points were all above the curve. The increase in the amount of effort expended in catching plaice when it was not the main species (dotted lines with arrows, Fig. 2A) can be attributed to the increase in the effort for yellowtail which replaced American plaice as the main species with greater frequency in recent years.

An annual yield of 35-40 thousand tons for Div. 3L and 15-20 thousand tons for Div. 3N was suggested in a previous assessment (Pitt, 1972). The sustainable yield for Div. 3L and 3N at the optimal level from yield-per-recruit curves is 60 thousand tons which was the quota established for 1973 including an estimate of 8 thousand tons for Div. 3O.

The quotas were set at the "optimum" yield rather than at the MSY. The type of yield curve produced

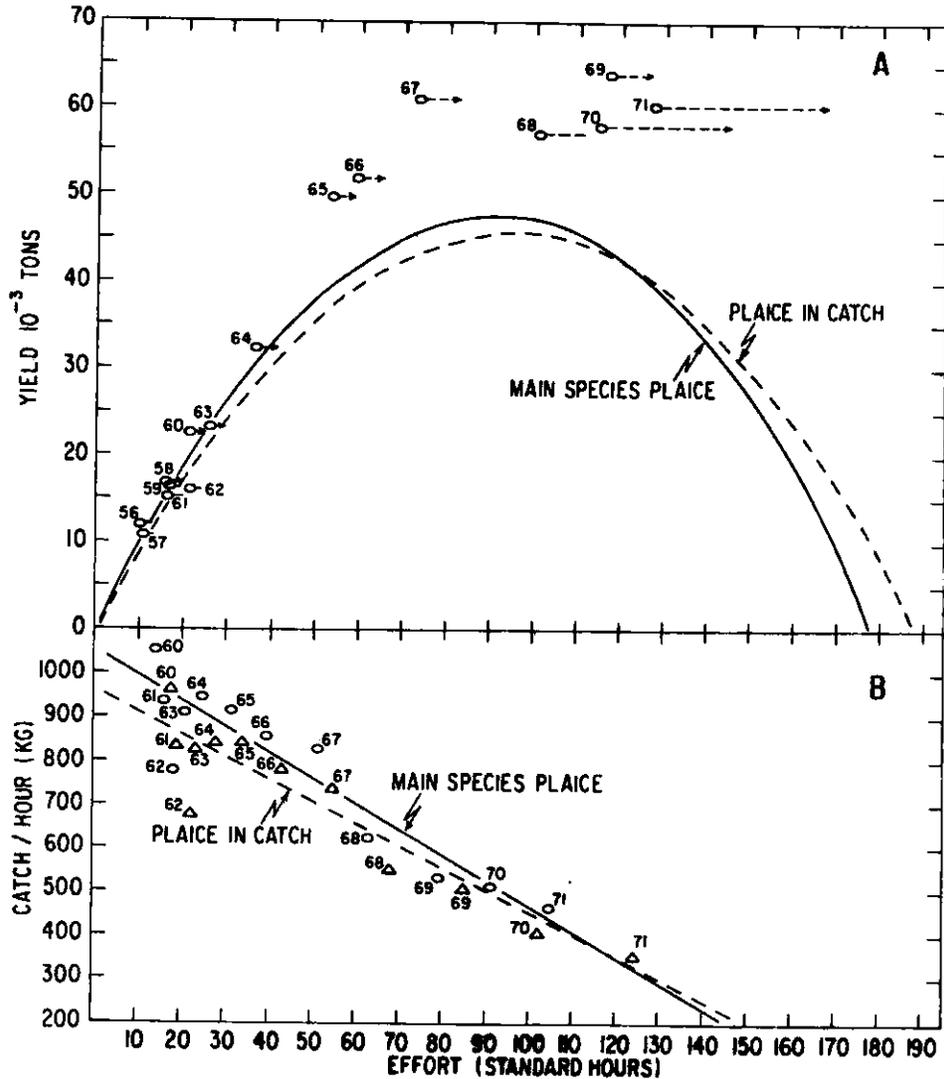


Fig. 2. A. Equilibrium yield curves for American plaice Div. 3L and 3N (1) solid lines: main species plaice; and (2) broken lines: plaice in the catch. Actual yield for the various years plotted, with arrows indicating position on X axis (effort) for "plaice recorded in the catch".
 B. Catch/effort or effort for (1) main species plaice, and (2) plaice in catch.

for plaice had a rather indefinite MSY with a gradual increase in yield per recruit to values of F of 2.0 and beyond. The independent assessment produced here while indicating an MSY below the previous assessment confirms that the quotas arrived at in 1972 were within the range of the MSY.

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13. Feeding patterns of yellowtail of two New England stocks¹

by V.N. Efanov and V.I. Vinogradov
AtlantNIRO, Kaliningrad, USSR

ABSTRACT

Based on the material collected in June 1971 by R/V *Argus*, feeding patterns of yellowtail from Georges Bank and Southern New England were studied. Stomach analysis shows that the food of yellowtail on Georges Bank consists mainly of three species, while in the Southern New England area it is represented by 12 species. In both cases, the bulk of the ration is made of one species, *Microdeutopus dammonensis*. Yellowtail on Georges Bank were feeding 1.6 times more intensively than in Southern New England. However, the feeding intensity of both stocks in June was estimated as low.

INTRODUCTION

Studies on yellowtail, *Limanda ferruginea* (Storer), which, in spite of its low abundance, attracts the attention of fishery scientists, have been focused on the estimation of the stock abundance and on the related problems. The feeding pattern of this species is discussed in only one of the available publications (Bigelow and Schroeder, 1953). These authors indicated that yellowtail feed on small crustaceans, such as *Amphipodae*, shrimps, *Mysidacea*, and on small univalve and bivalve molluscs and occasionally they also feed on small fish. The present paper aims at determining the species composition of food organisms and estimating the feeding intensity of two New England stocks during the summer period.

MATERIALS AND METHODS

The materials used for this study were collected during a trawl survey by R/V *Argus* in June 1971 in the area from Browns Bank to Wilmington Canyon (Fig. 1). The material was analyzed separately for Georges Bank (141 specimens) and Southern New England (524 specimens). Processing of the material was made according to methods described in the Soviet manual on the studies of feeding patterns of fishes in the natural conditions (Anon., 1961). Absolute and relative indices of stomach filling were estimated.

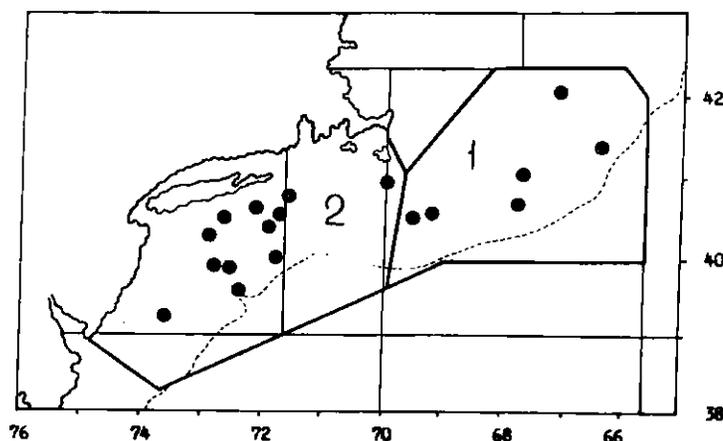


Fig. 1. Position of stomach samples of yellowtail collected in June 1971. 1 - Georges Bank stock; 2 - Southern New England stock.

Absolute index means the ratio of the total weight of food to the weight of all fish sampled in promilles (‰), while the relative index is the ratio of the particular food object weight to the weight of all fish (in ‰) (Zenkevich and Brotskaya, 1931).

FOOD ORGANISMS

The analysis of stomach contents of yellowtail from Georges Bank shows that their food mainly included only three species belonging to two orders (Table 1): *Polychaeta* and *Amphipoda*. *Polychaeta* species play a significant role in flounder feeding and is in second place by the relative index. However, the main food object is the *Amphipoda* species, *Microdeutopus dammonensis* (relative index of filling equals 6.0‰).

¹ Submitted to the 1973 Annual Meeting of ICNAF as ICNAF Res.Doc. 73/32.

Table 1. Species composition of food and indices of stomach filling of the two yellowtail stocks in the New England area.

Food organisms	Relative indices of stomach filling (‰)	
	Georges Bank	Southern New England
<i>Polychaeta</i> (unidentified)	4.7	0.5
<i>Nereis pelagica</i> Linnaeus	-	0.2
<i>Nephtys ingens</i> Stimpson	2.0	0.4
<i>Arabella opalina</i> Verrill	0.3	0.4
<i>Clymenella torquata</i> (Leidy)	-	0.1
Total <i>Polychaeta</i>	7.0	1.6
<i>Cirolana concharum</i> (Stimpson)	-	0.1
Total <i>Isopoda</i>	-	0.1
<i>Gammaridea</i> (unidentified)	1.4	0.3
<i>Ampelisca spinipes</i> Boeck	-	0.1
<i>Microdeutopus dammonensis</i> (Bate)	6.0	6.5
Total <i>Amphipoda</i>	7.4	6.9
<i>Thysanopoda acutifrons</i> (Holt and Tattersall)	-	0.2
Total <i>Euphausiacea</i>	-	0.2
<i>Crago septemspinosus</i> (Say)	-	0.1
<i>Cancer borealis</i> Stimpson	-	0.1
Total <i>Decapoda</i>	-	0.2
<i>Mesoderma deauratum</i> (Turton)	-	+
Total <i>Teleodesmacea</i>	-	+
<i>Margarites helicina</i> (Fabricius)	-	+
Total <i>Archeogastropoda</i>	-	+
Absolute index of filling (‰)	14.4	9.0
Total number of stomachs (No.)	141	524
Percentage of empty stomachs	53.9	58.7

The food of yellowtail from Southern New England consisted of 12 species belonging to 7 orders. Most numerous in the stomachs were 4 species of *Polychaeta* species, but they are insignificant by weight. A sum of the relative indices of these 4 species is 1.6‰, while on Georges Bank the value was 7.0‰. The bulk of the food of yellowtail from Southern New England consisted of *M. dammonensis* (relative index of filling was 6.5‰).

The analysis of the feeding patterns of the two yellowtail stocks indicated that the food of this species included a wider range of organisms in Southern New England than on Georges Bank, but the main food organism for both stocks was *M. dammonensis*.

FEEDING INTENSITY

Since the index of stomach filling (absolute and relative) is an index of feeding intensity (Zheltenkova, 1964), the second object of the investigation was to determine the feeding intensity on the basis of the stomach filling indices obtained (Table 1).

The mean absolute index of stomach filling for Georges Bank yellowtail was 14.4‰. The fish in this area was feeding poorly with only 46.1% of stomachs classified as 1 and 2 by the 5-grade scale of Lebedev (1950), while the rest of the stomachs were empty.

Absolute index of stomach filling for yellowtail of Southern New England was lower (9.0‰) than on Georges Bank and empty stomachs accounted for 58.7%. Consequently, yellowtail on Georges Bank was feeding more intensively than in Southern New England. However, food consumption by these stocks was rather poor. Low feeding intensity is characteristic of flatfish during spawning period (Bigelow and Schroeder, 1953; Nikolsky, 1965). Yellowtail flounder spawn during April-July with a peak in mid-May (Bigelow and Schroeder, 1953).

SUMMARY

Food range of yellowtail from Georges Bank in June included three species belonging to two orders, while for Southern New England it included 12 species (7 orders), but the bulk of food for both stocks consisted of one species - *M. lammonensis*.

The absolute index of stomach filling for yellowtail of the Georges Bank stock was 1.6 times higher than that of New England, indicating that yellowtail on Georges Bank was feeding more intensively than in Southern New England.

The feeding intensity of both stocks was considered as low which is confirmed by a large percentage of empty stomachs (average 57.7% for both stocks).

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14. The flatfish fisheries of the Scotian Shelf¹

by R.G. Halliday
 Fisheries and Marine Service, Biological Station
 St. Andrews, New Brunswick

INTRODUCTION

There are six species of the family Pleuronectidae fished commercially on the Scotian Shelf (ICNAF Subdiv. 4Vn, 4Vs, Div. 4W, 4X) - witch flounder [*Glyptocephalus cynoglossus* (L.)], American plaice [*Hippoglossoides platessoides* (Fabricius)], Atlantic halibut [*Hippoglossus hippoglossus* (L.)], yellowtail flounder [*Limanda ferruginea* (Storer)], winter flounder [*Pseudopleuronectes americanus* (Walbaum)], and Greenland halibut [*Reinhardtius hippoglossoides* (Walbaum)]. The Atlantic halibut and its fishery are not considered in this document. The nature of the halibut fishery in Subarea 4, prosecuted mainly by longline, and the high value of the species, set it apart from the other flounder species.

LANDINGS

Landings of flatfish (excluding halibut) from the Scotian Shelf increased from 10,000 metric tons in 1960 to 55,000 tons in 1968, and ranged from 20,000-37,000 tons in the 1969-71 period (Table 1). Canada has been the main exploiter although the USSR has made sporadic, large landings since 1965.

Table 1. Flatfish landings (excluding halibut) from the Scotian Shelf by ICNAF Division and country (metric tons round).

Year	ICNAF Division					Country								
	4Vn	4Vs	4W	4X	Total	Canada	Fr(SP)	FRG	Jap	Pol	Rom	USSR	UK	USA
1960	4,090	782	3,982	1,160	10,014	9,771	8	-	-	-	-	-	-	235
1961	1,983	1,916	5,788	990	10,677	10,438	-	-	-	-	-	28	-	211
1962	2,836	1,918	6,874	896	12,524	11,537	-	-	-	-	-	671	-	316
1963	5,906	2,198	5,336	1,022	14,462	13,532	-	-	-	-	-	586	-	344
1964	5,112	6,953	4,351	2,200	18,616	17,813	231	2	-	-	-	113	9	448
1965	4,912	9,315	11,980	2,467	28,674	19,867	182	-	-	1	-	8,324	1	299
1966	6,004	11,011	15,558	2,373	34,946	20,927	39	-	-	-	-	13,817	11	152
1967	4,559	13,956	3,596	2,661	24,772	24,144	-	-	-	1	-	324	2	301
1968	4,263	20,797	27,177	3,029	55,266	25,115	177	-	-	-	-	29,842	-	132
1969	4,518	10,466	14,898	3,267	33,149	19,945	140	-	-	45	-	12,914	-	105
1970	4,388	4,835	7,175	3,251	19,649	13,667	39	-	9	6	84	5,705	-	139
1971	4,843	9,707	19,108	3,391	37,049	16,816	26	-	1	-	-	20,053	-	153

A breakdown of flatfish landings by species is available from 1960 for most countries but only for 1970 and 1971 for USSR landings, earlier USSR landings being reported as "unspecified flounders". The average species composition in each Division in 1970-71 Soviet landings was used to prorate landings for earlier years. The breakdown used was:

Division	Plaice	Winter flounder	Witch	Yellowtail
4Vn	50%	-	50%	-
4Vs	49%	-	42%	9%
4W	32%	7%	47%	14%
4X	12%	11%	60%	17%

There were considerable differences between the Soviet catch compositions in 1970 and 1971, thus there is a high uncertainty associated with the breakdown by species for earlier years.

On the basis of this breakdown, landings of Greenland halibut from the Scotian Shelf have been negligible, the largest landing being 38 tons in 1969 (Table 2). Research vessel surveys confirm that Greenland

¹Submitted to the 1973 Annual Meeting of ICNAF as ICNAF Res.Doc. 73/102.

halibut are scarce on the Scotian Shelf, only occasional specimens being taken in the colder water on the eastern part of the Shelf. This is the southern extremity of the range of this northern, cold-water species, and it is unlikely that it will ever play a significant role in the flatfish fishery on the Scotian Shelf.

Table 2. Greenland halibut landings from the Scotian Shelf by ICNAF Division and country (metric tons round).

Year	ICNAF Division					Country		
	4Vn	4Vs	4W	4X	Total	Canada	FRG	Poland
1960	-	-	-	-	-	-	-	-
1961	-	-	-	-	-	-	-	-
1962	-	-	-	-	-	-	-	-
1963	-	-	-	-	-	-	-	-
1964	-	1	-	1	2	-	2	-
1965	-	-	-	-	-	-	-	-
1966	1	-	-	-	1	1	-	-
1967	2	-	-	-	2	2	-	-
1968	1	9	-	-	10	10	-	-
1969	16	20	-	2	38	18	-	20
1970	9	5	3	2	19	16	-	3
1971	15	4	2	3	24	24	-	-

Winter flounder landings were also low, reaching a maximum of about 3,000 tons in 1971 (Table 3). Winter flounder is a coastal species and is abundant inshore in bays along the coast of Nova Scotia and particularly in the Bay of Fundy. Offshore, the only sizeable population is found in the shallows of Sable Island Bank as shown by research vessel catches (Table 4). It is probably on Sable Island Bank where the bulk of the Soviet winter flounder catch is taken. However, it is likely that only the deeper fringe of the population is exploited as the bulk of the population resides in water shallower than that navigable by large fishing vessels and also lies within the Canadian 12-mile fishing zone. The Canadian catch is almost entirely coastal and made by small inshore vessels. Almost all is taken within Canadian territorial sea and thus outside the ICNAF Convention Area.

Table 3. Winter flounder landings from the Scotian Shelf by ICNAF Division and country (metric tons round).

Year	ICNAF Division					Country				
	4Vn	4Vs	4W	4X	Total	Canada	Fr (SP)	Jap	USSR	USA
1960	2	-	17	65	84	77	-	-	-	7
1961	70	-	79	702	851	846	-	-	2	3
1962	38	-	122	537	697	644	-	-	47	6
1963	11	6	104	561	682	613	-	-	42	27
1964	13	-	23	1,286	1,322	1,282	1	-	10	29
1965	27	5	637	1,183	1,852	1,237	-	-	610	5
1966	52	3	920	1,023	1,998	998	-	-	992	8
1967	35	1	28	902	966	925	-	-	23	18
1968	7	1	1,619	1,133	2,760	1,127	-	-	1,620	13
1969	3	-	842	1,398	2,243	1,393	-	-	843	7
1970	8	-	44	1,479	1,531	1,480	-	1	42	8
1971	8	229	1,364	1,484	3,085	1,430	-	1	1,647	7

Thus, neither Greenland halibut nor winter flounder is significant in a discussion of the international flatfish fishery on the Scotian Shelf and are not considered further here.

The landings from the remaining three species, plaice, witch, and yellowtail combined increased from about 10,000 tons in 1960 to 52,500 tons in 1968, fluctuating between 18,000 and 34,000 tons in 1969-71 (Table 5). Landings from Div. 4X have been small - always less than 2,000 tons annually. The bulk of the

landings have come from Div. 4W and Subdiv. 4Vs. Canadian landings have been highest from Subdiv. 4Vs, while Soviet landings have been predominantly from Div. 4W.

Table 4. Winter flounder. A. Estimated population biomass (metric tons) and kg/tow. B. Estimated population numbers ($\times 10^{-6}$) and No./tow, from Canadian research vessel surveys, July 1970-72.

Strata	ICNAF Div.	A						B						
		1970		1971		1972		1970		1971		1972		
		Bio-mass	kg/tow	Bio-mass	kg/tow	Bio-mass	kg/tow	Popn. No.	No./tow	Popn. No.	No./tow	Popn. No.	No./tow	
40-42	4Vn	-	-	-	-	-	-	-	-	-	-	-	-	-
43-52	4Vs	-	-	-	-	-	-	-	-	-	-	-	-	-
40-52	4V	-	-	-	-	-	-	-	-	-	-	-	-	-
53-66	4W	520	0.30	790	0.46	3,120	1.82	1.8	1.03	2.2	1.30	5.4	3.12	
70-95	4X	380	0.21	240	0.13	220	0.12	0.5	0.28	0.5	0.27	0.4	0.24	
40-95	4VWX	900	0.18	1,030	0.21	3,340	0.67	2.3	0.46	2.7	0.55	5.8	1.17	

Table 5. Landings of plaice, yellowtail and witch from the Scotian Shelf by ICNAF Division and country (metric tons round).

Year	ICNAF Division					Country							
	4Vn	4Vs	4W	4X	Total	Canada	France	Jap	Pol	Rom	USSR	UK	USA
1960	4,088	782	3,965	1,095	9,930	9,694	8	-	-	-	-	-	228
1961	1,913	1,916	5,709	288	9,826	9,592	-	-	-	-	26	-	208
1962	2,798	1,918	6,752	359	11,827	10,893	-	-	-	-	624	-	310
1963	5,895	2,192	5,232	461	13,780	12,919	-	-	-	-	544	-	317
1964	5,099	6,952	4,328	913	17,292	16,531	230	-	-	-	103	9	419
1965	4,885	9,310	11,343	1,284	26,822	18,630	182	-	1	-	7,714	1	294
1966	5,951	11,008	14,638	1,350	32,947	19,928	39	-	-	-	12,825	11	144
1967	4,522	13,955	3,568	1,759	23,804	23,217	-	-	1	-	301	2	283
1968	4,255	20,787	25,558	1,896	52,496	23,978	177	-	-	-	28,222	-	119
1969	4,499	10,446	14,056	1,867	30,868	18,534	140	-	25	-	12,071	-	98
1970	4,371	4,830	7,128	1,770	18,099	12,171	39	8	3	84	5,663	-	131
1971	4,820	9,474	17,742	1,904	33,940	15,362	26	-	-	-	18,406	-	146

CATCH PER UNIT EFFORT

The catch per unit effort (cpe) of Canadian otter trawlers of 151-500 gross tons of plaice, witch, and yellowtail combined declined in Subdiv. 4Vn and 4Vs, but did not change greatly in Div. 4W and 4X in the period 1965-72 (Table 6). For the Scotian Shelf as a whole, cpe declined from 150.7 kg/hr in 1965 to 104.5 kg/hr in 1972, a drop of 30%. This is associated with landings which were substantially higher than the stocks supported in the pre-1965 period (Table 5). It is almost exclusively the yellowtail stocks which are responsible for this decline in cpe, falling from 72.9 kg/hr in 1965 to 14.8 kg/hr in 1972, a drop of 80%.

These cpe data were obtained by averaging the monthly values in each Division and combining these by weighting by the area of each Division (to the 200-fm contour).

WITCH ASSESSMENT

Distribution and abundance - research vessel surveys

Canadian research vessel survey catch per tow data averaged for 1970-72 (for stratification scheme and methodology, see Halliday and Kohler, MS, 1971) indicate that witch are distributed widely on the Scotian

Shelf (Fig. 1), but in low concentrations. Localized areas of high abundance occur along the edge of the Laurentian Channel, in "the Gully" between Sable Island and Banquereau Banks, in the deep holes north of Banquereau and in the deeper holes at the mouth of the Bay of Fundy, *i.e.*, predominantly in depths greater than 100 fm.

Table 6. Catch per unit effort (kg/hr trawling) of plaice, witch and yellowtail on the Scotian Shelf (Canadian otter trawlers of 151-500 gross tons), A by species, B by area.

A				B					
Catch per unit effort by species				Catch per unit effort by Divisions					
Year	Plaice	Witch	Yellow-tail	Year	4Vn	4Vs	4W	4X	All Div.
1965	42.9	34.9	72.9	1965	195.9	487.4	86.3	5.8	150.7
1966	67.8	22.4	49.5	1966	153.7	535.1	32.4	6.1	139.7
1967	58.0	28.7	47.4	1967	225.7	435.5	62.3	8.2	134.1
1968	61.6	30.9	49.7	1968	173.0	478.3	67.2	10.1	142.2
1969	73.5	31.7	24.8	1969	152.3	454.4	50.1	10.9	130.0
1970	72.7	20.9	14.0	1970	134.6	392.6	30.6	7.8	107.6
1971	61.0	31.3	14.7	1971	135.7	338.8	61.2	9.0	107.0
1972	54.9	34.8	14.8	1972	112.4	321.1	71.4	7.1	104.5

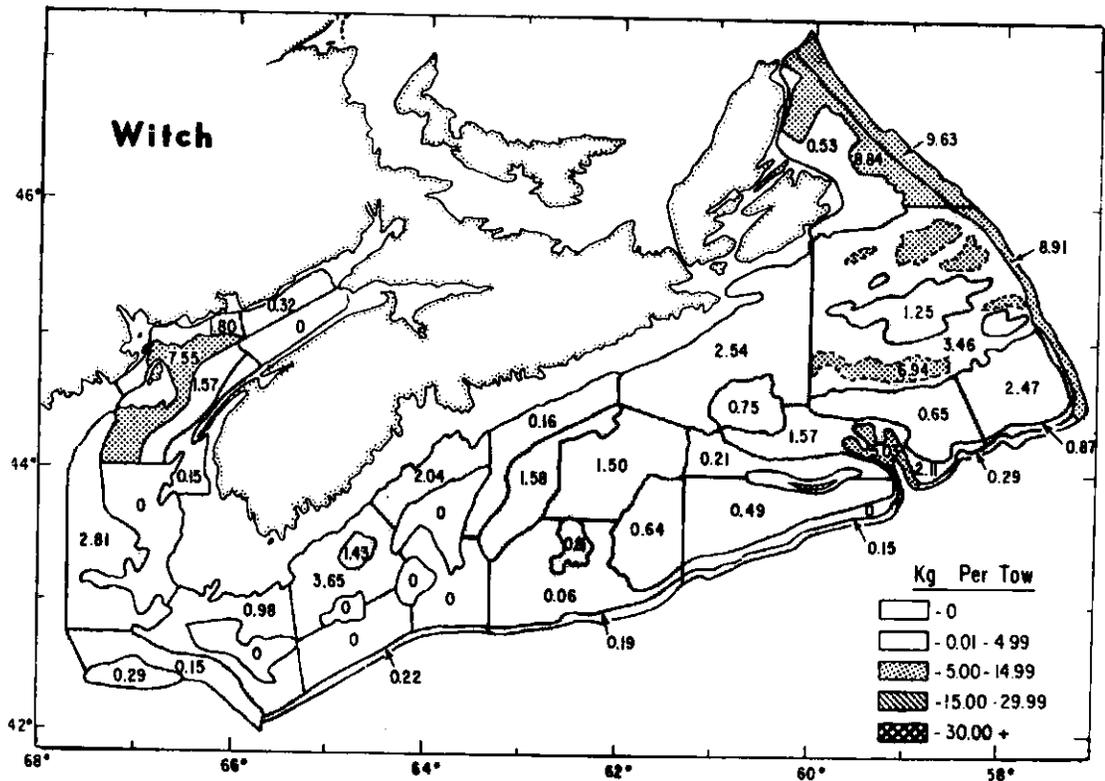


Fig. 1. Witch: stratified mean catch (kg/tow) on the Scotian Shelf in 1970-72 from Canadian research vessel surveys.

Survey abundance estimates do not indicate any substantial changes in the 1970-72 period (Table 7). Population number and biomass estimates, uncorrected for catchability, were about 20 million fish with a biomass of about 10,000 tons.

Table 7. Witch flounder. A. Estimated population biomass (metric tons) and kg/tow. B. Estimated population numbers ($\times 10^{-6}$) and no./tow, from Canadian research vessel surveys, July 1970-72.

Strata	ICNAF Div.	A						B					
		1970		1971		1972		1970		1971		1972	
		Bio-mass	kg/tow	Bio-mass	kg/tow	Bio-mass	kg/tow	Popn. No.	No./tow	Popn. No.	No./tow	Popn. No.	No./tow
40-42	4Vn	1,190	3.56	3,440	10.31	880	2.64	2.2	6.64	10.6	31.68	2.4	7.06
43-52	4Vs	4,120	3.83	2,960	2.76	3,140	2.92	10.0	9.29	5.3	4.89	6.8	6.27
40-52	4V	5,310	3.77	6,400	4.55	4,020	2.85	12.2	8.66	15.9	11.23	9.2	6.46
53-66	4W	1,640	0.96	1,420	0.83	2,170	1.26	4.1	2.40	3.1	1.81	4.2	2.45
70-95	4X	2,750	1.50	980	0.48	4,150	2.25	4.7	2.55	1.6	0.87	5.9	3.21
40-95	4VWX	9,700	1.96	8,800	1.76	10,340	2.08	21.0	4.23	20.6	4.14	19.3	3.87

Length and age composition of survey catches

Witch less than 20 cm are virtually absent from survey catches and very few less than 30 cm are caught, except in Subdiv. 4Vs where moderate numbers of fish 20-30 cm are caught (Fig. 2). Fish over 60 cm are rare. Full recruitment to the survey gear apparently occurs at age 8 for both males and females (Fig. 3). Very few fish as young as age 6 are taken. Only in Subdiv. 4Vs are age-groups 5 and 6 moderately represented in catches. Females older than age 12 are common but few males are in this age category.

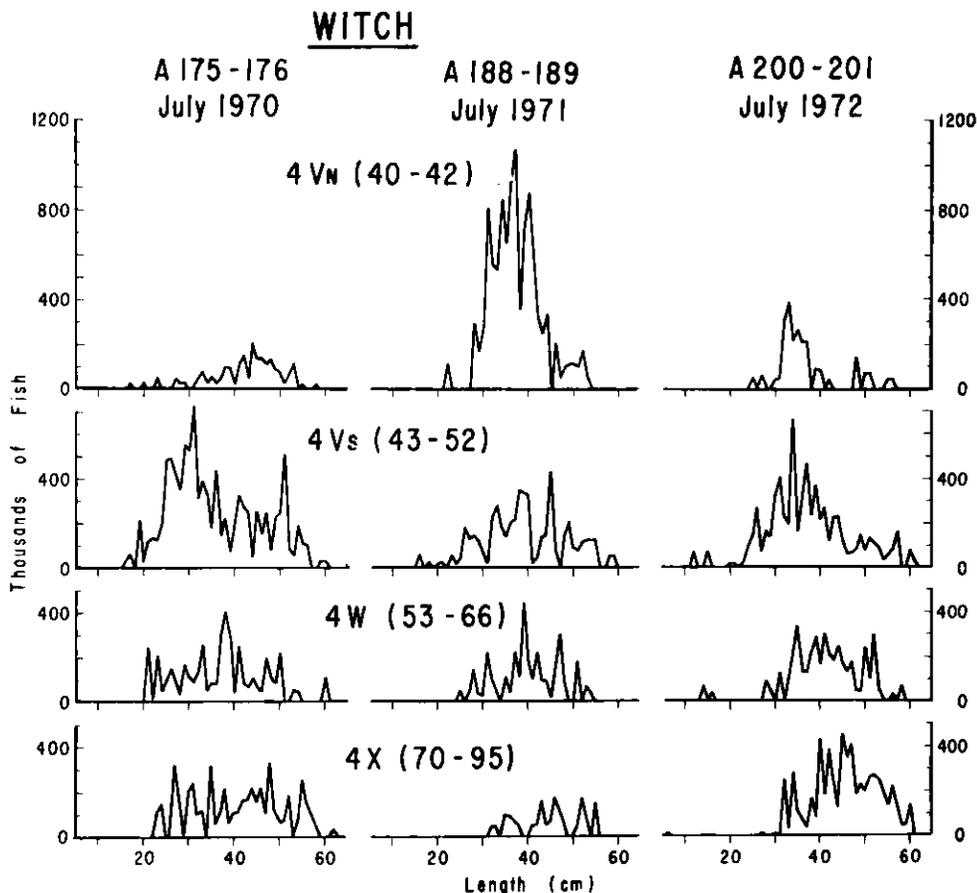


Fig. 2. Witch: length-frequency of the Scotian Shelf population by ICNAF Division estimated from Canadian research vessel surveys, 1970-72.

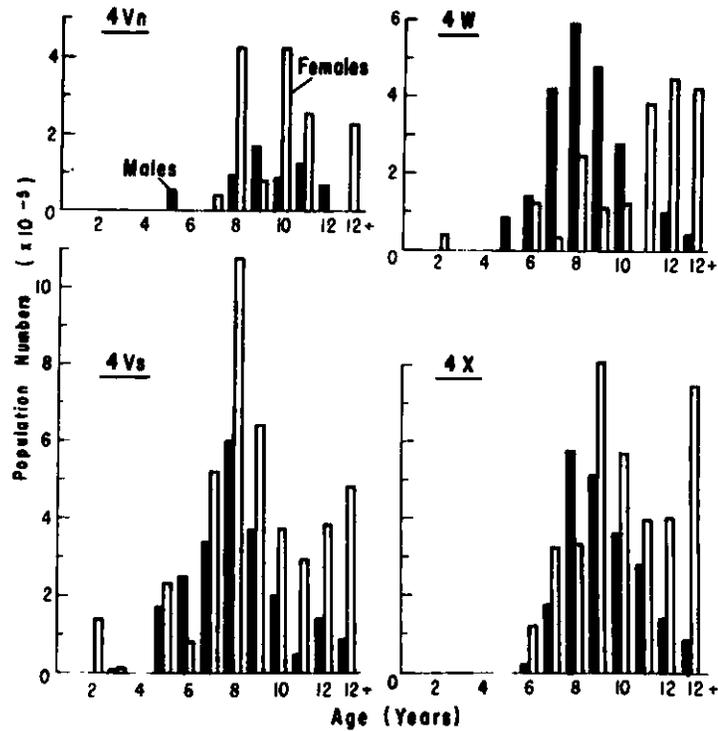


Fig. 3. Witch: age composition of the Scotian Shelf population by ICNAF Division estimated from Canadian research vessel surveys in 1972.

Nominal catches

Nominal catches fluctuated between 5,000 and 22,500 metric tons in 1960-71 (Table 8). The Canadian fishery has been fairly stable, ranging from 5,000-9,000 tons. However, nominal catches by the USSR have fluctuated greatly and may have been as high as 13,700 tons in 1968. Most Soviet landings were from Div. 4W but Subdiv. 4Vn and 4Vs are important to the Canadian fishery.

Table 8. Witch landings from the Scotian Shelf by ICNAF Division and country (metric tons round).

Year	ICNAF Division					Country						
	4Vn	4Va	4W	4X	Total	Canada	France(SP)	Japan	Poland	USSR	UK	USA
1960	3,192	209	2,623	46	6,070	5,914	6	-	-	-	-	150
1961	1,494	475	3,175	69	5,213	5,074	-	-	-	13	-	126
1962	2,030	342	3,774	65	6,211	5,697	-	-	-	313	-	201
1963	4,648	322	2,363	144	7,477	7,028	-	-	-	279	-	170
1964	4,040	1,925	2,556	291	8,812	8,406	157	-	-	60	-	189
1965	3,163	1,969	6,219	521	11,872	7,710	63	-	1	4,003	1	94
1966	3,720	1,524	7,910	521	13,675	7,046	19	-	-	6,586	4	20
1967	2,491	3,252	1,619	383	7,745	7,498	-	-	1	152	2	92
1968	2,608	6,384	12,804	751	22,547	8,771	52	-	-	13,695	-	29
1969	2,090	2,418	7,470	797	12,775	6,672	40	-	8	6,027	-	28
1970	2,263	1,022	1,960	809	6,054	4,921	14	3	2	1,059	-	55
1971	2,332	3,309	11,083	1,141	17,865	6,817	6	-	-	10,978	-	64

Although otter trawlers predominate in the fishery, significant quantities are taken by Canadian, Danish and Scottish seine vessels. In 1969-71, seiners accounted for 35% of the Canadian landings (18% of total landings by all countries).

Catch per unit effort

Between 1965 and 1972 catch rates of witch by Canadian otter trawlers declined in Subdiv. 4Vn but increased slightly in Div. 4W and 4X, resulting in no major trends in catch rates for the Scotian Shelf as a whole between 1965 and 1972 (Table 9).

Length and age composition of commercial landings

There have been no biological sampling data for Soviet witch landings reported to ICAF. Thus, it has been necessary to assume that Soviet trawler landings have the same size and age composition as those of Canadian trawlers. Insufficient Canadian sampling data are available to treat years and Divisions separately. Thus, the average 1970-72 length and age compositions were derived using the 12 otter trawl and 4 Danish seine samples available for these years (Fig. 4). The samples originated from Subdiv. 4Vn, 4Vs and Div. 4W.

Table 9. Catch per unit effort (kg/hr) of witch on the Scotian Shelf by Division - Canadian otter trawlers of 151-500 gross tons.

Year	Divisions				All Div.
	4Vn	4Vs	4W	4X	
1965	88.7	94.4	23.9	0.7	34.9
1966	72.3	59.5	12.3	1.0	22.4
1967	80.3	82.4	14.0	1.7	28.7
1968	86.3	80.0	19.9	2.4	30.9
1969	46.6	83.4	26.6	3.6	31.7
1970	50.5	61.3	10.0	2.2	20.9
1971	64.4	66.9	32.6	3.4	31.3
1972	56.4	79.6	37.7	1.9	34.8

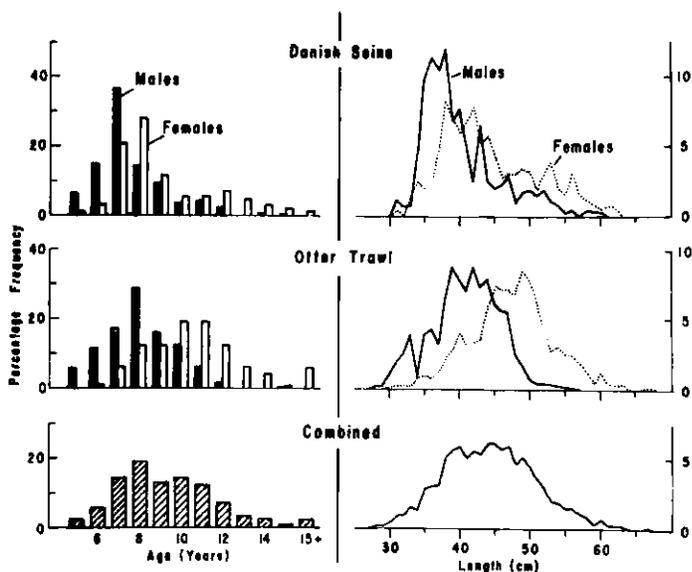


Fig. 4. Witch: length and age composition of commercial landings from Div. 4VW, 1970-72.

Commercial landings are composed of fish 30-60 cm long and age 5 to over 15 years. Danish seiners take smaller and younger fish than otter trawlers. Females are larger and older than males in landings of both gears but particularly in otter trawl landings. Very few 5-year-olds occur in commercial landings, full recruitment to the gear occurring at age 7 in the Danish seine fishery and age 8 in the otter trawl fishery for males, and at age 8 in the Danish seine fishery and about age 11 in the otter trawl fishery for females. Few males over age 12, and few females over age 15, are caught.

Mortality

Catch curves from commercial and survey age compositions give estimates of instantaneous total mortality (Z) of 0.33-0.56 for males and 0.30-0.50 for females (Table 10). The lower estimates of Z in Div. 4X are understandable as landings are low in relation to estimated population size from surveys. Values of Z = 0.55 for males and Z = 0.50 for females are taken as best estimates of mortality in the fished population.

No estimates of natural mortality of witch are available. As this is a fairly long-lived species, and as females are more abundant than males at older ages and thus probably have a lower natural mortality than males, values of M = 0.20 for males, and M = 0.15 for females are assumed.

Yield per recruit

The Beverton and Holt yield per recruit model was applied to males and females separately, using the following parameters:

	Males	Females
W_{∞} (asymptotic weight)	1.90 kg	5.1 kg
K (rate of completion of growth curve)	0.12	0.07
t_0 (growth correction factor)	-0.04	-0.42
t_p (age at entry to exploited area)	5 yrs	5 yrs
t_{p1} (mean age at entry to exploited phase)	6.5 yrs	8 yrs
t_{λ} (last age of significant contribution to fishery)	15 yrs	20 yrs

Table 10. Witch: Div. 4VWX. Instantaneous total mortality - Z, from catch curves.

Data base	Div.	Z Males		Z Females	
		Males	Ages	Females	Ages
Commercial age compositions, 1970-72	4VW	0.56	8-12	0.50	11-14
1972 survey age compositions	4Vs	0.55	8-12	0.47	8-11
1972 " " "	4W	0.45	8-12	-	-
1972 " " "	4X	0.33	8-12	0.30	9-12

Growth parameters were obtained from Powles and Kennedy (1967). Values of t_{p1} and t_{λ} were estimated from age compositions of commercial landings. Three values of M were used, 0.10, 0.15, 0.20.

For males, the current value of fishing mortality (F) of 0.35, assuming M = 0.20, is close to optimum ($F_{opt} \approx F_{0.1}$, as defined by Gulland, 1973) and gives about 93% of maximum yield per recruit (Fig. 5). For values of M less than 0.20, current F is close to that giving maximum yield per recruit.

For females, the current value of F = 0.35, assuming M = 0.15, is close to that giving maximum yield per recruit (Fig. 6). If M is less than 0.15, then F is above F_{max} . If M = 0.20, F is at the F_{opt} level, or 92% of F_{max} .

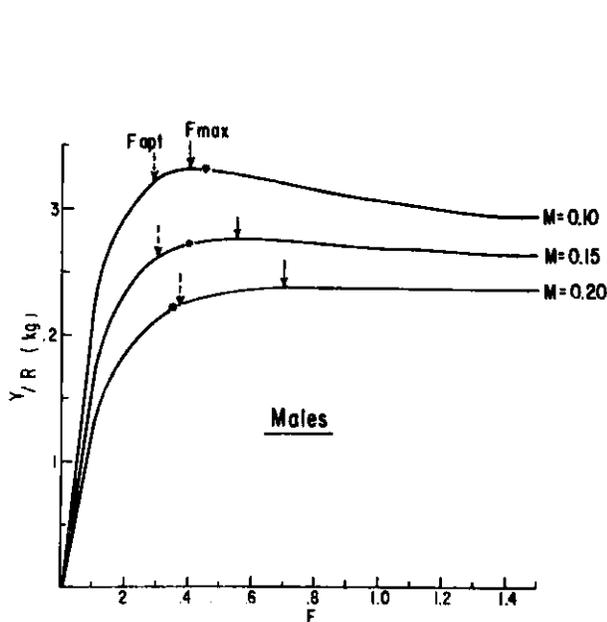


Fig. 5. Witch: yield per recruit of males. Dots indicate 1965-72 values of F.

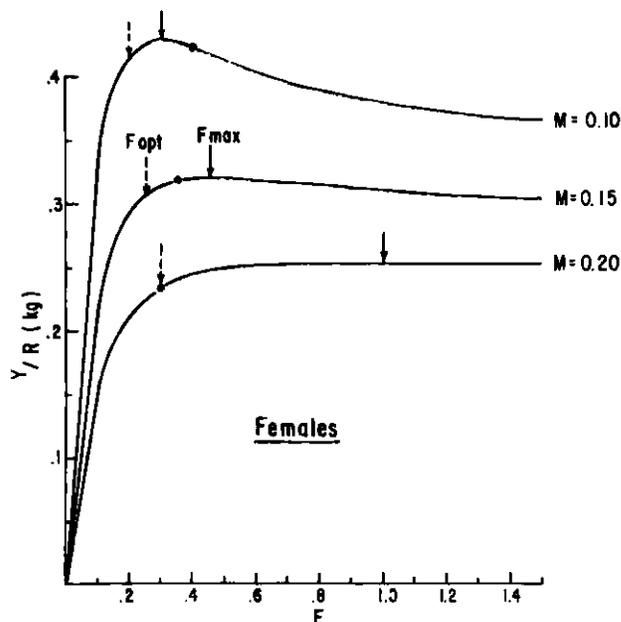


Fig. 6. Witch: yield per recruit of females. Dots indicate 1965-72 values of F.

There is some doubt as to the t_{p1} value, particularly for females. With gradual recruitment, the 50% recruitment point is difficult to judge by eye. However, this is not critical to the conclusions over the most likely range of t_{p1} for females of 7.5-8.5 years old (when $M = 0.15$) (Fig. 7).

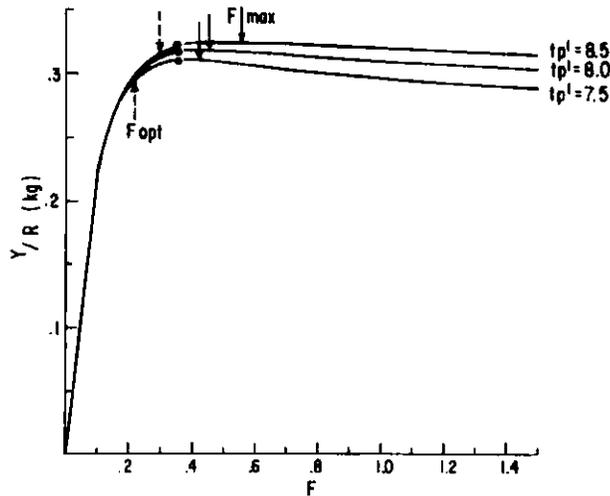


Fig. 7. Witch: yield per recruit of females for $M = 0.15$ and mean recruitment ages to the fishery of 7.5-8.5 years. Dots indicate 1965-72 values of F .

Conclusions

Although landings since 1965 have been higher than prior to 1965, there are no indications from cpe data that overall abundance of witch on the Scotian Shelf has declined since 1965. However, fishing mortality rates for both sexes are close to that giving maximum yield per recruit. These mortality rates are average values for the 1965-72 period. This implies that removals should not be allowed to significantly exceed those of the 1965-71 period when they averaged about 13,000 metric tons.

Discards of witch at sea by Canadian vessels are negligible as pre-commercial size are not vulnerable even to small mesh trawl gear (see Fig. 2). However, this also precludes estimates of future recruitment from research vessel surveys.

PLAICE ASSESSMENT

Distribution and abundance from research vessel surveys

Plaice are widely distributed on the Scotian Shelf but major concentrations occur only in Div. 4V in depths less than 100 fm, particularly in the cold water area to the north of Banquereau (Fig. 8). Biomass estimates from research vessel surveys (uncorrected for catchability) in 1970-72 range from about 40,000-51,000 metric tons (Table 11). Declines are indicated in Div. 4W and 4X but not in Div. 4V. Population numbers declined from 190 million in 1970 to 143 million in 1972, declines occurring in Div. 4V, 4W and 4X.

Table 11. American plaice. A. Estimated population biomass (metric tons) and kg/tow. B. Estimated population numbers ($\times 10^6$) and no./tow, from Canadian research vessel surveys, July 1970-72.

Strata	ICNAF Div.	A						B					
		1970		1971		1972		1970		1971		1972	
		Bio-mass	kg/tow	Bio-mass	kg/tow	Bio-mass	kg/tow	Popn. No.	No./tow	Popn. No.	No./tow	Popn. No.	No./tow
40-42	4Vn	1,760	5.29	5,380	16.12	6,210	18.63	11.6	34.91	7.7	23.14	24.7	73.93
43-52	4Vs	27,070	25.16	32,630	30.33	23,770	22.10	102.4	95.16	103.8	96.48	74.4	69.19
40-52	4V	28,830	20.46	38,010	26.46	29,980	21.28	114.0	80.89	111.5	79.11	99.1	70.32
53-66	4W	10,050	5.86	9,810	5.72	6,610	3.86	52.3	30.51	37.0	21.55	33.1	19.28
70-95	4X	6,860	3.73	3,430	1.85	3,060	1.66	23.7	12.86	11.2	6.08	10.4	5.66
40-95	4VWX	45,470	9.21	51,250	10.31	39,650	7.99	190.0	38.27	159.7	32.15	142.6	28.72

PLAICE

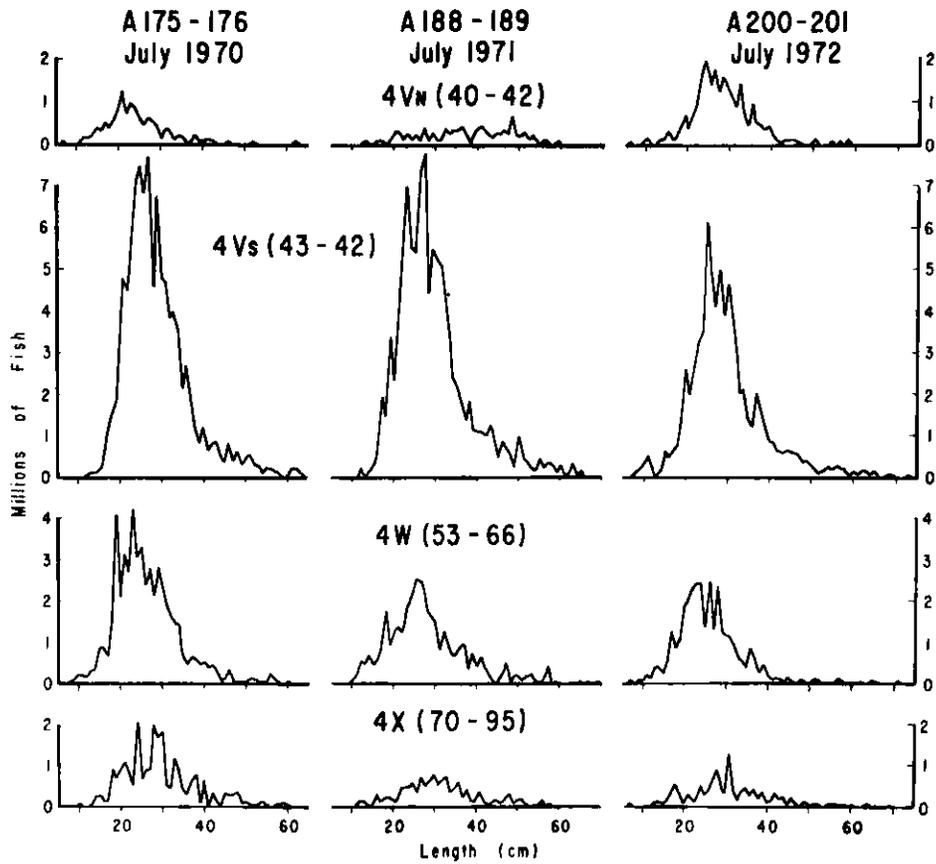


Fig. 9. Plaice: size composition of the population by Division estimated from Canadian research vessel surveys, 1970-72.

Table 12. American plaice landings from the Scotian Shelf by ICNAF Division and country (metric tons round).

Year	ICNAF Division					Country							
	4Vn	4Vs	4W	4X	Total	Canada	France(SP)	Japan	Poland	Romania	USSR	UK	USA
1960	896	192	786	1,035	2,909	2,844	2	-	-	-	-	-	63
1961	417	164	853	210	1,644	1,562	-	-	-	-	9	-	73
1962	750	112	868	267	1,997	1,695	-	-	-	-	216	-	86
1963	1,237	140	778	259	2,414	2,115	-	-	-	-	182	-	117
1964	938	1,059	617	519	3,133	2,838	67	-	-	-	25	9	194
1965	1,692	3,042	3,090	542	8,366	5,543	119	-	-	-	2,525	-	179
1966	2,215	5,979	4,706	637	13,537	9,112	20	-	-	-	4,288	7	110
1967	1,984	6,895	801	1,106	10,786	10,520	-	-	-	-	104	-	162
1968	1,641	9,521	8,591	941	20,694	9,829	114	-	-	-	10,684	-	67
1969	2,365	5,714	4,756	868	13,703	9,300	60	-	12	-	4,280	-	51
1970	2,069	3,177	2,482	635	8,363	6,303	19	5	1	84	1,896	-	55
1971	2,470	5,295	5,991	545	14,301	7,513	18	-	-	-	6,700	-	70

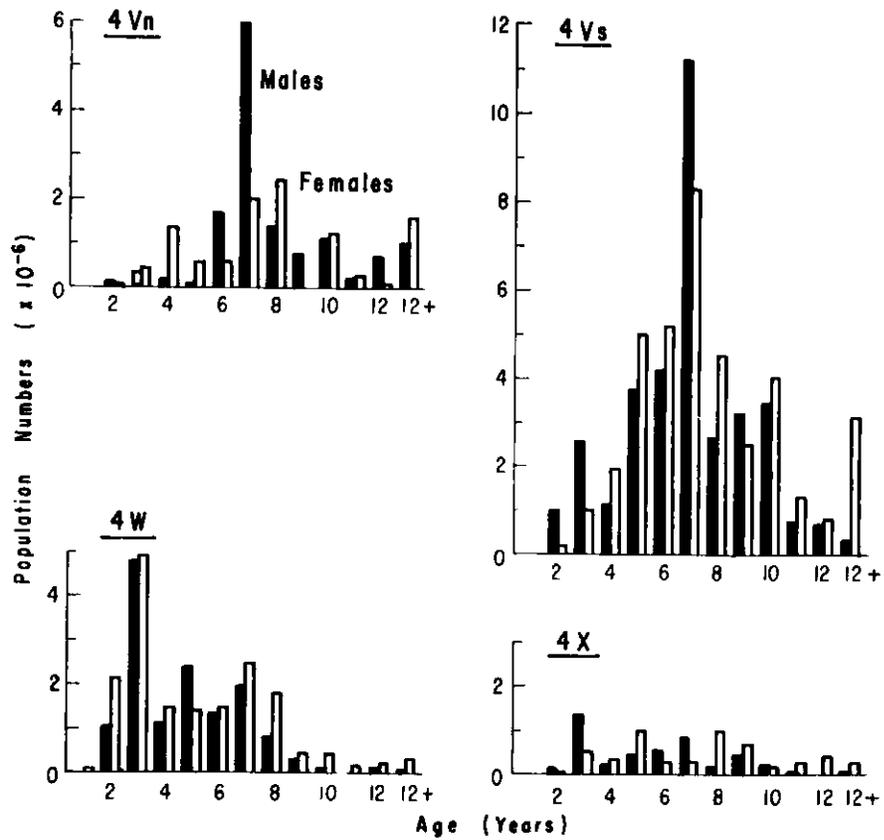


Fig. 10. Plaice: age composition of the population by Division estimated from the Canadian research vessel survey in 1972.

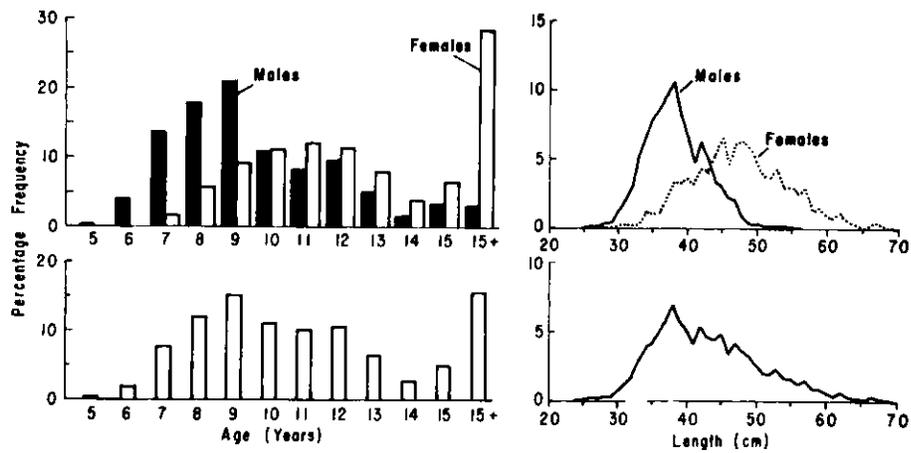


Fig. 11. Plaice: size and age composition of Canadian landings from Subdiv. 4Vn and 4Vs in 1968-72.

Catch per unit effort

Catch rates of Canadian trawlers of 151-500 gross tons between 1965 and 1972 imply that plaice abundance on the Scotian Shelf increased between 1965 and 1969, then declined through 1972 (Table 13). The decline in catch rates between 1970 and 1972 of 24% agrees well with the decline in survey estimates of population numbers of 25%. However, survey biomass estimates increased in 1971, then dropped in 1972 to 13% below the 1970 level.

Mortality

Total mortality rates (Z) estimated from catch curves from commercial and survey age compositions (Table 14) ranged from 0.46 to 0.79 for males and 0.49 to 0.80 for females. Survey estimates for the Scotian Shelf as a whole, obtained by weighting Division estimates by survey population estimates were Z = 0.65 for males and Z = 0.60 for females. These are higher estimates than the Z = 0.46 for males and Z = 0.54 for females obtained from commercial data and which are applicable to Div. 4V. However, the catch curve method gives estimates which are historical, and commercial data reflect exploitation rates as far back as 1962, while survey data reflect exploitation rates during the 1966-72 period when landings were highest. Thus survey data may give a more accurate estimate of mortality during the most recent period of the fishery. Values of Z = 0.65 for males and Z = 0.60 for females are used here.

Table 13. Plaice: catch per unit effort (kg/hr) on the Scotian Shelf by Division - Canadian otter trawlers of 151-500 gross tons.

Year	Divisions				All Div.
	4Vn	4Vs	4W	4X	
1965	93.6	144.3	11.8	3.4	42.9
1966	81.0	260.4	12.8	4.2	64.8
1967	135.7	191.7	15.3	5.5	58.0
1968	86.7	206.5	24.6	6.8	61.6
1969	105.2	265.1	19.4	6.3	73.5
1970	84.1	276.1	16.0	4.5	72.7
1971	70.9	216.5	23.9	2.9	61.0
1972	56.0	193.2	22.0	4.5	54.9

Table 14. Plaice: Div. 4VWX. Instantaneous total mortality - Z, from catch curves.

Data base	Div.	Z		Z	
		Males	Ages	Females	Ages
Commercial age compositions, 1968-72	4V	0.46	9-14	0.54	12-14
1972 survey age compositions	4Vn	0.73	7-12	0.80	8-12
1972 " " "	4Vs	0.58	7-12	0.55	7-12
1972 " " "	4W	0.79	7-12	0.61	7-12
1972 " " "	4X	0.55	7-12	0.49	8-12
1972 survey estimates weighted by population numbers	4VWX	0.65		0.60	

No estimates of natural mortality are available for Scotian Shelf plaice. Pitt (MS, 1972) obtained estimates of M = 0.25 for males and 0.20 for females in Subareas 2 and 3, while Powles (1969) obtained values of M varying between 0.11 and 0.16 for sexes combined in the southern Gulf of St. Lawrence (Div. 4T). Considering the longevity of the species, Pitt's estimates are likely to be maximal. However, his values are used here.

Growth

Survey mean lengths at age for each Division were weighted by estimated population numbers at age to give estimates representative of the Scotian Shelf as a whole (Table 15). These estimates are smaller than mean lengths at age from commercial landings which are representative of Div. 4V. Survey estimates were used to calculate parameters of the von Bertalanffy growth equation as younger ages were better represented in the data and because the data were average values for all of the Scotian Shelf.

The values obtained were:

	<u>Males</u>	<u>Females</u>
L_{∞}	44.6 cm	229.8 cm
K	0.114	0.013
t_0	-2.16	-3.70
Ages fitted	2-12	2-15

While the L_{∞} estimate for males is biologically realistic, that for females is not. However, the curves fit the data well over the range of ages fitted and should be adequate for use in the Beverton and Holt yield equation.

Table 15. Plaice: mean length (cm) at age from 1972 survey catches and 1968-72 commercial landings.

Age	Males		Females	
	Surveys	Commercial	Surveys	Commercial
2	16.7	-	16.7	-
3	20.7	-	21.3	-
4	21.4	-	22.4	-
5	25.3	-	25.3	-
6	26.6	-	27.9	-
7	27.0	33.5	29.5	-
8	33.4	35.9	31.7	39.4
9	31.8	36.3	36.3	40.8
10	33.2	37.6	37.9	43.2
11	34.8	39.7	42.1	44.9
12	35.3	39.6	46.0	47.3
13	-	41.0	46.2	46.5
14	-	42.5	48.6	49.8
15	-	41.4	50.0	48.1

Yield per recruit

The Beverton and Holt yield per recruit equation was calculated for males and females separately, using the growth parameters cited above and other parameters as follows:

	Males	Females
W_{α} (derived from L_{α})	0.76 kg	236.9 kg
t_{ρ}	2.0 yrs	2.0 yrs
$t_{\rho 1}$	7.5 yrs	9.5 yrs
t_{λ}	20 yrs	25 yrs

Values of $t_{\rho 1}$ were estimated visually from age compositions of commercial landings.

Yield per recruit curves for males are flat topped when M is in the range 0.15-0.25 (Fig. 12). When $M = 0.25$, the current value of $F = 0.40$ is close to F_{opt} , and gives about 80% of the yield per recruit obtainable at very high values of F . If M is less than 0.25, then F is above F_{opt} and closer to the asymptotic value.

If $M = 0.20$ for females, the current F value of 0.40 is higher than F_{opt} and yield per recruit is over 90% of that obtainable with very high F values (Fig. 13). If M is less than 0.20, then F is above F_{max} .

Conclusions

Although landings increased in 1965, catch rates also increased until 1969, then dropped to about 1965 levels by 1972. However, fishing mortality rates representative of the 1966-72 period were close to F_{opt} and little gain in yield would accrue from further increase. Thus, any substantial increase in landings above the 1966-71 average of 13,600 metric tons is unlikely to be sustainable.

Moderate quantities of plaice are discarded by the Canadian fleet and these have not been taken into account in this analysis. Increase in regulation mesh size from 4-1/2 inches to 5-1/8 inches on 1 January 1974 should result in some increase in sustainable yield.

The occurrence of substantial quantities of fish in the 20-30 cm size range in research vessel catches indicate that it should be possible to predict recruitment to the fished population of 30 cm+ fish.

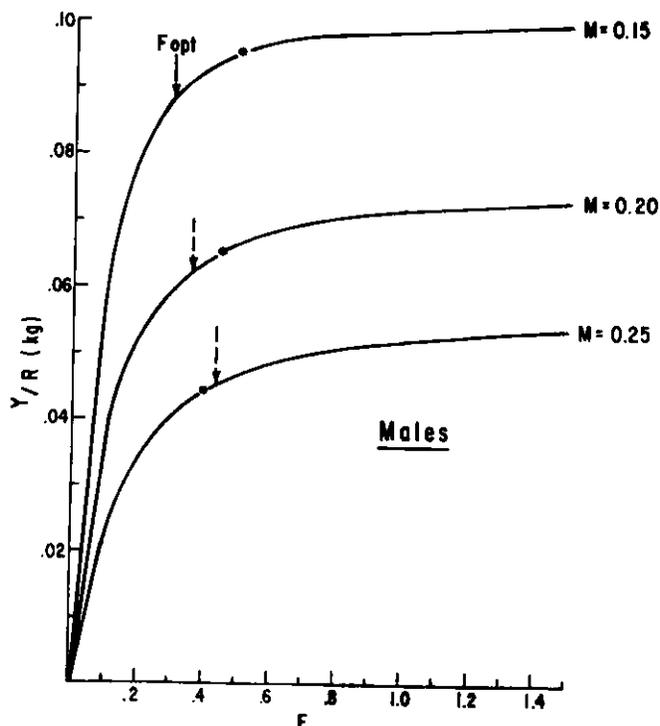


Fig. 12. Plaice: yield per recruit of males ($t_{p1} = 7.5$ yrs). Dots indicate current F values.

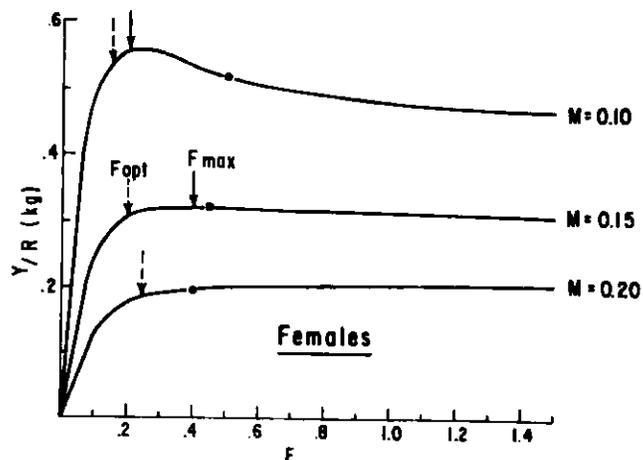


Fig. 13. Plaice: yield per recruit of females ($t_{p1} = 9.5$ yrs). Dots indicate current F values.

YELLOWTAIL ASSESSMENT

Distribution and abundance from research vessel surveys

Yellowtail has a localized distribution on the tops of offshore banks in depths less than 50 fm (Fig. 14). Densest concentrations are located on Banquereau, particularly on the Eastern Shoal, Sable Island and Middle Banks. Biomass estimates from research vessel surveys in 1970-72 (uncorrected for catchability) range from 18,000-24,000 metric tons (Table 16). Population numbers varied from 85-100 million.

Table 16. Yellowtail flounder. A. Estimated population biomass (metric tons) and kg/tow. B. Estimated population numbers ($\times 10^{-6}$) and no./tow, from Canadian research vessel surveys, July 1970-72.

Strata	ICNAF Div.	A						B					
		1970		1971		1972		1970		1971		1972	
		Bio-mass	kg/tow	Bio-mass	kg/tow	Bio-mass	kg/tow	Popn. No.	No./tow	Popn. No.	No./tow	Popn. No.	No./tow
40-42	4Vn	-	-	-	-	140	0.42	-	-	-	-	0.3	1.04
43-52	4Vs	9,750	9.43	7,960	7.39	13,910	12.91	31.4	29.19	26.9	24.93	44.0	40.83
40-52	4V	9,750	7.20	7,960	5.64	14,050	9.95	31.4	22.28	26.9	19.02	44.3	31.41
53-66	4W	12,370	7.21	9,800	5.72	9,430	5.50	68.1	39.68	57.5	33.52	44.4	25.89
70-95	4X	270	0.14	280	0.15	580	0.31	0.7	0.37	1.0	0.53	3.0	1.64
40-95	4VWX	22,390	4.59	18,040	3.63	24,060	4.84	100.2	20.16	85.4	17.17	91.7	18.46

Size and age composition from research vessel surveys

Survey catches were composed of fish with a length range of 10-50 cm but most fish lay within the size range 20-40 cm (Fig. 15). Modal lengths of Banquereau yellowtail lay between 30 and 35 cm, while those of Sable Island and Middle Bank fish lay between 25 and 30 cm. Catches in 1970 and 1971 contained fish aged 2-10 yrs but on Banquereau most were 5-7 years old in 1970 and 6-8 years old in 1971, while those in Div. 4W were predominantly 3-6 years old in both years (Fig. 16). Full recruitment to the survey gear appears to take place about age 6 for both sexes.

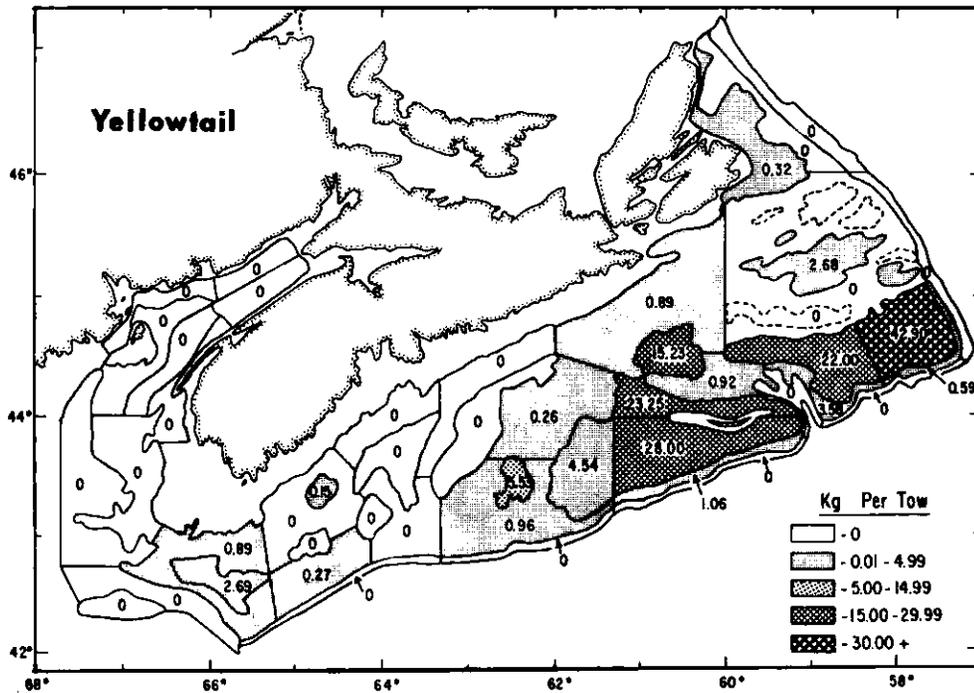


Fig. 14. Yellowtail: abundance on the Scotian Shelf from Canadian research vessel surveys, 1970-72.

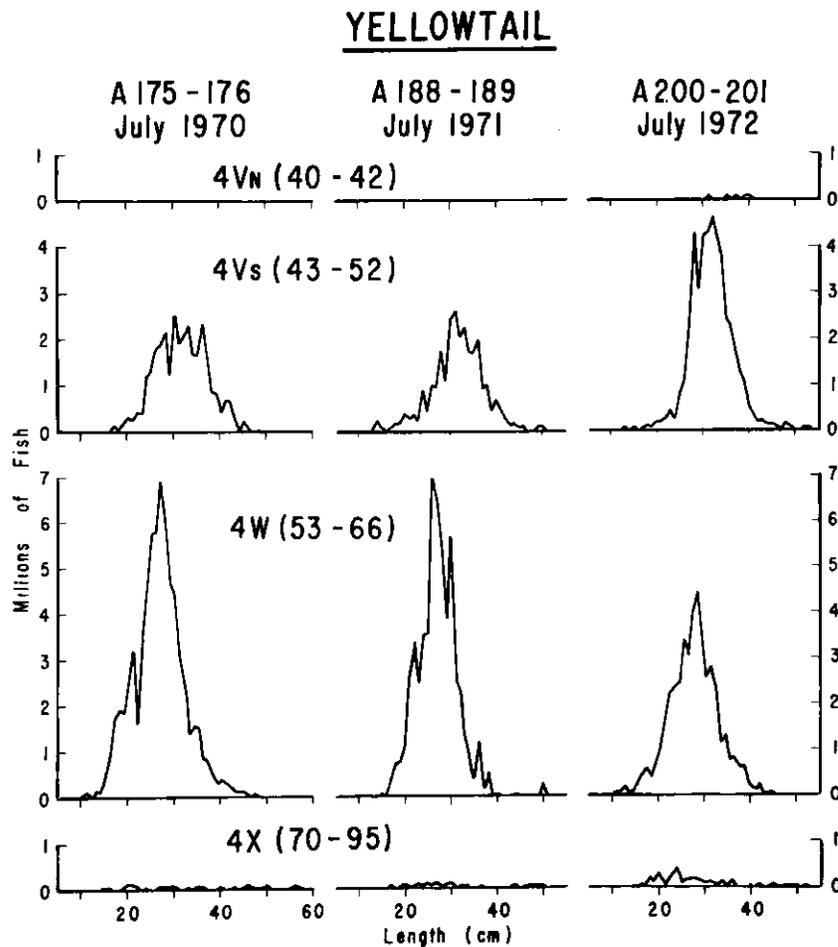


Fig. 15. Yellowtail: length compositions of the population by Division from Canadian research vessel surveys, 1970-72.

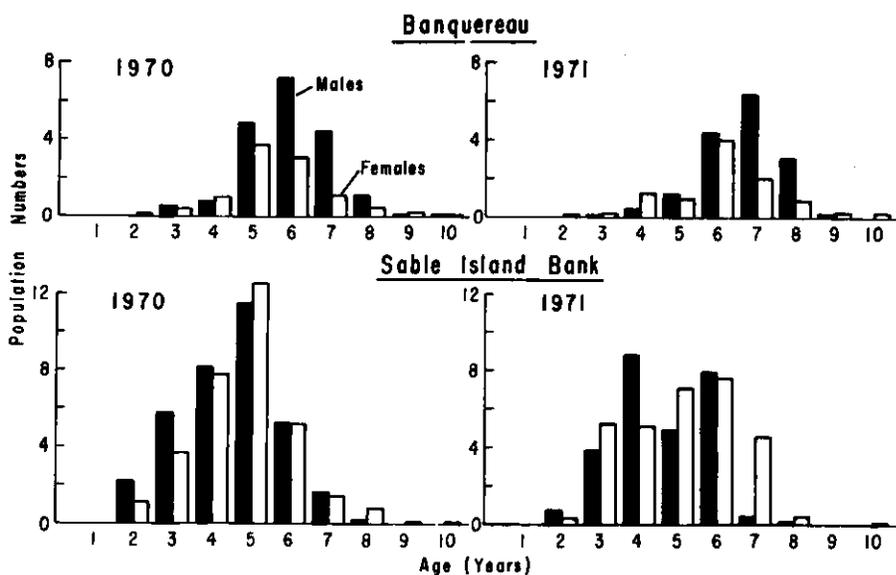


Fig. 16. Yellowtail: age composition on Banquereau and Sable Island-Middle Banks in 1970 and 1971 from Canadian research vessel surveys.

Commercial landings

Landings increased from less than 1,000 tons in 1960 to over 5,000 tons in 1964 and to over 9,000 tons in 1968, subsequently declining to about 1,800 tons in 1971 (Table 17). Soviet landings have originated mainly from Div. 4W and Canadian landings from Subdiv. 4Vs. Virtually all landings are made by otter trawlers.

Table 17. Yellowtail landings from the Scotian Shelf by ICNAF Division and country (metric tons round).

Year	ICNAF Division					Country				
	4Vn	4Vs	4W	4X	Total	Canada	France(SP)	Poland	USSR	USA
1960	-	381	556	14	951	936	-	-	-	15
1961	2	1,277	1,681	9	2,969	2,956	-	-	4	9
1962	18	1,464	2,110	27	3,619	3,501	-	-	95	23
1963	10	1,730	2,091	58	3,889	3,776	-	-	83	30
1964	121	3,968	1,155	103	5,347	5,287	6	-	18	36
1965	30	4,299	2,034	221	6,584	5,377	-	-	1,186	21
1966	16	3,505	2,022	192	5,735	3,770	-	-	1,951	14
1967	47	3,808	1,148	270	5,273	5,199	-	-	45	29
1968	6	4,882	4,163	204	9,255	5,378	11	-	3,843	23
1969	44	2,314	1,830	202	4,390	2,562	40	5	1,764	19
1970	39	631	2,686	326	3,682	947	6	-	2,708	21
1971	18	870	668	218	1,774	1,032	2	-	728	12

Size and age composition of commercial landings

There are no available biological sampling data for Soviet yellowtail landings. Thus, it has been necessary to assume that Soviet landings are identical to Canadian landings in size and age composition.

There was insufficient Canadian sampling data to treat areas and years separately, thus all samples for 1962-69 (total of 20, 6 from Div. 4W, 14 from Subdiv. 4Vs) were combined to give average size and age compositions of landings in this period.

Landings of males ranged in length from 25-50 cm with a mode at 36 cm (Fig. 17). Landings of females ranged in length from 30-55 cm with a mode at 38 cm.

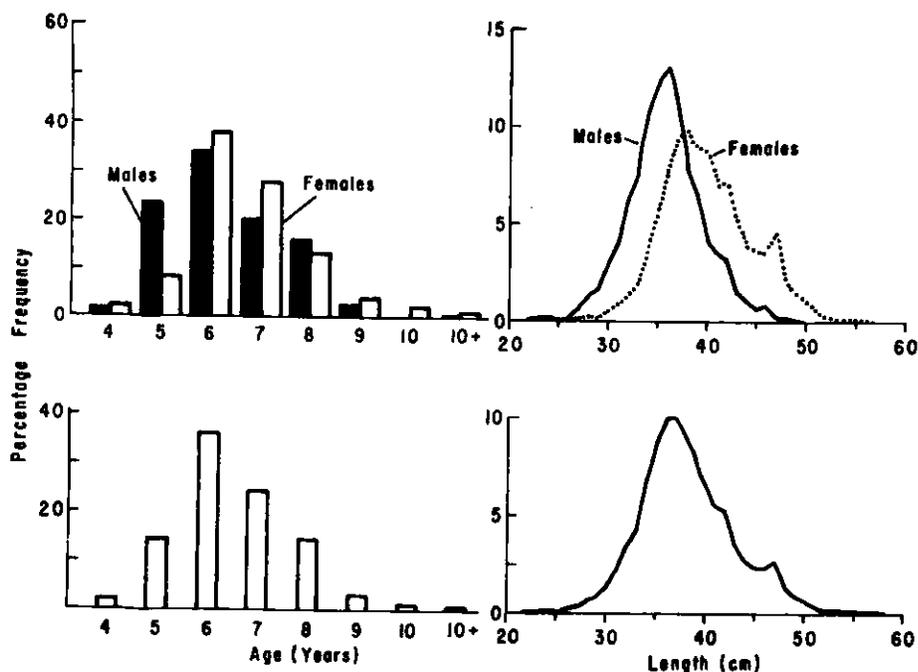


Fig. 17. Yellowtail: length and age compositions of Canadian commercial landings, 1960-69.

A few 4-year-olds and a few fish over 10 years old occur in the landings but most are 5-8 years old and there is little difference in the age composition of males and females (Fig. 17). There are slightly more females aged 7 and over and fewer 5-year-old females than males in the landings. Both sexes appear to be fully recruited at age 6.

Catch per unit effort

Catch rates of yellowtail by Canadian otter trawlers on the Scotian Shelf declined by 80% from 72.9 kg/hr in 1965 to 14.8 kg/hr in 1972 (Table 18). This decline occurred in both the Banquereau and Sable Island-Middle Bank concentrations to the same degree.

Mortality

Total mortality rate, Z , was calculated for males and females and for Banquereau and Sable Island Bank concentrations separately, from catch curves of 1960-69 commercial landings and 1970 and 1971 survey age compositions. Mortality was also calculated from the mean survival rates between 1970 and 1971 surveys (Table 19).

Mean estimates from surveys were $Z = 1.08$ for males and 0.74 for females on Banquereau, and 1.88 for males and 1.09 for females on Sable Island Bank. There were considerably higher than mortality rates from commercial age compositions of 0.66 for males and 0.74 for females. However, as commercial age compositions reflect mortality rates from about 1955, while survey data reflect those of the more recent period from 1965, survey data are likely to give the more accurate estimates of current mortality rates.

To obtain a single average value of Z representative of the whole Scotian Shelf, the values for males and females in each area were averaged, weighting by the sex ratio in commercial catches, to give $Z = 0.89$ for Banquereau and $Z = 1.43$ for Sable Island Bank. The values were then averaged, weighting by the population numbers in each region as determined in 1970-72 surveys, to give $Z = 1.23$ for the Scotian Shelf.

There are no estimates of natural mortality of Scotian Shelf yellowtail. Lux (1969) obtained a value

of $M = 0.22$ for New England populations. Natural mortality could be expected to be somewhat higher than that in more long-lived species such as plaice and witch, and the values $M = 0.20-0.40$ are considered here. Age compositions imply that there is little difference in survival of males and females, thus natural mortality is assumed to be the same for both sexes.

Table 18. Yellowtail: catch per unit effort (kg/hr) on the Scotian Shelf by Division - Canadian otter trawlers of 151-500 gross tons.

Year	Divisions				All Div.
	4Vn	4Vs	4W	4X	
1965	13.6	248.7	50.6	1.7	72.9
1966	0.4	215.2	7.3	0.9	49.5
1967	9.7	161.4	33.0	1.0	47.4
1968	0	191.8	22.7	0.9	49.7
1969	0.5	105.9	4.1	1.0	24.8
1970	0	55.2	4.6	1.1	14.0
1971	0.4	55.4	4.7	2.7	14.7
1972	0	48.3	11.7	0.7	14.8

Table 19. Yellowtail instantaneous mortality rates - Z.

Method	Banquereau (4Vs)		Sable Island Bank (4W)	
	Males	Females	Males	Females
Commercial landings 1960-69 catch curves	0.66*	0.74*	...	...
1970 survey catch curves	1.38	0.57	1.28	1.23
1971 " " "	1.24	0.78	1.23	1.55
1970-71 survey combined catch curves	1.39	0.69	1.81	1.53
1970-71 survey mean survival for ages 6-10	1.06	0.95	2.53	0.74
1970-71 survey survival $\Sigma(7-10) / \Sigma(6-9)$	0.32	0.70	2.56	0.39
Mean of survey estimates	1.08	0.74	1.88	1.09

* 4Vs + 4W combined

Growth

Mean lengths at age from Canadian research vessel surveys are almost identical for males and females and between Banquereau and Sable Island Banks (Table 20). Therefore, all survey data were combined to calculate von Bertalanffy growth equation parameters giving:

$$L_{\alpha} = 77.9 \text{ cm } (W_{\alpha} = 3.8 \text{ kg})$$

$$K = 0.063$$

$$t_0 = -2.10 \text{ yrs.}$$

Table 20. Yellowtail: mean length at age (cm) from 1970 and 1971 Canadian research vessel surveys combined.

Age	Banquereau		Sable Island Bank	
	Males	Females	Males	Females
2	-	15.8	17.5	17.0
3	21.1	22.0	21.0	21.3
4	25.8	25.3	25.6	24.7
5	27.5	27.5	27.2	28.4
6	31.7	31.7	29.7	31.5
7	35.1	35.6	32.7	34.4
8	34.4	37.9	35.8	38.3
9	41.3	41.2	-	41.6
10	43.0	43.8	-	44.1

Year per recruit

The Beverton and Holt yield per recruit equation was calculated using the growth parameters cited above and other parameters as follows:

$$\begin{aligned}t_{\rho} &= 2.0 \text{ yrs} \\t_{\rho 1} &= 5.5 \text{ yrs} \\t_{\lambda} &= 12 \text{ yrs.}\end{aligned}$$

These values were obtained by inspection of commercial age composition.

Taking $Z = 1.20$, when $M = 0.30$, $F = 0.90$. This is above F_{opt} (0.50) and gives about 95% of the yield per recruit obtainable at very high values of F (Fig. 18). If $M = 0.20$, current F is above $F_{max} = 0.80$, and if $M = 0.40$ current F is still above F_{opt} and gives about 90% of the yield per recruit obtainable at very high F values.

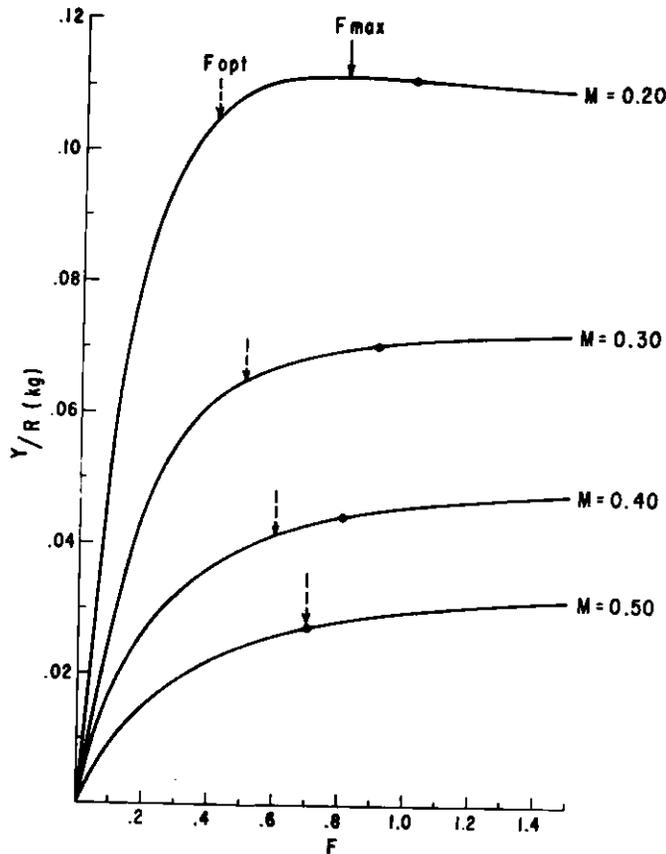


Fig. 18. Yellowtail: yield per recruit curves for $t_{\rho 1} = 5.5$ yrs. Dots indicate current F values.

Conclusions

In the 1965-69 period when landings averaged 6,250 tons after a period of lower landings, cpe fell from 72.9 kg/hr to 24.8 kg/hr - a decline of 66%. In 1970-72 cpe has remained at the low level of about 15 kg/hr, implying that current lower levels of landings are not resulting in further stock decline. During the 1965-72 period, F has been above F_{opt} and yield per recruit has been close to maximum. This implies that the sustained yield of yellowtail from the Scotian Shelf is lower than 6,000 tons per annum.

There are moderate quantities of yellowtail discarded by the Canadian fleet, and probably also by other fleets fishing regulated species. Thus, the increase in regulation mesh size from 4-1/2 inches to 5-1/8 inches on 1 January 1974 could result in some increase in long-term yield. Research vessel surveys

indicate that 2-4-year-olds are in part vulnerable to small mesh trawls and thus prediction of the strength of incoming year-classes may be possible.

GENERAL CONCLUSIONS

Individual species assessments indicate that witch landings should not greatly exceed 13,000 tons, plaice landings 13,600 tons and yellowtail landings should be less than 6,000 tons to obtain rational exploitation of the flatfish resources of the Scotian Shelf. Thus, total landings should probably not exceed 30,000-35,000 tons. Combined landings of these three species exceeded 35,000 tons only in 1968.

As the separation of landings by species prior to 1970 is largely guesswork, the level of landings associated with the mortality rates calculated is only approximate. However, in total these errors should largely balance out.

Important aspect of these fisheries, particularly relevant to plaice and yellowtail, are the quantities discarded at sea, and the quantities taken incidentally in small mesh fisheries, and it has not been possible to consider these here. Some estimates of the effects of discards should be possible with available data although this is far from complete. An assessment of the effects of small-mesh fisheries, however, cannot be made until data on the quantities involved and their size and age compositions are collected. If the effects of these factors could be minimized, some increase in yield from Scotian Shelf flatfish stocks should accrue.

ACKNOWLEDGEMENTS

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**SECTION E
OTHER GROUND FISH**

15. Maturity, feeding and length and age composition of white hake, *Urophycis tenuis* (Mitch.), in ICNAF Subarea 3, 1969-72¹

by V.N. Petrov
PINRO, Murmansk, USSR

ABSTRACT

The paper presents information on white hake which, up to the present time, has not been heavily exploited. It is suggested that in Subarea 3 there is one local population. Study of feeding indicated that white hake are active predators. Their main food objects are various fishes. Spawning takes place in the middle of summer. The main part of catches in 1969 consisted of specimens of ages 4 and 5 years (1965 and 1964 year-classes), and in 1971 fish aged 5-7 years (1966-1964 year-classes) were important. In 1972, 37.5% of the age composition of fish in catches included fish of the 1969 year-class (3-year-olds). There was a very small number of fish older than 10 years. White hake avoid low (close to 0°C) water temperatures.

INTRODUCTION

White hake, *Urophycis tenuis* (Mitch.), in the Northwest Atlantic has been poorly studied and its exploitation has generally been at a low level. The aim of this paper is to present evidence on the life pattern, typical occurrence and food value of this species in the southern part of ICNAF Subarea 3.

MATERIALS AND METHODS

Biological data on white hake were collected during surveys by the research vessels *Rossiya* and *Perseus III* in Subarea 3 in the years 1969, 1971 and 1972. Samples were taken from catches by bottom trawl with small meshed nylon netting (8-mm knot to knot) in the codend. Trawlings lasted for one hour.

Specimens were measured from the tip of the snout to the end of the tail fin. Stages of maturity were determined by the 6-mark scale of Sorokin (1957, 1960) and the index of stomach fullness by the 5-mark scale. The ages of fish were determined from otoliths and checked by scales. The complicated composition of zones on white hake otoliths makes it difficult to determine age, and it is necessary to treat the surface of the cross-cut by the method of Savvatimsky (1971) in ageing grenadiers.

The volume of data used is indicated in the various tables and figures.

RESULTS

Maturity

According to Leim and Scott (1966), the spawning of white hake takes place in early autumn off south-eastern Nova Scotia, in winter or spring in the Bay of Fundy and during summer in the Gulf of St. Lawrence. In Subarea 3 spawning seems to occur in the middle of summer (Table 1). It is interesting to note that in May-June no females with running sexual products were recorded, whereas a considerable number of males at maturity stage V were found. This is probably due to the different vertical distribution of males and females when spawning.

Table 1. Maturity condition of white hake in Subarea 3, 1969-72.

Maturity stage	Division 30						Division 3P					
	October 1969		June 1971		May 1972		October 1969		June 1971		May 1972	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
II	89	91	13	47	79	74	58	131	2	7	38	78
III	53	47	4	34	3	15	45	33	-	-	2	6
IV	10	-	41	34	49	21	19	-	9	4	9	18
V	3	-	86	-	230	1	1	-	12	-	35	-
VI	1	1	4	1	15	3	4	1	-	-	1	-
VI-II	2	4	7	17	5	74	1	12	-	11	-	49
No. of fish	158	143	155	133	381	188	128	177	23	22	85	151

¹ Submitted to the 1973 Annual Meeting of ICNAF as ICNAF Res.Doc. 73/39.

Feeding and Fatness

Bigelow and Schroeder (1953) state that after young hake settle near the bottom, they move up off the bottom only to seek food as they do not feed on bottom molluscs and echinoderms. Our observations confirm this, as there is a rather insignificant occurrence of these types of benthic fauna in the stomachs analyzed (Table 2). Various species of fish are predominant in the food of white hake: cod, haddock, flatfish, sand eel, capelin, anchovies, grenadiers, gobies and other fish species living together with white hake. Also, rather important as food objects are large and small crustaceans (shrimps, isopods, amphipods and crabs) which are found by white hake on or near the bottom with the help of their sensitive ventral fins, as Bigelow and Schroeder (1953) and Leim and Scott (1966) indicate. On St. Pierre Bank (Div. 3P) the frequency of occurrence of planktonic crustaceans (euphausiids and amphipods) and shrimps is higher than on the southwest slope of the Grand Bank (Div. 30), but that of fish food is lower.

Table 2. Frequency of occurrence (% of stomachs analyzed) of food components in white hake in Divisions 30 and 3P.

Food groups	Division 30			Division 3P		
	October 1969	May 1971	May 1972	October 1969	May 1971	May 1972
Fish	29.5	48.7	70.2	27.2	38.2	39.8
Planktonic crustaceans	12.9	3.3	17.9	24.4	8.8	9.3
Shrimp	2.2	5.5	0.4	5.9	-	4.2
Large bottom crustaceans	0.4	2.6	-	2.4	-	0.8
Bottom molluscs	0.7	1.1	0.4	0.4	-	-
Cephalopoda	0.4	5.9	0.4	3.1	-	0.8
Echinoderms	1.5	0.4	0.4	-	-	-
Worms	0.7	0.7	-	2.0	-	0.8
Other food	-	2.6	-	2.0	-	0.8
Ground particles	0.4	-	-	0.4	-	-
Number of stomachs	271	271	262	254	34	118
Average index of stomach fullness	0.82	1.10	2.22	0.99	1.01	1.08

The fatness¹ of white hake in Subarea 3 ranges from 2.5 to 10.0%. Fatness increases with increasing length of fish, but there is no essential difference in fatness between males and females.

Length and age composition

The maximum length of white hake observed in Subarea 3 is 120 cm and, as a rule, only females reach such a length and their weight is about 11 kg. Males did not exceed 90 cm in length and 5 kg in weight. The length composition curves for white hake in Div. 30 and 3P at different times are almost completely synchronous, suggesting that those living in Div. 30 and 3P belong to the same population (or stock) (Fig. 1A-C).

The main part of the catches in 1969 consisted of 4- and 5-year-old fish of the 1965 and 1964 year-classes (Fig. 2A). In 1971, aged 6- and 7-year-old fish of the 1965 and 1964 year-classes dominated in the catches (Fig. 2B). Although not shown in the age composition for 1971, the length compositions of Fig. 1B show the occurrence in the catches of the 1969 year-class (12-20 cm fish), which in 1972 (as 3-year-olds) constituted 37.5% of the age composition of the catches (Fig. 2C), together with 6- and 7-year-old fish of the 1966 and 1965 year-classes. The number of fish older than 10 years was insignificant in the catches.

Distribution and utilization

There is no special fishery for white hake in Subarea 3 by Soviet trawlers, but the species is in general taken as by-catch. Soviet observations show that the optimum depth range for catching white hake is 100-250 m, and the most favourable temperatures are between 2.8° and 8.4°C. Since white hake are not

¹ $\frac{\text{weight of liver}}{\text{weight of fish}}$ (in %)

found in trawl catches on the Grand Bank where temperatures in the near-bottom layer are close to 0°C or below, it can be assumed that they avoid areas of low water temperature (Fig. 3A-C).

According to Minder (1968), the meat of white hake contains less fat than that of cod and more water, and consequently, is coarse and unsavoury. However, the fat content of the white hake liver is not different from that of cod, and it is equally used with the latter for melting out fat and preparing canned liver.

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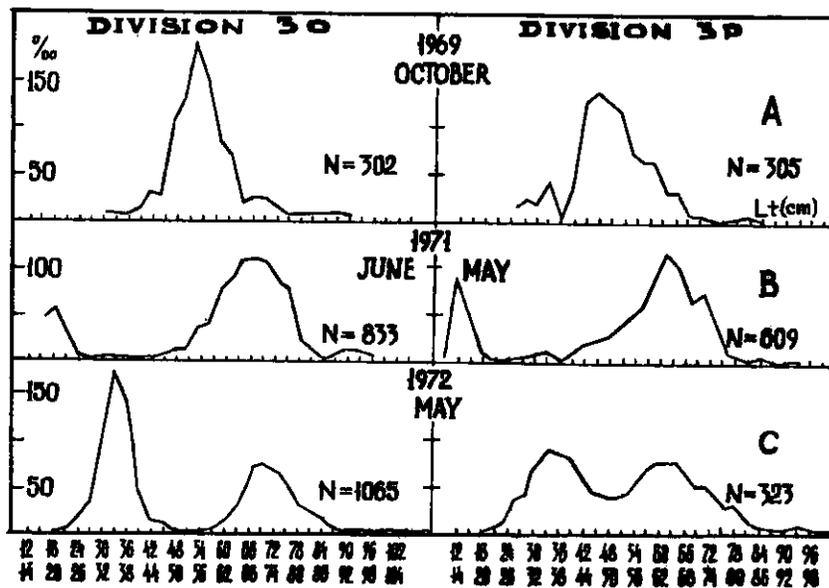


Fig. 1. Length composition of white hake in Div. 30 and 3P, 1969, 1971 and 1972.

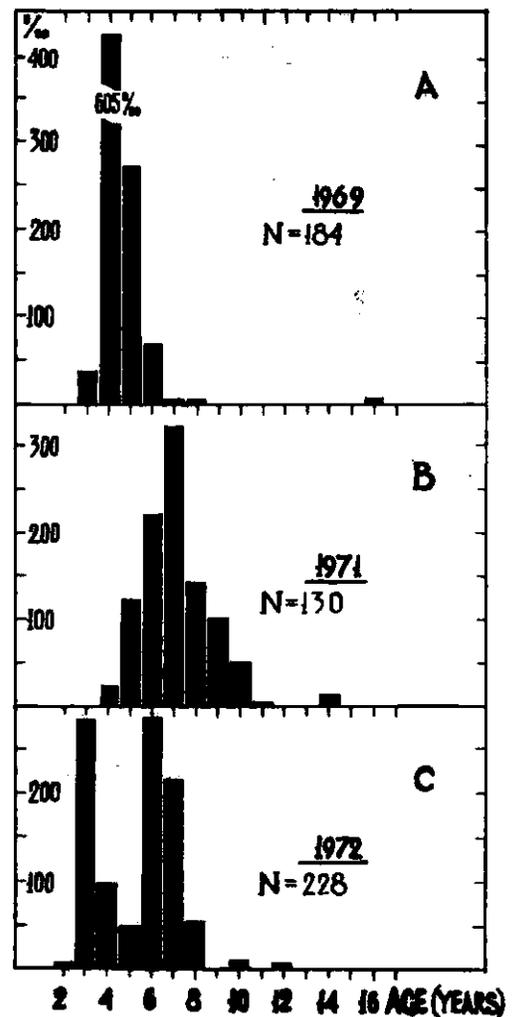


Fig. 2. Age composition of white hake in Div. 30 in 1969, 1971 and 1972.

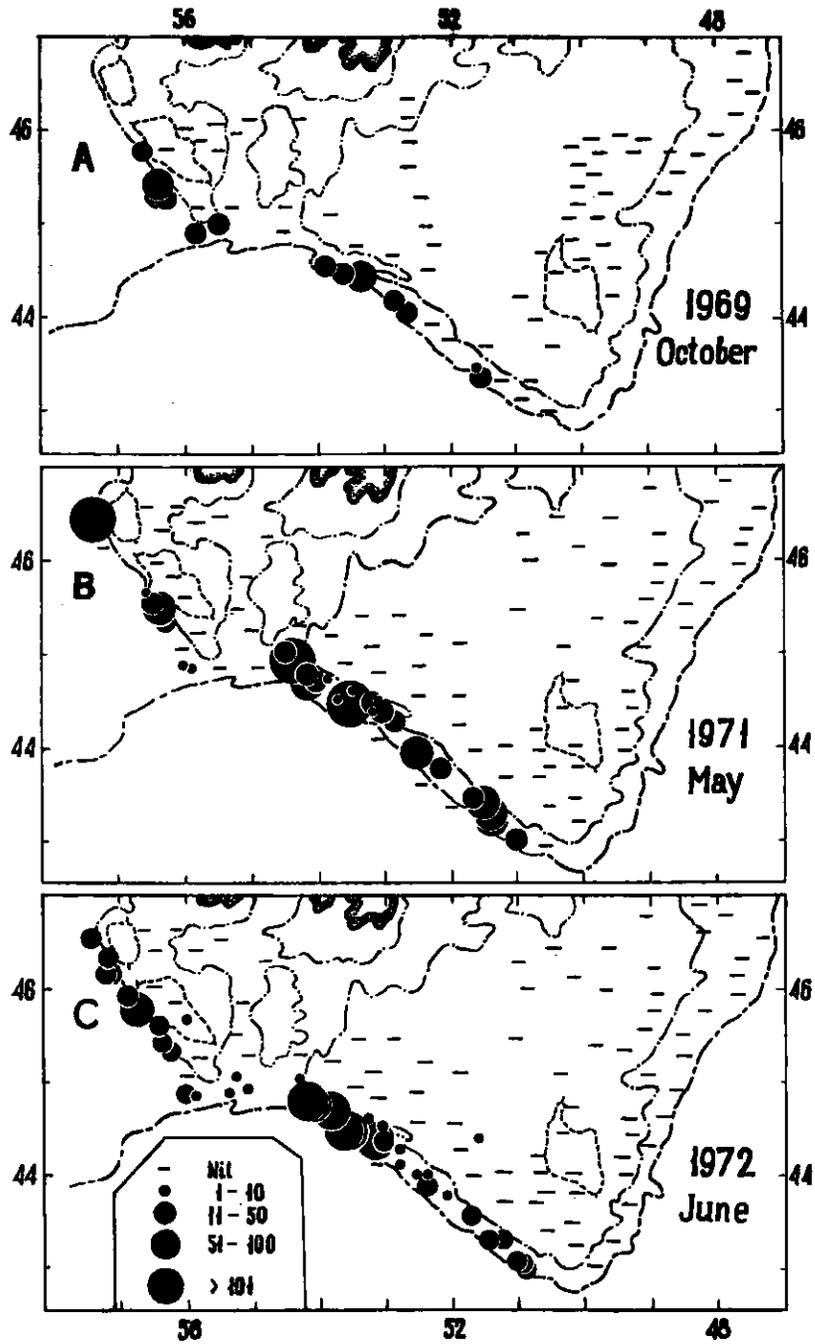


Fig. 3. Distribution of white hake catches.

SECTION F
HERRING

16. Estimates of fishing mortality and stock size for Georges Bank herring¹

by B. Draganik²
Sea Fisheries Institute
Gdynia, Poland

INTRODUCTION

At the 1972 Annual Meeting of ICNAF, during consideration of herring assessments by the Standing Committee on Research and Statistics, Polish scientists reported that an independent assessment of the Georges Bank herring stock was in progress and that the results would be presented to the Mid-Term Meeting in January 1973. This paper presents the results of that analysis.

AGE COMPOSITION OF CATCHES

The age composition of the herring population in 1971 was estimated from sampling data collected on Polish vessels during the period from March to October 1971. The age compositions for the years 1961-64 were obtained from USSR data (Dr A.S. Noskov, pers. comm.), and for the 1965-70 period from Polish data (Chrzan and Draganik, 1968, 1969, 1970; Draganik, 1966; Draganik and Zukowski, 1967).

In order to obtain an average annual age composition of herring in Polish catches, the sampling data were applied to the catches in each of three periods: January-May, June-August and September-October (Table 1) and the "per mille" age frequencies averaged. The "per mille" age frequencies for the years 1961-71 from USSR and Polish data are given in Table 2. From these figures the abundance of age-groups in herring catches in 1966-71 (millions of fish) were estimated (Table 3).

Table 1. Age composition of Polish herring catches in 1971.

Months	Year-classes									
	1969	1968	1967	1966	1965	1964	1963	1962	1961	1960
January-May	-	46	136	258	178	109	129	32	66	46
June-August	3	318	210	270	125	35	21	8	6	4
September-October	-	157	180	266	188	93	64	24	16	12
Average	1	178	179	265	165	80	66	21	25	18

Table 2. Frequency (‰) of year-classes in Polish catches of herring from Georges Bank.

Year of capture	Age-group									
	2	3	4	5	6	7	8	9	10	>10
1961	20	78	279	508	101	14	-	-	-	-
1962	-	5	81	163	520	153	62	16	-	-
1963	-	338	135	297	138	30	12	-	-	-
1964	25	229	350	195	148	53	-	-	-	-
1965	-	47	159	529	131	64	48	15	7	-
1966	5	75	64	202	517	60	44	25	8	-
1967	-	3	100	108	183	433	90	49	34	-
1968	-	14	57	196	113	195	368	48	9	-
1969	-	31	275	156	127	81	126	172	32	-
1970	3	116	460	229	50	44	19	32	40	7
1971	1	178	179	265	167	80	66	21	25	18

¹ Submitted to the 1973 Annual Meeting of ICNAF as ICNAF Res.Doc. 73/17.

² Present address: International Commission for the Southeast Atlantic Fisheries, Paseo de la Habana, 65, Madrid, Spain.

Table 3. Abundance of age-groups in herring catches, 1966-71 (in millions of fish).

Year	Age-group										Total
	2	3	4	5	6	7	8	9	10	>10	
1966	3	47	40	125	321	37	27	16	5	-	621
1967	-	3	86	92	157	370	77	42	29	-	856
1968	-	20	82	283	163	282	531	69	13	-	1,442
1969	-	39	348	198	161	103	160	218	41	-	1,268
1970	4	141	558	278	61	53	23	39	49	8	1,214
1971	1	211	212	314	198	95	78	25	30	21	1,185

MORTALITY AND STOCK SIZE ESTIMATE

The observations on changes in the abundance of year-classes in the daily catches of trawlers, types B-10 and B-14, during successive years enabled the assessment of the total mortality coefficient (Z). The coefficient of natural mortality (M) was estimated on the basis of the relationship between the total mortality coefficient and the fishing effort concentrated on the exploitation of the stock in the respective periods. The value of M obtained by this method is 0.4. Some evidence in support of this value is obtained from the total mortality coefficient for the Georges Bank herring stock in 1959, when it was relatively unexploited (F close to zero). On the basis of age composition data, the value of Z for 1959 was estimated as 0.69.

For calculations of fishing mortality coefficients by virtual population technique, it was necessary to assume the "initial" value of the fishing mortality coefficient for the various age-groups. In determining the arbitrary "initial" values to use, the data presented at previous meetings by Schumacher and Dornheim (1971) were taken into consideration.

The estimated values for fishing mortality coefficients for the stock in the years 1966-71 are given in Table 4. It should be noted that the fishing mortality of younger fish are not completely reliable. The fishing mortality coefficients for 1971 were estimated from the difference between the amount of fishing effort in the years 1970 and 1971.

Table 4. Fishing mortality of Georges Bank herring.

Year	Age-group								Average
	3	4	5	6	7	8	9	9+	
1966	0.02	0.03	0.07	0.12	0.08	0.25	0.28	1.00	0.07
1967	0.01	0.06	0.12	0.14	0.26	0.30	1.03	1.00	0.17
1968	0.01	0.06	0.34	0.43	0.50	0.52	0.61	1.00	0.27
1969	0.02	0.28	0.44	0.37	0.70	0.77	0.99	1.35	0.31
1970	0.10	0.48	0.48	0.29	0.32	0.42	0.56	0.84	0.35
1971	0.14	0.64	0.64	0.39	0.43	0.56	0.75	1.13	0.39

There is no evidence for estimating the stock recruitment value for 1972 and 1973, and the actual values may vary significantly from that estimated for 1971. However, in this analysis, it was assumed that the recruitment level in 1972 and 1973 will remain unchanged from that for 1971. On the basis of the estimated mortality coefficients and the various assumptions, the stock size by number of herring was assessed (Table 5).

The principles of herring fishery regulations adopted by the Herring Working Group (ICNAF, 1972) are based on assumptions that the fishing intensity in 1972 should be maintained at such a level as to prevent any further stock decline, thus permitting the stock in 1973 to be at about the same level as in 1972. If the fishing intensity in 1972 remained at the 1971 level, the stock would be reduced to 664,000 tons at the beginning of 1973. In order to maintain the stock at the 1972 level (706,000 tons), the fishing intensity in 1972 should be reduced by 44% in comparison with that in 1971, and this corresponds to a catch of 140,000 tons in 1972 (Fig. 1).

Table 5. Stock size of Georges Bank herring.

Year	Age-group								Number (millions of fish)	Total weight ('000 tons)
	3	4	5	6	7	8	9	9+		
1966 ¹	2,821	1,638	2,234	3,928	582	147	79	9	10,938	2,220
1967 ¹	361	1,970	982	1,452	1,944	357	77	53	6,986	1,603
1968 ¹	2,412	1,169	1,179	556	852	1,561	179	24	7,932	1,681
1969 ¹	2,374	1,712	665	624	243	352	407	64	6,441	1,251
1970 ¹	1,789	1,823	908	291	232	80	108	101	5,331	975
1971 ³	1,951 ¹	1,085	756	376	146	113	35	41	4,503	817
1972 ³	1,951 ²	1,137	383	267	171	64	43	12	4,028	706

¹ Calculated from $\frac{CZ}{F(1-e^{-Z})}$.

² Assumed same as in 1971.

³ Calculated from $N_{i+1} = N_i e^{-Z}$.

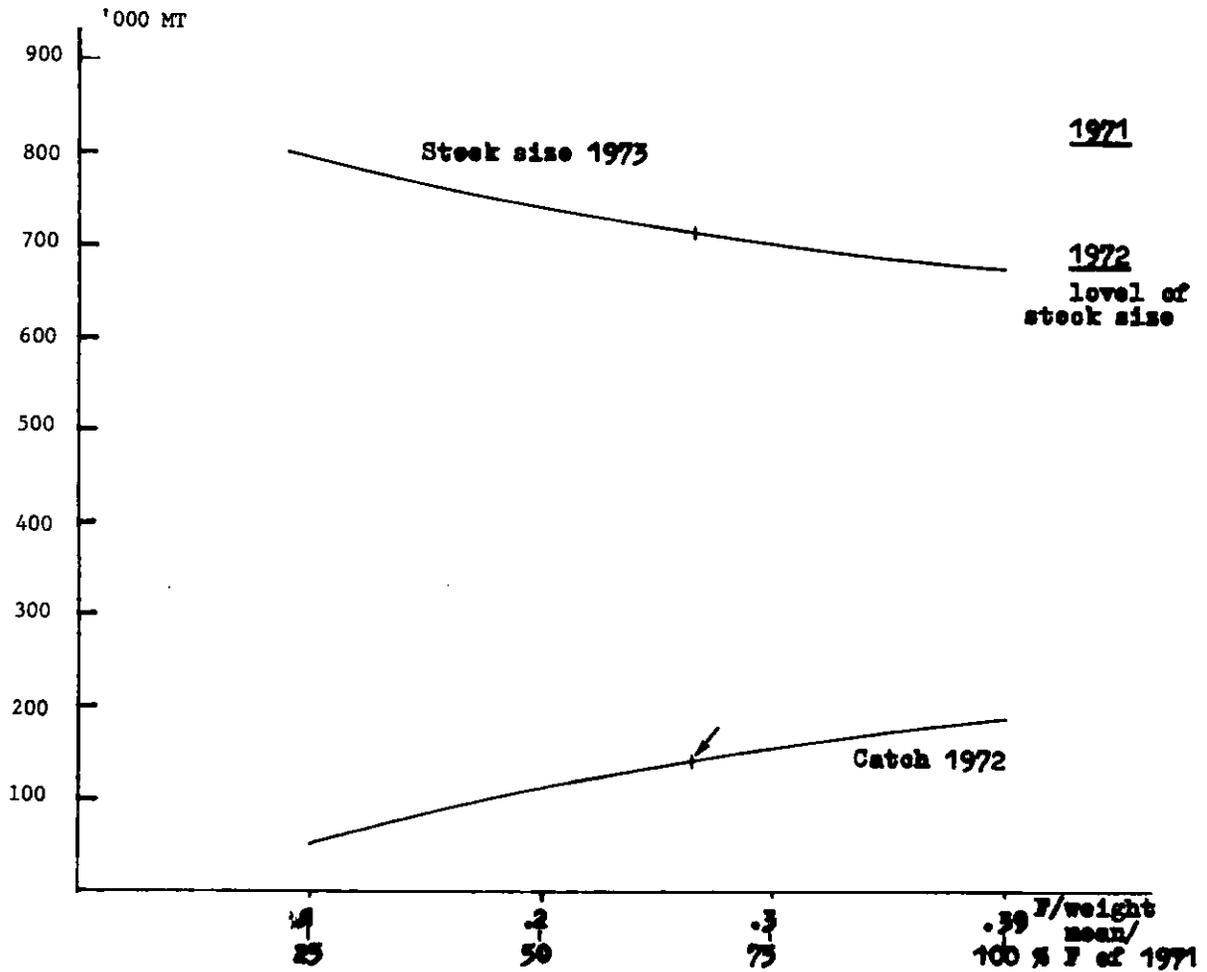


Fig. 1. Georges Bank herring stock sizes in 1973 by levels of catch and fishing mortality in 1972.

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17. Some biological data on the herring (*Clupea harengus harengus* L.) in the Gulf of St. Lawrence, southwestern Newfoundland and Banquereau areas in 1972¹

by Ph. Décamps and D. Briand
ISTPM, Saint-Pierre and Miquelon

INTRODUCTION

Herring which feed and spawn in the southern part of the Gulf of St. Lawrence (Div. 4T) during the summer migrate eastward toward the Magdalen Islands in the autumn. Hodder and Parsons (1971a) have shown that some of these move eastward to overwinter along the south coast of Newfoundland, while others probably move southward around Cape Breton to overwinter in the coastal waters of eastern Cape Breton and/or along the southern slope of the Laurentian Channel. While the seasonal movement between the Gulf of St. Lawrence and southwest Newfoundland has been definitely established, the degree of movement from the Gulf to the northern part of the Scotian Shelf and the extent of mixing of these herring with other resident populations on the Scotian Shelf (Hodder and Parsons, 1971b) is not quite so clear. This paper provides additional data which might help to further clarify the stock inter-relationships.

MATERIALS AND METHODS

Research vessel sampling of herring was carried out using bottom and pelagic trawls at various times and places during March to November 1972 (Fig. 1). The sampling locations and dates are as follows:

Area	Location	Trawl type	Dates
Coastal	Cape St. George	Bottom	16-17 April
	" " "	Pelagic	19 April
	Isle aux Morts	Pelagic	20 April
	St. Paul Island	Pelagic	21 April
	Table Point	Bottom	13 July
	Cape Dauphin	Bottom	30 November
Offshore	South slope of Banquereau	Bottom	5 March
	East Gully of Sable Island	Pelagic	24 April
	South slope of Banquereau	Bottom	26 April
	East Gully of Sable Island	Bottom	24 May

All samples were taken from catches varying from 1,000 to 5,000 kg, except those from the south slope of Banquereau in March and the Cape Dauphin area in November, in which cases the catches were small and all fish were examined.

The usual biological measurements were made to determine length, age, sex, stage of maturity, gonad weight, gonad-somatic relationship, fat content, stomach contents and five meristic characters (number of left pectoral rays, number of gillrakers, number of dorsal rays, number of keeled scales K_2 , and the number of vertebrae). The methods used in the examination of the specimens are described by Décamps (1971, 1972).

The separation of spring and autumn spawners was based on the maturity condition of the gonads. The various stages of sexual maturity were noted and confirmed by evaluation of the gonad-somatic relationship (RGS), the gonads being weighted to the nearest centigram and the fish to the nearest gram.

RESULTS

Maturity stage composition

In the April samples the RGS values of the autumn spawners were in the range of 0.5-4.99 (maturity stages VIII and VIII-III), while those of spring spawners were 5.0-24.0 (maturity stages III, IV and V) (Fig. 2). The Banquereau data illustrate the progression of maturation stages during March, April and May.

In the Gulf of St. Lawrence and off Southwest Newfoundland (Table 1, No. 1-4) the proportion of autumn to spring spawners in the April samples was more or less constant, with autumn spawners constituting 62-73% and spring spawners 19-37% of the catches. Immature herring were not very prevalent (1-8%).

In the northern part of the Gulf in July (Table Point area), the sample consisted entirely of adult

¹ Submitted to the 1973 Annual Meeting of ICNAF as ICNAF Res.Doc. 73/37.

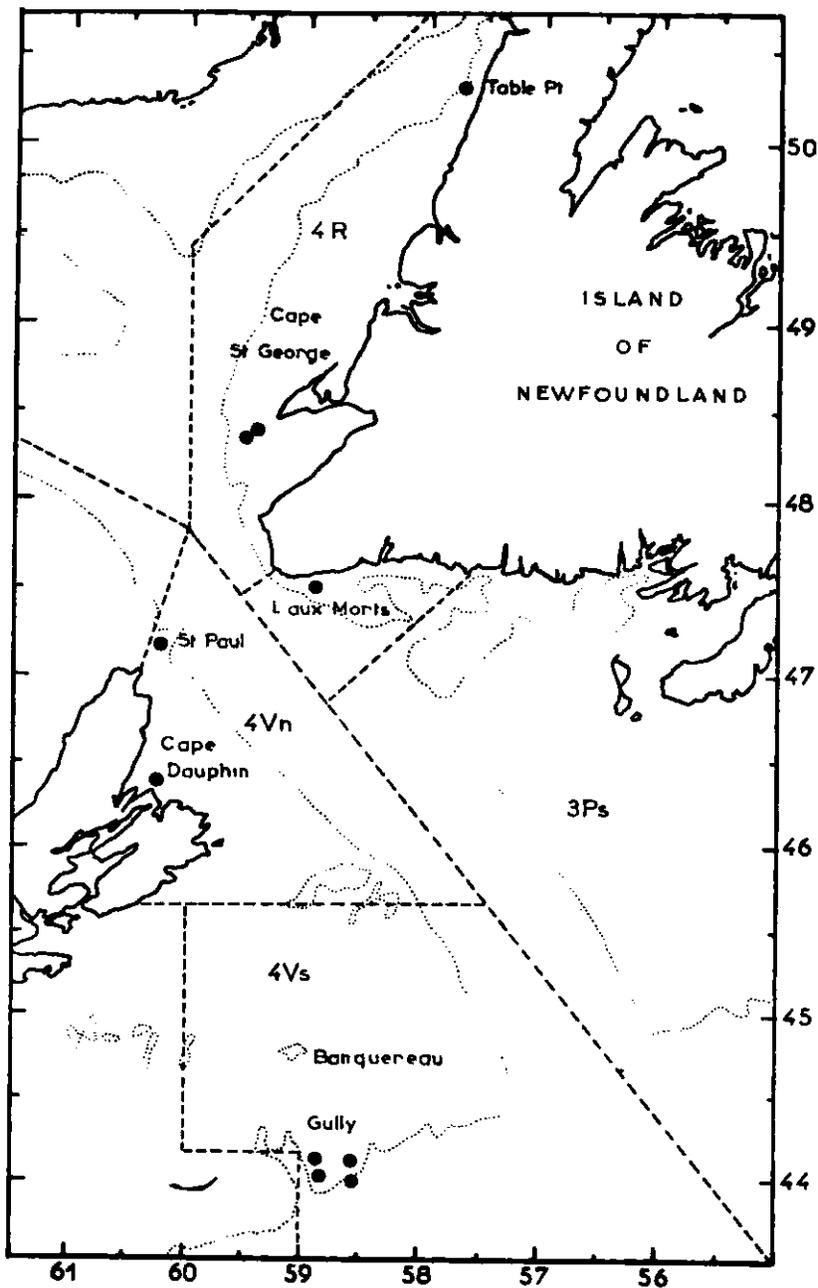


Fig. 1. Location of sampling areas in Div. 4R and Subdiv. 3Pn, 4Vn and 4Vs.

fish and over 80% were autumn spawners.

In the Cape Dauphin area in November, autumn spawners made up 39% of the catch, spring spawners 11% and juveniles 50%.

In the Banquereau-Sable Island area in March to May, the samples consisted almost entirely of autumn spawners (93-99%).

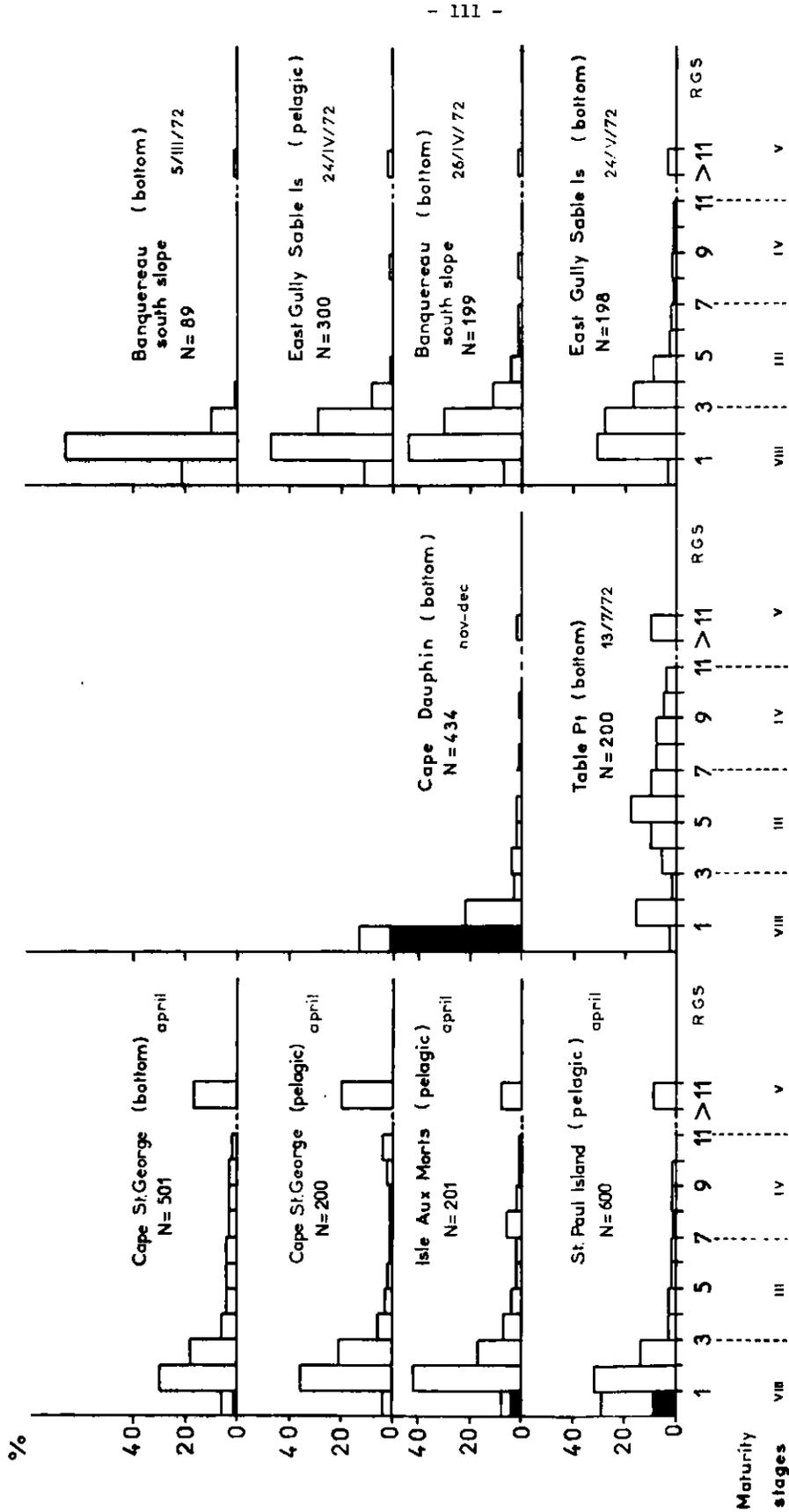


Fig. 2. Gonadal development of herring from areas (dashed line: immatures).

Table 1. Herring - frequency and percentage of autumn and spring spawners in the various areas.

Locality and spawning group		No. of specimens	Percentage		
			Autumn	Spring	Immatures
1. Cape St. George (bottom)	Autumn	308	62	37	1
	Spring	185			
	Immatures	8			
2. Cape St. George (pelagic)	Autumn	138	69	31	
	Spring	62			
3. Isle aux Morts (pelagic)	Autumn	145	72	23	5
	Spring	47			
	Immatures	9			
4. St. Paul Island (pelagic)	Autumn	431	73	19	8
	Spring	115			
	Immatures	54			
5. Table Point (bottom)	Autumn	162	81	19	
	Spring	38			
6. Cape Dauphin (bottom)	Autumn	171	39	11	50
	Spring	46			
	Immatures	217			
7. South slope of Banquereau (bottom)	Mar Autumn	88	99	1	
	Spring	1			
8. East Gully Sable Island (pelagic)	Apr Autumn	292	97	3	
	Spring	8			
9. South slope of Banquereau (bottom)	Apr Autumn	194	97	3	
	Spring	5			
10. East Gully Sable Island (bottom)	May Autumn	184	93	7	
	Spring	14			
		2,922			

Age composition

The length and age compositions of the samples from the various areas are shown in Fig. 3. Those from Cape St. George and Isle aux Morts are very similar, with age-group 4 being the dominant one, followed by age-groups 8-11. In the St. Paul Island sample, age-groups 4-8 were the most significant with very few fish over 30 cm. In contrast, the Table Point sample consisted of larger and older fish. In the Cape Dauphin area, half of the catch consisted of immature herring, mostly 2- and 3-year-olds. In the Banquereau-Sable Island area herring older than age 7 dominated in the catches.

Meristic characters

Method of analysis. A comparison of averages was used to differentiate the autumn and spring spawners within each area. For the statistical test employed, the value of P is given in the normal distribution table of Fisher and Yates (1953). To facilitate the comparisons the data are set out in a tabular form similar to that used by Parsons (1973). The calculation of averages and variances were taken to the fifth decimal place but rounded to three decimals in the presentation. The data for the limited number of spring spawners in the Banquereau area are noted in brackets. The data are summarized in Tables 2 to 7.

Comparison of autumn and spring spawners. The average number of rays in the pectoral fin and number of gillrakers are greater for autumn spawners than for spring spawners. In all cases, the differences are significant ($P < 0.01$). The average number of dorsal rays in autumn spawners is greater than that for spring spawners, but the difference is not always significant (only about half the samples show a significant difference at $P = 0.01$). The number of keeled scales in the April samples varied very little between spawning types of southwest Newfoundland, but the differences are significant in the other areas ($P < 0.01$ for St. Paul Island and Cape Dauphin samples, and $P = 0.05$ for Table Point sample).

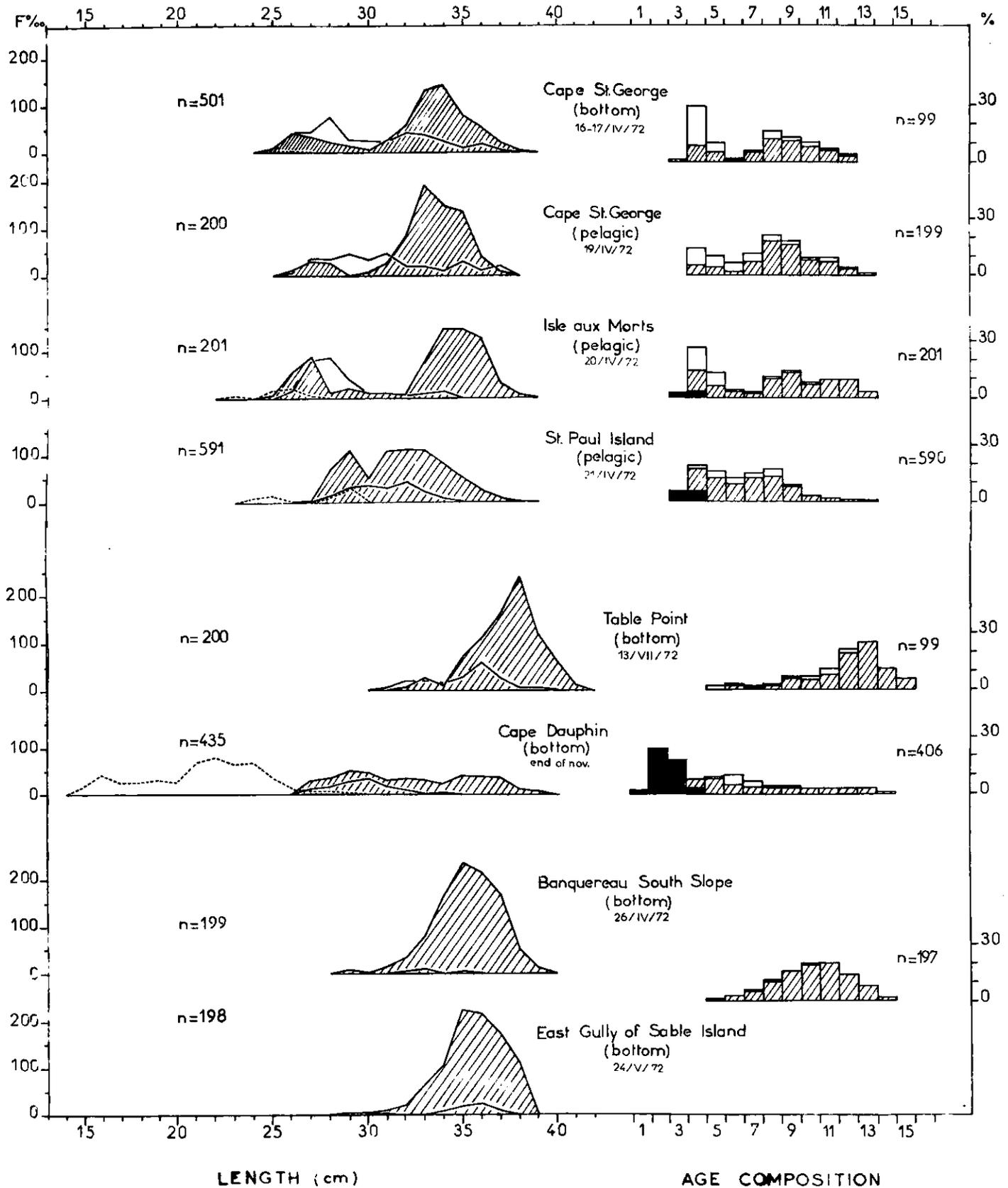


Fig. 3. Length frequencies and age composition of herring from areas (hatched portion: autumn spawners; solid portion and dashed line: immatures).

Table 2. Herring - vertebral numbers of autumn and spring spawners (* indicates significance at 1% level).

Area	Autumn spawners (A)										Spring spawners (S)										$\bar{x}_A - \bar{x}_S$	
	52	53	54	55	56	57	58	59	N	\bar{x}^1	Var ²	SE ³	53	54	55	56	57	58	N	\bar{x}^1		Var ²	SE^{3}
Cape St. George (bot)	11	121	153	20	3	308	55.620	0.498	0.040				7	73	89	15	1	185	55.622	0.508	0.053	-0.002
Cape St. George (pel)	4	52	70	9	2	137	55.657	0.507	0.061				19	37	5	1	62	55.806	0.421	0.083	-0.149	
Isle aux Morts (pel)	2	1	54	70	16	2	145	55.710	0.610	0.065			16	24	7		47	55.808	0.463	0.100	-0.098	
St. Paul Is. (pel)	1	3	20	169	201	32	4	430	55.577	0.613	0.038		1	14	49	42	7	2	115	55.400	0.768	0.177*
Table Point (bot)	6	59	74	22		161	55.696	0.563	0.059				3	12	18	4	1	38	55.684	0.762	0.144	0.012
Cape Dauphin (bot)	1	12	68	76	12	1	171	55.544	0.674	0.063			5	29	11		45	55.133	0.346	0.089	0.411*	
Banquereau (bot)	Mar	1	5	32	39	11	88	55.614	0.677	0.088												
Sable Is. (pel)	Apr	9	101	141	20	1	272	55.643	0.467	0.041												
Banquereau (bot)	Apr	1	8	80	88	16	1	194	55.582	0.556	0.054											
Sable Is. (bot)	May	12	66	84	21	183	55.623	0.599	0.057				(12	14	1		27	55.592	0.328	0.112	0.031)	

¹ \bar{x} = average vertebral number
² Var = variance
³ SE = standard error
 bot = bottom
 pel = pelagic

Table 3. Herring - pectoral fin ray numbers of autumn and spring spawners (* indicates significance at 1% level).

Area	Autumn spawners (A)										Spring spawners (S)										$\bar{x}_A - \bar{x}_S$	
	16	17	18	19	20	21	N	\bar{x}^1	Var ²	SE ³	15	16	17	18	19	20	N	\bar{x}^1	Var ²	SE ³		
Cape St. George (bot)	5	48	130	100	23	2	308	18.305	0.812	0.051			12	99	69	4	1	185	17.368	0.440	0.050	0.937*
Cape St. George (pel)	2	13	54	51	16	2	138	18.522	0.850	0.079			7	32	21	2	62	17.290	0.504	0.091	1.232*	
Isle aux Morts (pel)	4	21	59	51	10	145	18.290	0.805	0.075			6	22	18	1	47	17.297	0.518	0.106	0.993*		
St. Paul Is. (pel)	3	40	152	187	47	429	18.548	0.697	0.040			6	51	46	11	1	115	17.565	0.599	0.072	0.983*	
Table Point (bot)	9	64	67	21	161	18.621	0.612	0.062				1	18	15	4	38	17.579	0.521	0.119	1.042*		
Cape Dauphin (bot)	6	26	62	62	13	1	170	18.312	0.926	0.074		1	3	23	18	45	17.289	0.483	0.105	1.023		
Banquereau (bot)	Mar	7	34	44	3	88	18.489	0.483	0.075													
Sable Is. (pel)	Apr	18	120	131	22	1	292	18.548	0.544	0.043												
Banquereau (bot)	Apr	16	76	77	23	1	193	18.570	0.684	0.060												
Sable Is. (bot)	May	1	9	72	83	18	1	184	18.603	0.601	0.057		(5	10	8	5	28	18.464	0.999	0.192	0.139)	

¹ \bar{x} = average pectoral fin ray number
² Var = variance
³ SE = standard error
 bot = bottom
 pel = pelagic

Table 4. Herring - gillraker numbers of autumn and spring spawners (* indicates significance at 1% level).

Area	Autumn spawners (A)					Spring spawners (S)					$\bar{X}_A - \bar{X}_S$																				
	43	44	45	46	47	48	49	50	51	52		53	54	N	\bar{X}^1	Var ²	SE ³														
Cape St. George (bot)	4	11	31	62	59	64	47	23	4	2	307	49	261	2.946	0.098	7	13	27	40	48	34	9	6	1	185	48.530	2.588	0.119	0.731*		
Cape St. George (pel)	1	5	10	25	29	29	22	9	7	1	138	49	500	3.113	0.151	2	8	6	13	12	12	8	1		62	48.581	3.002	0.222	0.919*		
Isle aux Morts (pel)	1	5	15	23	42	24	18	13	4	145	49	296	2.835	0.140	1	2	8	12	13	6	3	2		47	48.574	2.294	0.223	0.722*			
St. Paul Is. (pel)	5	9	39	57	81	91	69	46	18	10	5	430	48.783	3.750	0.093	1	4	8	15	26	25	20	11	2	2	1	115	46.652	3.264	0.169	2.131*
Table Point (bot)	3	3	18	24	38	40	18	14	2	1	161	49	311	2.816	0.133	1	1	1	9	8	10	5	3		37	48.405	2.026	0.237	0.906*		
Cape Dauphin (bot)	1	3	11	25	20	33	26	21	7	2	170	48	288	4.372	0.161	1	3	10	12	15	3	1	1		46	46.196	1.805	0.200	2.092*		
Banquereau (bot)	1	2	8	14	24	11	17	8	1	2	88	49	489	3.173	0.191																
Sable Is. (pel)	1	4	18	38	61	69	57	31	10	3	292	49	825	2.660	0.096																
Banquereau (bot)	4	12	24	57	45	33	13	5	1	194	49	593	2.274	0.108																	
Sable Is. (bot)	3	5	17	39	50	28	25	13	4	184	50	179	2.750	0.123																	
May																1	4	1	9	6	5	1	1	28	50.357	2.979	0.332	-0.178			

1 \bar{X} = average gillraker number
 2 Var = variance
 3 SE = standard error

bot = bottom
 pel = pelagic

Table 5. Herring - dorsal fin ray numbers of autumn and spring spawners (* indicates significance at 1% level).

Area	Autumn spawners (A)					Spring spawners (S)					$\bar{X}_A - \bar{X}_S$								
	17	18	19	20	21	22	N	18	19	20		21	22	N	\bar{X}^1	Var ²	SE ³		
Cape St. George (bot)	18	136	137	17	308	19.497	0.479	0.039	28	98	53	4	183	19.180	0.501	0.052	0.317*		
Cape St. George (pel)	1	4	58	67	7	137	19.547	0.455	0.058	10	34	17	1	62	19.145	0.487	0.089	0.402*	
Isle aux Morts (pel)	14	56	71	4	145	19.448	0.499	0.059	6	21	19	1	47	19.319	0.527	0.107	0.129		
St. Paul Is. (pel)	1	15	185	206	23	1	431	19.552	0.453	0.032	13	62	35	4	114	19.263	0.497	0.066	0.289*
Table Point (bot)	8	68	76	8	160	19.525	0.452	0.053	3	21	13	1	38	19.316	0.438	0.109	0.209		
Cape Dauphin (bot)	1	16	65	80	7	169	19.450	0.559	0.058	3	28	15		46	19.261	0.331	0.086	0.189	
Banquereau (bot)	4	46	35	2	87	19.402	0.383	0.067											
Sable Is. (pel)	12	142	120	13	1	288	19.476	0.445	0.039										
Banquereau (bot)	12	84	85	12	193	19.503	0.501	0.051											
Sable Is. (bot)	11	95	73	5	184	19.391	0.414	0.047											

1 \bar{X} = dorsal fin ray number
 2 Var = variance
 3 SE = standard error

bot = bottom
 pel = pelagic

Table 6. Herring - keeled scales K₂ numbers of autumn and spring spawners (* indicates significance at 1% level).

Area	Autumn spawners (A)												Spring spawners (S)						$\bar{X}_A - \bar{X}_S$	
	12	13	14	15	16	17	18	19	N	\bar{X}^1	Var ²	SE ³	12	13	14	15	16	N		\bar{X}^1	Var^{2}	SE^{3}
Cape St. George (bot)	4	89	159	52	2	2	1	307	13.883	0.607	0.044	2	59	96	27	1	185	13.816	0.499	0.052
Cape St. George (pel)	3	49	60	23	3	3	138	13.812	0.665	0.070	21	32	8	1	62	13.822	0.509	0.091		
Isle aux Morts (pel)	2	39	73	30	1	1	145	13.924	0.557	0.062	2	13	24	7	1	47	13.830	0.666	0.120	
St. Paul Is. (pel)	13	105	227	81	4	1	431	13.909	0.603	0.037	9	55	42	6	2	114	13.447	0.621	0.074	
Table Point (bot)	5	39	82	35	1	1	162	13.926	0.603	0.061	3	13	17	3	1	37	13.622	0.742	0.143	
Cape Dauphin (bot)	4	49	91	25	2	2	171	13.836	0.550	0.057	2	25	19			46	13.370	0.327	0.085	
Banquereau (bot)	2	20	38	19	6	3	88	14.182	1.093	0.112										
Sable Is. (pel)	7	53	140	77	12	2	292	14.151	0.802	0.052										
Banquereau (bot)	2	37	101	43	10	1	194	14.129	0.693	0.060										
Sable Is. (bot)	3	36	76	58	9	1	183	14.202	0.789	0.066	(7	11	7	3	28	14.214	0.915	0.184		

1 \bar{X} = keeled scales K₂ number
 2 Var = variance
 3 SE = standard error

bot = bottom
 pel = pelagic

Table 7. Herring - keeled scales K₂ numbers of males and females.

Area and spawning group	Male (M)												Female (F)						$\bar{X}_M - \bar{X}_F$		
	12	13	14	15	16	17	19	N	\bar{X}^1	Var ²	SE ³	12	13	14	15	16	17	18		N	\bar{X}^1	Var^{2}	SE^{3}
Cape St. George (bot)	2	42	75	20	2	1	142	13.880	0.716	0.071	2	46	84	32		164	13.890	0.516	0.056		
Cape St. George (pel)	2	35	51	15	1	104	13.788	0.557	0.074	24	45	12			81	13.852	0.428	0.073			
Isle aux Morts (pel)	3	28	35	9	1	76	13.697	0.614	0.090	21	25	14	2		62	13.952	0.703	0.107			
St. Paul Is. (pel)	1	22	40	19		82	13.939	0.552	0.082	1	17	33	11	1	63	13.905	0.571	0.096			
Table Point (bot)	3	53	107	38	2	203	13.916	0.543	0.051	10	52	120	43	2	228	13.903	0.660	0.054			
Cape Dauphin (bot)	7	26	25	2	1	61	13.410	0.646	0.104	2	29	17	4	1	53	13.491	0.601	0.107			
Banquereau (bot)	3	22	39	17	1	82	13.890	0.670	0.091	2	17	43	18		80	13.962	0.543	0.083			
Sable Is. (bot)	1	18	39	12		70	13.886	0.480	0.083	3	31	52	13	2	101	13.802	0.600	0.077			
Banquereau (bot) Mar	1	10	20	9	4	45	14.178	1.059	0.155	1	10	18	10	2	43	14.186	1.155	0.166			
Sable Is. (pel) Apr	4	28	64	37	3	136	14.051	0.686	0.071	3	25	76	40	9	2	156	14.237	0.892	0.076		
Banquereau (bot) Apr	2	17	41	17	5	82	14.073	0.760	0.097	20	60	26	5	1	112	14.170	0.647	0.076			
Sable Is. (bot) May	3	15	43	26	5	93	14.193	0.854	0.096	21	33	32	4		90	14.211	0.730	0.091			

1 \bar{X} = keeled scales K₂ number
 2 Var = variance
 3 SE = standard error

bot = bottom
 pel = pelagic

A = autumn
 S = spring

In the West and Southwest Newfoundland populations, the average number of vertebrae of spring spawners was slightly greater than that for autumn spawners, but the differences are not significant. For the Cape Breton area, however, autumn spawners have a higher vertebral average than spring spawners ($P = 0.5$ for St. Paul Island and $P \leq 0.01$ for Cape Dauphin).

Comparison between areas for spring spawners. Four meristic characters ($P < 0.1$ for each of pectoral rays, gillrakers, keeled scales and vertebrae) indicate that there is no mixing between spring spawners of St. Paul Island and Southwest Newfoundland in the spring, on the basis of the April samples, whereas the meristic averages are almost identical for bottom catches off Cape St. George and pelagic catches off Southwest Newfoundland.

Comparison between areas for autumn spawners. In the April samples, the differences in meristic characters are less apparent than for spring spawners; only the number of left pectoral rays and the number of gillrakers in certain cases are significant ($P < 0.05$). Statistically, the data indicate very little mixing between pelagic concentrations off Cape St. George and off Isle aux Morts ($P < 0.05$ for left pectoral). The high vertebral average for herring off Isle aux Morts (55.71) may be compared with that given for Fortune Bay herring (55.78) by Parsons (1973). With regard to the St. Paul Island and the Cape St. George concentrations two contradictory results are evident: $P = 0.77$ for number of left pectoral rays and $P \leq 0.05$ for number of gillrakers.

In the Banquereau-Sable Island area the autumn spawning population can be readily distinguished from those of the Gulf of St. Lawrence and Southwest Newfoundland by the higher average number of keeled scales and gillrakers in the former area.

Comparison of keeled scales between areas by sex. In 10 of 12 cases, females tended to have a slightly higher keeled scale average than males but the differences are not significant (Table 7).

Stomach and fat contents

About 90% of the herring caught on the bottom had empty stomachs, whereas 40-100% of the herring in the samples taken from pelagic concentrations had stomachs containing food. The stomach contents were composed mainly of *Calanus finmarchicus*: 99% for herring taken in the Gulf of St. Lawrence and Southwest Newfoundland and 88% for herring in the Banquereau area.

The fat determinations were carried out in the laboratory following the BBS method. The fat content varied somewhat with the different populations, but those sampled in April were generally the lowest, *i.e.*, 2.87% for 34 autumn spawners and 4.99% for 17 spring spawners in the Cape St. George, Isle aux Morts, and St. Paul Island samples. In the Banquereau area in March and April, the average fat content of autumn spawners was 3.70% (20 fish), whereas in May it had increased to 9.77% (8 fish). The average of 6 specimens taken in July at Table Point was 18.44%.

CONCLUSIONS

1. The observations made during 17-21 April 1972 show that the herring concentrations of the Gulf of St. Lawrence, Southwest Newfoundland and Cape Breton are composed of a mixture of autumn and spring spawners.
2. There are clear differences in meristic character averages between pelagic concentrations of spring spawners on either side of the Laurentian Channel. On the other hand, the autumn spawners often show minimal differences, and may represent a mixture of different populations.
3. The number of keeled scales (K_2) clearly indicates that the autumn spawners of the Gulf of St. Lawrence and Southwest Newfoundland are distinct from those of the Banquereau stock complex.
4. The fat content of the samples varied considerably according to the season and fishing area; it ranged from an average of 2.87% for the Gulf of St. Lawrence (near Cabot Strait) in April to 18.87% in a sample off Table Point in July.
5. The pelagic concentrations seem to be associated with the presence of *Calanus finmarchicus*: 99% in the stomachs of herring in 5,000-kg catches in the St. Paul Island area to 87% for a 340-kg catch in the East Sable Island area.

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18. Length-weight relationships for the herring of the Bay of Fundy (ICNAF Division 4X)¹

by T.D. Iles
Resource Management Branch, Fisheries and Marine Service
Environment Canada, Ottawa, Ontario

and

D.S. Miller
Fisheries and Marine Service, Environment Canada
Biological Station, St. Andrews, New Brunswick

The Canadian herring fisheries in the Bay of Fundy are carried on throughout the year and exploit a wide length-range. Over the period 1969-72 length and weight data have been accumulated which allows the presentation of length-weight tables on a quarterly basis. These are presented in Table 1. Length is overall length to the end of the extended caudal fin and measured in millimeters. Grouping in the table is to the centimeter below. Weight is total weight of the whole fish measured to the nearest 0.1 gram.

Curves of the form $W = aL^n$ were fitted to the data for each quarter, where W = weight (g), L = length (mm), a = the coefficient, and n = the exponent of the length-weight relationship. The curves were fitted by the method of least squares after logarithmic transformation of both length and weight. The quarterly coefficients (a) and exponents (n), together with the length range of the available data (mm), are given in Table 2.

Although the data on which the tables are based refer to a restricted area, they represent a reasonably comprehensive coverage of almost the total length range of Northwest Atlantic herring over much of the year. In the absence of similar information from other areas, they could thus serve as a useful approximation of the length-weight relationships in those areas. It must be stressed that no direct biological interpretation of the coefficients and exponents or their seasonal variation was intended or is to be implied.

Table 1. Mean weights by quarters of the year for herring sampled in Div. 4X, 1969-72.

Size Group (cm)	Quarter 1		Quarter 2		Quarter 3		Quarter 4		Total	
	No.	Mean Wt. (g)	No.	Mean Wt. (g)						
6	-	-	2	-	3	1.4	-	-	3	1.4
7	8	2.4	2	2.7	19	2.6	6	2.5	35	10.2
8	96	3.6	40	3.4	54	3.8	41	3.8	231	3.7
9	416	5.0	267	5.1	204	6.0	133	5.1	1,020	5.3
10	631	7.0	633	6.9	263	8.9	259	7.2	1,786	7.5
11	544	10.2	821	9.1	308	7.3	389	9.5	2,062	9.0
12	423	17.1	797	11.9	488	14.4	409	12.6	2,117	14.0
13	309	21.1	869	15.2	747	17.6	341	16.6	2,266	17.6
14	155	19.8	855	19.0	1,106	21.4	164	20.8	2,280	20.3
15	93	23.9	758	23.8	1,666	26.5	107	24.7	2,624	24.7
16	52	28.5	565	30.1	1,867	32.0	183	30.3	2,667	30.2
17	92	34.2	421	35.5	1,302	38.9	224	34.1	2,039	35.7
18	111	39.1	268	41.9	1,000	46.6	246	41.7	1,625	42.3
19	69	45.1	149	48.7	730	54.8	272	50.4	1,220	49.8
20	40	51.8	122	55.6	407	64.7	256	60.1	825	58.1
21	11	64.3	165	65.7	275	75.9	177	69.5	628	68.9
22	4	69.3	192	78.1	267	85.6	86	85.2	549	79.6
23	1	77.6	181	94.4	255	95.8	42	95.7	479	90.9
24	1	91.1	206	102.6	258	109.0	47	106.4	512	102.3
25	-	-	212	118.2	286	130.0	64	117.4	562	121.9
26	-	-	266	137.5	446	149.8	122	135.1	834	140.8
27	-	-	362	146.0	696	168.7	164	155.8	1,222	156.8
28	-	-	490	164.4	853	187.5	169	179.6	1,512	177.2
29	-	-	618	187.5	1,037	208.0	121	201.5	1,776	199.0
30	-	-	697	211.5	1,208	234.4	77	236.3	1,982	227.4
31	-	-	791	233.0	1,214	259.6	65	249.9	2,070	247.5
32	-	-	873	258.7	1,083	284.6	58	265.6	2,014	269.6
33	-	-	672	303.6	964	310.7	50	290.2	1,686	301.5
34	-	-	363	340.9	553	336.9	46	316.9	962	331.6
35	-	-	160	373.0	232	372.4	16	326.7	408	357.4

¹ Submitted to 1973 Annual Meeting of ICNAF as ICNAF Res.Doc. 73/92.

Table 2. Quarterly length-weight relationships for Div. 4X herring, 1969-72 (parameters of relationship: weight (g) = a x lengthⁿ (mm)).

Quarter	Coefficient (a)	Exponent (n)	Length range (mm)
1	6.572×10^{-6}	2.995	75 - 245
2	2.155×10^{-6}	3.218	75 - 385
3	2.753×10^{-6}	3.185	65 - 415
4	2.965×10^{-6}	3.161	75 - 385
Total	2.686×10^{-6}	3.181	65 - 415

**SECTION 6
OTHER FISH**

19. Soviet investigations on capelin in the Northwest Atlantic in 1971 and 1972¹

by S.M. Kovalyov and B.D. Kudrin
Polar Research Institute of Marine
Fisheries and Oceanography (PINRO)
Murmansk, USSR

ABSTRACT

Distribution characteristics of capelin on the continental shelf from southern Labrador to southern Grand Bank was investigated in 1971 and 1972. While capelin concentrations are widespread in various areas and months, the densest schools, suitable for commercial fishing, occur on the Grand Bank, particularly on the southeastern part during spawning time. The bulk of the spawning stock consists of age-groups 3 and 4 years. Data on the feeding intensity by month is presented as well as on the food constituents found in capelin stomachs.

INTRODUCTION

That some local capelin stocks inhabit the continental bank and slope areas off Newfoundland, particularly on the Grand Bank, has been indicated by Templeman (1948), Pitt (1958), and Rikhter (1962). Both Pitt and Templeman indicated the presence of two groups of capelin: those that migrate to the coast to spawn on the beaches, i.e., "coastal" capelin, and those that spawn on the shallow areas of the Grand Bank, i.e., "bank" capelin. According to Templeman (1965), the latter type form abundant concentrations on the southeastern part of the Grand Bank in July-August, when large catches can be made with bottom and pelagic trawls. This paper presents the results of Soviet investigations on the distribution of capelin on the continental shelf from southern Labrador to the southern Grand Bank in 1971 and 1972.

OBSERVATIONS IN 1971

During May to July 1971, expeditions to the Northwest Atlantic, aimed at exploring the possibilities of the commercial exploitation of capelin in the Grand Bank area, were undertaken aboard the research vessels *Perseus III* and *Academik Knipovich*. Biological material were collected during 25 May-19 July with bottom trawls lined with small mesh netting. Specimens were measured from the tip of the snout to the end of the middle rays of the caudal fin (fork length). Ages were determined from otoliths treated with glycerine. Data on the occurrence of capelin in cod stomachs and in the catches, with allowance for the density of echo-recordings, are plotted to show the distribution of capelin on the Grand Bank during the May-June period of the investigations in 1971 (Fig. 1).

During the early phase of the investigations in late May on St. Pierre and Green Banks, no suitable concentrations for a fishery were recorded, the capelin shoals being small and distributed over depths of 50-100 m.

During the first half of June considerable concentrations of pre-spawning capelin were distributed on the southwest slope of the Grand Bank and the densest shoals occurred over depths of 100-200 m in the area bounded by 44°30' to 45°00'N and 52°30' to 54°00'W.

During the second half of June trawlings on the southeast part of the Grand Bank indicated that the spawning concentrations of capelin formed at the end of June. Their density permitted catches of 3-10 tons per half hour trawling to be obtained with bottom trawls. The densest concentrations occurred at this time in depths of 45-55 m in an area bounded by 43°31' to 45°10'N and 49°10' to 51°00'W, where spawning occurred. In the northern part of the designated area, 97% of capelin in the catches were females and post-spawning specimens dominated. The capelin fed on their own young 20-42 mm long, and their stomach contents consisted of capelin eggs, *Calanus*, *Euphausiids* and *Amphipoda* (Tables 1 and 2).

Table 1. Intensity of capelin feeding in June 1971.

Stomach content index	0	1	2	3	4	Total
Number of specimens	163	17	18	23	29	250
Percent frequency	65.2	6.8	7.2	9.2	11.6	100

¹ Submitted to the 1972 and 1973 Annual Meetings of ICNAF as ICNAF Res.Doc. 72/102 and 73/26, and re-written as one paper.

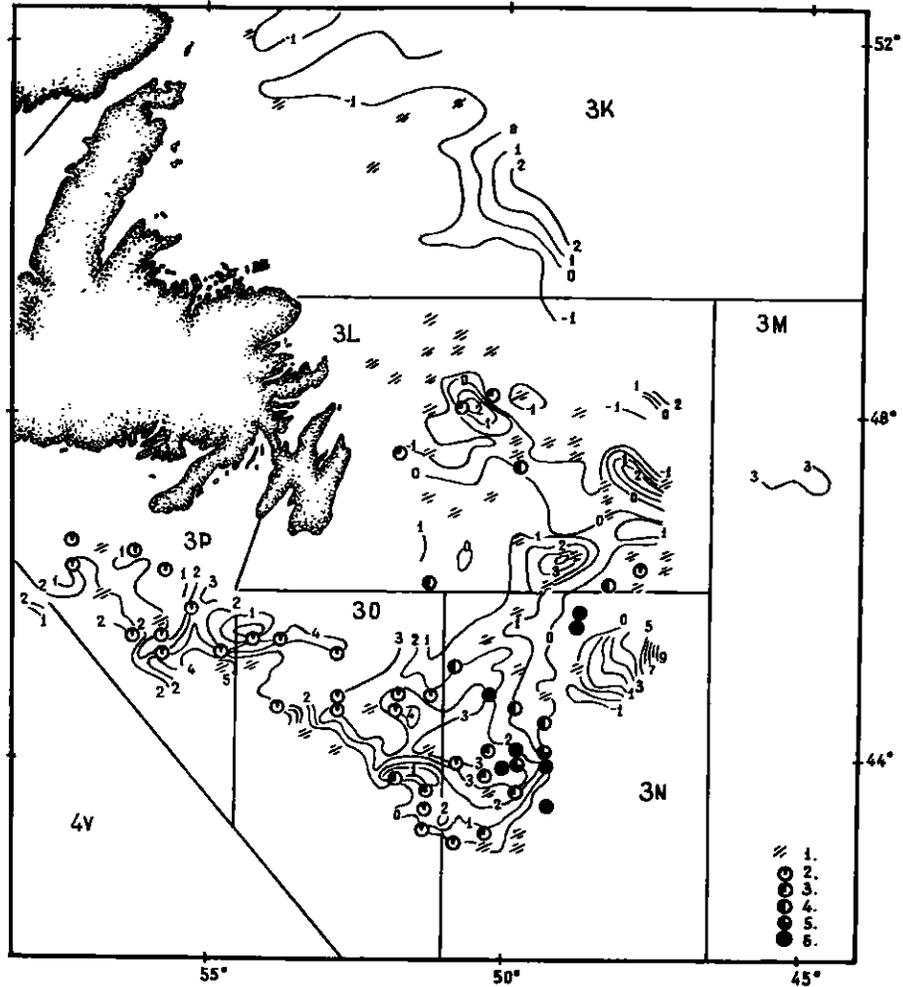


Fig. 1. Distribution of capelin in May-June 1971.
 1 - Occurrence of capelin in cod stomachs.
 2 - Capture with trawl of 1-100 specimens.
 3 - Capture with trawl of 101-1,000 specimens.
 4 - Capture with trawl of 0.5-3 tons.
 5 - Capture with trawl of 3-5 tons.
 6 - Capture with trawl of 5-10 tons.

Table 2. Frequency of occurrence of food organisms in capelin in June 1971.

Food organisms	Number of stomachs	Percent of stomachs with food	Food organisms	Number of stomachs	Percent of stomachs with food
Capelin eggs	22	25.3	<i>Euphausiids</i>	2	2.3
Capelin larvae	38	47.7	<i>Amphipoda</i>	1	1.2
<i>Calanus</i>	22	25.3	Digested material	14	16.1

Observations show that the Grand Bank capelin evidently have no long-distance migrations, but inhabit the shelf area and slopes. After spawning the surviving fish migrate to the northeast part of the bank where fattening takes place. Observations on the northeast slope in July tend to confirm this assumption, as trawlings in this area did not result in any large catches, but those fish taken were found to be feeding intensively and it is probable that they migrated here from the spawning area. Hydro-acoustic recordings

indicated separate small schools in mid-water and near-bottom layers.

During the pre- and post-spawning periods, well-defined diurnal vertical migrations of capelin were observed. During the day they were distributed in the near-bottom layer in rather dense schools with a vertical extent of 30-70 m, whereas at night the schools rapidly moved upward into the near-surface layer (20-35 m) and dispersed, the thickness of the layer containing the dispersed fish being 10-15 m. As soon as daylight came, the capelin rapidly formed into larger schools and descended to the bottom. However, post-spawning capelin formed less dense schools in the day and stayed somewhat higher off the bottom than spawning fish, and consequently, the catches of post-spawning fish by bottom trawl were small.

During the period of investigation the capelin were distributed in areas where the water temperature ranged from -0.2° to 5°C .

The length and age compositions of Grand Bank capelin (Fig. 2) indicate a length range of 10-20 cm and an age range of 2-5 complete years (1969-1965 year-classes). Specimens at age 3 (61-65%) and age 4 (29-37%) formed the basis of the spawning stock on the Grand Bank.

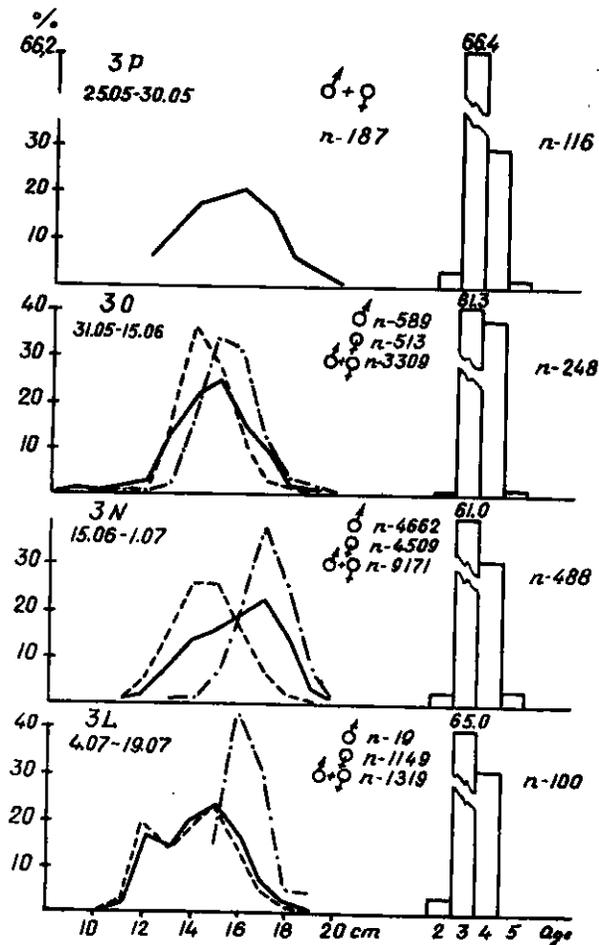


Fig. 2. Length and age compositions of capelin in the Grand Bank and St. Pierre Bank areas, May-June 1971.

OBSERVATIONS IN 1972

Studies on the biology of Grand Bank capelin were continued in 1972 and were aimed at determining the migration patterns and routes. Observations and materials were collected on board the R/V *Perseus III* and scouting vessels on the Grand Bank area during February to June and in the south Labrador area during September to December. Biological materials were collected from bottom and pelagic catches; the trawls used had 10-mm mesh size netting in the codend. Specimens were measured and aged as stated above for 1971. The maturity condition of gonads was determined according to the 6-point scale suggested by Sorokin (1957).

The distribution charts of capelin in 1972 (Fig. 3A, B and C) were prepared on the basis of the results of hydro-acoustic detection and trawlings.

Observations were begun in the second half of February, when some small schools were found on the northeastern slope of the Grand Bank (Fig. 3A) along the 150-250 m isobaths. In March capelin were observed on the northwestern part of the Bank and concentrations were found in the area bounded by 46°00' to 48°00'N and 50°00' to 53°00'W. By the middle of March some considerable concentrations migrated to the Virgin Rocks area, but dense schools remained in the Avalon Channel area. By the end of March capelin were distributed over a large area from the southeastern part of Newfoundland to the southwest slope of the Grand Bank.

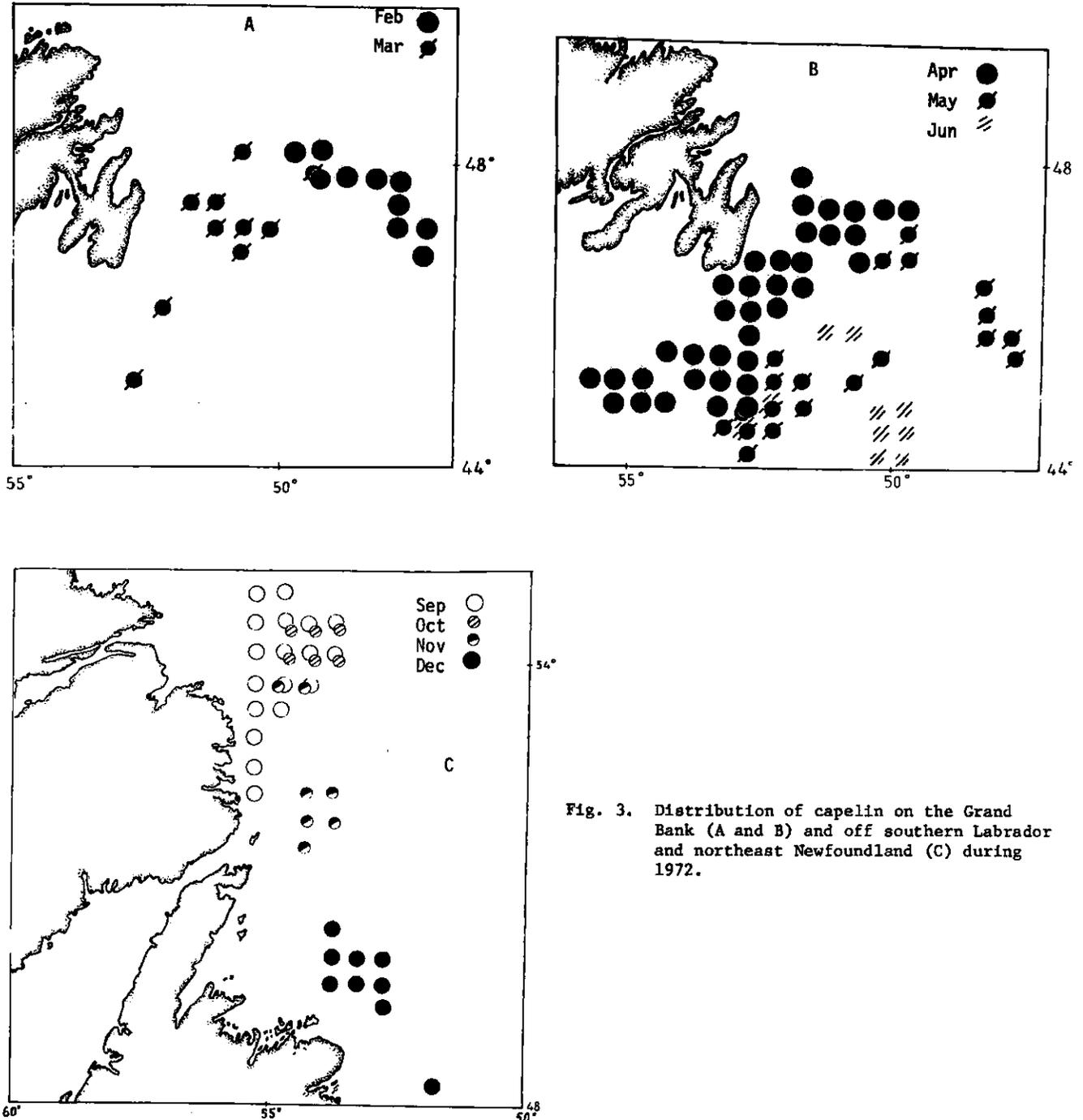


Fig. 3. Distribution of capelin on the Grand Bank (A and B) and off southern Labrador and northeast Newfoundland (C) during 1972.

In April fish-detection apparatus recorded capelin schools on the northeastern part of the Grand Bank (Virgin Rocks area), on the southwest slope of the Grand Bank, and also on St. Pierre and Green Banks (Fig. 3B). In May capelin migrated intensively to the southern and southeastern areas of the Grand Bank, arriving on the southeastern slope at the end of May, and the mature part of the stock was concentrated there in June. Immature capelin were distributed widely over the northeastern slope of the Grand Bank above depths of 100-150 m. Spawning started during 7-10 June and intensive spawning took place in the shallow parts of southeastern Grand Bank during the second half of June. According to Hinds (1972) fishable concentrations of capelin appeared in the spawning area (Southeast Shoal) on 7 June.

In September Soviet investigations were continued off southern Labrador and dense concentrations were found on Hamilton Bank, where they were also observed in October. In November capelin were distributed more to the southeast than in October; schools were found in the area of 53°40'N and between 54°00' and 55°00'W. By the end of the month some schools were found in the area of 51°50' to 52°30'N and 53°30' to 54°30'W. In the first half of December hydro-acoustic devices recorded capelin in the area of 50°00' to 51°00'N and 52°30' to 54°00'W (Fig. 3C).

Capelin were intensively feeding in the spring and summer. Feeding intensity decreased from March to June (Table 3). *Calanus*, *Euphausiidae* and *Amphipoda* were the main food constituents during March to June 1972 (Table 4).

Table 3. Feeding intensity of capelin from March to September 1972.

Month ¹		Index of stomach fullness					Total
		0	1	2	3	4	
March	No. of specimens	93	3	6	42	56	200
	%	46.5	1.5	3.0	21.0	28.0	
April	No. of specimens	191	21	47	70	96	425
	%	44.8	4.9	11.1	16.6	22.6	
May	No. of specimens	74	17	31	20	3	145
	%	51.3	11.7	21.3	13.7	2.0	
June	No. of specimens	157	52	63	16	12	300
	%	52.4	17.3	21.0	5.3	4.0	
September	No. of specimens	26	8	15	28	23	100
	%	26.0	8.0	15.0	28.0	23.0	

¹ No observations were carried out in July and August. Data on the length composition and feeding in October-December are not available.

Table 4. Frequency of occurrence of food organisms in capelin during March-June 1972.

Food organisms	Number of stomachs	Percent of stomachs with food	Food organisms	Number of stomachs	Percent of stomachs with food
<i>Calanus</i>	347	55.4	<i>Ctenophora</i>	5	0.8
<i>Euphausiidae</i>	276	44.1	Fish larvae	24	3.8
<i>Amphipoda</i>	198	31.5	<i>Sagitta</i>	77	12.3
Food digested	35	5.6	Capelin eggs	15	2.4

During March-June 1972 pre-spawning and spawning concentrations consisted of capelin of 10-19 cm in length and of 2-5 years of age (Fig. 4). Age-groups 3 and 4 constituted the bulk of the spawning stock.

CONCLUSIONS

1. In spring and early summer the densest concentrations of capelin were distributed in the Avalon Channel area and on the southwestern and southeastern parts of the Grand Bank.
2. Capelin spawning took place in June on the shallow parts (45-55 m) of the southeastern Grand Bank.
3. Temperatures recorded in the spawning area were 2.8° to 3.5°C in 1971.

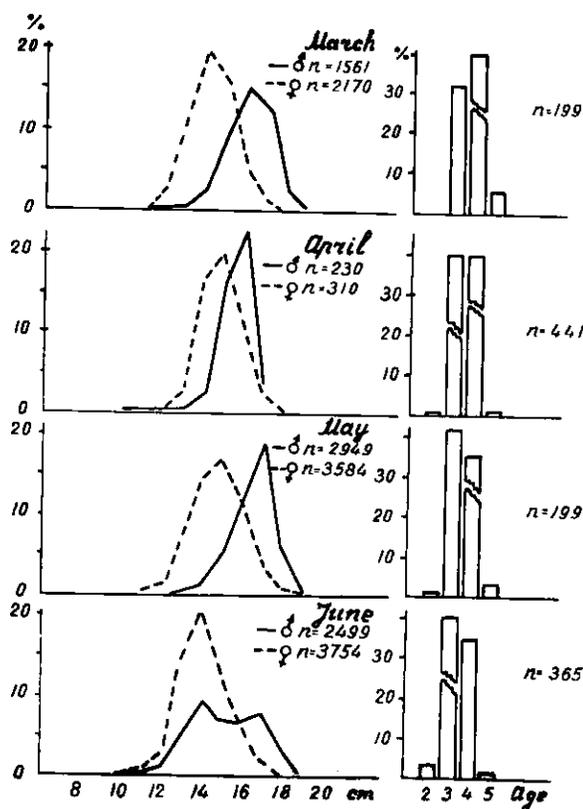


Fig. 4. The length and age compositions of capelin in the Grand Bank area in March-June 1972.

4. The stock of bank capelin consisted of 2-5-year-old fish (10-20 cm fork length), with age-groups 3 and 4 forming the bulk of the spawning stock.
5. Observations during September-December 1972 indicate widespread concentrations of capelin off southern Labrador and northeast Newfoundland.

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20. Observations on capelin, *Mallotus villosus*, in Newfoundland waters¹

by O. Dragesund and T. Monstad
Institute of Marine Research
Bergen, Norway

INTRODUCTION

Annually capelin migrate towards the shores of Newfoundland and Labrador to spawn. Mass beach spawning of capelin occurs mainly in June off the east coast of Newfoundland and progressively later northwards along the coast. The Labrador coast spawning commences in mid-July. Off the west and south coast beach spawning begins at the end of May. The beach spawning lasts from four to six weeks at temperatures ranging from 5.5° to 8.5°C. When beach spawning is completed, spawning may continue in deeper waters near shore (Templeman, 1948, 1968). Capelin also spawn at the Southeast Shoal on the Grand Bank in June-July (Pitt, 1958). At this time mature capelin have also been trawled on the eastern slope of the Grand Bank and on St. Pierre Bank.

Little information is available on the distribution and migration of capelin prior to the time they approach the different spawning grounds. The presence of the capelin on the Grand Bank, at the same time as along the coast, suggests that the inshore capelin may be discrete from those spawning offshore on the banks.

Several authors (Templeman, 1948, 1968; Winters, 1970; Devold, *et al.*, 1972) suggest that the capelin resource off Newfoundland and Labrador must be large. However, the utilization of the capelin has been very limited, and no exact information exists on the size of this resource.

The aim of the present paper is to report some preliminary results of Norwegian capelin investigations carried out in Newfoundland waters in early summer of 1972, with emphasis on 1) distribution and migration; 2) structure and size of the capelin resource; and 3) catchability of capelin, especially the mature stock just prior to and during the spawning season.

MATERIAL AND METHODS

The material is obtained from a survey carried out by R/V *Johan Hjort* from 17 May to 19 June 1972. The distribution and abundance of the capelin were studied from combined acoustic surveys and fish sampling with trawl. R/V *Johan Hjort* was equipped with vertical echo sounders and horizontal ranging sonar. A Simrad echo integrator was linked to a Simrad EK 50 kHz echo sounder. The setting of the EK sounder was: output power 1 kW, time varied gain (TVG) 20 Log R, and receiver gain 0 dB. The source level was 121.8 dB, receiving voltage response 5.2 dB, the beamwidth 7° and 13° along and athwartship between the 3 dB points. The threshold on the integrator was set at 1, and the gain at 30 dB. In order to avoid saturation of the echo integrator, the gain was adjusted when necessary.

Two integrator channels covered the depth intervals from 5 to 50 m, and from 50 m to the bottom. Echo integrator readings were made each nautical mile and average values for each five nautical miles were plotted on maps. When other fish species were recorded within the same depth interval, the echo abundance was divided between capelin and the other species. Both experimental fishing and analysis of the echo traces were used for dividing the total echo abundance (Blindheim, *et al.*, 1971).

The method used to estimate the stock size is described by Midttun and Nakken (1971), Blindheim and Nakken (1971), and later applied by Nakken (personal communication), Jakupstovu and Midttun (1972), and Dragesund, Gjøsaeter and Monstad (1972). The constant C was calculated from the relation of Midttun and Nakken (1971). The equation is

$$S = CM$$

where *S* is given in number of fish or fish weight per unit area and *M*, the integrator echo intensity.

Capelin were caught with a Norwegian capelin trawl with an opening of 12 x 12 fm, mesh size (stretched) ranging from 200 mm (wings and squares) graded down to 22 mm (codend). An ordinary Granton bottom trawl with cover net equipped with bobbins was also available.

The capelin were examined fresh. Total length was measured to the nearest mm and grouped in half cm class intervals. Otoliths, taken stratified, were used for age determination and age/length keys were established. The maturity stages were classified according to a scale modified from Nikolsky (1963). The weight was estimated by measuring the volume of individual fish using the displacement method.

Hydrographic stations using Nansen bottles were taken at six sections in different regions on the Grand Bank. Hydrographic stations with bathythermograph were taken at average intervals of 25 nautical miles

¹ Submitted to the 1973 Annual Meeting of ICNAF as ICNAF Res.Doc. 73/33.

along the survey route. The sea thermograph recorded the temperature at a depth of about 4 m during the whole survey. A map showing the general bathymetric features on the Grand Bank and names used in the text are given in Fig. 1. The survey routes and grid of stations are shown in Fig. 2.

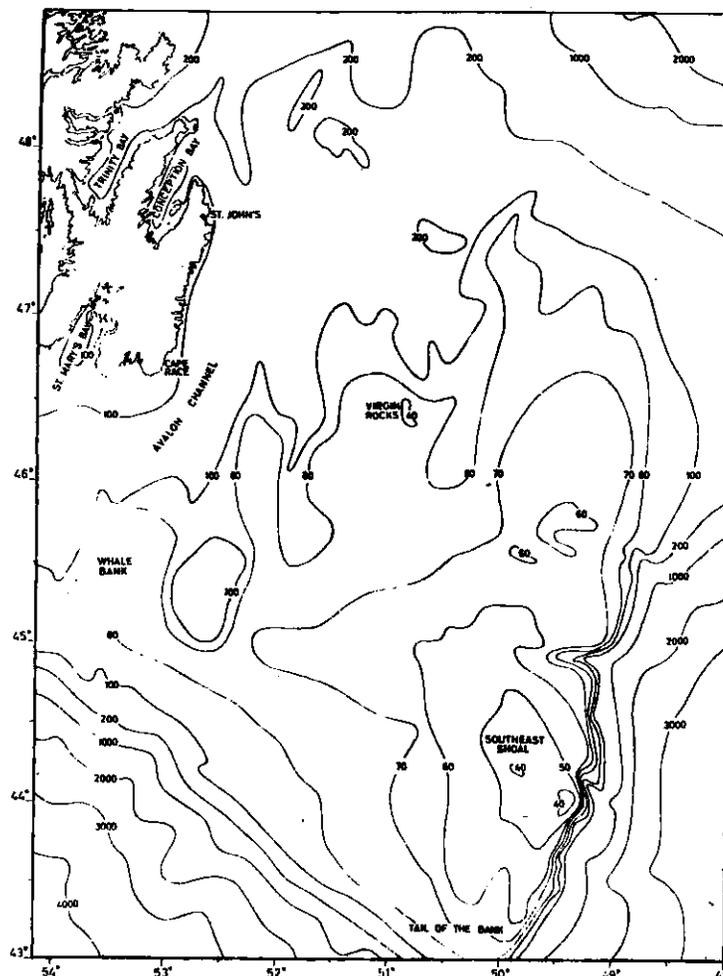


Fig. 1. Map showing the general bathymetric features of the Grand Bank (depth in m) and names used in the text.

DISTRIBUTION AND MIGRATION

Three surveys were carried out during the period of investigation. During the first survey, which was planned to provide preliminary information on distribution, only scattered concentrations of capelin were recorded (Fig. 3). The survey did not cover the whole area, and the survey lines were too far apart to give a representative picture of the distribution. The second and third surveys (Figs. 4 and 5) showed that capelin were distributed throughout the Grand Bank area from the ice border to the tail of the bank. Capelin were most concentrated in the northern part of the area surveyed and at the Southeast Shoal. The capelin on the northern Grand Bank had moved slightly towards the south and west between the second and third surveys.

During the day capelin were recorded in the midwater layer or just above the bottom, *i.e.*, in depths ranging from 30 to 150 m. On the northern and central Grand Bank, they appeared in small and scattered shoals during the day, whereas at the Southeast Shoal they were recorded in denser shoals in daytime (Fig. 6). With diminished light in the evening, capelin came close to the surface and dispersed. At dawn the fish again clustered in shoals which soon migrated to deeper water.

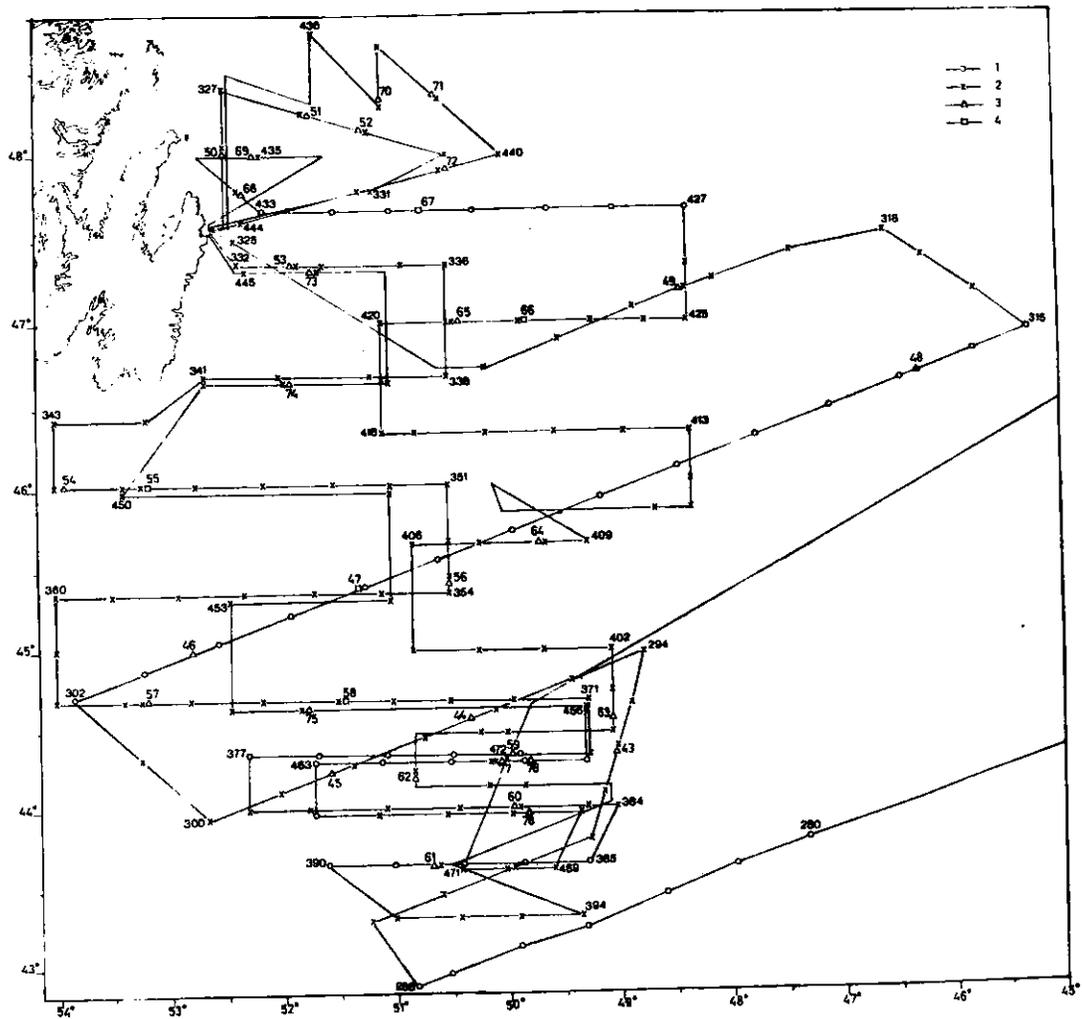


Fig. 2. Survey routes of R/V *Johan Hjort* and grid of stations 18 May-19 June 1972: (1) hydrographic station with Nansen bottles, (2) hydrographic station with bathythermograph, (3) pelagic trawl station, and (4) bottom trawl station.

The capelin in the northern area were mainly found in water with temperatures below 0°C (Fig. 7 and 8). At the southern Grand Bank capelin were recorded in water of temperatures above 1°C. At the Southeast Shoal the temperatures varied between 2.5° and 3.2°C.

STRUCTURE AND SIZE OF THE STOCK

In the samples collected south of 46°30'N, 97.5% (weight percentage) of the capelin were mature fish, whereas north of this latitude only 34.7% of the capelin were mature. Figure 9 shows the age and length composition of mature capelin in different areas on the Grand Bank. The 1969 year-class dominated in all areas, followed by the 1968 year-class. The age composition was very similar in the northern and western areas, whereas on the southern Grand Bank somewhat larger and older fish occurred. Among the mature fish females were by far the most frequently observed in the samples from the western and southern Grand Bank.

The age and length composition of immature fish is illustrated in Fig. 10. In the southern area the 1969 year-class strongly dominated, while farther north the 1969 and 1968 year-classes were equally represented. The 1971 year-class appeared in the catches mostly on the southern Grand Bank, *i.e.*, south of 46°30'N. The length composition of this year-class in different sampling areas is illustrated in Fig. 11.

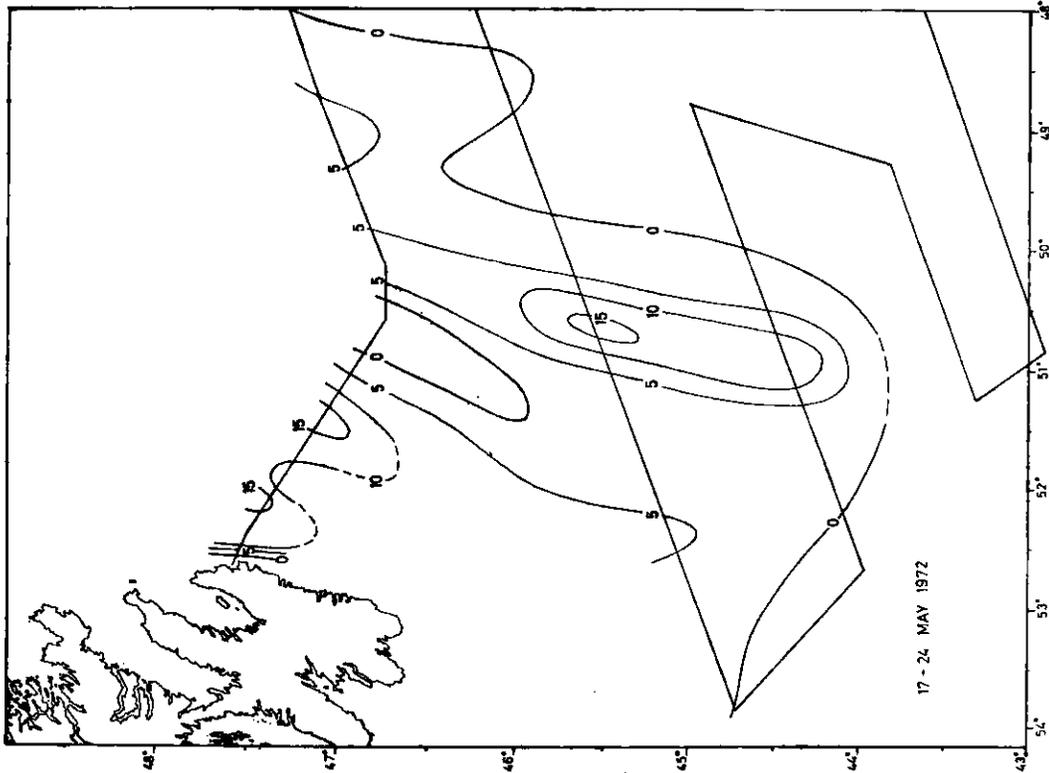


Fig. 3. Survey route and distribution of capelin 17-24 May 1972. The iselines indicate echo integrator readings.

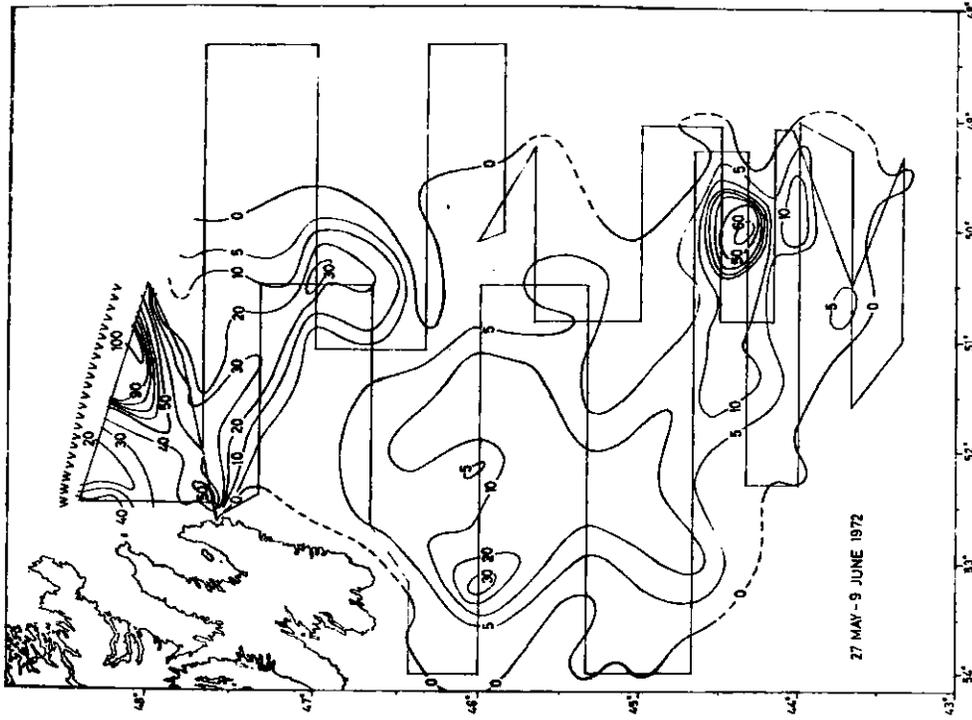


Fig. 4. Survey route and distribution of capelin 27 May-9 June 1972. The iselines indicate echo integrator readings. The route taken on 7-9 June is the same as in Fig. 5.

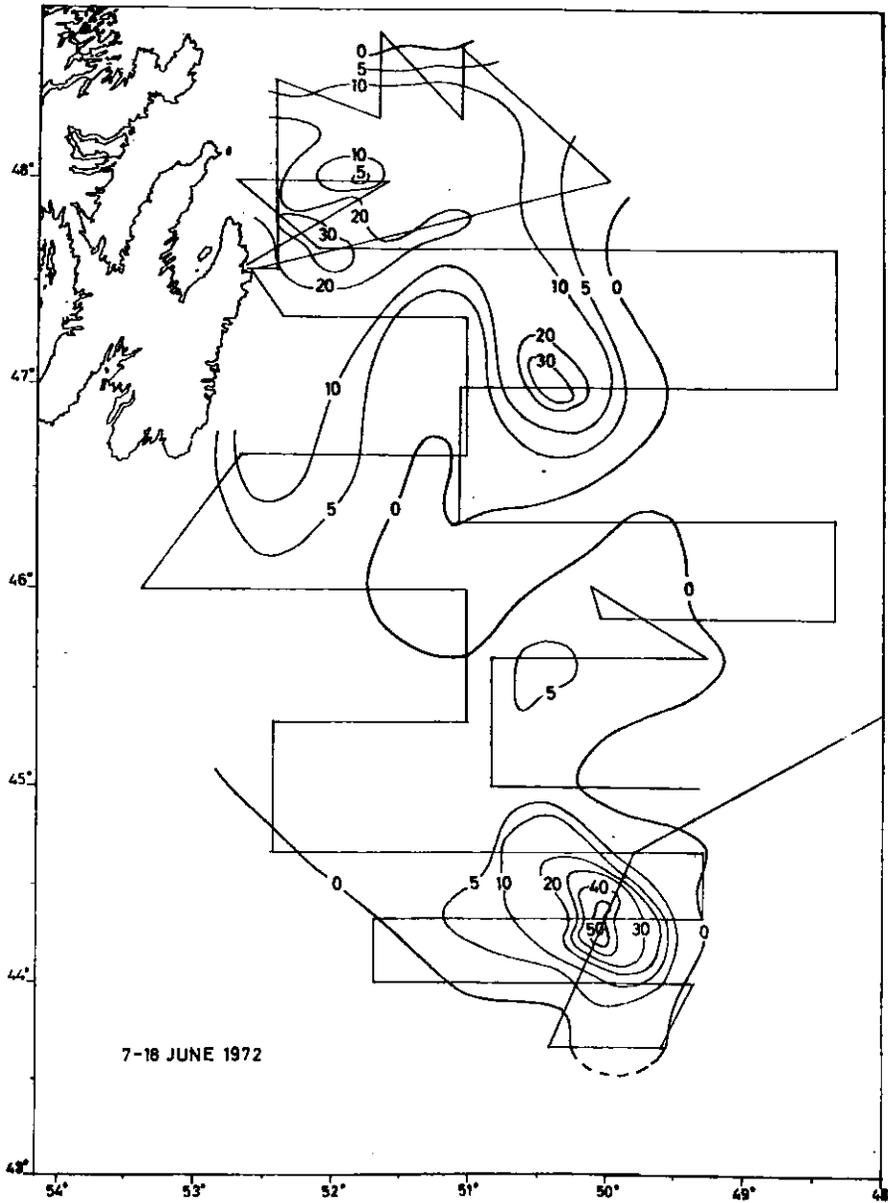


Fig. 5. Survey route and distribution of capelin 7-18 June 1972. The isolines indicate echo integrator readings. The route taken on 7-9 June is the same as in Fig. 4.

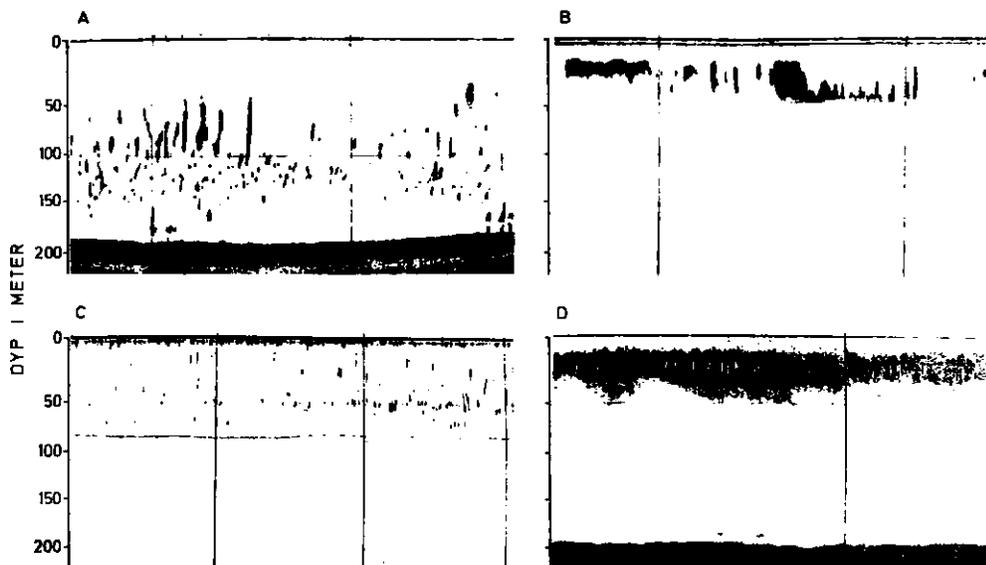


Fig. 6. Echo recordings of capelin (Simrad EK echo sounder) by day, (A) to (C), and by night (D). (A) is from the northern, (B) southern, and (C) central Grand Bank.

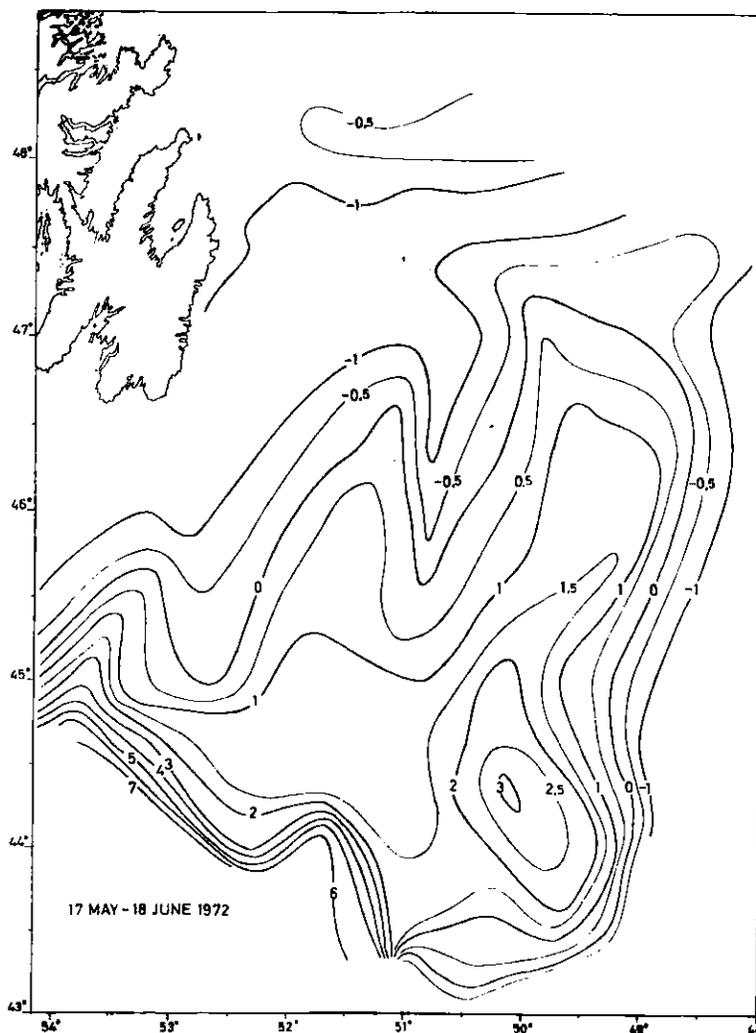


Fig. 7. Isotherms at the bottom 17 May-18 June 1972.

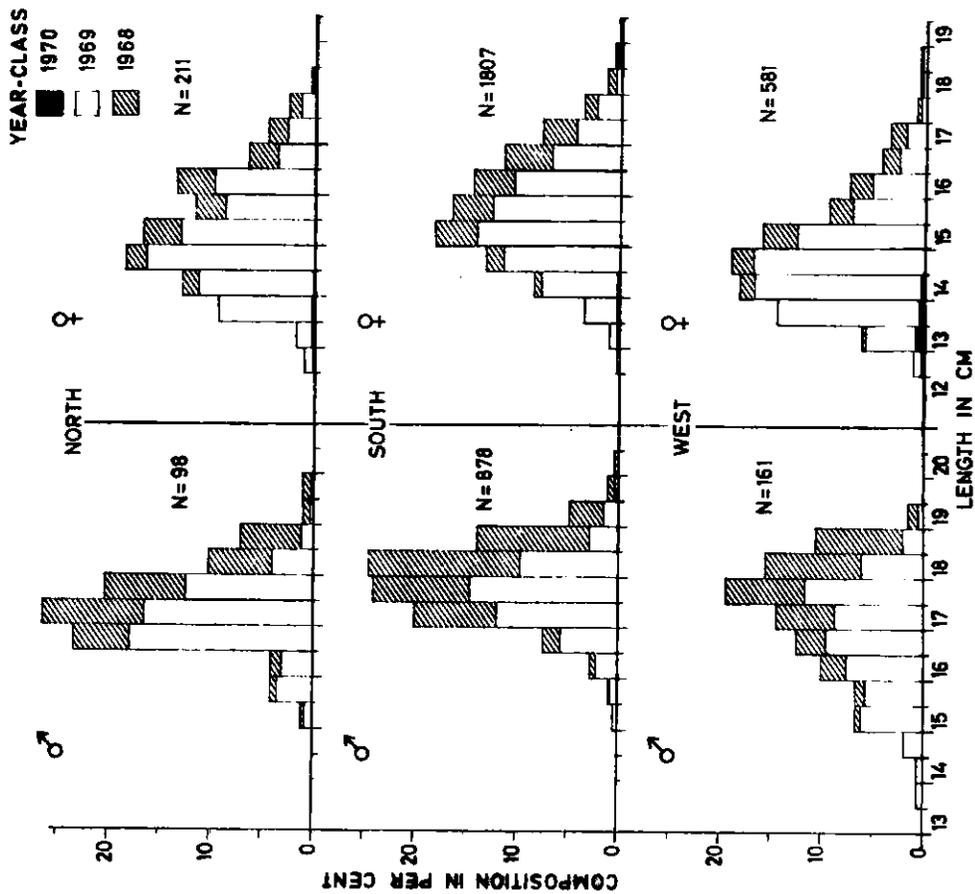


Fig. 9. Age and length composition of mature capelin by sex on the Grand Bank in May-June 1972. The border between south and north is set at 46°30'N and for the western area at 52°W.

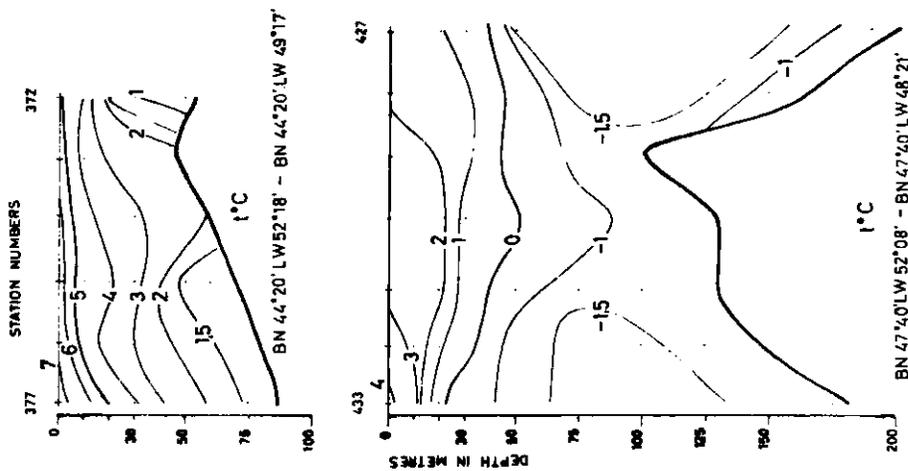


Fig. 8. Temperature in two sections on the Grand Bank in June 1972.

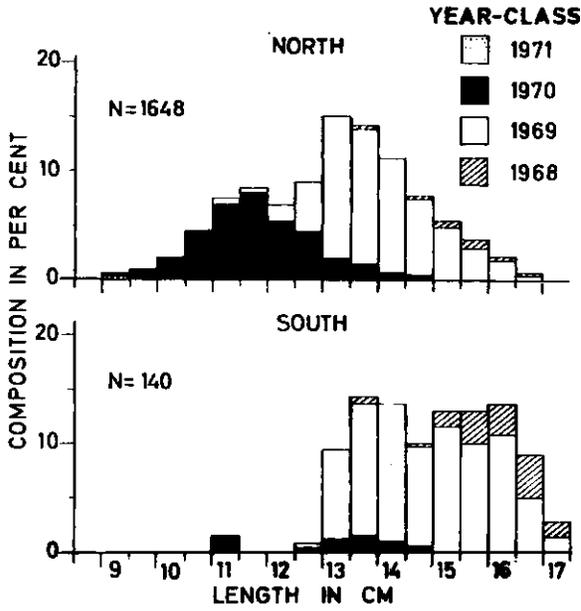


Fig. 10. Age and length composition of immature capelin on the Grand Bank in May-June 1972. The border between south and north is set at 46°30'N.

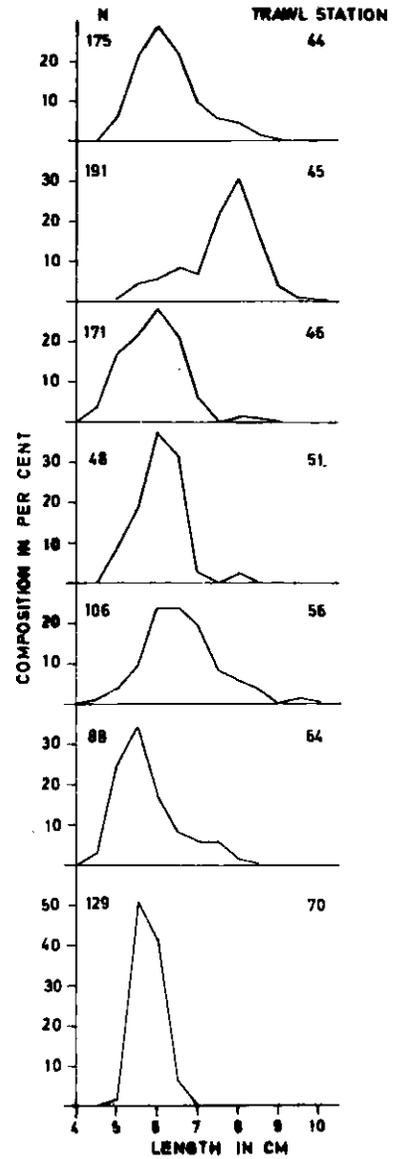


Fig. 11. Length distribution of the 1971 year-class of capelin on the Grand Bank in May-June 1972.

During the first and the second surveys the bulk of the fish were in maturity stages 1 and 2, whereas during the third survey capelin were nearer to spawning on the southern Grand Bank (maturity stages 3 and 4). Some of the capelin caught on 18 June at the Southeast Shoal were already spent (maturity stage 5). In the northern area the maturing fish were still in stages 1 and 2 on 10-12 June.

The echo abundance of capelin in the area was estimated on the basis of the second and third surveys (Fig. 4 and 5). The total abundance of capelin in the area covered was estimated to be about 800,000 tons (Table 1), using a C of 1.9 tons/mm x (n.m.)². However, the calculation of C is somewhat inaccurate, and the results should be interpreted with some caution. The constant C was estimated to be 2.17 tons/mm x (n.m.)² for maturing capelin in the Barents Sea. It is suggested that this figure was somewhat high and a value of about 2.0 tons/mm x (n.m.)² seems reasonable.

Table 1. Echo abundance (in tons) of capelin on the Grand Bank in different areas in May-June 1972.

Date	North of 46°30'N	South of 46°30'N		Total
		East of 52°20'W	West of 52°20'W	
27 May- 9 June	365	170	250	785
7 June- 18 June	325	125	35	485

The concentrations of mature capelin observed south of Cape Race (*i.e.*, south of about 46°30'N and west of 52°20'W) during the second survey (Fig. 4) were not recorded there during the third survey (Fig. 5). Assuming that these capelin had moved farther west to spawn outside the area covered during the surveys, the stock size at the Southeast Shoal (south of 46°30'N and east of 52°20'W) was estimated to be 125,000-170,000 tons (Table 1). The stock size north of 46°30'N was estimated to be 325,000-365,000 tons, of which 34.7% were mature.

CATCHABILITY OF CAPELIN

Devold, *et al.* (1972) held the opinion that off Newfoundland and Labrador a capelin shoal of 50 tons during summer and early autumn is a relatively large shoal. During this period of the year, therefore, the catchability of capelin with purse seine is not the best. He concluded that pelagic trawl probably was the most suitable gear for catching capelin off Newfoundland and Labrador.

Experiences from other fisheries are that catchability improves during the spawning migration. At this time the fish come together from different areas and are grouped in larger and denser shoals than during the feeding period. The present survey covered the period just prior to spawning. The conditions for fishing at this time should, therefore, be the best. Three Norwegian purse-seiners accompanied R/V *Johan Hjørt* during the survey. In the northern area the concentrations were not found to be dense enough for purse-seining during 18-30 May. The conditions for purse-seining were also poor at the Southeast Shoal from 18 May to 3 June. However, from the first week of June onwards, as concentrations became denser, purse-seining seemed a possibility. The conditions for trawling improved gradually during the first week of June at the Southeast Shoal, and throughout this month capelin were available for trawling with midwater trawl. The season, however, seemed to be relatively short since spawning had already started on 18-19 June, and probably would have been completed by the first half of July (Devold, *et al.*, 1972).

CONCLUDING REMARKS

The behaviour of capelin off Newfoundland during the spawning migration is apparently somewhat different from that observed for the Barents Sea capelin. No dense shoals were observed during the spawning migration on the Grand Bank towards the Southeast Shoal. The mature capelin were segregated from the immature part of the stock at the time the investigations were carried out and gradually approached the spawning grounds in rather small shoals, showing up as a dense but patchy scattering layer at the Southeast Shoal. In this shallow part of the bank, capelin find suitable spawning temperatures in about 50 m depth by mid-June when spawning commences.

It is tentatively concluded that not all the capelin recorded south of 46°30'N during the second survey migrated to the Southeast Shoal for spawning. The concentrations recorded in the area south of Cape Race might have migrated westward to spawn either along the south coast of Newfoundland, or at the St. Pierre Bank where spawning has been recorded in earlier years (Pitt, 1958; Templeman, 1968). No spawning concentrations were observed in the Virgin Rock region, although the environmental conditions for spawning in this region might be suitable. It is difficult to state where the mature part of the capelin stock recorded

on the northern Grand Bank migrated for spawning. It is suggested that most of the fish gradually approached the coast (Conception Bay, Trinity Bay and the area south of St. John's, Newfoundland). In contrast to the distribution of the maturing capelin in the Barents Sea, where the pre-spawners segregate from the immature part of the stock five to six weeks before they reach the Finnmark coast for spawning, both immature and mature fish were recorded off the east coast of Newfoundland. This may indicate that the wintering area, for maturing capelin approaching the east coast for spawning, is not far from the land and that the capelin do not undertake long distance spawning migration. Winters (1970) suggests that the most promising periods of the year during which coastal capelin can be commercially exploited are during the wintering period and the spawning season. The present investigations indicated that the concentrations did not appear in shoals suitable for purse-seining at the time the investigations were carried out, except at the Southeast Shoal. It might be that the conditions for purse-seining would improve as the pre-spawning capelin move closer to the shore.

The resources of capelin in the area surveyed were relatively low compared with the abundance observed along the Finnmark coast in 1971 and 1972 just prior to spawning (Dragesund, *et al.*, 1972). However, the abundance recorded may only be a small part of the total resource available off Newfoundland and Labrador. In order to obtain more information on the capelin resource in the Northwest Atlantic, research is required farther north along the coast throughout the summer and early autumn.

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21. Some biological characteristics of capelin, *Mallotus villosus*, in the Newfoundland area¹

by J.S. Campbell and G.H. Winters
Fisheries and Marine Service, Environment Canada
Biological Station, St. John's, Newfoundland

INTRODUCTION

Traditionally, the capelin fishery in the Newfoundland area has been mainly associated with the exploitation of coastal stocks of capelin during the beach-spawning period, when they are easily available to such primitive gear as beach seines and cast nets. Landings have generally amounted to less than 10,000 tons and most of the catches have been used for bait or as raw fertilizer. The recent decline in the herring fishery of the Northwest Atlantic, together with the increased world demand for fish, have focused attention on the capelin resources of the Newfoundland-Labrador area. As a result, landings of capelin increased from about 6,000 tons in 1971 to an estimated 70,000 tons in 1972 of which a substantial proportion was taken by the Soviet fleet in offshore waters. A further increase in landings is expected in 1973 as other Member Countries become involved in the fishery.

The anticipated rapid expansion of an offshore fishery for capelin has led to concern that over-exploitation of the capelin resource may have a detrimental effect on other fish species which support important fisheries both offshore and inshore in the Newfoundland area. Coastal fishermen may be particularly affected as capelin are known to attract cod, salmon and other species to coastal waters where they can be caught by a variety of fixed gears.

This paper examines the available information on the biology of capelin stocks in the hope that management measures may be implemented at an early stage while additional biological data are collected.

DISTRIBUTION

Capelin have a boreo-Arctic distribution and so are found in the northern regions of the Atlantic and Pacific Oceans. In the eastern Atlantic, the species is abundant from the Trondheim Fjord of Norway north to the vicinities of Jan Mayen, Spitzbergen and western Novaya Zemlya at the eastern extremity of the Barents Sea. Capelin not only occur around the shores of Iceland and the Faroes but also off Greenland where they are found as far north as Thule (76°N) on the west and Scoresby Sound (70°N) on the east. Capelin have been reported from the Coronation Gulf, Bathurst Inlet and Great Fish River of the Canadian Arctic as well as from the southern half of Hudson Bay including James Bay and from Ungava Bay. From Saglek south along the Labrador coast, capelin occur in large quantities wherever suitable spawning beaches are found and their distribution extends over the banks of the Labrador Shelf, the Grand Bank and St. Pierre Bank. They are especially abundant off the southern, eastern and northeastern shores of Newfoundland. In the western Gulf of St. Lawrence capelin are common on the northern shore, although in colder years they also occur extensively around Gaspé, Anticosti Island and Bay Chaleur. South of the Cabot Strait, they occur sporadically and in cold periods have been reported from southeastern Cape Breton and occasionally from the Bay of Fundy and the Gulf of Maine. In the Pacific, capelin are distributed from Cape Barrow, Alaska around the Bering Sea south along the Pacific coast of Canada to the State of Washington and on the Asiatic coast from the Sea of Chukotsk south to Hokkaido Island, Japan and the T'umen River, Korea (McAllister, 1963; Templeman, 1968; Winters, MS, 1966).

REPRODUCTION

Two types of spawning occur in the Northwest Atlantic area, demersal offshore spawning and inshore beach-spawning. Offshore spawning aggregations of capelin were first discovered in 1950 on the Southeast Shoal of the Grand Bank (Pitt, 1958). These offshore capelin were found to spawn under highly specific conditions requiring a narrow temperature range (2.5°-4.5°C) and a well defined substrate (fine gravel between 0.5 and 2.2 mm in diameter). In the Southeast Shoal area spawning normally begins during the third week of June and is generally completed by mid-July. In cold years, however, spawning may extend into early August (Pitt, 1958). Although demersal spawnings have not been reported from other offshore areas, it is possible that capelin also spawn on the shallow parts of St. Pierre Bank and perhaps also Whale and Green Banks off the south coast of Newfoundland. It is unlikely that offshore spawning occurs on Hamilton Inlet Bank as temperature, depth and substrate conditions conducive to bottom spawning do not appear to be available in that area.

Beach-spawning of capelin begins progressively later from south to north in the Canadian Atlantic area. In the southern Gulf of St. Lawrence, spawning begins in early May, which is several weeks earlier than the spawning period on the south coast of Newfoundland where mass beach-spawning usually begins the first week in June (Templeman, 1948). Along the east coast of Newfoundland, beach-spawning does not begin until

¹ Submitted to the 1973 Annual Meeting of ICNAF as ICNAF Res.Doc. 73/90.

the third or fourth week in June and in northern Labrador, it is usually mid-August before mass beach-spawning occurs. The most favourable temperatures for beach-spawning ranges from 6.0° to 8.5°C and the best spawning beaches are made up of gravel 5 to 15 mm in diameter.

Capelin may reach sexual maturity as early as age-group 2, but mass maturation normally occurs at age-groups 3 and 4 (Fig. 1). The larger and older fish spawn first and, in the case of males, remain on the spawning grounds longer than the younger fish. Fecundity ranges from 16,550 eggs to 61,500 eggs with a mean of 33,850 eggs (Winters, 1971).

Following the spawning season, masses of dead capelin have been found on the surface indicating a high mortality at this time. Preliminary results show that repeat spawning does occur in capelin and on a percentage basis, repeat spawning is more common in females (30%) than among males (10%). Thus, the size of the spawning stock of capelin is not entirely determined by recruitment alone but also in part by the survival of fish from previous spawnings (Winters, MS, 1970a).

SEASONAL DISTRIBUTION AND MOVEMENT OF STOCKS

At least some of the capelin stocks along the east coast of Newfoundland remain near the coast during the winter and spring months. During the overwintering period (January-March), Winters (1970b) found coastal capelin concentrated in large inactive schools in Trinity Bay, Newfoundland at a depth range of 140-200 m. These aggregations were composed of both sexes, quite high in fat content but were not feeding. In early April echo-sounder surveys, verified by midwater trawl hauls, indicated that the overwintering capelin moved up into the warming surface waters and dispersed to feed. At this time the maturing fish became segregated from the immatures which tended to form relatively larger schools than the maturing fish. Feeding continued into early June when the ripening fish were approaching the beaches for spawning.

That capelin are present in coastal waters all along the coast of Newfoundland and Labrador during the overwintering and pre-spawning period has been substantiated by the following observations:

- (1) Many reports of mass mortalities of capelin in winter and spring in inshore bays due to the effect of cold water (Templeman, 1948).
- (2) Sporadic occurrences of capelin in shallow water close inshore in late winter-early spring; these so-called "whitefish" are often taken by the local residents for food.
- (3) Presence of capelin in the stomachs of cod, salmon, Greenland halibut, seals and sea-birds in coastal waters during the winter and spring.
- (4) Frequent catches of capelin by commercial trawlers and purse seiners in various Newfoundland bays during winter and spring.

Capelin are also abundant on the Grand Bank in winter and spring (Templeman, MS, 1967). On the northern section of the Grand Bank in late March 1961, large quantities of cod were present feeding on concentrations of capelin (Templeman, 1965). In February 1972, Soviet vessels located schools of capelin in deep water (150-250 m) on the northern slope of the Grand Bank and on the northern and northwestern parts of the Bank in March (Kovalyov and Kudrin, MS, 1973). During this period concentrations of capelin were also present in the Avalon Channel area. During May and June the same vessels reported an intensive southerly migration towards the southern part of the Bank where fishable concentrations of capelin were present in early June (Hinds, MS, 1973).

During late May and early June 1972, Norwegian survey vessels showed capelin to be widely distributed throughout the Grand Bank area from the ice border to the tail of the Bank (Dragesund and Monstad, MS, 1972). The largest concentrations at this time were in the northern area of the Grand Bank and consisted mainly of immature capelin. This observation agrees with those of Templeman (MS, 1967) and Kovalyov and Kudrin (MS, 1973), suggesting that the northern part of the Grand Bank is a major nursery area for immature and pre-recruiting capelin. Kovalyov (MS, 1972) also reports that the survivors of the Southeast Shoal spawning migrate to the northern part of the Bank after spawning. This is supported by the capture of spent capelin by the R/V *A.T. Cameron* in the northern and central area of the Bank in June 1969.

There is some evidence to suggest that a portion of the Grand Bank capelin, particularly those on the western and northwest slopes, migrate inshore to spawn on the beaches of eastern Newfoundland. Templeman and Fleming (1962) report that cod tagged on the northwest part of the Grand Bank in early June were feeding heavily on capelin. These cod approached the Avalon Peninsula very rapidly and tagged fish were recaptured on the western side of the Avalon Peninsula in late June during the capelin spawning period in that area. Since capelin form almost the sole food of the cod at this time, it seems likely that the cod followed the capelin from the Grand Bank to shore.

The post-spawning movements of the survivors of inshore spawning are not known but presumably they move offshore to feed, perhaps joining the pre-recruits of the subsequent spawning season. Substantial concentrations of adult and immature capelin have been found in the Hamilton Inlet Bank in late August-September

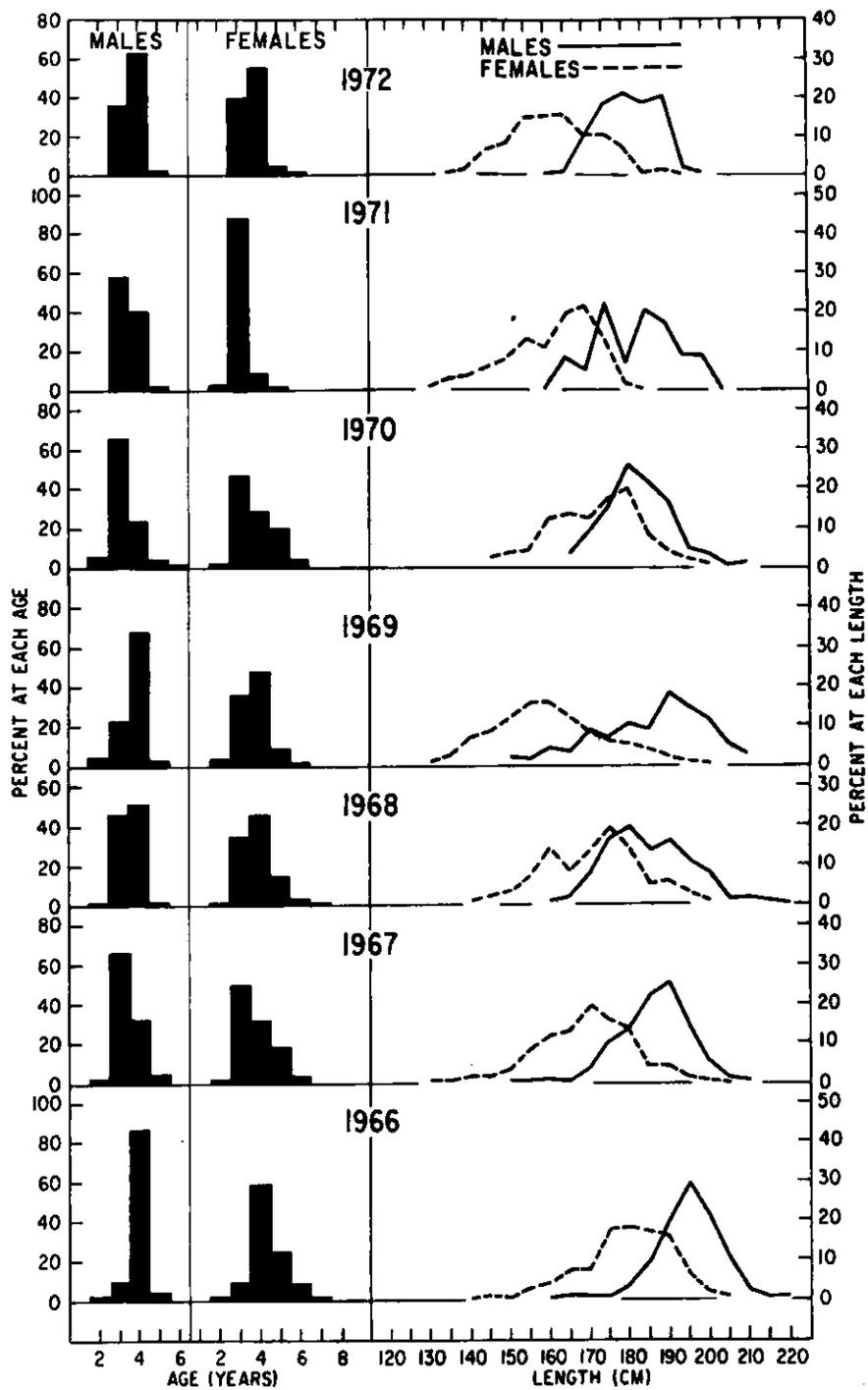


Fig. 1. Age and length frequency by percent of pre-spawning capelin from the Grand Bank, June 1966-72.

of 1970 and 1971 by Norwegian survey vessels (Devold, 1970; Devold and Westergaard, 1972). Soviet surveys of the area from September to December in 1972 (Kovalyov and Kudrin, MS, 1973) indicate that these capelin gradually migrate southwards in the autumn and by early December are mainly located off Notre Dame Bay, Newfoundland between 50°00'-51°00'N and 52°30'-54°00'W (Fig. 2). It is possible that these capelin subsequently migrate inshore to overwinter under the ice in Notre Dame Bay.

FEEDING INTENSITY AND FAT CONTENT

Mature capelin do not appear to feed from late January to March but by early April, feeding resumes and becomes very intense in mid-May (Winters, 1970b). Feeding intensity greatly decreased by early June. Immature capelin follow the same pattern when feeding except that there is no decrease in June. By the start of the spawning season in mid-June, capelin cease feeding, except for capelin eggs swallowed incidental to their respiratory activities. The survivors of spawning resume feeding again several weeks after the end of the spawning period and feeding proceeds at a high intensity until late fall when feeding ceases.

There is a gradual decline in the fat content of mature capelin from the overwintering to the spawning period. Fat content of ripe capelin captured at the beginning of the spawning season ranges from 3% to 8% and may decline to between 1-2% during the spawning period. During the post-spawning season the survivors of spawning appear to regain their fat content rapidly and by late autumn possess a fat content as high as 20%. Capelin caught off the coast of Labrador in the vicinity of Hamilton Inlet in 1972 had a fat content of from 13% to 20%.

LANDINGS OF CAPELIN

Concentrations of capelin which can be commercially exploited occur during the spawning period and the overwintering or feeding period. The location, distribution and movement of these aggregations indicate that both an inshore and offshore fishery can exist.

During the early 1900's capelin were used extensively for raw fertilizer, dog food and bait. Landings were as high as 25,000 tons (Templeman, MS, 1967) for the Newfoundland area. In 1950 about 20,000 tons were reduced into meal and oil on an experimental basis and since then, landings have declined continuously to around 5,000 tons between 1960 and 1970 (Table 1). This decline has been mainly due to a change in fishing methods for cod (gillnets instead of baited hook and line), and a decrease in the domestic use of capelin as fertilizer and dog food. Canadian offshore landings of capelin were reported for the first time in 1972 as a result of exploratory fishing surveys conducted by vessels under charter to the Fisheries and Marine Service of Environment Canada (Hinds, MS, 1973).

Table 1. Landings of capelin (metric tons) for the period 1960-72 (data from the Annual Statistical Review of Canada's Fisheries, Environment Canada).

Year	Newfoundland		Quebec	Total
	Inshore	Offshore	Inshore	
1960	7,014	-	-	7,014
1961	5,106	-	-	5,106
1962	4,449	-	-	4,449
1963	5,374	-	-	5,374
1964	4,877	-	-	4,877
1965	4,784	-	-	4,784
1966	4,848	-	-	4,848
1967	3,456	-	188	3,644
1968	3,314	-	62	3,376
1969	3,446	-	157	3,603
1970	3,340	-	119	3,459
1971	2,517	-	49	2,566
1972	881	3,487	165	4,533
Total	53,406	3,487	740	57,633

CAPELIN PREDATORS

Capelin are the main prey organism for a great variety of fish, marine mammals and sea-birds in the Newfoundland-Labrador area and as such play a vital role in the trophic ecology. Off the east coast of Newfoundland, cod migrate from the northwestern edge of the Grand Bank to the Avalon Peninsula in pursuit of capelin during the months of June and July (Templeman, MS, 1967). These cod have mostly spawned and by feeding almost entirely on capelin regain condition and put on a large proportion of their annual growth (Templeman, 1965). Consequently, the inshore codtrap fishery in most areas of Newfoundland is, at least to

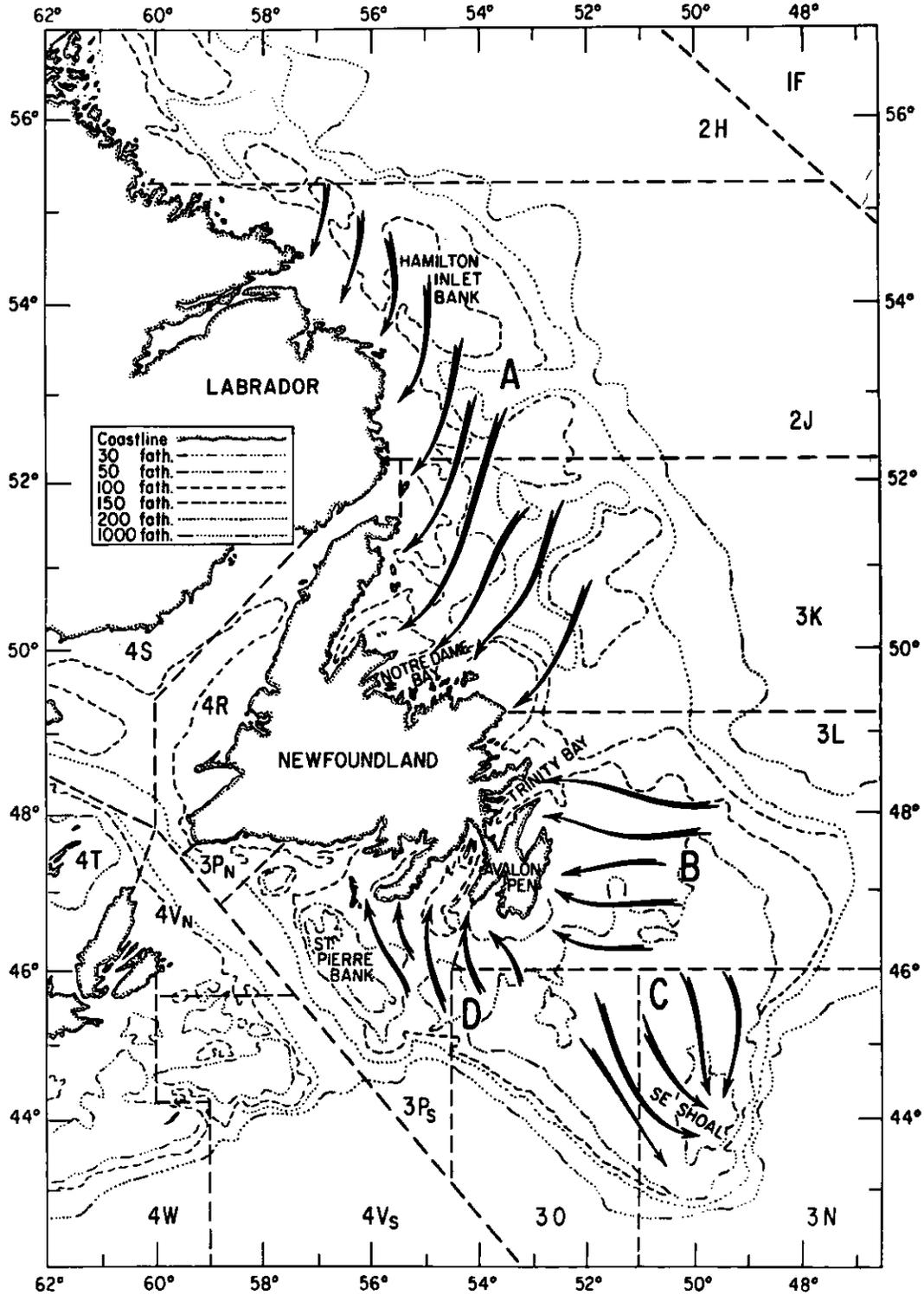


Fig. 2. Possible migration pattern of mature capelin off Newfoundland and Labrador.
A. Labrador-Northeast Newfoundland stock
B. Northern Grand Bank-Avalon stock
C. South Grand Bank stock
D. St. Pierre-Green Bank stock

some extent, dependent on the movement, availability and abundance of capelin. Later in the summer, cod in deeper water are found to feed almost exclusively on small 1-year-old capelin (Templeman, 1948). Salmon which approach the coast in May and June feed mainly on capelin while haddock, American plaice and halibut also prey on capelin or capelin eggs at certain times in the year.

DISCUSSION AND CONCLUSIONS

The development of an intensive fishery for capelin in the Newfoundland area will undoubtedly reduce the biomass of capelin available to its major predators. In terms of the predator-prey relationship, this reduction can have two effects. Firstly, if food is a limiting factor to the survival of the species and no suitable alternative prey organism is available in similar quantities, a reduction in the biomass of capelin would result in a reduction in the abundance of the predator. This may have a selective effect, having its greatest influence at those times of the year when the predator is either dependent on capelin to regain body condition after the overwintering and spawning period (*i.e.*, cod) or when the predator requires capelin to nourish its young (*i.e.*, sea-birds). Secondly, assuming that suitable alternative prey organisms are available, a reduction in capelin abundance may greatly affect the predator's distribution and migratory pattern. This could have a great effect on the fishery prospects of inshore fishermen who depend on the spawning migration of capelin to attract various fish species towards shore where they become available to fixed gear. Cod and salmon are of particular importance in this instance even though natural migration instincts may also play a role.

A crude estimate of the biomass of capelin in the Newfoundland-Labrador area may be obtained from estimates of the biomass of the major predators and their consumption rates of capelin. Population numbers for the period 1966-69 of the Div. 2J-3KL and 3NO stocks of cod are available from Pinhorn and Wells (MS, 1972; MS, 1973). Application of mean weights to these numbers gives an average stock size of approximately 2,500,000 tons for the Div. 2J-3KL stock and 300,000 tons for the Div. 3NO stock for the 1966-69 period. The Div. 2GH cod stock complex averaged about 150,000 tons over the same period (Wells, pers. comm.). This provides a total stock biomass of cod along the eastern coast of 2,950,000 tons.

Data collected from feeding studies on cod in Div. 2J-3KLNO indicate that during the month of May and June, cod feed almost exclusively on capelin but from November to April, capelin make only a minor contribution by volume to the total food consumed (Fig. 3), (Templeman, 1965; Templeman, pers. comm.). The mean percent by volume of capelin taken by cod for different periods is shown below:

<u>Interval</u>	<u>Mean percent</u>
February-November	25.4
June-November	39.0
April-October	48.0
January-October	18.9
All data combined	31.9

From preliminary data collected on the food of cod in Div. 3L, it appears that, on the average, cod consume from 0.5 to 1.0 times their own weight in capelin annually. Assuming that this consumption rate applies all along the coast of Newfoundland and Labrador, then a crude estimate ranging from 1,475,000 to 2,950,000 tons of capelin would be consumed by cod annually.

Sergeant (1973) has estimated that the harp seal population along the Canadian east coast consume about 400,000 tons of capelin annually. Other species of seal (grey, harbour, hood) may consume upwards to 50,000 tons of capelin annually. Muir (MS, 1973) provides estimates of 150,000 tons of small fish consumed by sea-birds, most of which are located along the coast of Newfoundland and Labrador and feed principally on capelin. Fin whales off Newfoundland and Nova Scotia consume approximately 120,000 tons of fish annually (Muir, MS, 1973), some of which are capelin. The dominant food item of Minke whales off Newfoundland is capelin (Sergeant, 1963). These consume 15-30 tons of fish per whale during their stay in the North Atlantic area but no estimate is available of the stock size. Besides the above species, predating on capelin at some time in their life history are salmon, dogfish, yellowtail flounder, turbot and tuna. Thus, a rough estimate of the annual consumption of capelin along the east coast of Newfoundland and Labrador ranges from 2,200,000 to 3,700,000 tons. This amount is essentially then a minimum estimate of the surplus production of capelin for this area.

The Div. 2J-3KL cod stock prior to the development of an offshore fishery in the mid 1950's was probably substantially larger than current levels of stock abundance and comprised a greater proportion of large adult fish (Pinhorn, pers. comm.). Also, the larger adult portion of the stock in cod from Div. 3NO in recent years is less than in the early 1960's. Furthermore, the harp seal population as recently as 1950 was most likely twice the current size. Haddock which feed on capelin eggs on the Grand Bank have been reduced to a small fraction of their former population size; however, the yellowtail population on the Grand Bank has increased substantially (Pitt, 1970). Since yellowtail also feed on capelin eggs

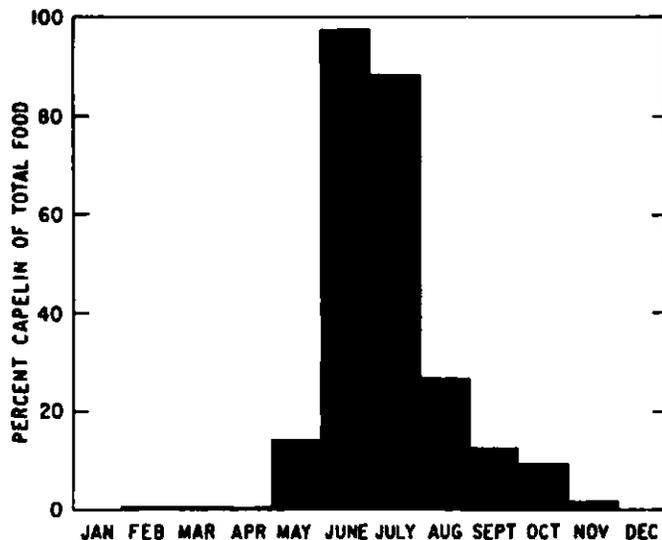


Fig. 3. Contribution of capelin to the total food consumed by cod as a percentage by volume by month. Div. 2J-3KLNO, all gears combined.

(Pitt, pers. comm.), some of the capelin production released by the decline of the haddock stock has possibly been taken up by the yellowtail. Nevertheless, there would appear to be a substantial amount of surplus production of capelin released by the decline in stock abundance of its major predators. This surplus production may be partially taken up by other species which compete with the major predators for the capelin resource.

In conclusion, there is probably a significant surplus production of capelin available on the east coast of Newfoundland and Labrador which could be commercially exploited without undue detriment to the viability of its major predators. However, any attempts to exploit vast quantities of capelin must first be reviewed in the light of the resultant effect such a depletion would have on the important commercial species for which capelin form an important source of food.

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**SECTION H
SHELLFISH**

22. Stock assessment of common American squid in ICNAF Subarea 5 and Statistical Area 6^{1,2}

by I. Ikeda and F. Nagasaki
Far Seas Fisheries Research Laboratory, Shimizu, Japan

and

H. Imanaga
Nippon Suisan Co., Ltd., Tokyo, Japan

INTRODUCTION

In ICNAF Subarea 5 and Statistical Area 6, the Japanese trawl fleet first fished the common American squid in January 1968. The first year of operation was experimental and yielded about 170 tons of squid. The fishery developed rapidly and almost all of the wintering area of this species was covered by the Japanese fleet in the 1968-69 season when a total of 4,446 tons was landed. The fishing season extends from November to May. Since the 1969-70 season, the fishing operation has been stable with annual catches between 10,000 and 15,000 tons.

Fairly detailed catch statistics of squid from the ICNAF waters are given in ICNAF Statistical Bulletin, Vol. 21 for 1971. In 1971, about 22,000 tons were caught in Subarea 5 and Statistical Area 6 combined, 48% by Japan, 28% by USSR, 19% by Spain, and 5% by USA. In the commercial sense, however, two species of squid are observed in this area - the common American squid (*Loligo pealei*) and shortfinned squid (*Illex illecebrosus*). Almost all of the squid taken by Japanese trawlers are the common American squid.

In the present report, stock assessment of the common American squid in this area are made on the basis of daily catch records by Japanese trawlers throughout four seasons from 1968-69 to 1971-72. Almost all of the catch records are used for this analysis.

MATERIALS AND METHODS

The daily catch records by vessels include the locations where fished, fishing effort in terms of the number of hauls made and the catch in weight by size categories. These daily records were grouped by small statistical areas (10' x 10') and by 10-day intervals. The catches were carefully sorted on board the vessels, into each size category, so that the size classification does not change with season, location, and vessel. The catch in weight, therefore, can easily be converted to the catch in number of squid, on the basis of the appended table which shows number of individuals per case for each category.

Stock size in numbers and other parameters are estimated by two different methods - directly by areal estimate (density-area method) and indirectly by DeLury's method. By the DeLury, the following equation can be applied to the relationship between the number of squid caught per haul and the accumulated catch up to that time:

$$C_t = k(N_0 - K_t)$$

where C_t = number of squid caught by haul during the time period t
 k = catchability coefficient
 N_0 = stock size in number at the beginning of the season
 K_t = accumulated catch up to the period t .

RESULTS

Seasonal change in the catch and the catch per haul

The catch of squid and the catch per haul (in numbers) by 10-day periods in Subarea 5 and Statistical Area 6 combined are shown in Fig. 1. The diagrams indicate that the seasonal pattern of fishing (i.e., the time of beginning, closing and the peak of operations) varied considerably year by year. It is also shown that, when the catch by 10-day periods is larger, the catch-per-haul value during that period is also high and vice-versa.

Estimation by areal method

Relative stock size on the fishing grounds can be obtained from the catch-per-haul value multiplied by the area of the grounds. The values thus calculated by 10-day periods for each season are indicated in Fig. 2. Intra-seasonal change in relative abundance suggests that the abundance increases through immigration

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² Contribution No. 104 from the Far Seas Fisheries Research Laboratory

during the first half of the season and decreases not only through fishing but also through emigration during the latter half. It is assumed, therefore, that immigration is completed at the time when the estimated relative abundance becomes largest. As is shown in Fig. 2, the time of full immigration varies year by year (i.e., the last ten days of February in 1968-69, the last ten days of January in 1969-70, the early ten days of February in 1970-71, and the last ten days of December in 1971-72). Based on the highest value of relative abundance, absolute numbers of squid on the fishing grounds are estimated as given in Table 1. In order to obtain the initial stock size, the accumulated catches to that period are added to the stock size on the grounds.

Table 1. Estimated abundance in number of squids in Subarea 5 and Statistical Area 6.

Item	Season			
	1968-69	1969-70	1970-71	1971-72
Area of fishing grounds (km ²)	5,145	6,688	7,974	5,917
Catch per haul in number (10 ³)	33.41	29.07	21.28	32.75
Hours per haul	1.61	1.72	1.64	1.82
Speed of net (knots)	3.75	3.75	3.75	3.75
Width of the wing (m)	25	25	25	25
Area covered by one haul (km ²)	0.280	0.299	0.285	0.317
Density (10 ³ /km ²)	119.3	97.2	74.7	103.3
Stock size on the grounds (10 ⁶)	613.8	649.4	595.7	611.2
Initial stock size (10 ⁶)	628.6	693.1	641.7	634.6

The results obtained show that almost the same number of squid immigrated into the fishing grounds each year. In the estimations mentioned above, however, the effective area covered by the net is calculated from the width at the mouth of the wing. It is likely that the density of squid thus calculated would be more or less over-estimated. Although the trawl net used by the Japanese vessels fishes from the bottom up to about 7 m from the bottom, echo reflection reveals that a school of squid may be up to 10 m from the bottom. Taking these indications into account together with the fact that this species moves upwards at night, it is quite reasonable to accept that the estimated values tend to be higher than the real ones. Bias from various sources might be included in the estimates. However, these estimated values may be accepted as a first approximation at least at the present stage of knowledge.

Estimation by DeLury's method

The catch per haul by 10-day periods are plotted against the accumulated catch in Fig. 3. Since the catch per haul increases during the first half of the fishing season, the data up to the period when half of the total annual catch was reached and those near the end of the season when the catch per haul drops sharply are omitted from the calculations for the regression between the two series of figures. The results thus obtained are as follows:

$$\begin{aligned}
 1968-69 \text{ season} & C_t = 1.06 \times 10^{-3}(35.9 \times 10^6 - K_t) \\
 1969-70 \text{ season} & C_t = 0.43 \times 10^{-3}(94.4 \times 10^6 - K_t) \\
 1970-71 \text{ season} & C_t = 0.31 \times 10^{-3}(87.6 \times 10^6 - K_t) \\
 1971-72 \text{ season} & C_t = 0.34 \times 10^{-3}(101.4 \times 10^6 - K_t)
 \end{aligned}$$

The initial stock sizes given in the above equations are those at the period from which regression equations are applied. These estimated stock sizes appear to be more or less under-estimated because that for the 1971-72 season, for instance, is less than the actual catch. The catchability coefficients estimated, on the other hand, are quite similar for three years (the 1969-70 to 1971-72 seasons), but they are probably over-estimated because of considerable emigration from the fishing grounds.

Fishing and catchability coefficients and dispersion rate

The fishing rates and the catchability coefficients for Japanese trawlers are calculated from the estimated stock size in numbers together with the total catch and the catch per haul. The fishing rates and the catchability coefficients for recent years are estimated to be in the range of 10-20% and 2.2×10^{-5} to 3.4×10^{-5} , respectively.

Table 2. Fishing rates and catchability coefficients by Japanese trawlers.

Season	Stock size in number (10 ⁶)	Catch in number (10 ⁶)	Fishing rate	Number of hauls (10 ³)	Catchability (10 ⁻⁵)
1968-69	628.6	47.9	0.08	3.3	2.5
1969-70	693.1	112.2	0.16	5.4	3.4
1970-71	641.7	64.5	0.10	5.2	2.2
1971-72	634.6	130.9	0.21	7.2	2.9

It should be noted that the catchability coefficients (q) thus calculated from the areal method are much less than those (k) estimated from DeLury's method. Values estimated by the DeLury for the recent three years (since 1969-70) are proportional to these by the direct method, and the difference between these two figures must be caused by dispersion from the fishing grounds covered. Assuming that no natural mortality occurs during the fishing season, the dispersion rate (d) can be calculated from the following equation:

$$d = (1 - e^{-kX}) - (1 - e^{-qX})$$

where X is the number of hauls expended during the later part of the fishing season, e.g. from the height of the fishing to the end of the season. The dispersion rates thus calculated are 0.88, 0.64, 0.42 and 0.57 in the 1968-69, 1969-70, 1970-71 and 1971-72 seasons, respectively.

DISCUSSION

The degree of dispersion from the fishing grounds estimated above are considerably larger than the reduction by current fishing. Therefore, the observed decrease in catch-per-unit effort during the later half of the season does not at all represent the decrease of the stock by fishing.

The direct estimate stands on the assumption that the immigration to the fishing grounds is completed at the time when the relative abundance becomes largest. However, commercial operations are not carried out on the grounds where the density of squid is lower than a certain level. There must be some groups of squid in less density outside the fishing grounds. Therefore, the stock size estimated by the direct method must be a minimum value. Assuming that the squid catch of 22,000 tons from Subarea 5 and Statistical Area 6 during the 1970-71 season did not include any other species than common American squid, the Japanese catch amounted to about 50% of the total which is estimated to be about 0.1 in the fishing rate (see Table 2). Therefore, the overall fishing rate must be 0.2. Although no information is available for the stock-recruitment relationship of this species, it is thought that 20% of the initial stock size can produce sufficient recruits. If this is the case, four times the 1971 catch, i.e., about 80,000 tons, can be expected as the allowable catch from the squid stock in this area.

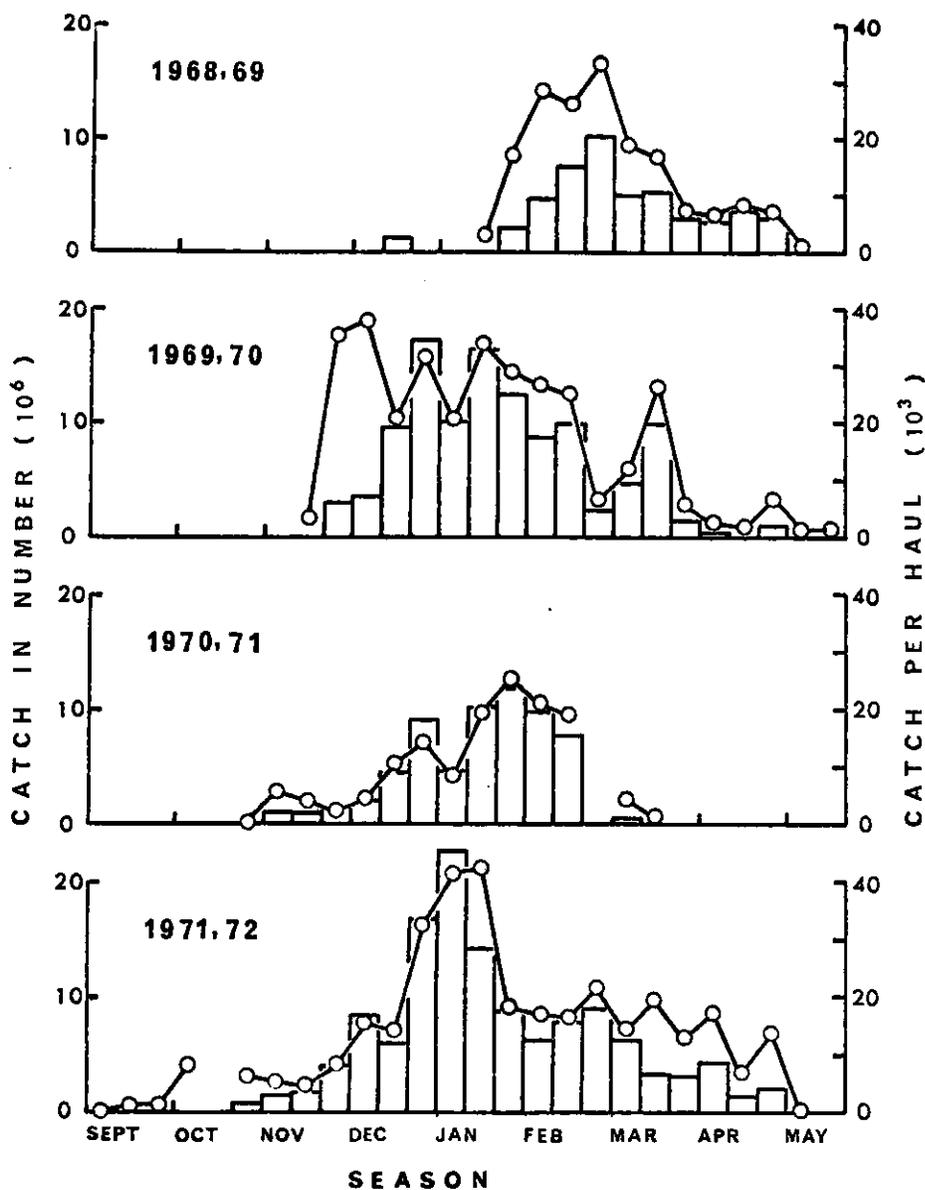


Fig. 1. Seasonal change in the catch and the catch-per-haul of common American squid in ICNAF Subarea 5 and Statistical Area 6 by 10-day periods (the catch by bar graph and the catch-per-haul by circle).

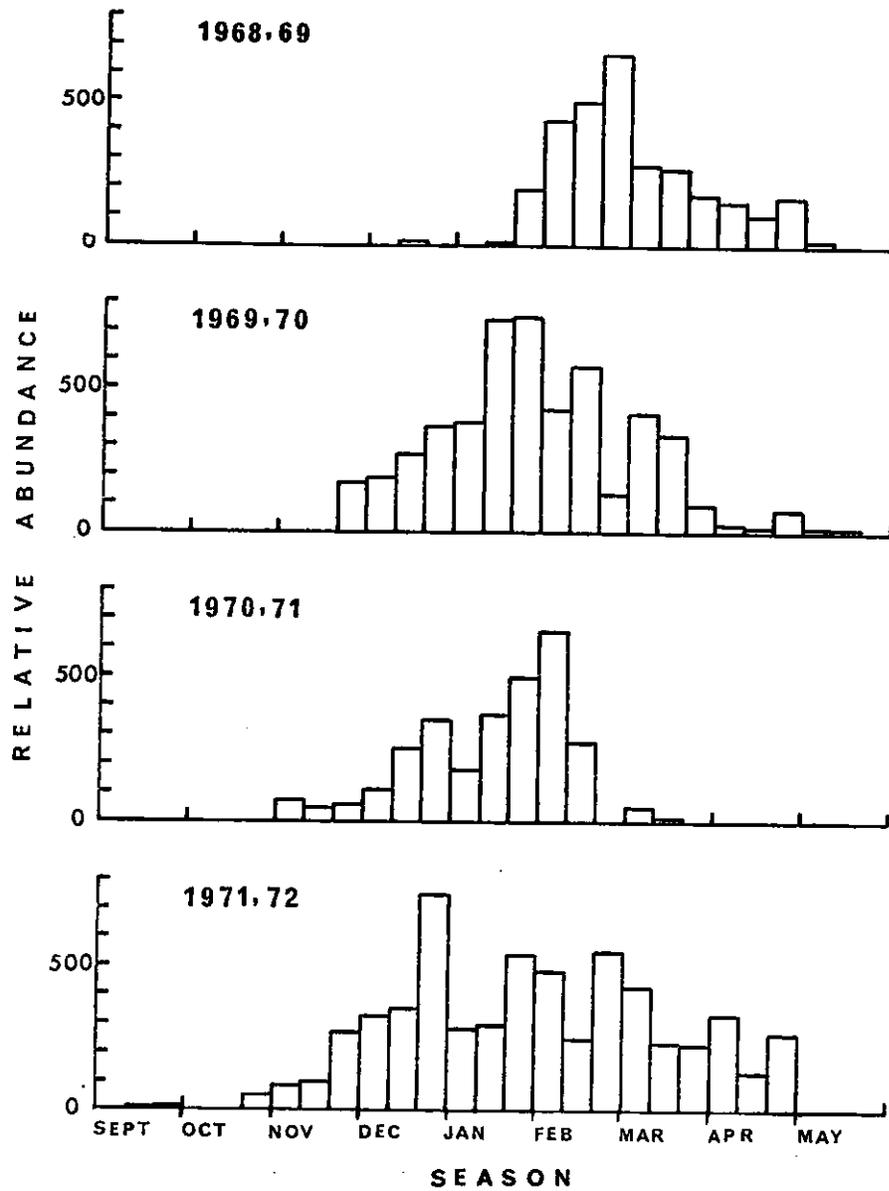


Fig. 2. Seasonal change in the relative abundance (catch-per-haul X area of fishing grounds) of common American squid in Subarea 5 and Statistical Area 6.

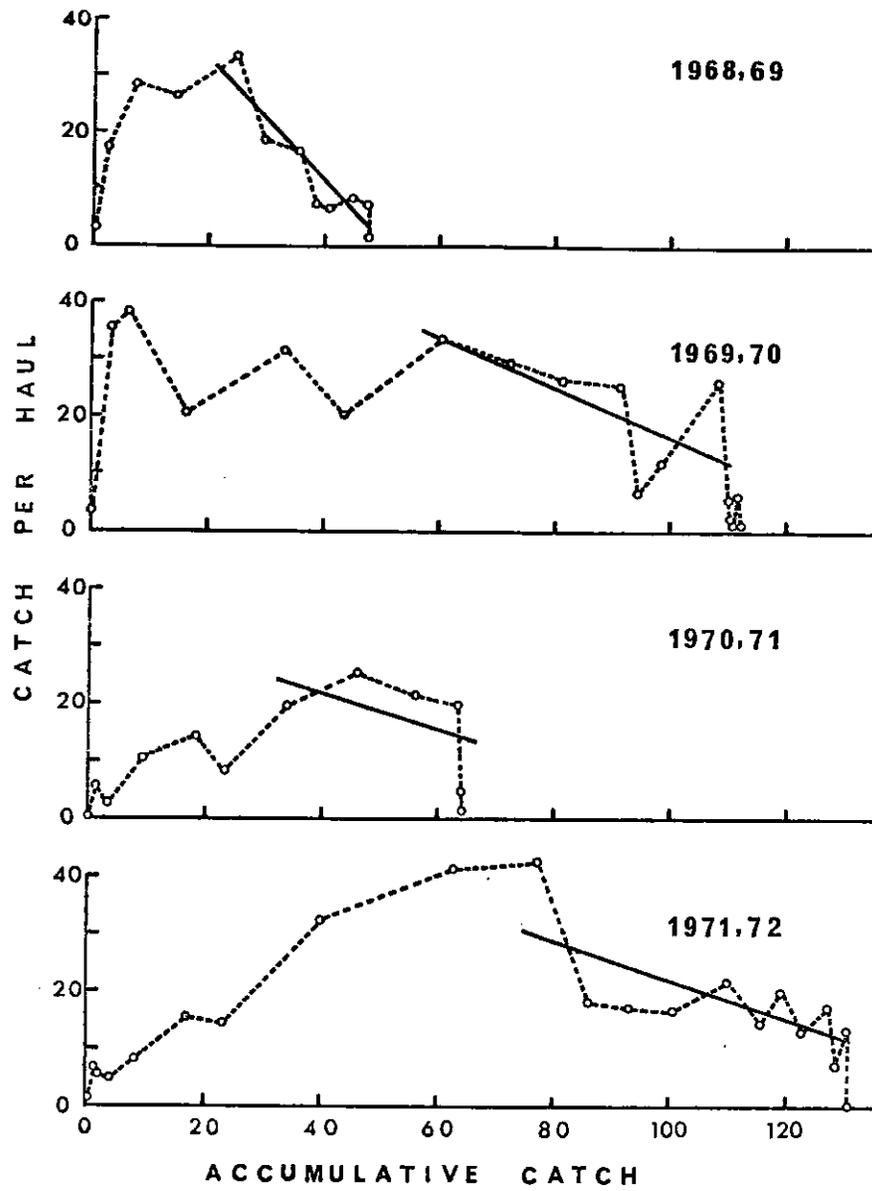


Fig. 3. Relationship between the catch-per-haul and the accumulated catch (the catch-per-haul in 10^3 and the accumulated catch in 10^5).

Appendix Table. Length compositions by size categories of common American squid in ICNAF Sub-area 5 and Statistical Area 6.

Mantle length (cm)	Body weight (g) ¹	Size category							
		5L	4L	3L	LL	L	M	S	SS
3- 4	3								
4- 5	5								3
5- 6	8							1	17
6- 7	12							9	68
7- 8	17						1	38	166
8- 9	23						6	103	257
9-10	29					1	27	197	255
10-11	37					5	81	250	155
11-12	46					18	166	215	61
12-13	55				1	50	235	122	15
13-14	66				3	108	229	49	2
14-15	78				11	174	156	13	
15-16	91			1	30	212	70	2	
16-17	105			2	69	194	22		
17-18	120		1	7	123	133	5		
18-19	137		2	21	173	69	1		
19-20	155		5	47	194	27			
20-21	174		14	86	171	8			
21-22	194	1	30	135	119	2			
22-23	216	3	56	170	66				
23-24	236	8	93	173	29				
24-25	262	20	130	150	10				
25-26	288	40	150	103	3				
26-27	315	73	157	61	1				
27-28	351	107	137	29					
28-29	372	138	100	11					
29-30	403	158	65	4					
30-31	436	147	36	1					
31-32	469	124	16						
32-33	505	85	7						
33-34	541	51	2						
34-35	579	27	1						
35-36	619	12							
36-37	660	5							
37-38	703	2							
38-39	747								
39-40	795								
Mean weight per individual (g)		415	310	234	157	95	61	39	25
Number of individuals per case		30	40	53	80	132	205	321	500

¹ Calculated from the formula, $W = 7.766 \times 10^{-4} \times ML^{2.314}$, where W is the body weight (g) and ML is the mantle length (mm).

23. Nominal catch of squid in Canadian Atlantic waters (Subareas 2-4), 1920 to 1968¹

by M.C. Mercer
Fisheries and Marine Service, Environment Canada
Biological Station, St. John's, Newfoundland

INTRODUCTION

The migratory ommastrephid squid, *Illex illecebrosus* (LeSueur), has historically supported small summer and fall inshore fisheries at the northern end of its western Atlantic range, particularly at Newfoundland where recent annual landings have ranged from nil to 10,500 metric tons. The inshore fisheries are passive in that they are based on availability of squid to jigging devices (and, to a much lesser extent, traps) in waters of less than about 20-m depth. However, in the past few years, large trawl fisheries for squid have developed in the ICNAF Convention Area and in Statistical Area 6. The 1971 ICNAF statistics for Subarea 3 show only 1 ton landed offshore (by Japan) with the remaining 1,606 tons being Newfoundland inshore landings. In 1972 landings offshore increased to 8 tons and inshore landings declined to 18 tons. In Subarea 4 offshore landings were 7,283 and 1,834 tons, respectively, in 1971 and 1972, whereas landings inshore totalled only 16 and 8 tons. In Subareas 3 and 4 *Illex illecebrosus* can be considered to have comprised practically the total catch as *Loligo pealei* ranges northwards only to the Bay of Fundy and occasionally to the south-western part of the Scotian Shelf where it is not abundant (see Mercer, 1970). The landings of 11,368 and 24,200 tons in Subarea 5 and 10,842 and 17,094 tons in Statistical Area 6 in the years 1971 and 1972, respectively, were mixed catches. These were predominantly *Loligo pealei* trawled in its wintering area; however, an indeterminate part of the catch was *Illex illecebrosus* taken both as a by-catch and as a result of directed fishing operations.

RESULTS

The following collation of Canadian catch statistics was abstracted completely from the monthly and annual "Fisheries Statistics of Canada" published by Statistics Canada (formerly Dominion Bureau of Statistics). Blank data fields in the area breakdowns indicate that no listings are given for squid in the "Fisheries Statistics". In such cases small squid landings are sometimes included under such headings as "Other Shellfish"; the total catches then obtained by adding across the columns are less than the listed total landings. Landings prior to 1938 are given in barrels; approximate conversion to pounds can be obtained by applying a factor of 200 lb/barrel.

Newfoundland

A monthly breakdown is given for the period 1956-72 (Table 1) and an area breakdown for the period 1955-68 (Table 2). Detailed statistics are unavailable for earlier years but Squires (1957) gives an account of relative annual abundance.

Nova Scotia

A breakdown by area for the period 1920-68 is given (Table 3).

New Brunswick

Squid catch was listed as 0 in 1952. In 1955 landings of 1,000 lb were given for Grand Manan Island (Bay of Fundy). In 1921-26 the only catches were listed as coming from Gloucester County (Districts 64-68), these being 20, 10, 5, 6, 5, 25 barrels, respectively. For all other years, 1920-72, no separate listings for squid were given.

Prince Edward Island

The only listing for squid in 1920-72 was 500 lb taken in District 88 in 1946.

Quebec

A breakdown by area for the period 1920-68 is given (Table 4).

ICNAF Area

As no area breakdowns are available for Newfoundland prior to 1955, summaries are not given for Div. 3K, 3L, 3P and 4R in the breakdown by years prior to this date (Table 5). Discrepancies between the total landings for the Canadian Atlantic and those obtained by adding Division totals are caused by occasional lumping of squid under such headings as "Other Molluscs" in the area totals used to compile the table. The relation of the Statistical Districts to the ICNAF Divisions is indicated in Appendix I.

¹ Submitted to the 1973 Annual Meeting of ICNAF as ICNAF Res.Doc. 73/73.

Table 3. Area breakdown of squid landings at Nova Scotia, 1920-68 ('000 lb, 1938-68, and barrels, 1920-37) by statistical areas as delineated in Fig. 2. When listed, totals do not coincide with landings obtained by totalling the landings by area; the latter total is indicated in parentheses.

Year	1	2	3	4	6	7	8	9	11	12	13	14	15	16	17	19	20	21	22	23
1920	3	148	0	4	0	0	0	0	0	0	32	(	1371			0		115A		
1921	0	300	916	9	0	0	180	0	0	0	65	(	3959			0		32		
1922	0	500	118	0	30	4	12	208	0	0	78	(	954			0		32		
1923	0	720	1128	0	77	8	20	30	0	0	43	(	4934			0		106		
1924	0	400	241	20	47	0	30	8	0	0	80	(	1261			0		360		
1925	4	660	2845	270	128	0	0	159	0	10	160	(	5376			0		561		
1926	8	425	2977	196	629	22	48	86	0	17	170	(	2810			22		1194		
1927	12	420	176	0	40	20	10	6	0	20	162	(	801			20	30	0		0
1928	0	1000	27	0	0	27	8	23	0	0	90	(	274			0		240		0
1929	0	700	112	0	555	0	0	37	0	0	112	(	489			0		52		0
1930	0	830	96	0	0	0	0	0	0	0	110	(	4900			0		0		0
1931	19	310	181	0	401	0	0	3	0	0	10	(	16			0		0		0
1932	0	160	23	32	0	0	0	7	0	0	40	(	308			0		0		0
1933	0	30	1	0	0	0	0	0	0	0	40	(	2922			0		0		0
1934	0	70	32	0	0	0	0	0	0	0	40	(	200			0		0		0
1935	0	318	4	0	36	15	8	5	0	0	30	(	2205			0		0		0
1936	0	806	17	0	40	0	0	0	0	0	30	(	354			0	3	0		0
1937	0	80	1	0	0	0	0	0	0	0	0	(	462			0	0	4		10
1938	0	70	1	0	2	3	4	0	0	0	10	(	122.8			0		0		0
1939	0	50	0.6	6.2	0	0	0	0	0	0	4.5	(	290.5			0		0		0
1940	0	80	1.7	0	79.2	0	0	0	0	0	6.0	(	291.8			0		0		0
1941	0	0	0.2	0	0	0	0	0	0	0	3.0	(	426.1			0		0		0
1942	0	29	0.2	0	0	0	0	0.5	0	0	2.0	(	21.2			0		0		0
1943	0	0	0	0	0	0	0	0	0	0	3.0	(	11.1			0		0		0
1944	0	8	0	0	0	0	0	0	0	0	2	(	22.5			0		19.9		0
1945	0	10	0	0	0	0	0	0	0	0	0	(	38.2			0		0		0
1946	0	105	0	212.4	13.9	0	0	8.1	0	0	0	(	112.8			0		0		0
1947	0	60	52	0	0	0	0	0	0	0	0	(	305			0		7		0
1948	0	5	6	0	0	0	0	0	0	0	0	(	76			0		0		0
1949	0	0	0	0	0	0	0	0	0	0	0	(	25			0		4		0
1950	0	59	60	0	0	0	0	0	0	0	0	(	188			0		0		0
1951	1	20	41	0	0	0	0	0	0	0	0	(	21			0		34		0
1952	60	0	0	66	0	39	0	0	0	0	0	(	2			0		0		0
1953	0	4	0	36	1	2	0	10	0	0	0	(	14			0		18		0
1954	0	21	2	9	119	20	0	12	0	0	0	(	14			0		20		0
1955	6	9	0	52	0	0	0	1	0	0	0	(	21			0		25		0
1956	0	16	5.0	175	0	487	0	0	0	0	10	(	109			0		4		10
1957	152	0	8	0	30	0	0	2	0	1	30	(	201			0		4		3
1958	0	2	0	0	1	1	0	0	0	0	0	(	100			0		0		26
1959	0	9	6	0	18	0	0	4	0	0	0	(	322			0		0		0
1960	6	7	0	0	13	0	0	0	0	0	0	(	13			0		0		0
1961	1	4	2	0	27	0	0	0	0	0	1	(	52			0		0		0
1962	1	2	4	0	30	1	0	26	0	0	47	(	68			0		1		23
1963	0	3	0	0	2	1	0	10	0	0	4	(	179			0		1		0
1964	16	5	4	0	258	1	0	32	0	0	0	(	127			0		3		1
1965	2	1	0	0	118	2	0	22	0	0	0	(	145			0		2		1
1966	0	2	0	0	12	0	0	1	0	0	27	(	35			0		0		0
1967	0	2	0	0	0	0	0	0	0	0	0	(	7			0		0		0
1968	0	0	0	0	1	0	0	4	0	0	0	(	6			0		1		0

Table 3. Cont'd.

Year	25	26	27	28	30	31	32	33	34	36	37	38	39	40	42	43	44	45	46	Total
1920	13	0	0	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,746
1921	0	0	0	6	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	5,567
1922	10	0	0	100	(	35	)	0	0	(	20	)	0	0	0	0	0	0	0	2,101
1923	10	0	0	6	(	20	)	0	0	(	10	)	0	0	0	0	0	0	0	7,112
1924	4	0	0	25	0	0	0	0	0	(	20	)	0	0	0	0	0	0	0	2,496
1925	8	0	0	665	(	210	)	0	0	(	500	)	0	0	0	0	0	0	0	11,556
1926	11	(	650	520	(	115	)	0	0	(	6000	)	0	0	0	0	(	800b	)	16,747
1927	25	(	97	120	(	15	)	0	0	0	0	0	0	0	0	0	0	0	0	1,974
1928	44	42	0	350	141	41	0	0	0	0	25	0	12	0	0	0	0	0	0	2,862
1929	5	20	0	215	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,897
1930	15	0	0	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5,965
1931	0	(	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	954
1932	0	(	150	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	760
1933	0	(	80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3,073
1934	0	0	0	0	(	2	)	0	0	0	0	0	0	0	0	0	0	0	0	337
1935	0	0	0	80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,674
1936	0	0	0	200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,272
1937	0	0	0	0	0	0	0	0	0	0	90	0	0	5	0	0	0	0	0	638
1938	0	0	0	4.8	0	0	0	0	0	(	4	)	0	0	0	0	0	0	0	221.6
1939	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	381.3
1940	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	504.6
1941	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	463.4
1942	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	53.3
1943	0	2.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16.7
1944	0	11.5	0	0	0	0	0	0.4	0	0	0	0	0	0	0	0	0	0	0	80
1945	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	55.4
1946	0	80	0	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	817.7(813.5)
1947																				562 (424)
1948																				109 (87)
1949																				52 (29)
1950																				364 (307)
1951																				139 (117)
1952	0	0	0	0	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	207
1953	0	3	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	96
1954	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	224
1955	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	108 (107)
1956	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	943
1957	37	1	0	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	652
1958	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	180
1959	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	567
1960	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	49
1961	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	102
1962	88	18	1	0	2	4	0	0	0	0	4	6	1	0	0	0	0	0	0	585
1963	23	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	244
1964	61	2	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	824 (819)
1965	7	3	0	0	7	2	0	0	0	0	0	0	0	0	0	0	0	0	0	379
1966	3	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	227
1967	1	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	256
1968	1	3	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	24 (17)

a Cole Harbour to Lunenburg County line for listings 1920-26. Equally divided among districts 44, 45, 46 for ICNAF summary.

Table 5. Breakdown of squid landings by ICNAF Divisions, 1920-68 ('000 lb, except prior to 1938 when landings are given in barrels). Where reported yearly, totals for the Canadian Atlantic do not agree with totals obtained by summing the division totals; the latter are indicated in parentheses.

Year	Div.	3K	3L	3P	4R	4S	4T	4Vn	4W	4X	Total
1920						119	3,265	7	1,486	73	
1921						5	8,031	9	4,171	106	
1922						70	5,196	34	1,206	165	
1923						32	3,227	85	5,090	46	
1924						162	1,843	67	1,659	49	
1925						109	4,549	402	6,096	1,383	
1926						640	8,667	855	4,160	7,609	
1927						410	1,570	72	867	257	
1928						621	2,207	27	1,063	655	
1929						28	3,296	555	1,178	240	
1930						7	1,636	0	4,900	29	
1931						8	1,252	420	23	10	
1932						16	748	32	315	190	
1933						7	411	0	2,922	80	
1934						10	472	0	203	2	
1935						9	1,357	51	2,221	80	
1936						7	1,453	40	3,169	210	
1937						12	85	0	462	95	
1938						18	89	5	127	9	
1939						0	60	6	320	0	
1940						0.4	119	79	338	0	
1941						0	53	0	460	0	
1942						0	39	0	22	0	
1943						0	3	0	11	2	
1944						0	12	0	58	12	
1945						0	107	0	45	0	
1946						0.4	161	226	372	110	
1947						-	98	52	312	-	
1948						-	8	6	76	-	
1949						-	0	0	29	-	
1950						-	59	60	188	-	
1951						-	27	42	55	-	
1952						1	5	165	20	22	
1953						1	20	39	46	7	
1954						1	52	148	53	0	
1955		1,049	11,845	2,130	451	2	42	58	26	15	15,673(15,618)
1956		268	16,161	721	0	2	79	662	246	4	18,203(18,143)
1957		847	4,641	228	71	2	53	182	363	68	6,487 (6,455)
1958		28	1,240	316	0	3	4	2	174	2	1,769
1959		773	4,969	547	0	0	17	18	533	1	6,858
1960		1,414	8,935	821	0	4	7	19	23	0	11,260(11,223)
1961		1,763	16,400	1,607	8	0	7	28	64	3	19,884(19,880)
1962		120	305	636	2	0	53	32	353	147	1,648
1963		279	3,497	1,196	0	0	7	3	210	24	5,216
1964		1,258	19,110	2,560	0	0	9	275	473	5	23,755(23,690)
1965		1,365	13,647	2,187	0	0	1	3	355	13	17,578(17,571)
1966		2,045	7,508	1,507	0	0	2	120	100	2	11,287(11,284)
1967		1,227	12,435	1,560	0	0	29	12	212	2	15,478(15,477)
1968		2	0	0	0	0	0	1	11	4	26 (18)

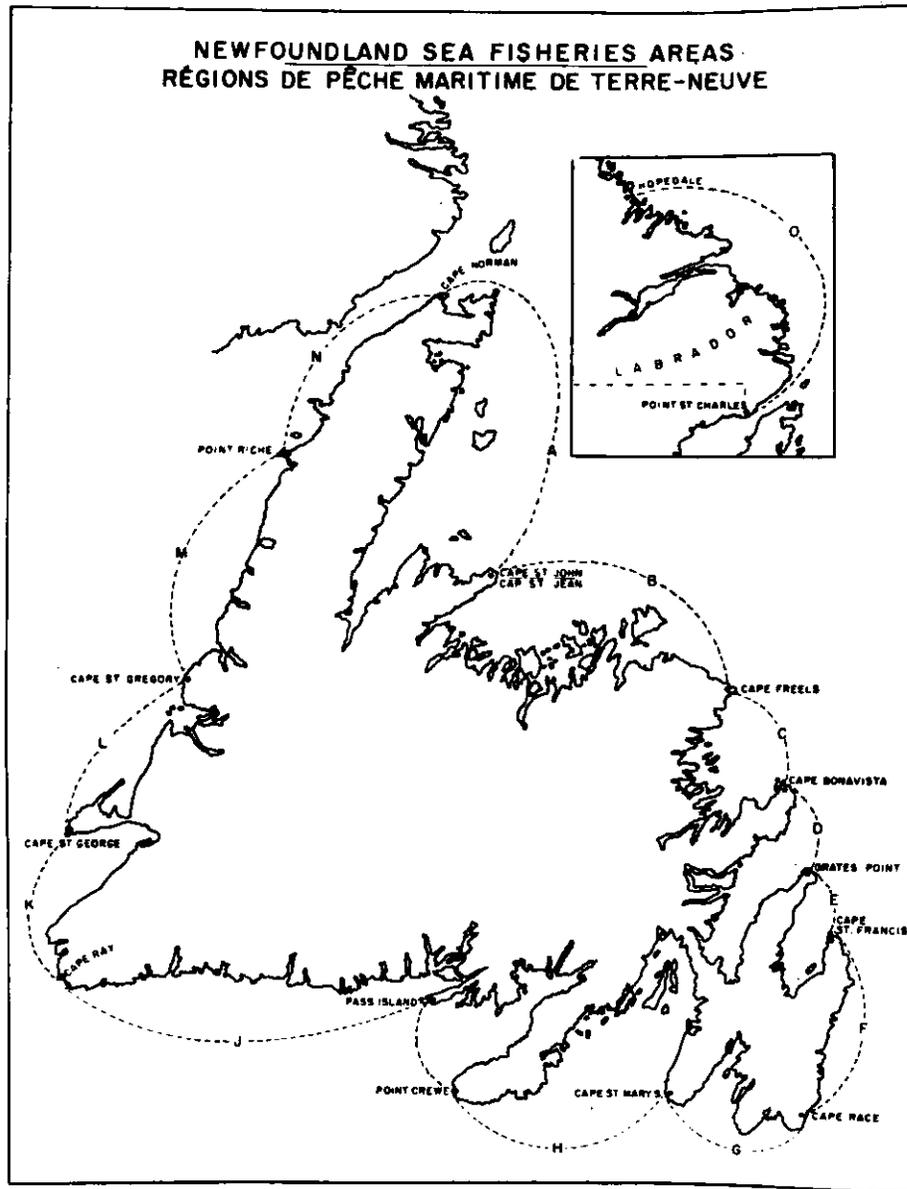


Fig. 1. Newfoundland sea fisheries statistical areas.

APPENDIX I

<u>ICNAF Divisions</u>	<u>Statistical Districts</u>
3K	Newfoundland Districts A and B (including section 1 of A which is actually in 4R. Landings here are approximately nil.)
3L	Newfoundland Districts C, D, E, F, G
3P	Newfoundland Districts H, I, J (and section 50 of K which is actually in 4R)
4R	Newfoundland Districts K, L, M, N
4S	Quebec Districts 18 ¹ (part), 19-25
4T	Maritime Districts 2, 3, 11-13, 43b, 45, 46, 63-68, 70, 73, 75-78, 80 (80a), 82, 83, 85-88 Quebec Districts 1-17, 18 ¹ (part), 26-28
4Vn	Maritime Districts 1, 4, 6, 7
4W	Maritime Districts 8, 9, 14-21
4X	Maritime Districts 22, 23, 25-28, 30-34, 36-40, 42, 43a, 44, 48-53, 55-61, 79, 80b

¹ Quebec statistical area 18 is partly in Division 4S and partly in 4T; landings have been assigned on a 50:50 basis.

**SECTION I
SPECIES MIX
AND
FISHING EFFORT**

24. Mixture of species in Subareas 5 and 6^{1,2}

by M.D. Grosslein and E. Bowman
 Northeast Fisheries Center
 National Marine Fisheries Service
 Woods Hole, Massachusetts 02543, USA

INTRODUCTION

The high degree of mixture of species in Subarea 5 and Statistical Area 6 has been well documented in the commercial fisheries as well as research vessel surveys in the area. For example, the US industrial bottom trawl fishery has traditionally taken a wide variety of groundfish in Subdiv. 52w and Div. 6A. In 1958 this fishery took significant quantities of 20 species, including the three principal hake species, three species of skates, four species of flounder, alewife, sea herring, scup, butterfish, ocean pout, sculpin, sea robins, sea raven and spring dogfish (Fig. 1, Table 1). In the same general area a wide mixture of species has also been observed in research vessel surveys on an individual catch basis. For example, in the 1971 joint USA-USSR groundfish survey, the USSR vessel made 37 random 30-minute hauls in sampling strata 1, 2, 5, 6, 9, and 10, and with few exceptions there were 10 or more species per haul, with a mean of 13 species per haul (Table 2). Sampling strata used in the surveys are shown in Fig. 2 and a typical station pattern is shown in Fig. 3. Comparable numbers of species were caught by the US vessel at an independent set of random stations in the same strata (Table 2). The only species represented by the industrial trawl statistics which were not taken in the 1971 survey are indicated by asterisks in Table 1.

Table 1. Species composition (in thousands of pounds) of Point Judith industrial trawl-fish landings from the offshore area, by months, 1958. (+ indicates less than 1,000 pounds).

Species	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep ¹	Oct	Nov	Dec
Red hake	4	20	5	1,300	2,751	821	348	959	242	1,639	651	13
White hake	5	1	-	-	-	-	-	+	1	98	12	-
Silver hake	23	19	6	32	180	878	431	595	460	1,932	168	60
Little skate	33	78	127	562	100	284	172	53	77	362	200	117
Big skate	83	159	130	516	54	-	-	72	-	79	156	50
Immature skate	4	-	-	65	-	-	-	-	-	-	-	-
Spotted hake	-	-	-	-	-	-	-	-	-	-	2	-
Eel pout	54	217	302	608	882	727	187	35	-	56	12	21
Longhorn sculpin	13	19	61	83	68	-	-	7	-	5	20	4
Sea robin	-	-	-	-	18	-	-	-	98	116	154	+
Striped sea robin	-	-	-	-	-	-	-	-	2	-	-	-
Angler	41	108	151	733	249	-	59	250	18	37	63	55
Four-spot flounder	4	+	5	18	23	34	10	26	6	-	7	7
Sand flounder	42	41	20	83	14	-	-	-	4	+	24	+
Gulf Stream flounder	-	2	-	-	-	-	-	-	1	-	-	-
Yellowtail flounder	60	45	23	106	50	63	-	2	1	-	12	-
Blackback flounder	1	2	+	+	5	-	15	46	7	28	5	-
Sea raven	-	-	-	9	14	-	-	-	-	-	-	-
Spiny dogfish	145	29	37	346	77	-	-	-	-	-	927	257
Smooth dogfish	-	-	-	-	23	-	-	114	-	-	-	-
Barndoor skate	48	32	17	111	+	-	-	-	-	23	7	+
*Alewife	33	8	33	18	+	34	8	13	-	149	7	22
Herring	3	2	7	14	9	-	-	-	-	5	-	-
Scup	-	-	-	-	-	-	-	-	15	79	+	2
Butterfish	-	-	-	5	-	-	49	13	31	23	7	-
Gunner	-	-	-	-	-	-	-	-	-	+	-	-
*Three-bearded rockling	-	-	-	-	-	-	+	-	-	+	-	-
Total	596	782	924	4,609	4,517	2,841	1,279	2,185	963	4,631	2,434	608

¹ Based on 1955, 1956, and 1957 samples.

¹ Statistical Area 6

² Submitted to the 1973 Annual Meeting of ICNAF as ICNAF Res.Doc. 73/9.

Table 2. Frequency distributions of species per haul on 1971 joint USA-USSR trawl survey for selected strata in Southern New England.

Number of species per haul	Number of hauls in stratum												No. of hauls	
	1		2		5		6		9		10			
	USA	USSR	USA	USSR	USA	USSR	USA	USSR	USA	USSR	USA	USSR	USA	USSR
0														
1														
2	-	-	-	-	-	-	-	-	1	-	-	-	1	-
3	-	-	-	-	-	1	-	-	-	-	-	-	-	1
4														
5	-	-	2	-	-	-	-	-	-	-	-	-	2	-
6	-	-	-	-	-	-	-	-	-	-	3	-	3	-
7	-	-	2	-	1	-	-	1	-	-	-	-	3	1
8	-	-	2	-	-	-	1	-	1	-	1	1	5	1
9	-	1	2	1	1	-	2	-	-	-	-	-	5	2
10	-	1	-	2	-	-	3	-	-	-	-	-	3	3
11	4	2	-	1	-	-	1	1	-	-	2	1	7	5
12**	-	-	-	1	-	-	-	2	-	1	2	1	2	5
13*	1	2	-	-	-	-	-	-	-	-	-	-	1	2
14	1	-	-	2	1	-	2	3	2	-	-	2	6	7
15	-	-	-	-	1	1	1	1	2	1	1	1	5	4
16	1	1	-	-	1	1	-	-	-	-	-	-	2	2
17	-	-	-	-	1	1	-	-	1	-	1	-	3	1
18	-	-	-	-	1	-	1	-	-	-	-	1	2	1
19	1	-	-	-	-	-	-	-	1	1	1	-	3	1
20														
21	-	-	-	-	-	-	-	-	-	1	-	-	-	1
22	-	-	-	-	1	-	-	-	-	-	-	-	1	-
23														
24														
25														
Total no. of hauls	8	7	8	7	8	4	11	8	8	4	11	7	54	37

* Mean of USSR haul
 ** Mean of US haul

Commercial fishermen do not, of course, fish at random and the degree of mixing is normally much less in commercial catches as, for example, has been documented for US research and commercial catches in Subarea 5 (ICNAF, 1968). Nevertheless, the problem of by-catch is a serious one in Subareas 5 and 6 as indicated in ICNAF Commissioners Document 73/3 (ICNAF, 1973a) and illustrated in the 1973 report of the Assessments Subcommittee (ICNAF, 1973b). It is simply not possible to conduct a bottom trawl fishery in this region without harvesting a substantial mixture of species.

The purpose of this document is to provide a more accurate and comprehensive description of the distribution patterns of major species in Subareas 5 and 6, which in turn should provide a better basis for formulating and evaluating management measures designed to alleviate the by-catch problem. The distribution patterns shown here are based on individual trawl catches from USA and USSR groundfish surveys, conducted since 1968. Sample plots for 16 species are shown in the Appendix for both spring and fall surveys. Virtually all of the species sought by the major trawl fisheries are included in the series of plots. Also included are species taken more or less incidentally in the trawl fisheries such as scup, fluke, sea bass, alewives, and lobsters, which are vulnerable to offshore bottom trawl fisheries, particularly in winter and spring.

Although only spring and fall distributions are shown here, distribution patterns at other times of year generally are intermediate between these two seasons since the spring and fall represent approximately the minimum and maximum bottom water temperatures found in shoal waters. This document presents a first approach to a classification scheme for the nature and location of mixed fisheries in Subareas 5 and 6, based chiefly on the groundfish surveys. A complete picture of the species mixture problem will require pooling data from both surveys and the fisheries for all areas and seasons; and this will require breakdown of commercial catches by species and individual hauls.

SPECIES DISTRIBUTION OVERLAP IN SUBAREAS 5 AND 6

Spring (March-April)

During winter and spring months many groundfish species aggregate offshore in depths greater than 100 m along the edge of the shelf in Subarea 6 and Div. 5Z. For example, among species sought by the major fishing fleets, aggregations of red and silver hake are found mixed together, particularly in Subdiv. 5Zw and Div. 6A (Fig. 4); and mackerel and sea herring aggregations are mixed at times in Div. 6B and 6C (Fig. 5).

Many other species also aggregate along the shelf including squid, butterfish, alewife, sea bass, scup, fluke and lobster (see sample plots: Appendix Charts 10, 13-18). In shoaler depths (generally less than 80 m) aggregations of sea herring are often found over yellowtail grounds in the vicinity of Hudson Canyon (Fig. 5).

When distributions of all 16 selected species based on three or four surveys are all plotted on a single chart, the picture becomes too complicated to portray with different shadings. However, it is possible to identify at least seven different regions from Cape Hatteras to western Nova Scotia within which the species mixture can be classified as more or less severe according to the number, density and priority of the species found there, and in relation to the intensity of bottom trawling effort (Fig. 6). For example, in the shoal areas in Subdiv. 5Zw and Div. 6A, a large amount of bottom trawling directed at sea herring will result in significant by-catches of yellowtail, cod and winter flounder, and hence this area is shaded as a "heavy mixture" area (Fig. 6). The immediately adjacent offshore region is also labelled as a "heavy mixture" area since the presence of red and silver hake aggregations as well as mackerel attracts considerable bottom trawling effort, resulting in potentially significant by-catches of alewives, squid, butterfish and lobster (Fig. 6). In general, it has been shown that in the spring months, the by-catch problem is much more severe in Subdiv. 5Zw and Statistical Area 6 than in the remainder of Subarea 5 and the western part of Div. 4X, because of the heavy fishing directed at mackerel, sea herring, and the hakes, and the mixture of other species associated with these species.

Fall (October-November)

In the fall the mixed fishery problem shifts to the north and east and more into shoal waters, largely in response to the corresponding movement of hake, mackerel and sea herring. Red and silver hake are now mixed with yellowtail, largely inside 80 m in Subdiv. 5Zw and Div. 6A (Fig. 7). In the same region, mixed with the hakes and yellowtail, are found sea herring, mackerel, squid, scup, butterfish, lobsters and flounders inside 80 m in Subdiv. 5Zw and Div. 6A (see Appendix Charts 23-27, 31-34, 36). An even greater mixture is found on Georges Bank (Subdiv. 5Ze) where the above species are found as well as cod, haddock and alewives. The generalized picture of species mixture for fall is shown in Fig. 6.

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- 1973a. Memorandum by the US Commissioners on the regulation of fishing effort (as presented to the Special Commission Meeting - January 1973). *Annu. Meet. int. Comm. Northw. Atlant. Fish.*, Commissioners Document 73/3, Serial No. 2898. (mimeographed).
- 1973b. Proceedings of Special Commission Meeting, FAO, Rome, Italy, 8-26 January 1973. *Annu. Meet. int. Comm. Northw. Atlant. Fish.*, Summary Document 73/1, Serial No. 2941. (mimeographed).

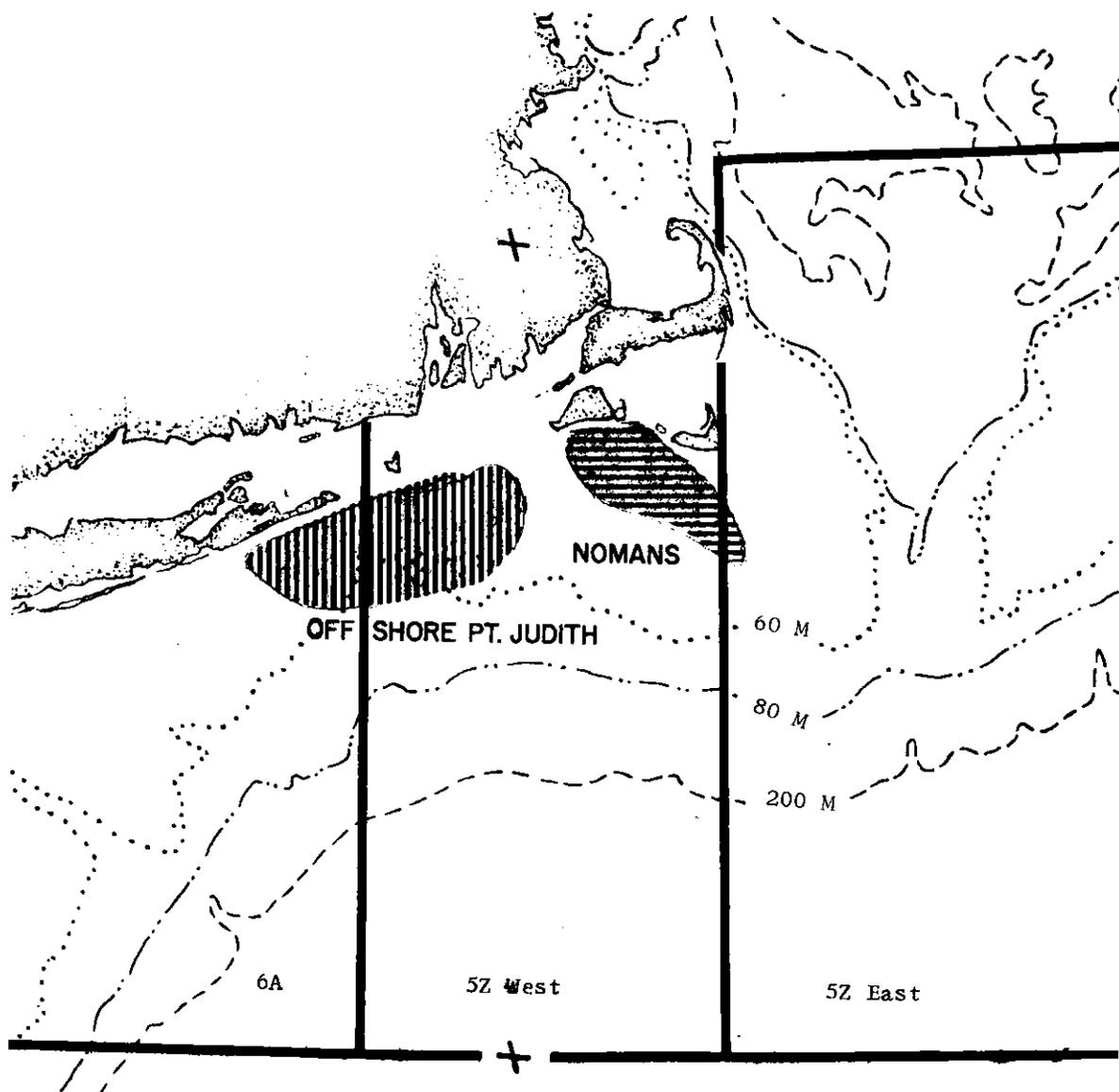


Fig. 1. Areas of US industrial fisheries, taken from "Edwards, R.L., and L. Lawday. 1960. Species composition of industrial trawl-fish landings in New England, 1958". US Fish and Wildlife Service, Special Scientific Report, Fisheries No. 346.

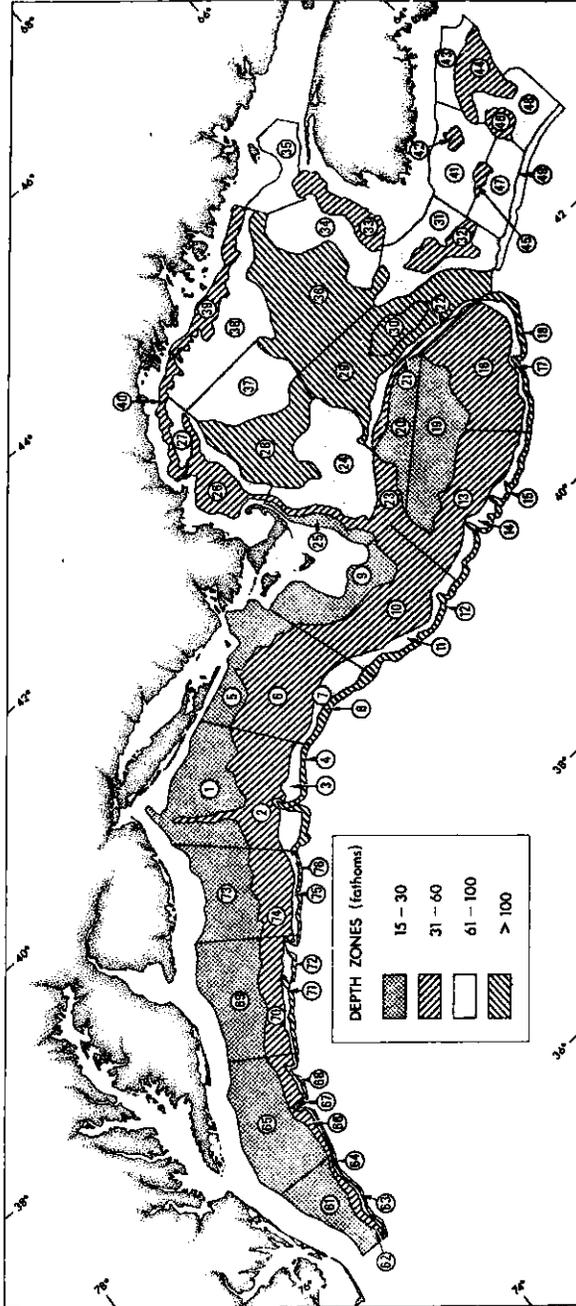


Fig. 2. Sampling strata used in US and USSR groundfish surveys. Joint USA-USSR surveys in Subareas "5 and 6" occupied strata 1-25 and 61-76. US surveys also included strata 26-49 in spring and autumn.

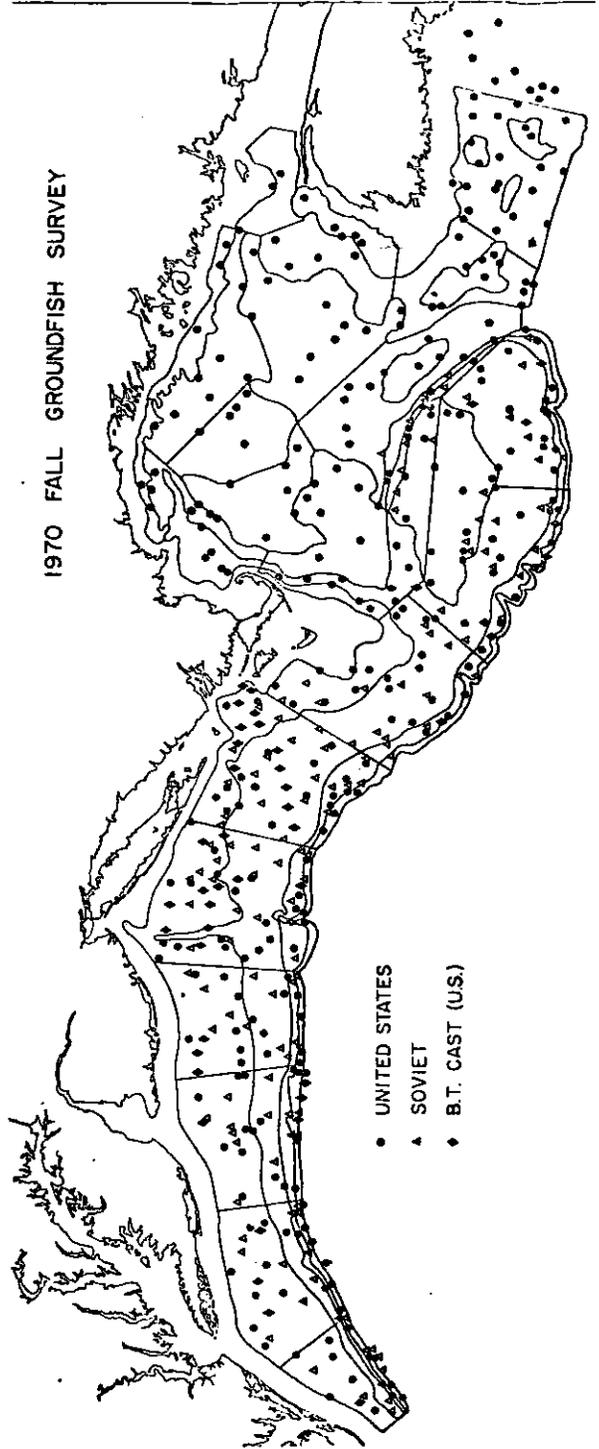


Fig. 3. Station pattern for autumn groundfish survey in 1970.

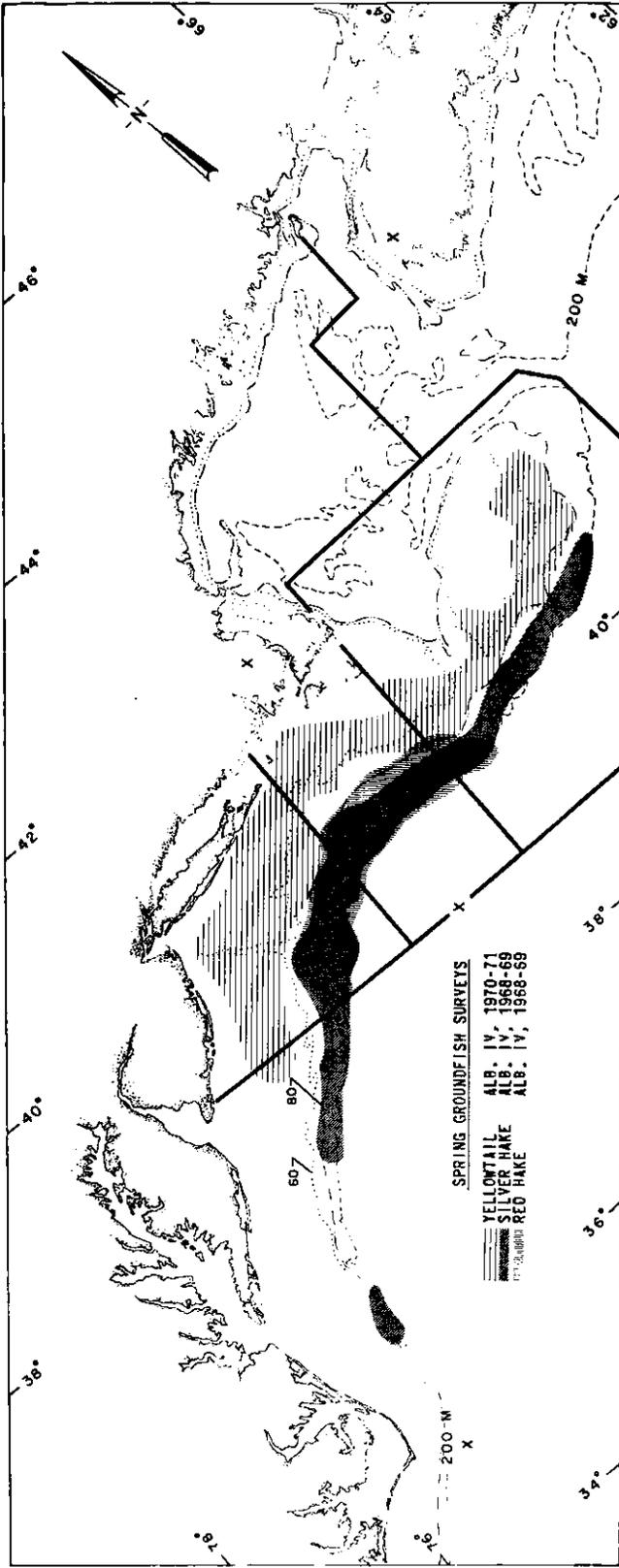


Fig. 4. Aggregations of red and silver hake, and yellowtail flounder, based on plots of individual catches (greater than 20 pounds) on two consecutive spring surveys combined.

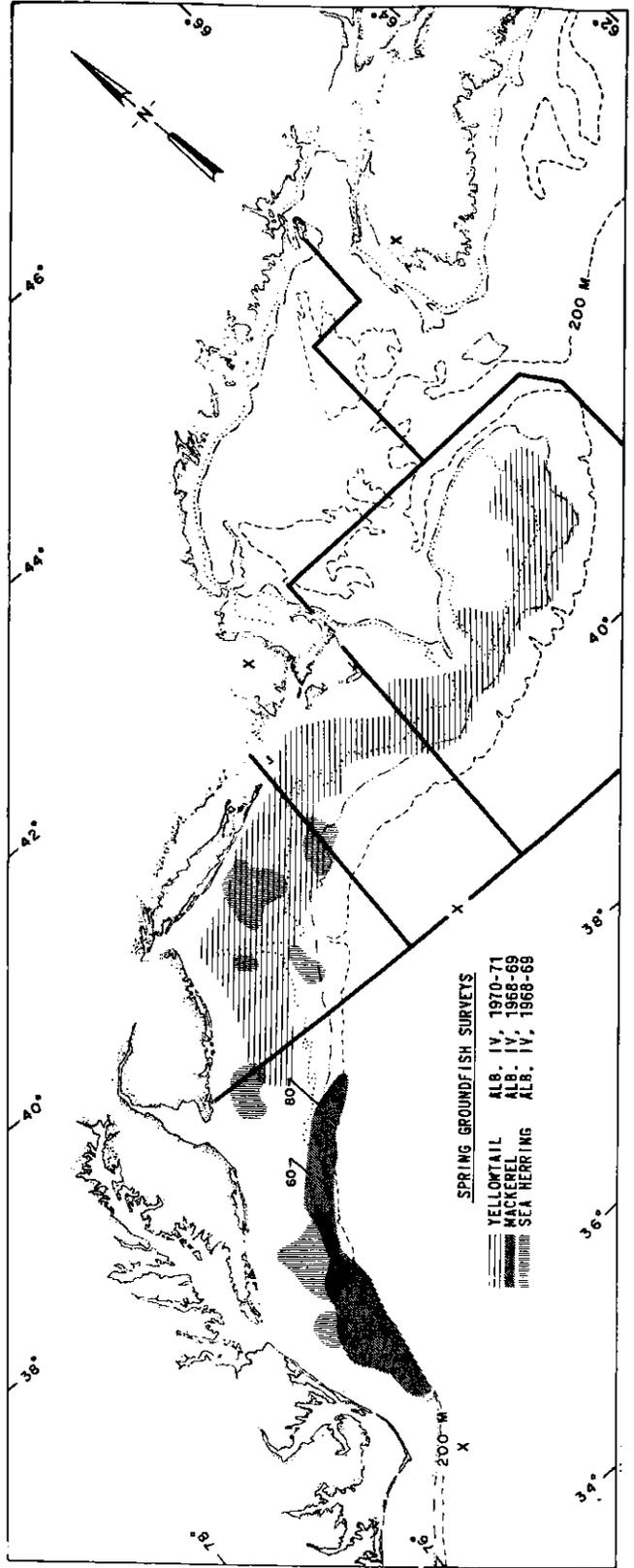


Fig. 5. Aggregations of sea herring, mackerel, and yellowtail flounder, based on plots of individual catches on two consecutive spring groundfish surveys.

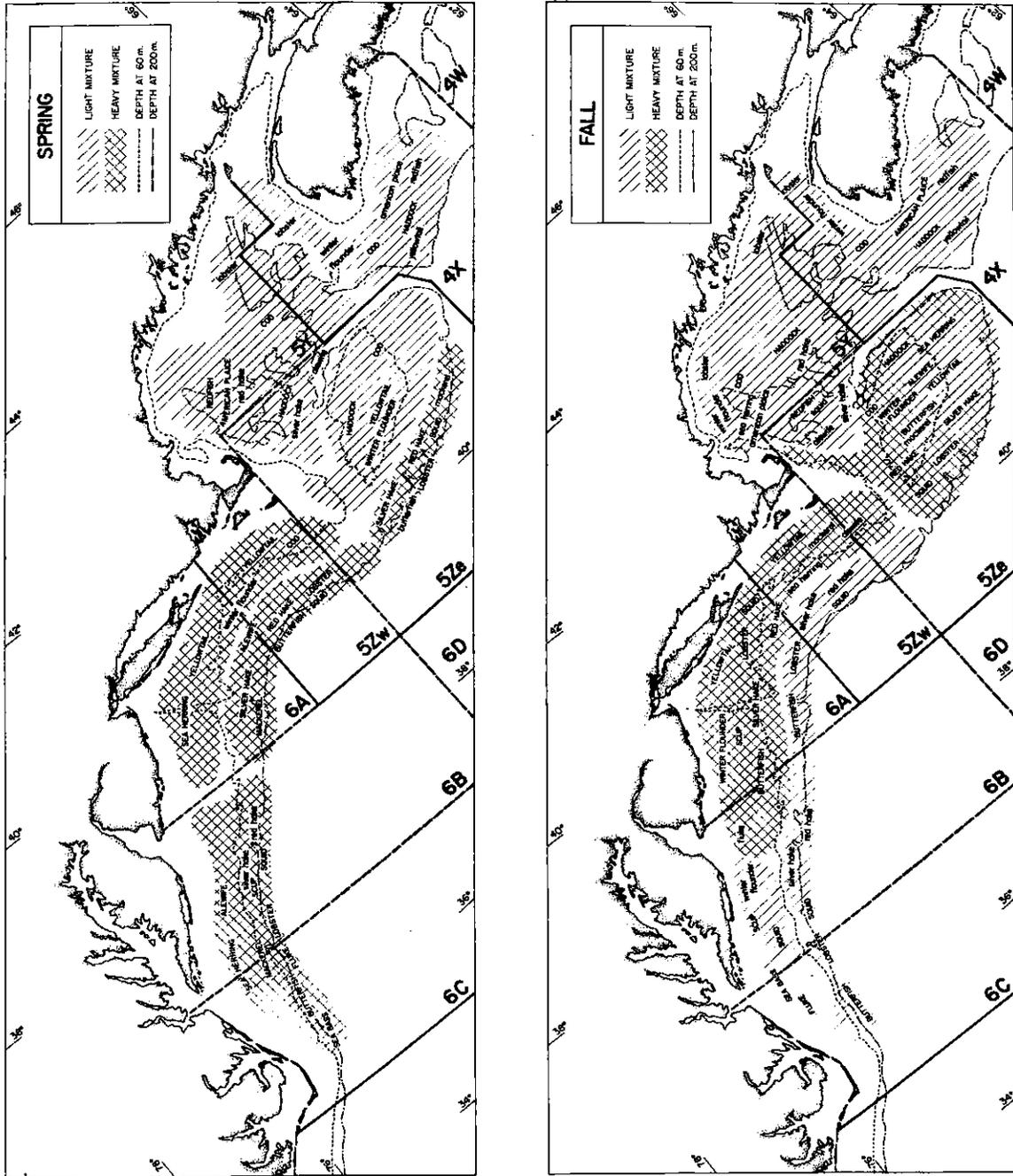


Fig. 6. Generalized picture of mixture of important species vulnerable to bottom trawling - based on plots of individual catches of groundfish surveys. (see Appendix for sample plots).

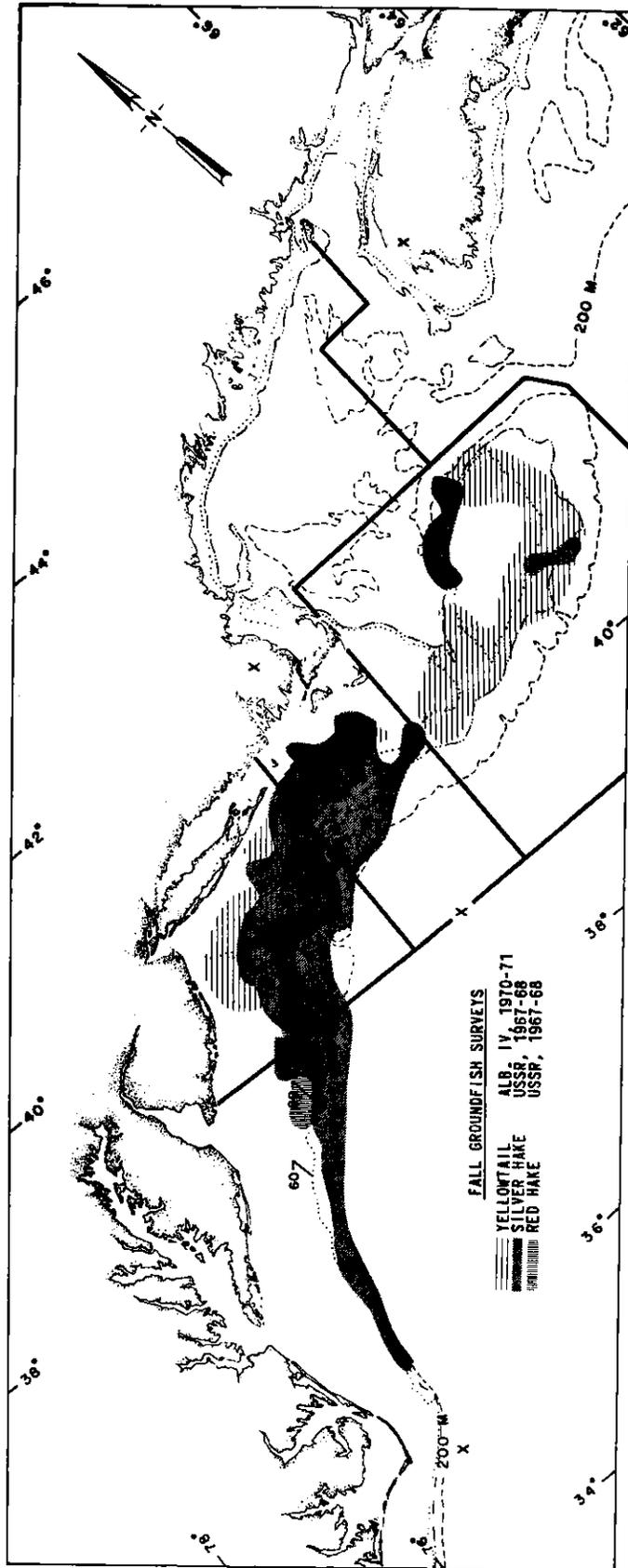


Fig. 7. Aggregations of red and silver hake, and yellowtail flounder, based on plots of individual catches (greater than 20 pounds) on two consecutive fall surveys combined.

APPENDIX

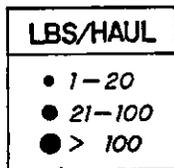
Plots of individual catches of 16 species taken on spring and autumn groundfish surveys. Species include:

	<u>Spring</u>	<u>Autumn</u>
Cod - - - - -	Chart 1	Chart 19
Haddock - - - - -	" 2	" 20
Redfish - - - - -	" 3	" 21
Yellowtail flounder - - - - -	" 4	" 22
Winter flounder - - - - -	" 5	" 23
Sea herring - - - - -	" 6, 7	" 24, 25
Mackerel - - - - -	" 8, 9	" 26, 27
Alewife - - - - -	" 10	" 28
Red hake - - - - -	" 11	" 29
Silver hake - - - - -	" 12	" 30
Butterfish - - - - -	" 13	" 31
Squid (<i>Loligo</i>) - - - - -	" 14	" 32
Fluke (Summer flounder) - - - - -	" 15	" 33
Scup - - - - -	" 16	" 34
Sea bass - - - - -	" 17	" 35
Lobster - - - - -	" 18	" 36

All strata shown in Fig. 2 were sampled by USA; only strata 1-25, 61-76 were sampled by USSR (Charts 25, 27, 28 and 31).

Note that in nearly all cases, catches for two consecutive years are shown on one chart.

The same scale (shown below) relating size of catch to size of dot is used for all plots.



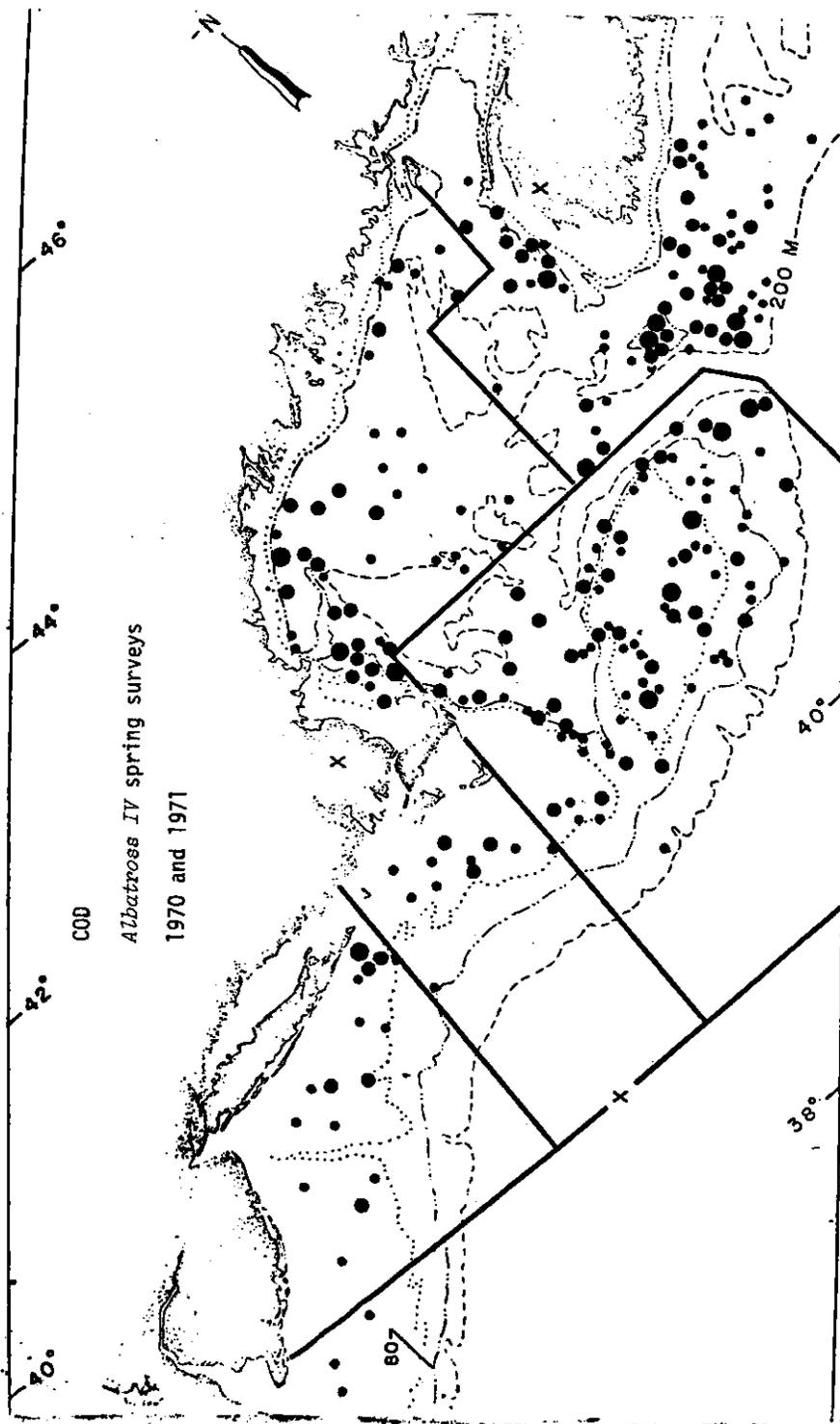


Chart 1.

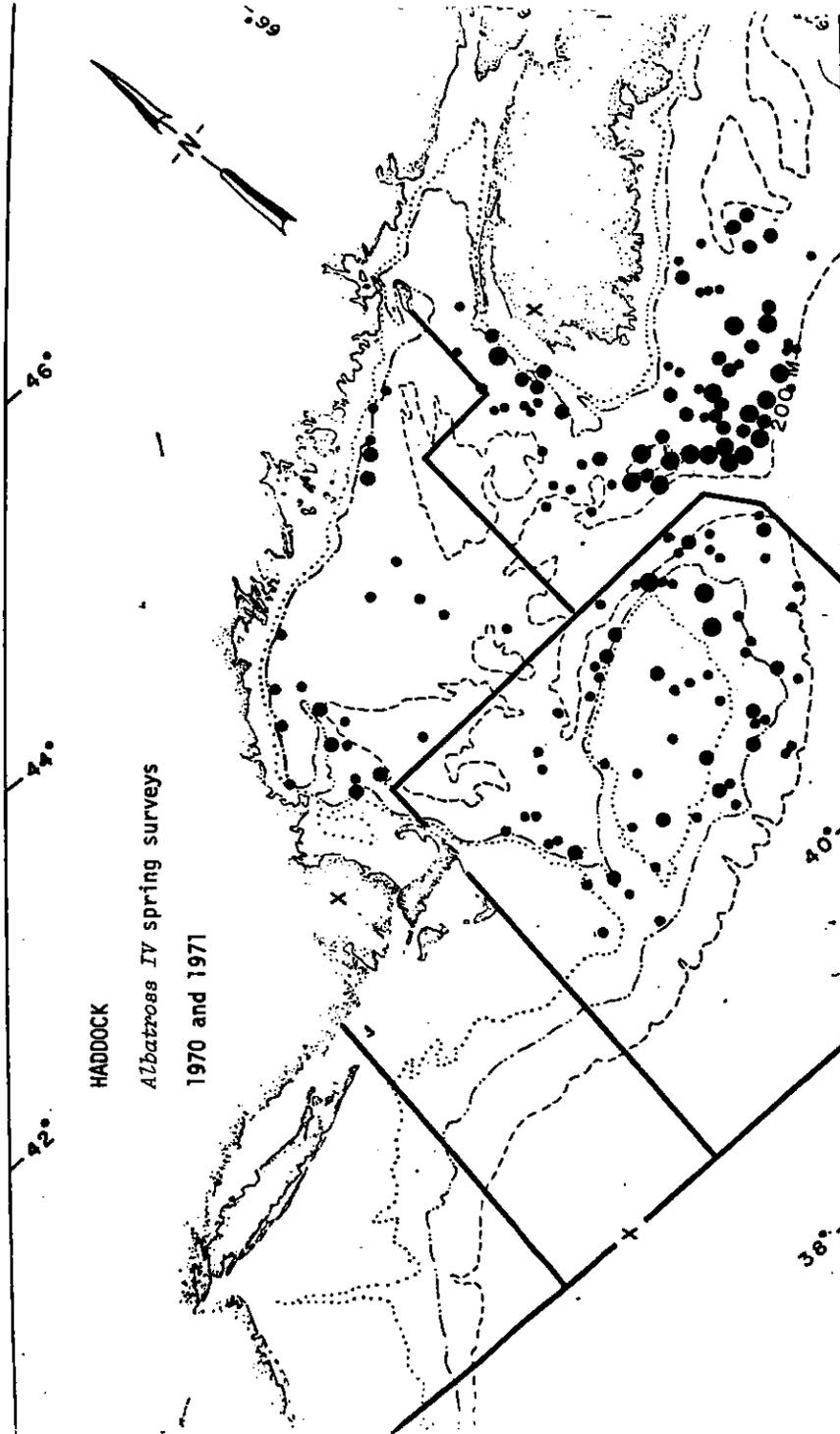


Chart 2.

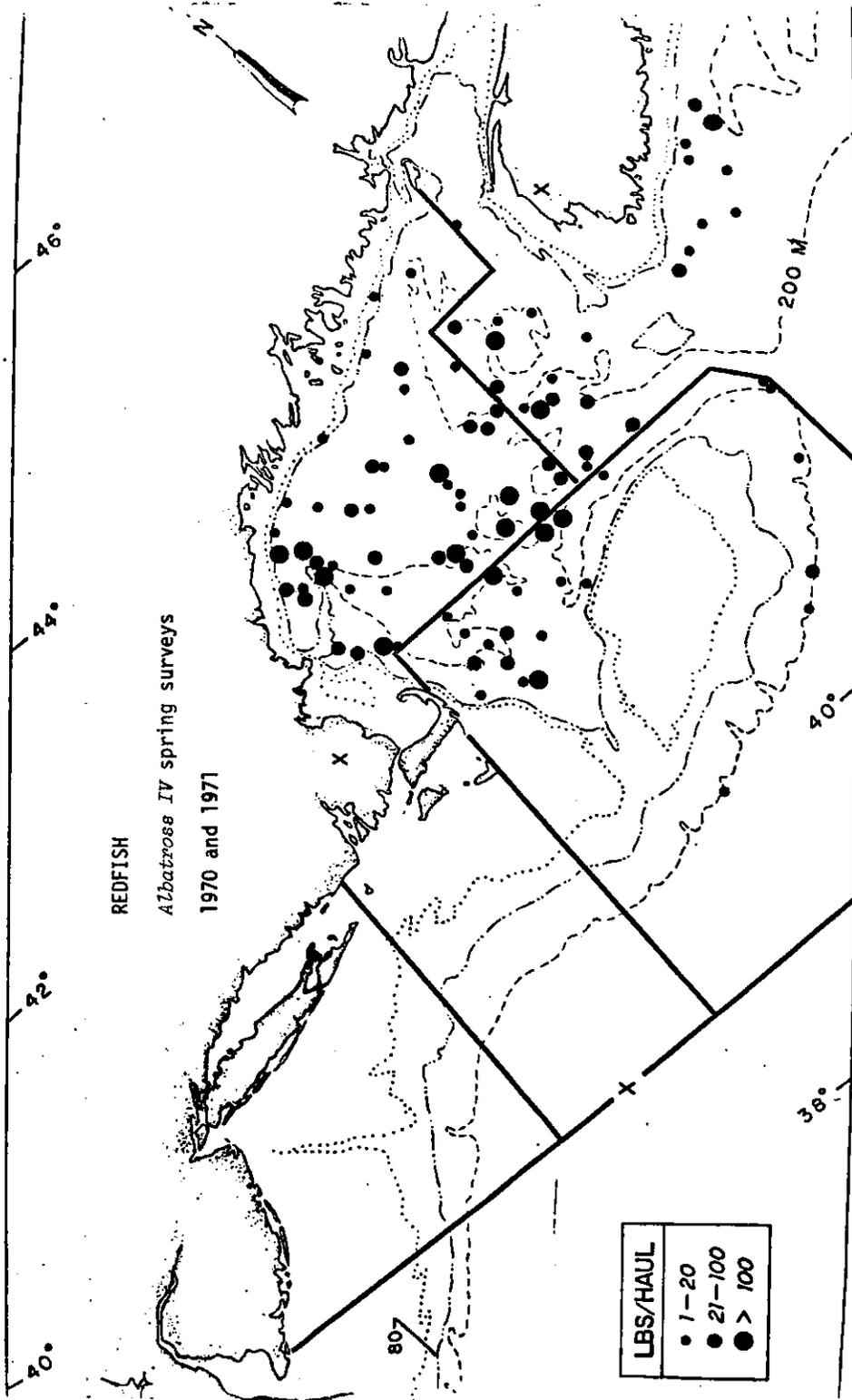


Chart 3.

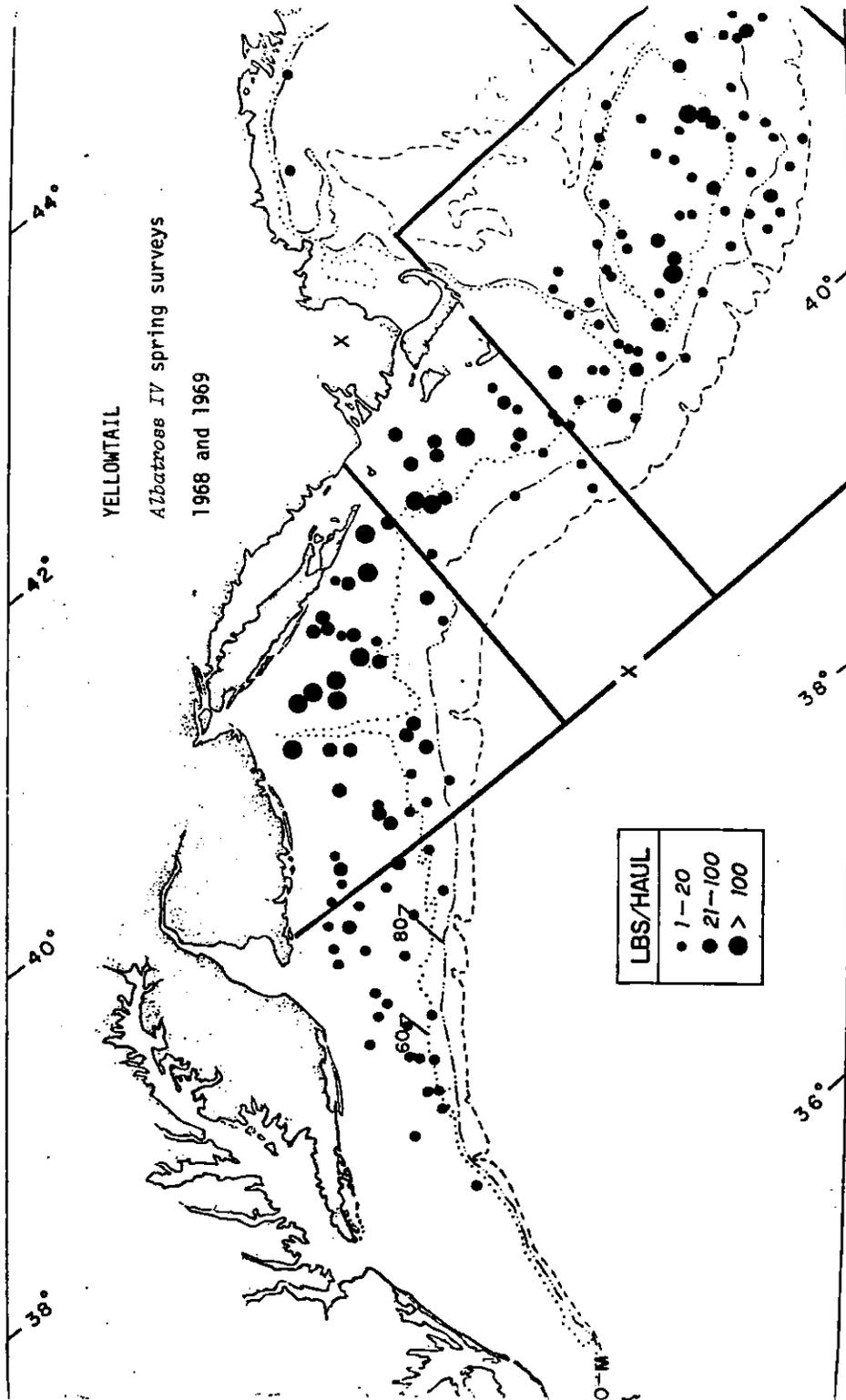


Chart 4.

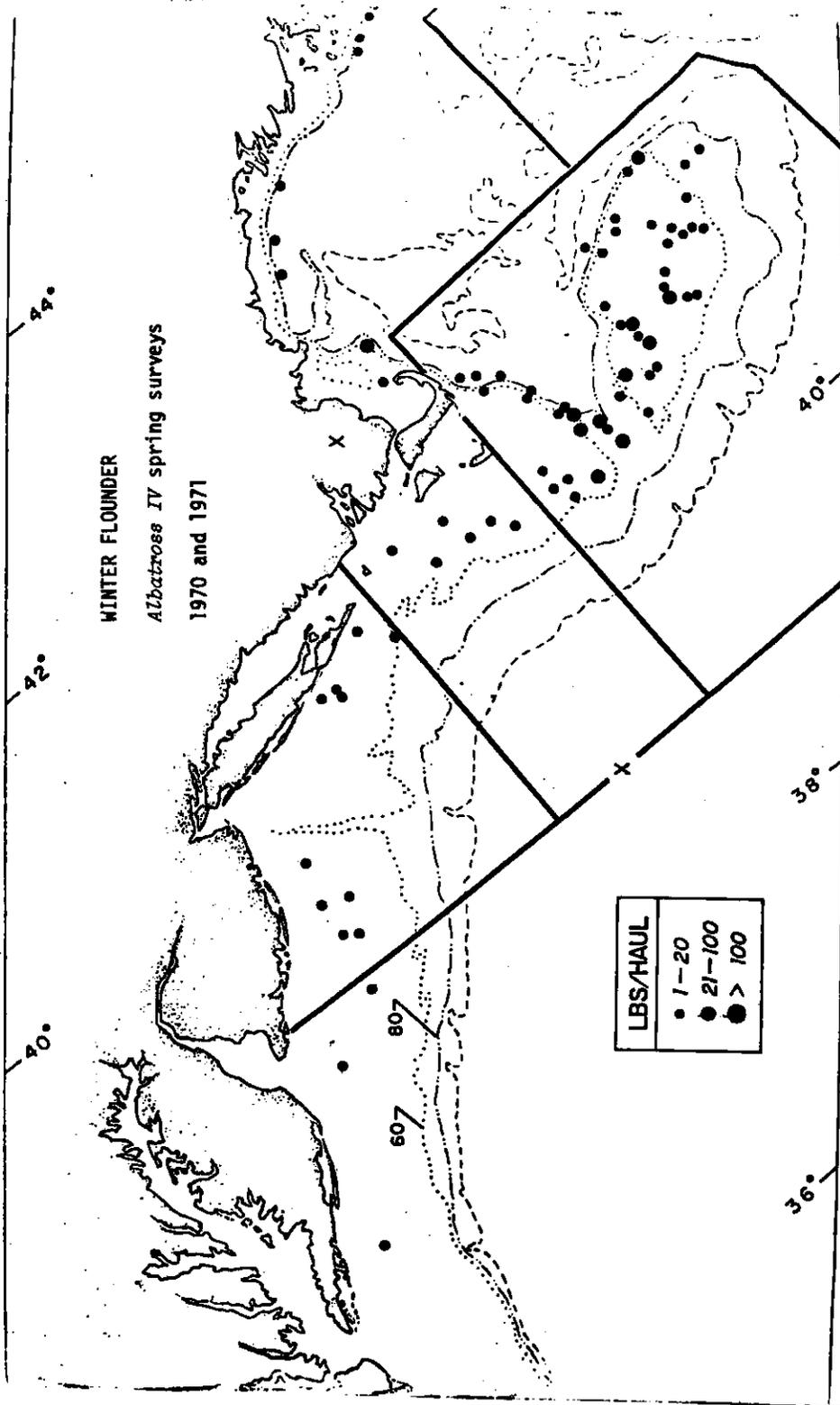


Chart 5.

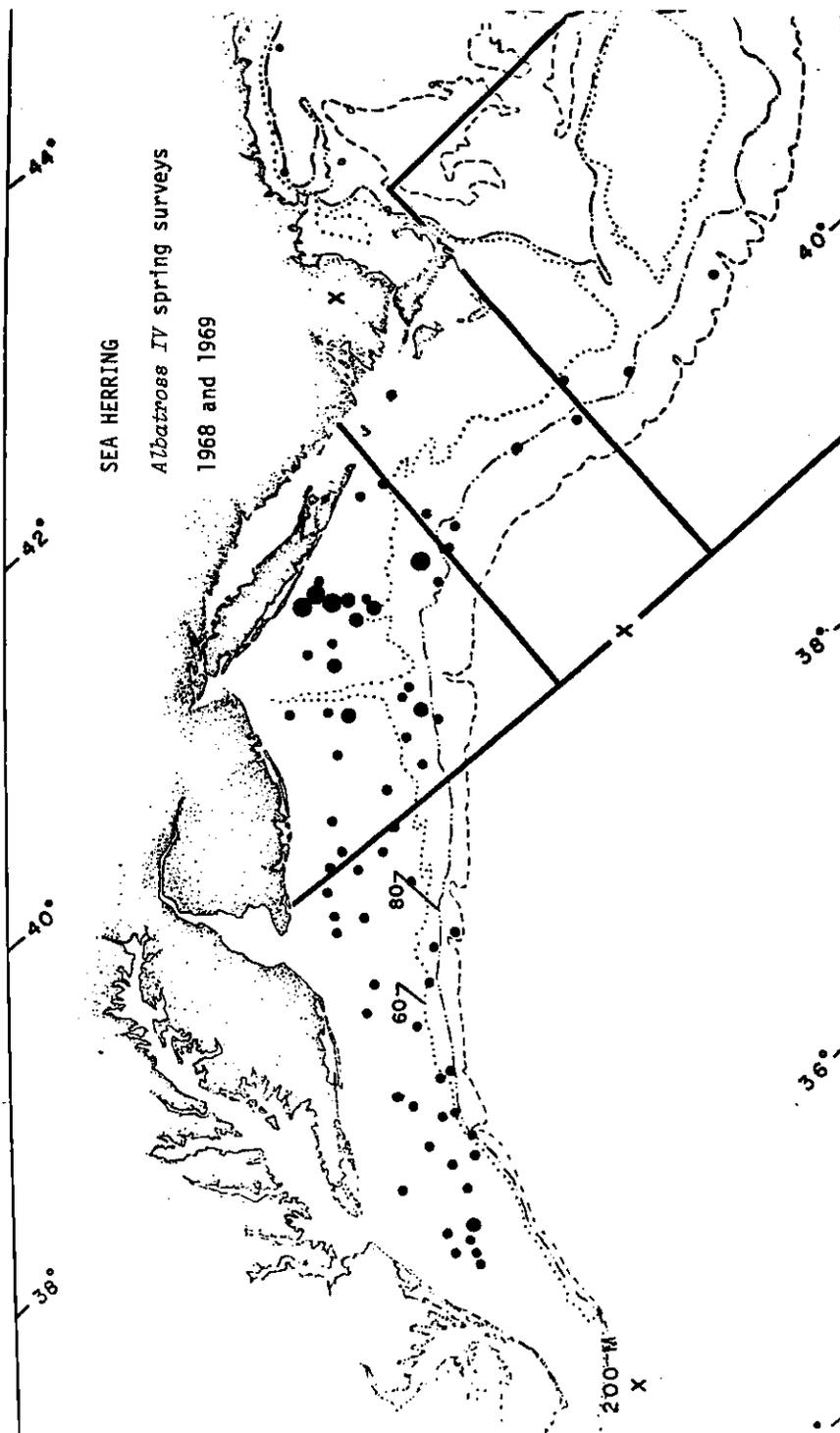


Chart 6.

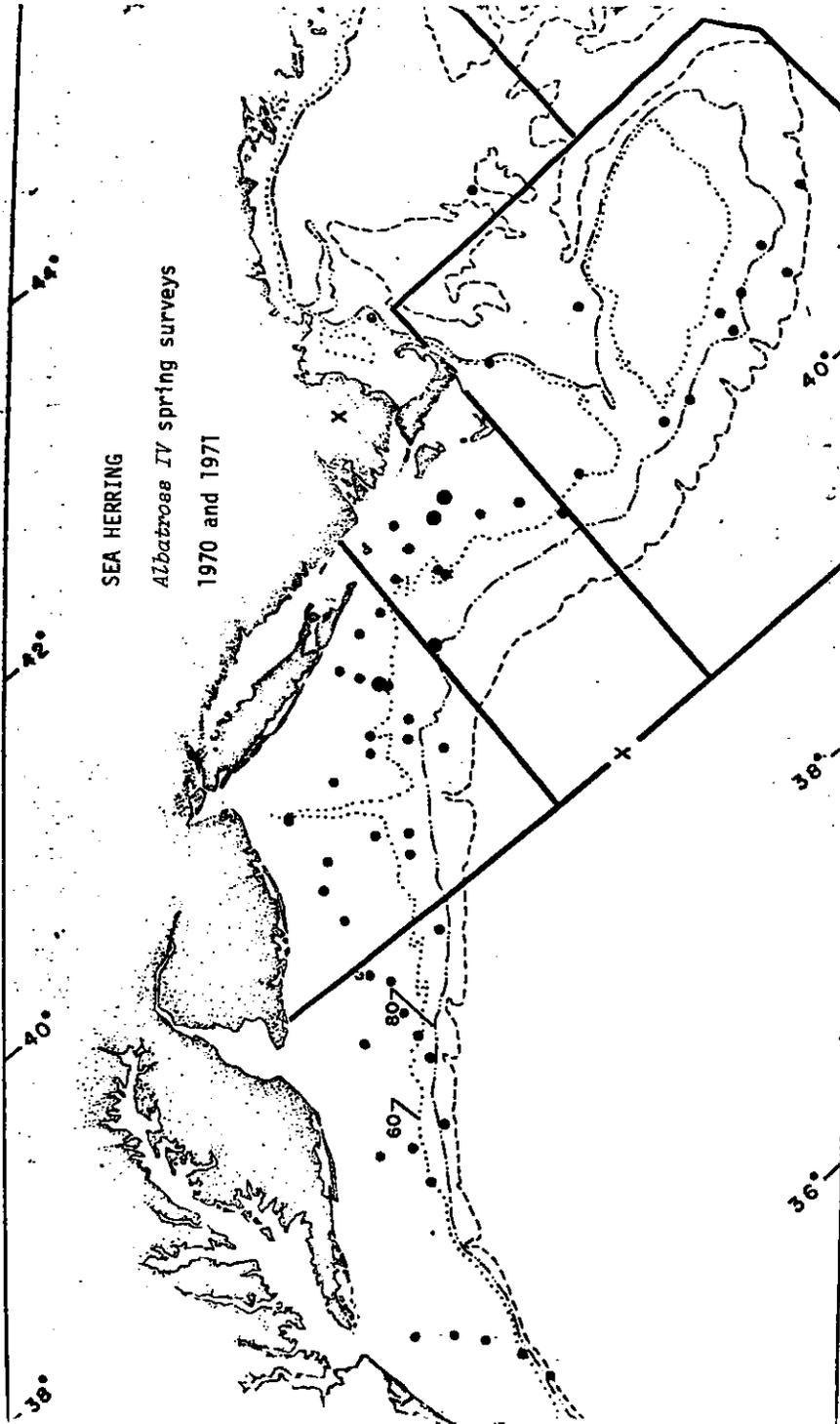


Chart 7.

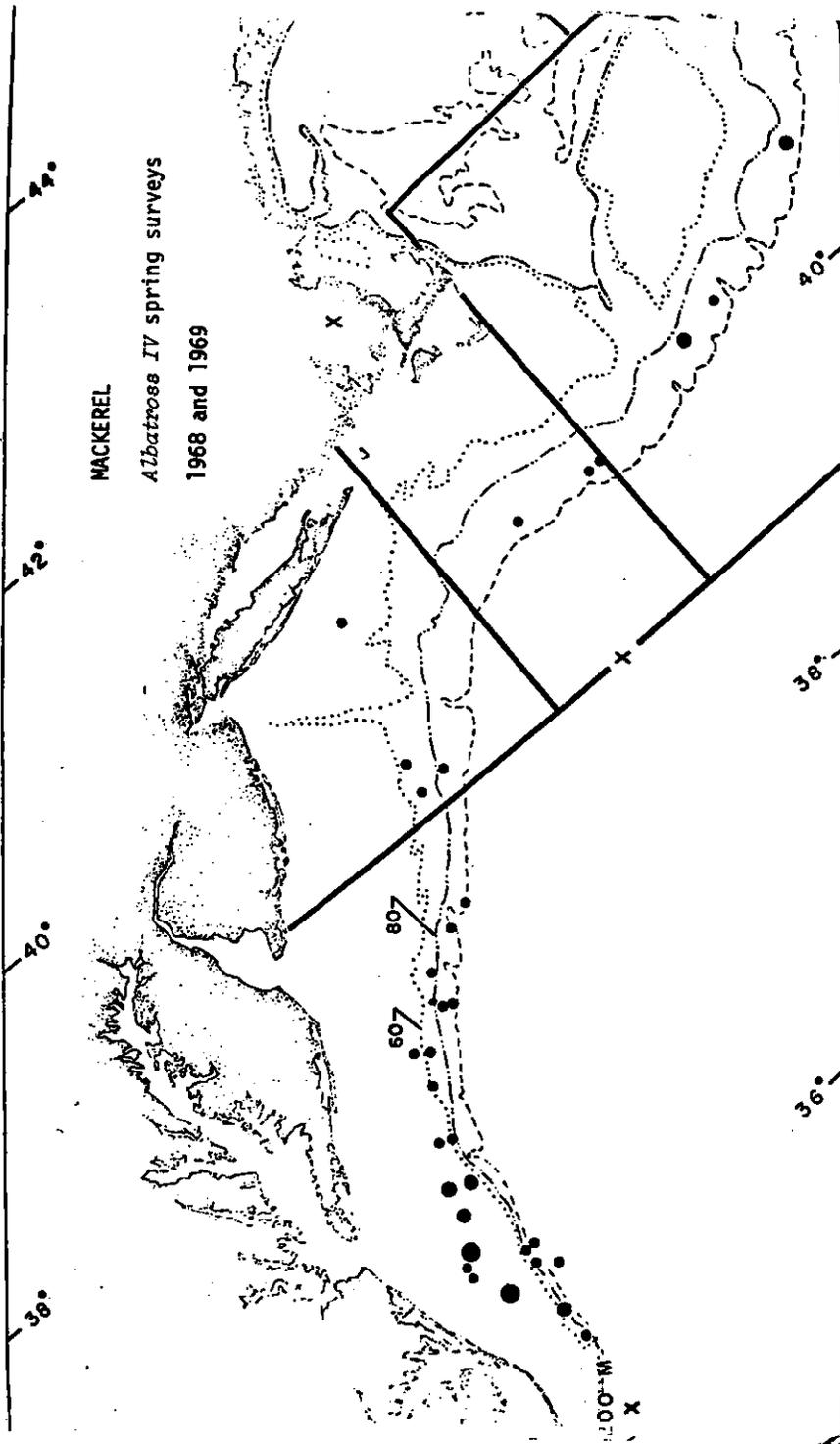


Chart 8.

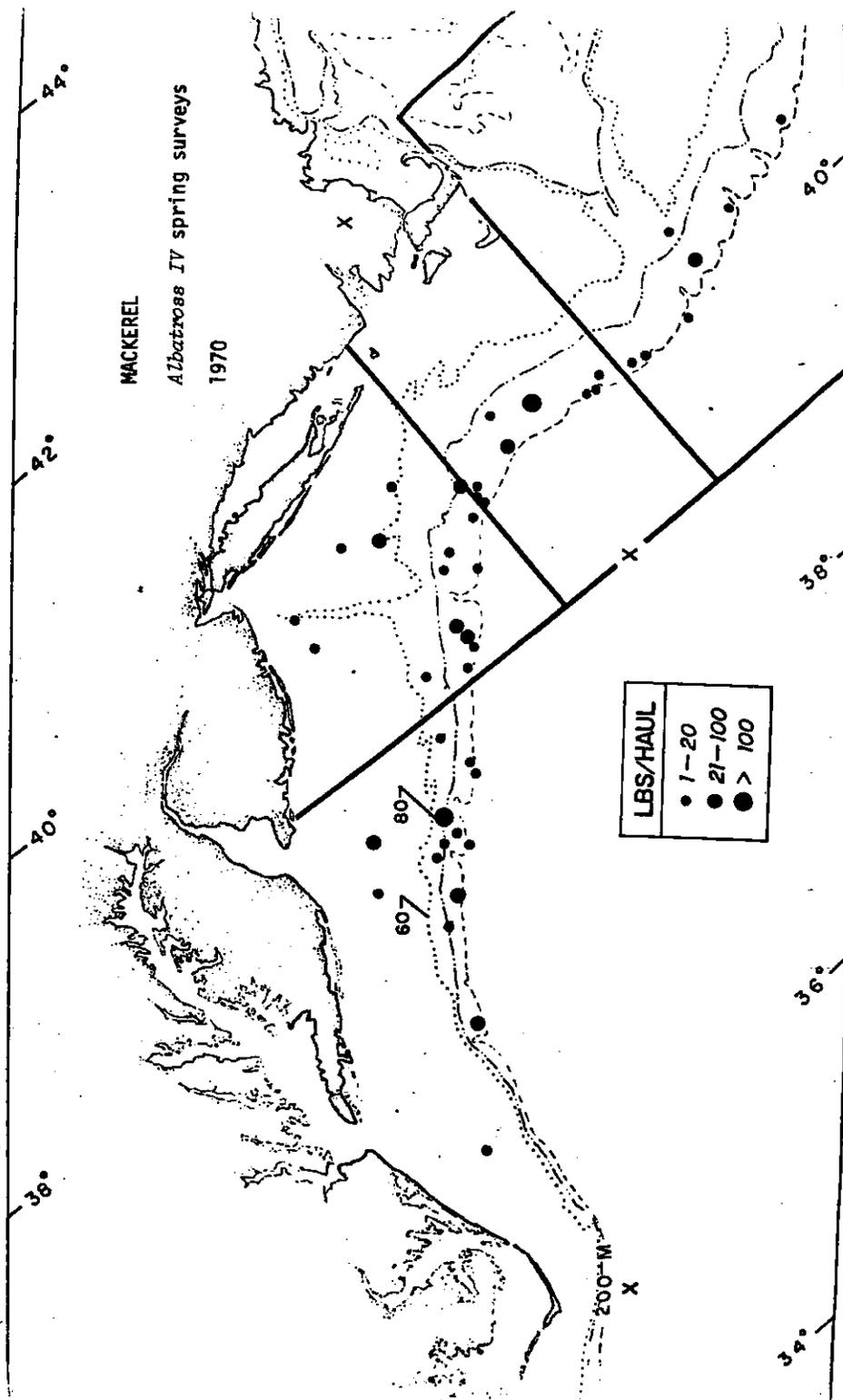


Chart 9.

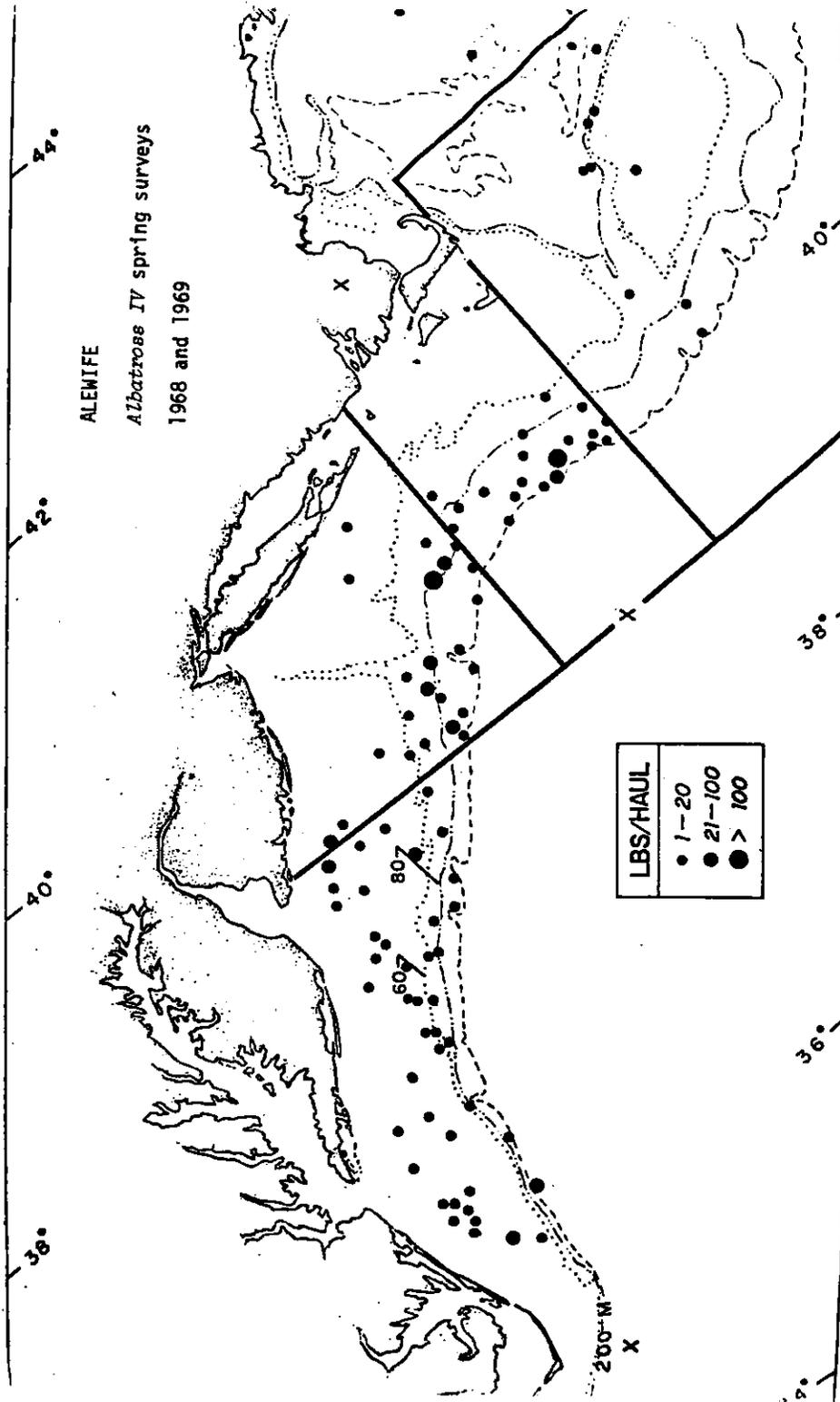


Chart 10.

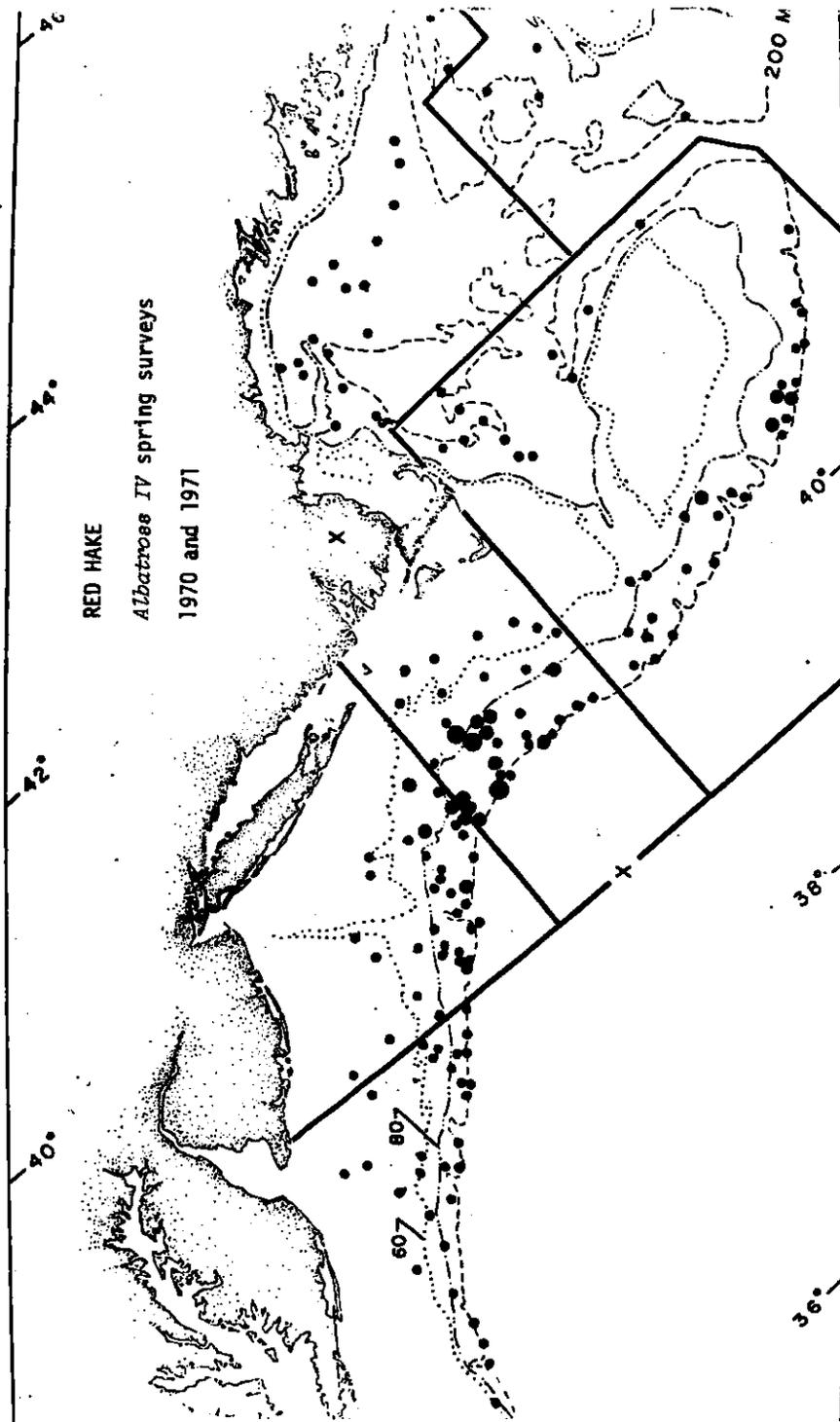


Chart 11.

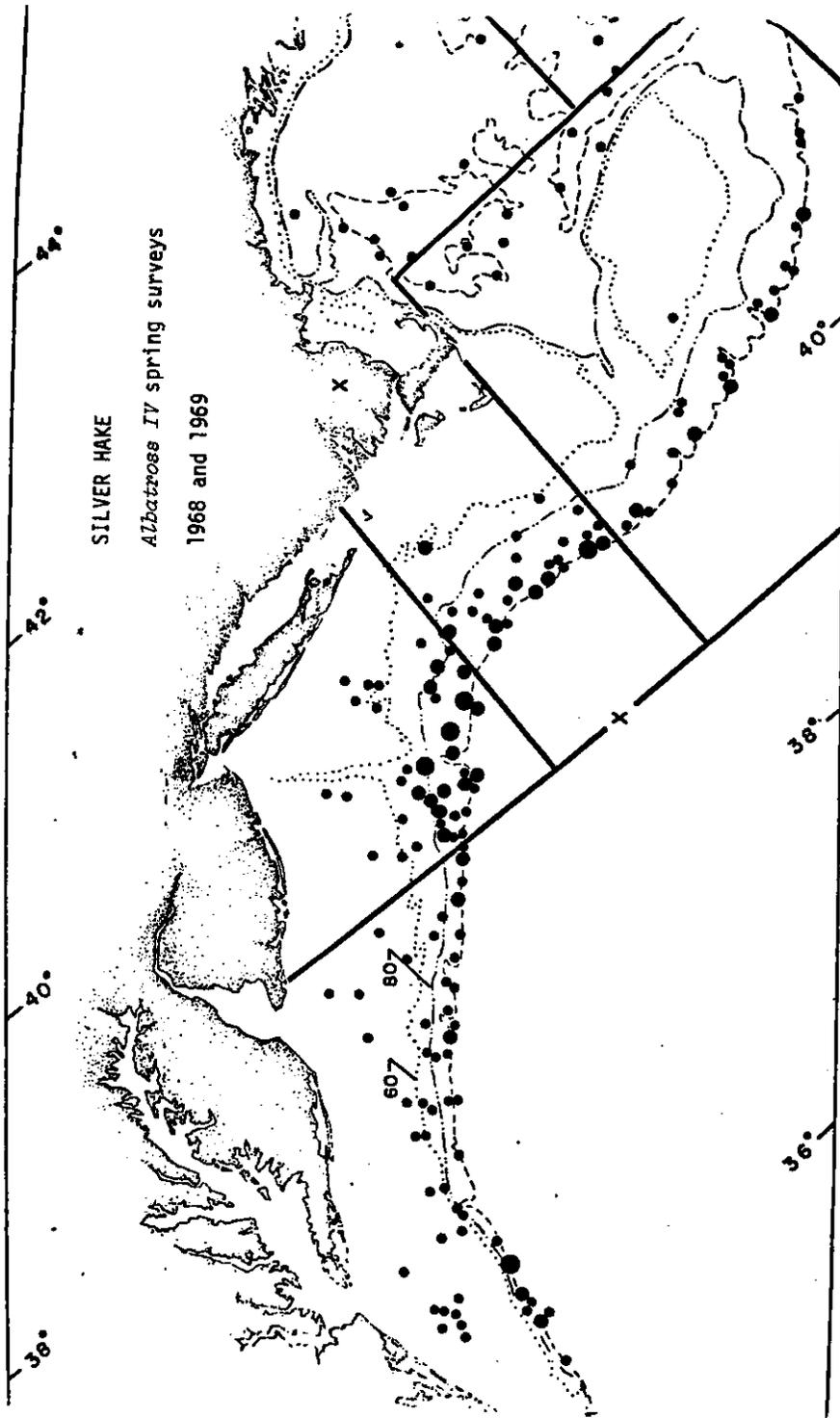


Chart 12.

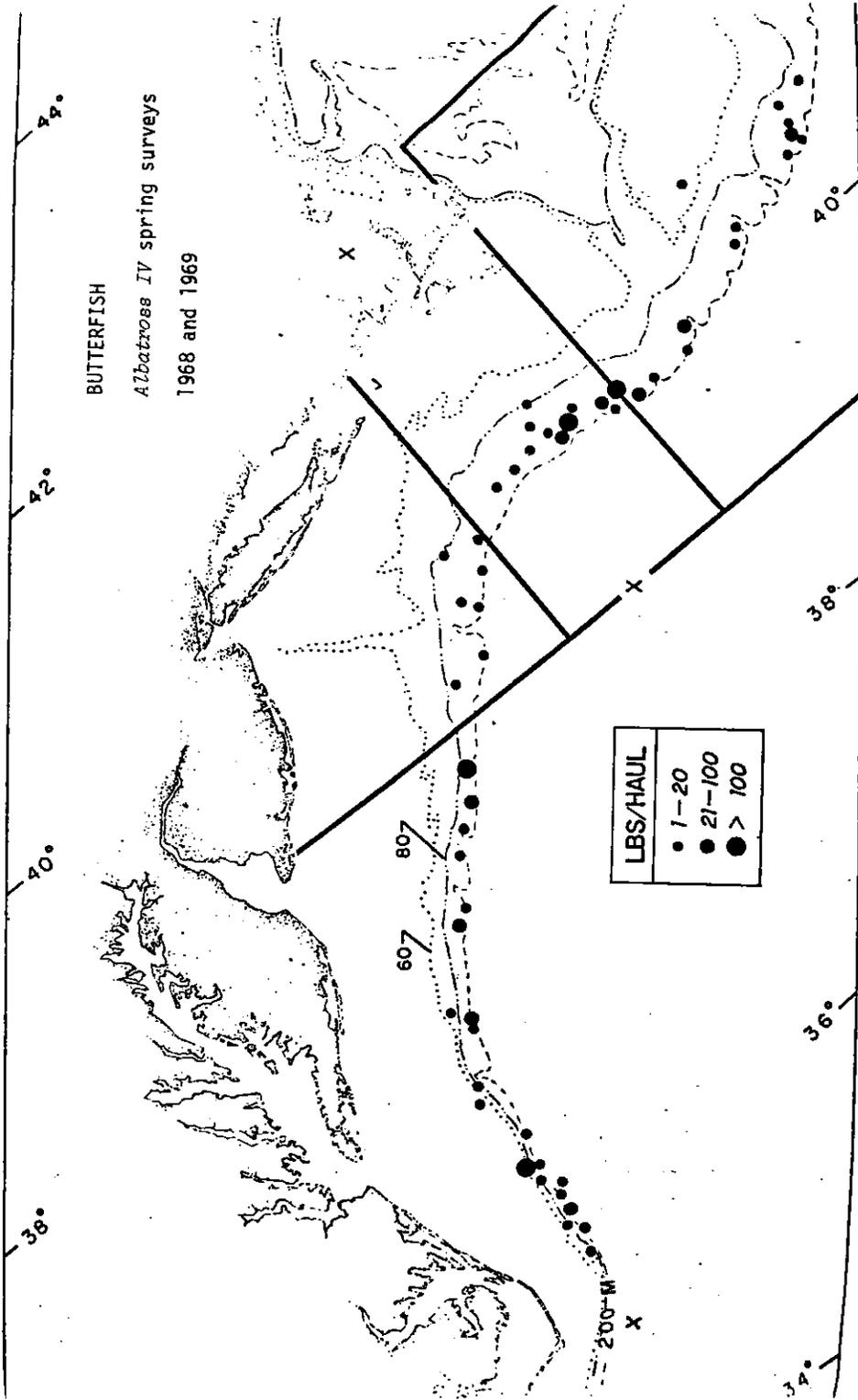


Chart 13.

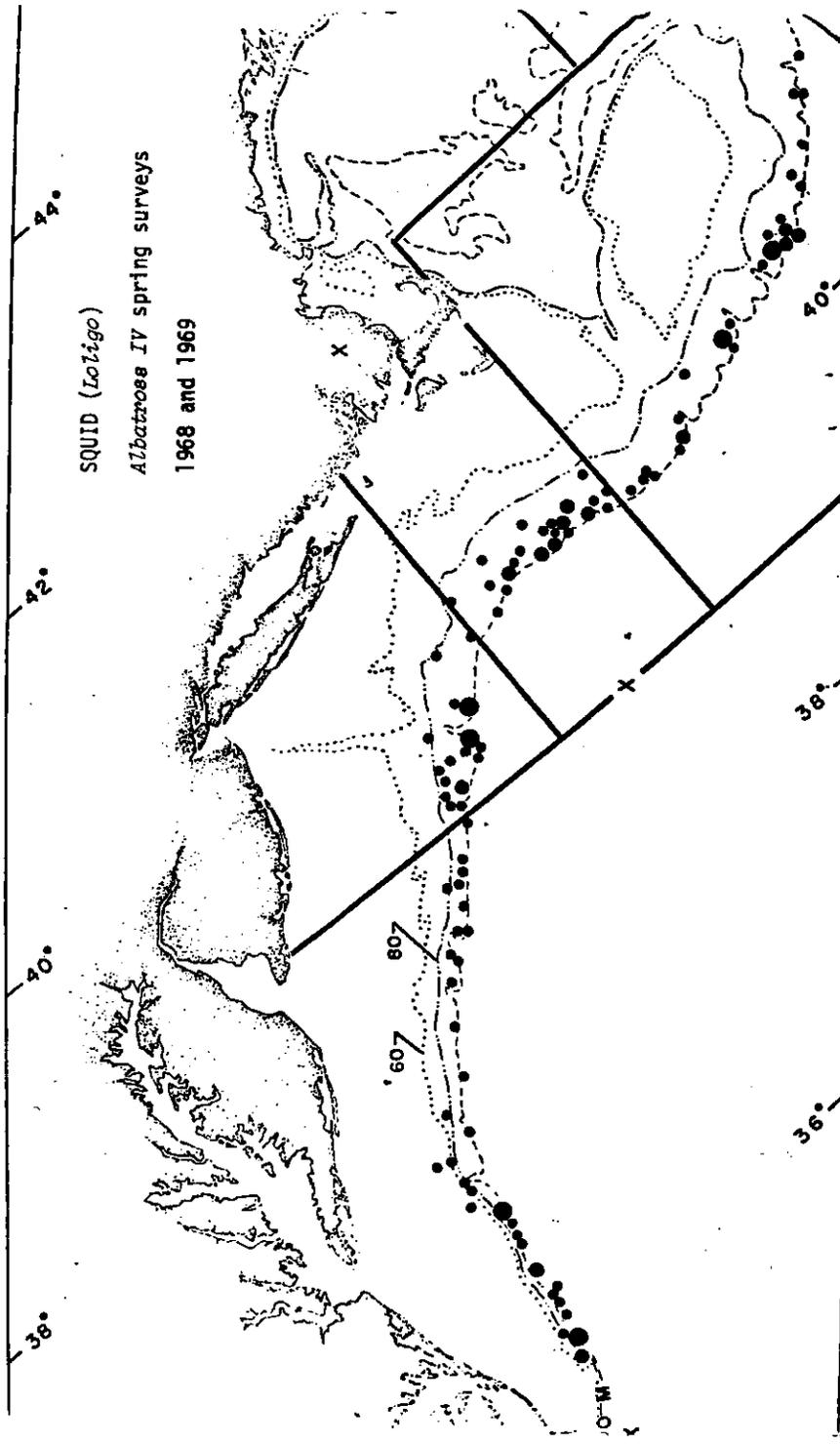


Chart 14.

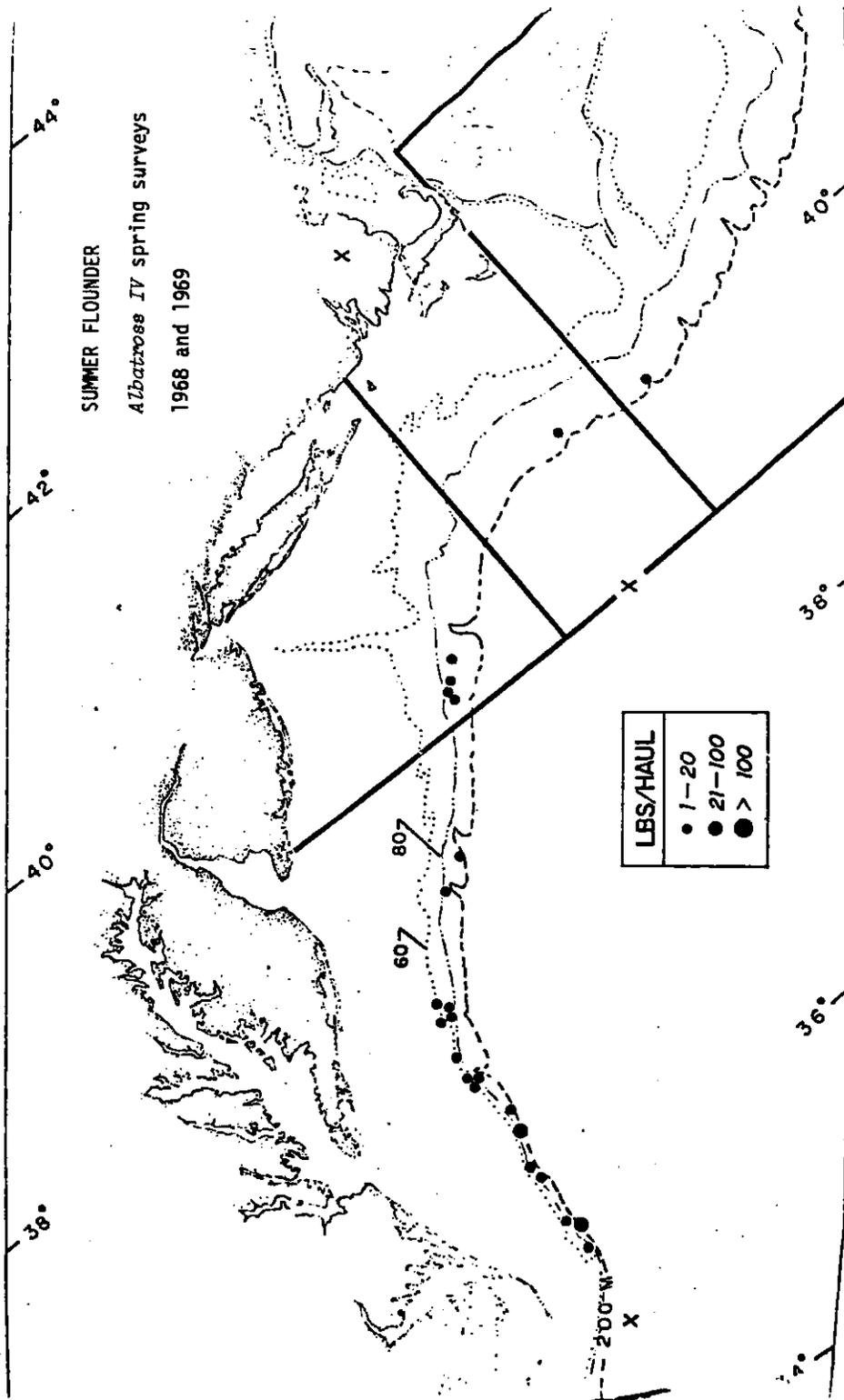


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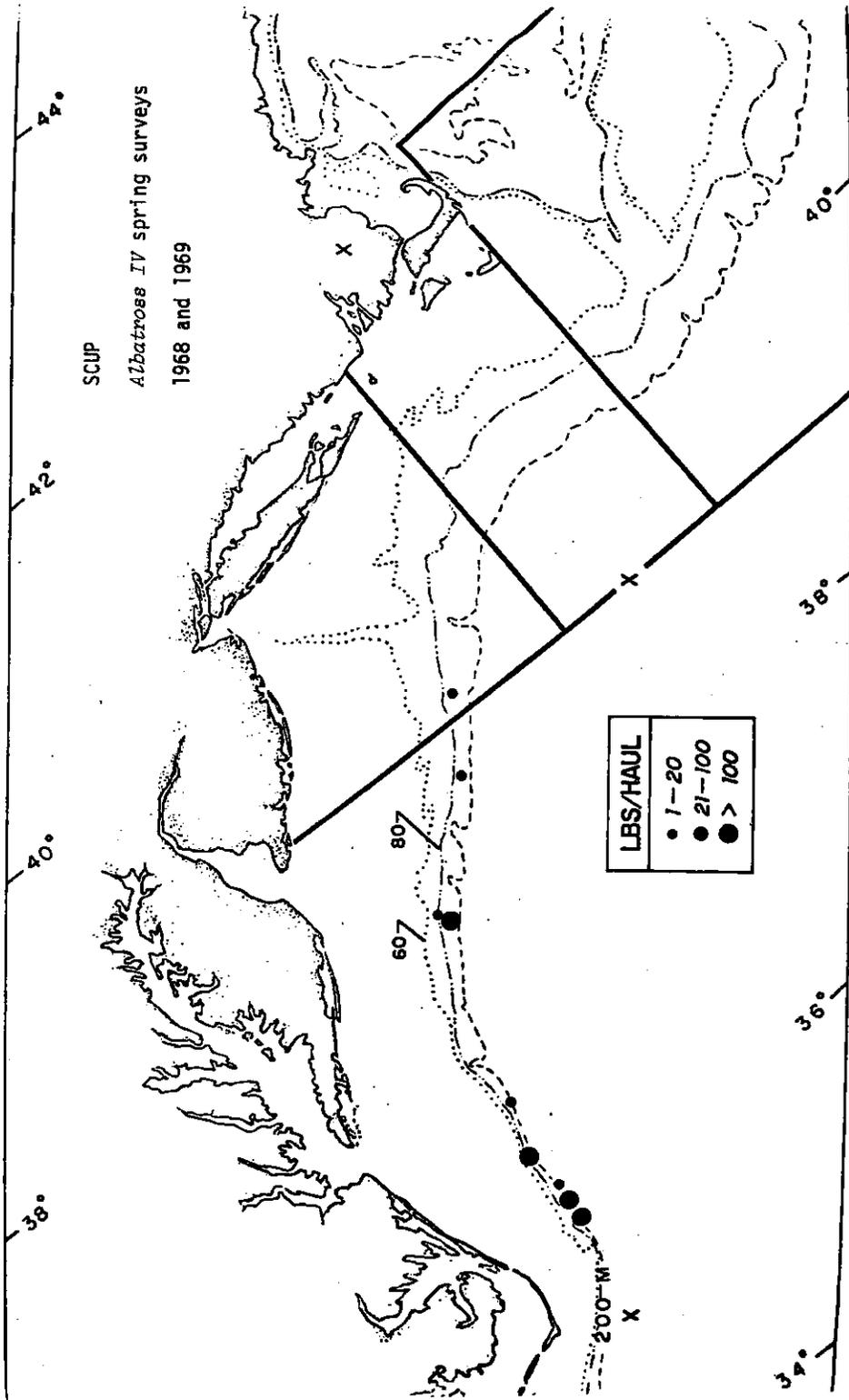


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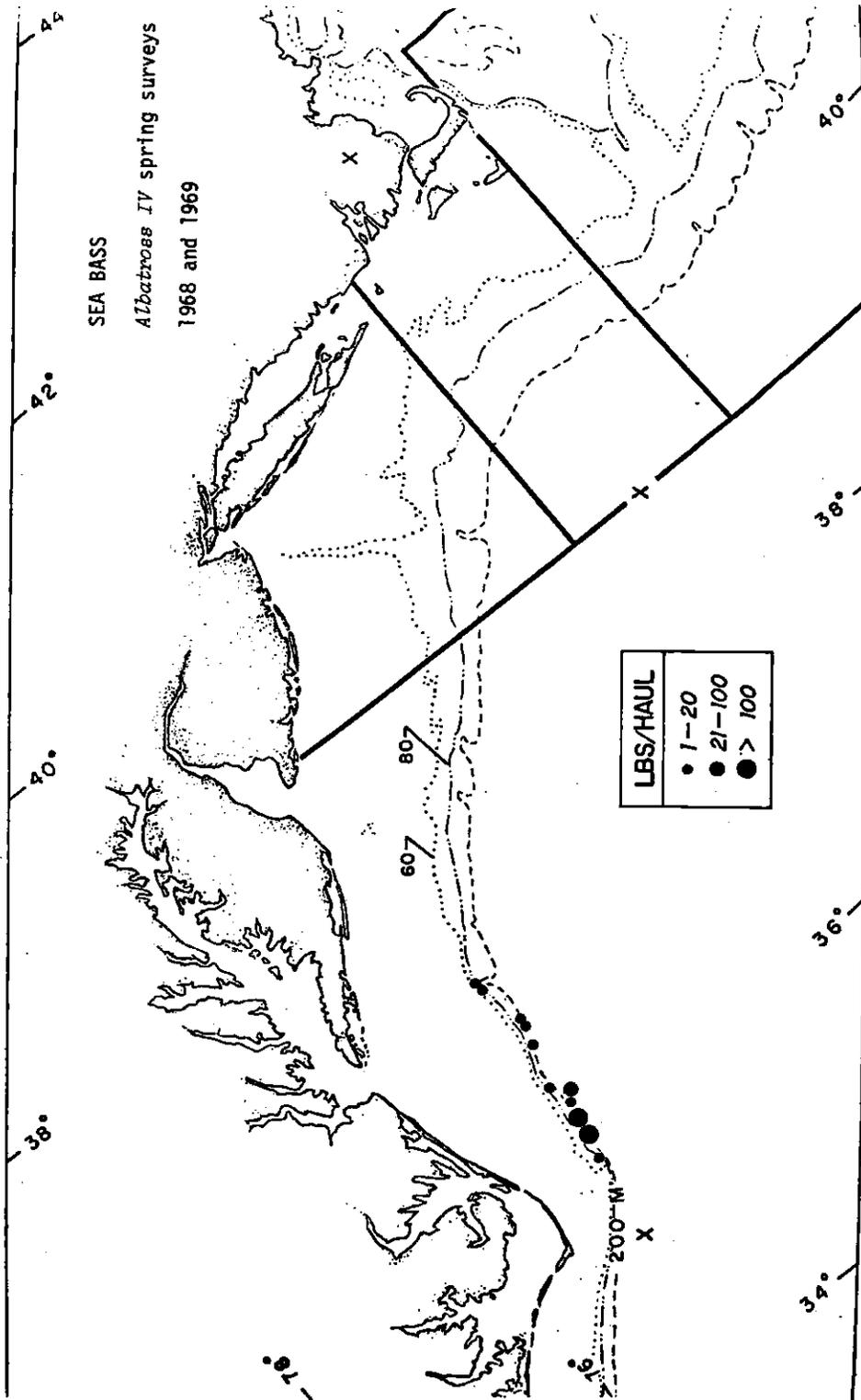


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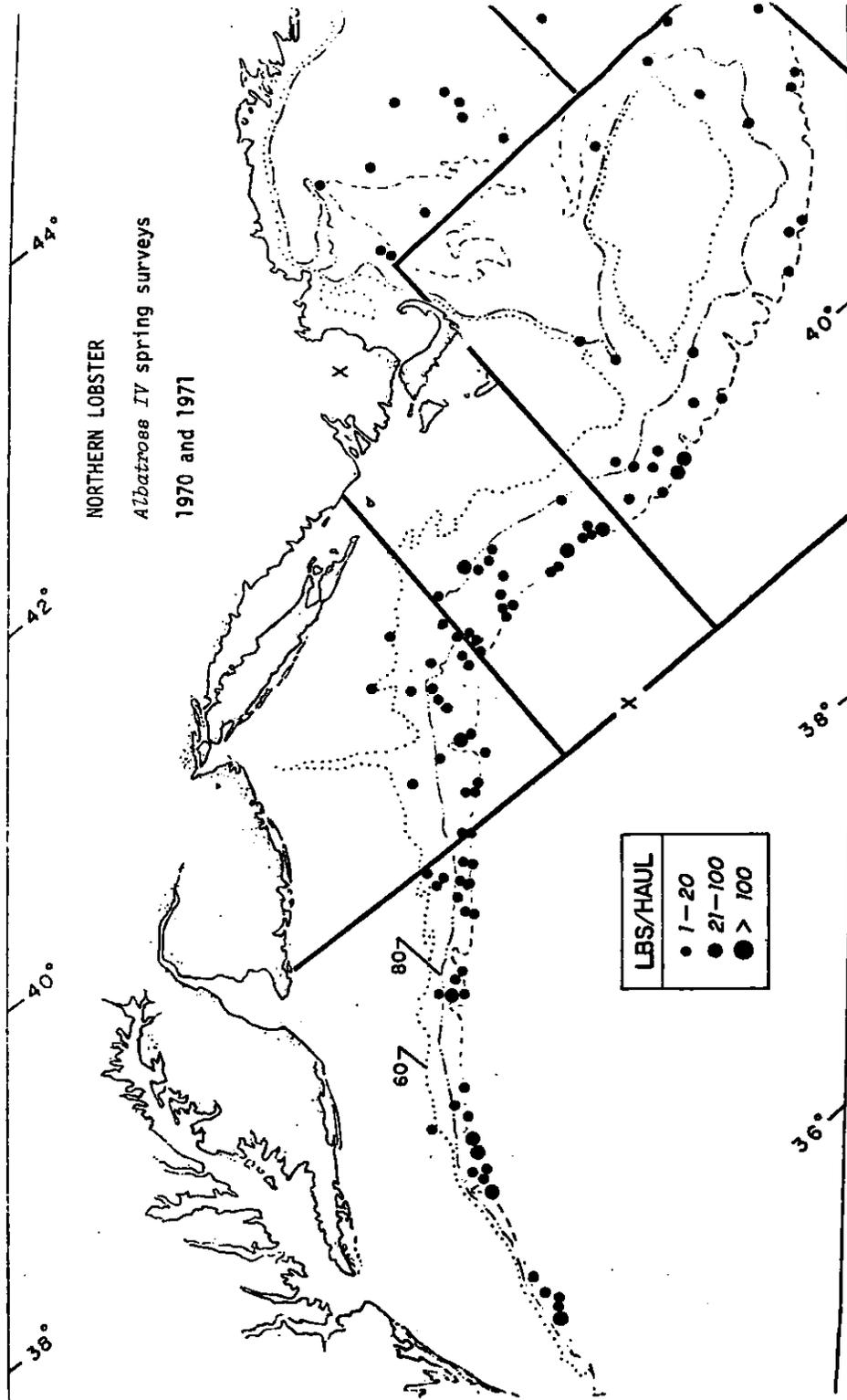


Chart 18.

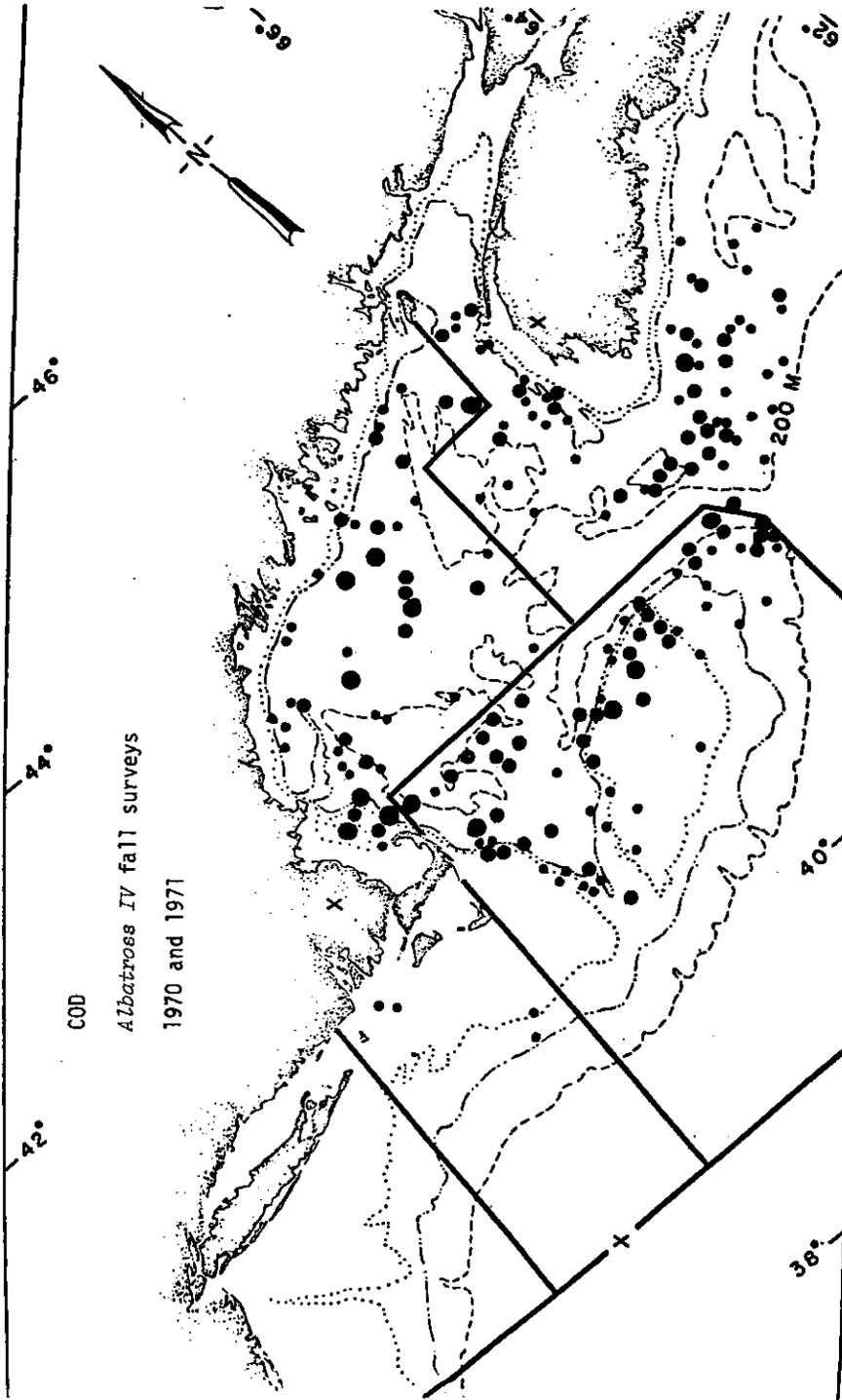


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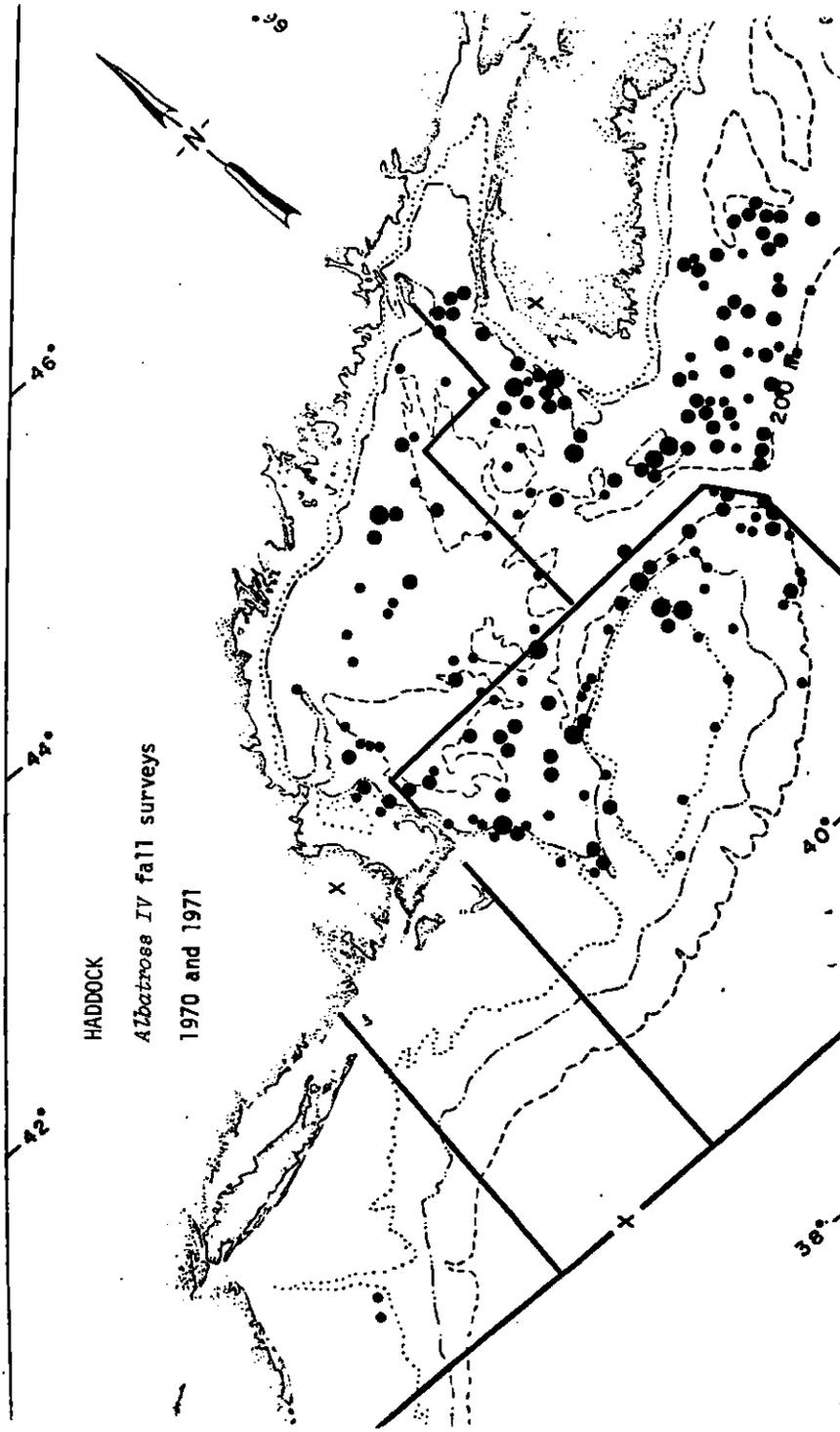


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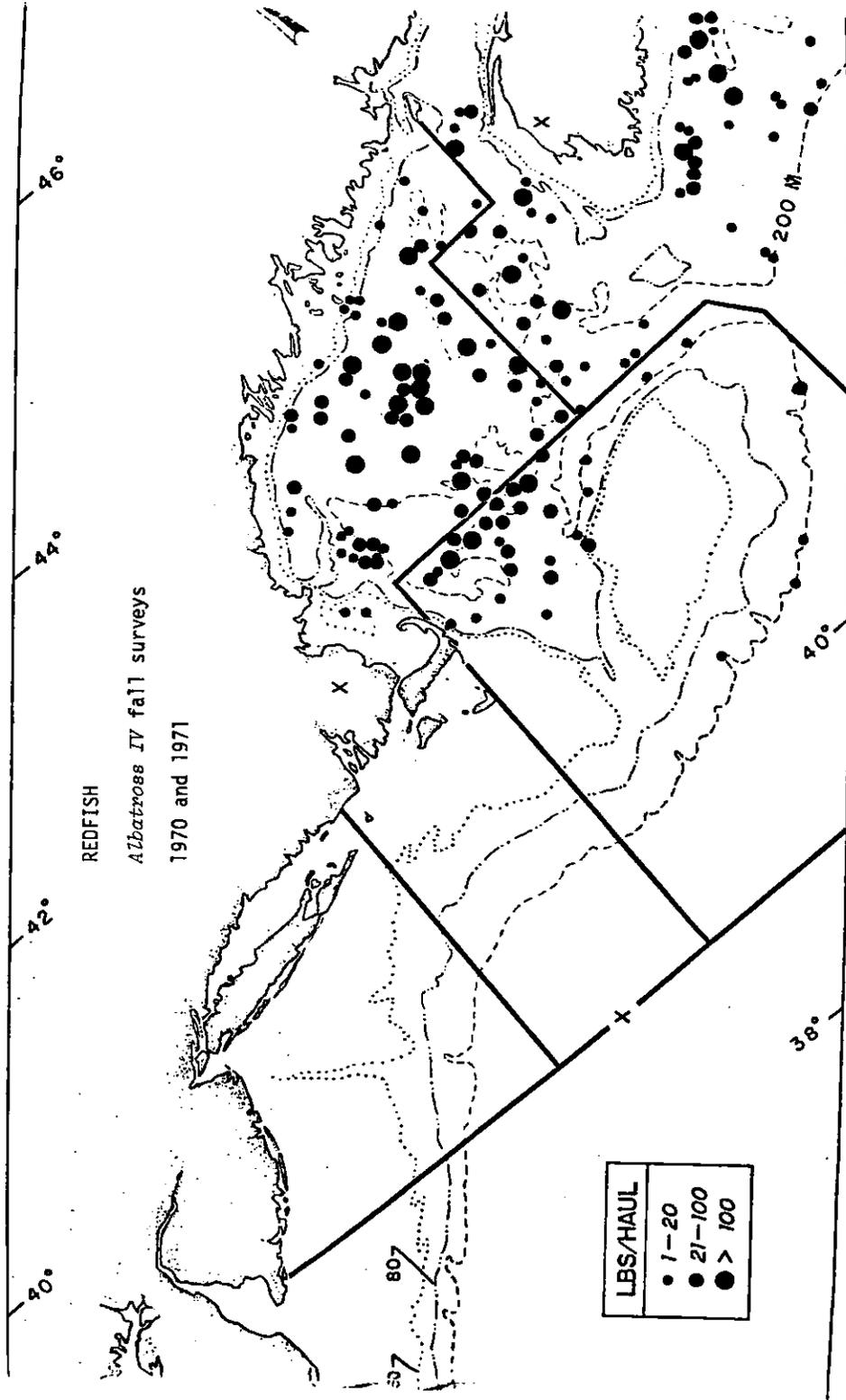


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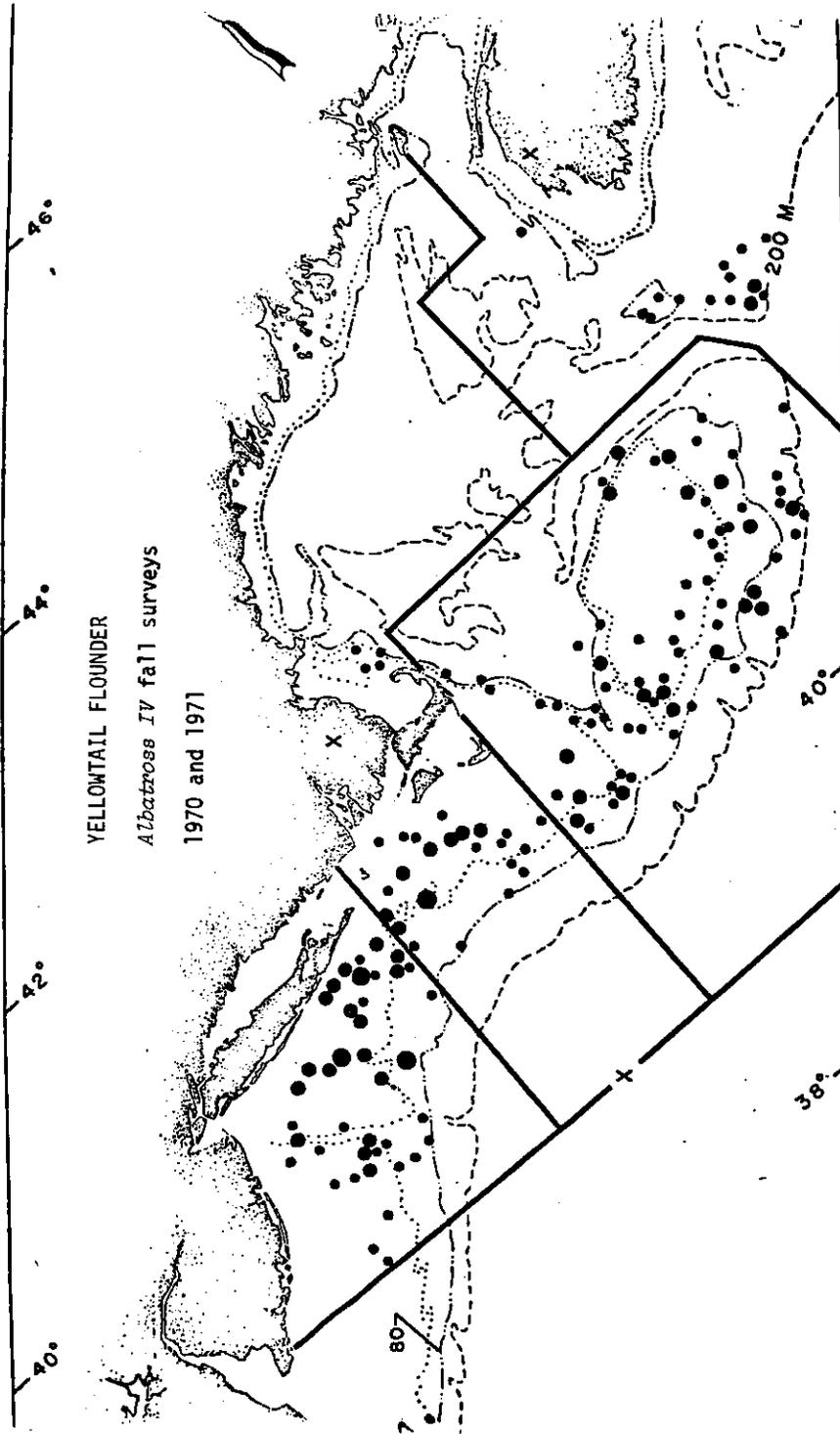


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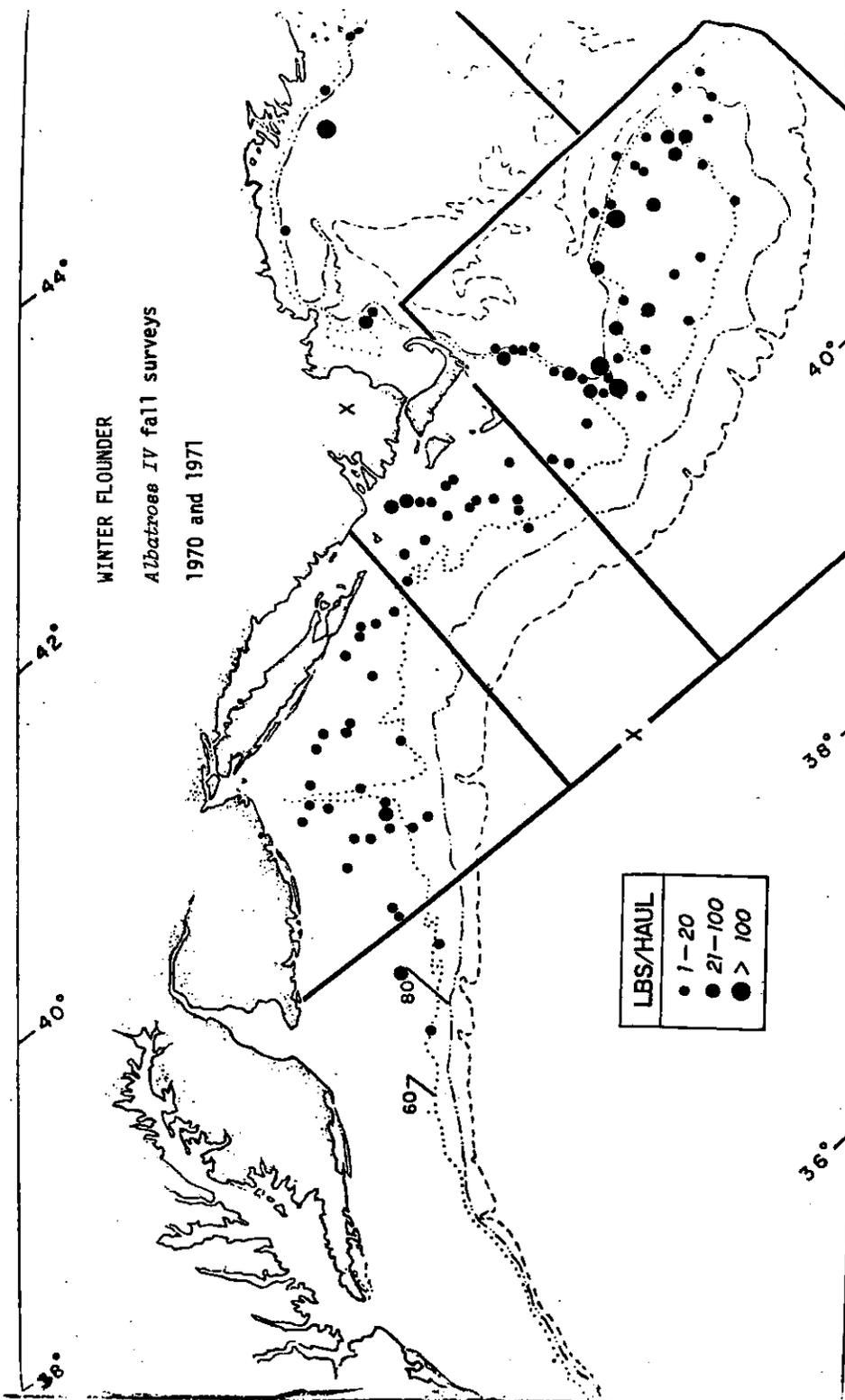


Chart 23.

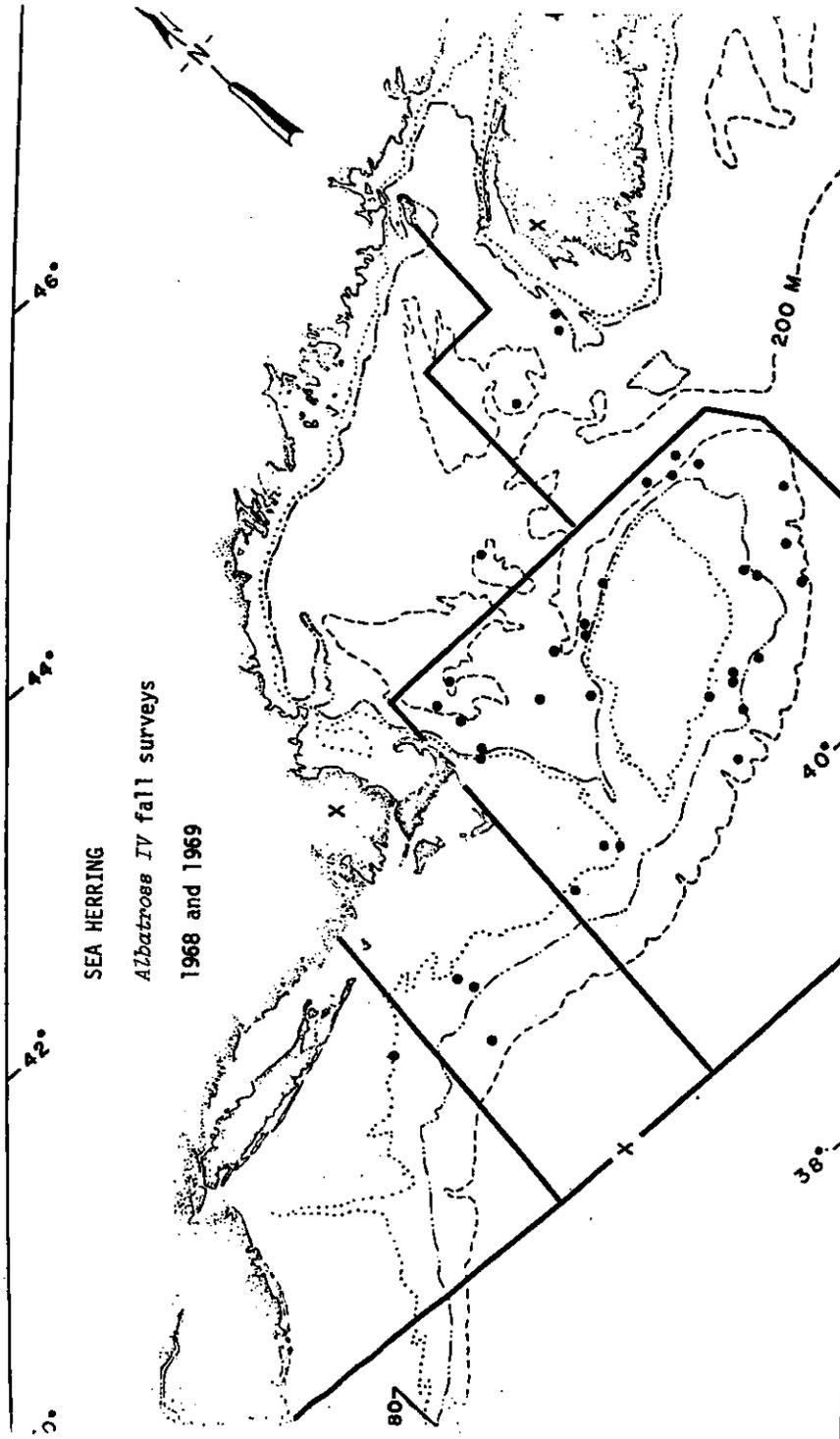
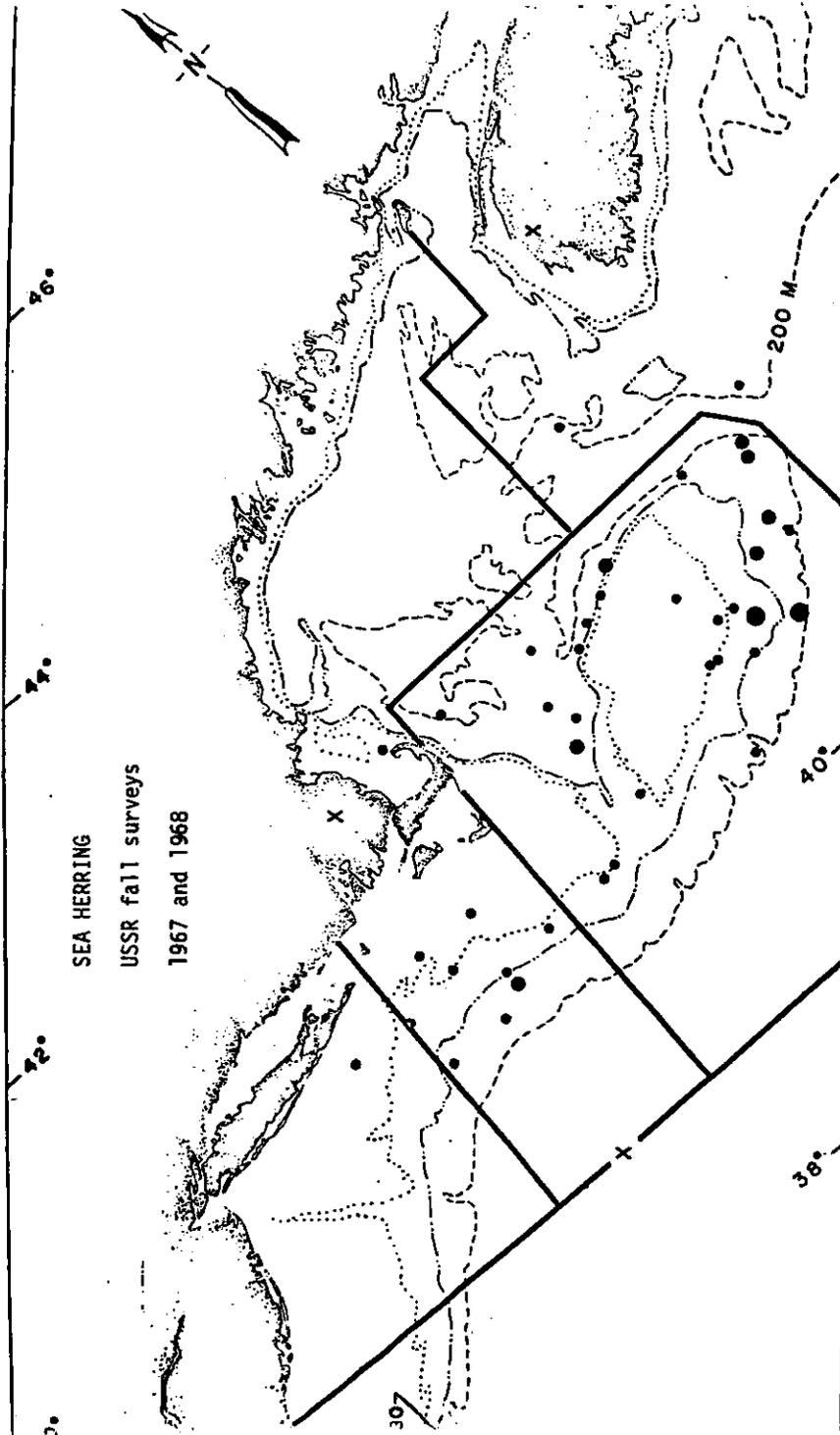


Chart 24.



SEA HERRING
USSR fall surveys
1967 and 1968

Chart 25.

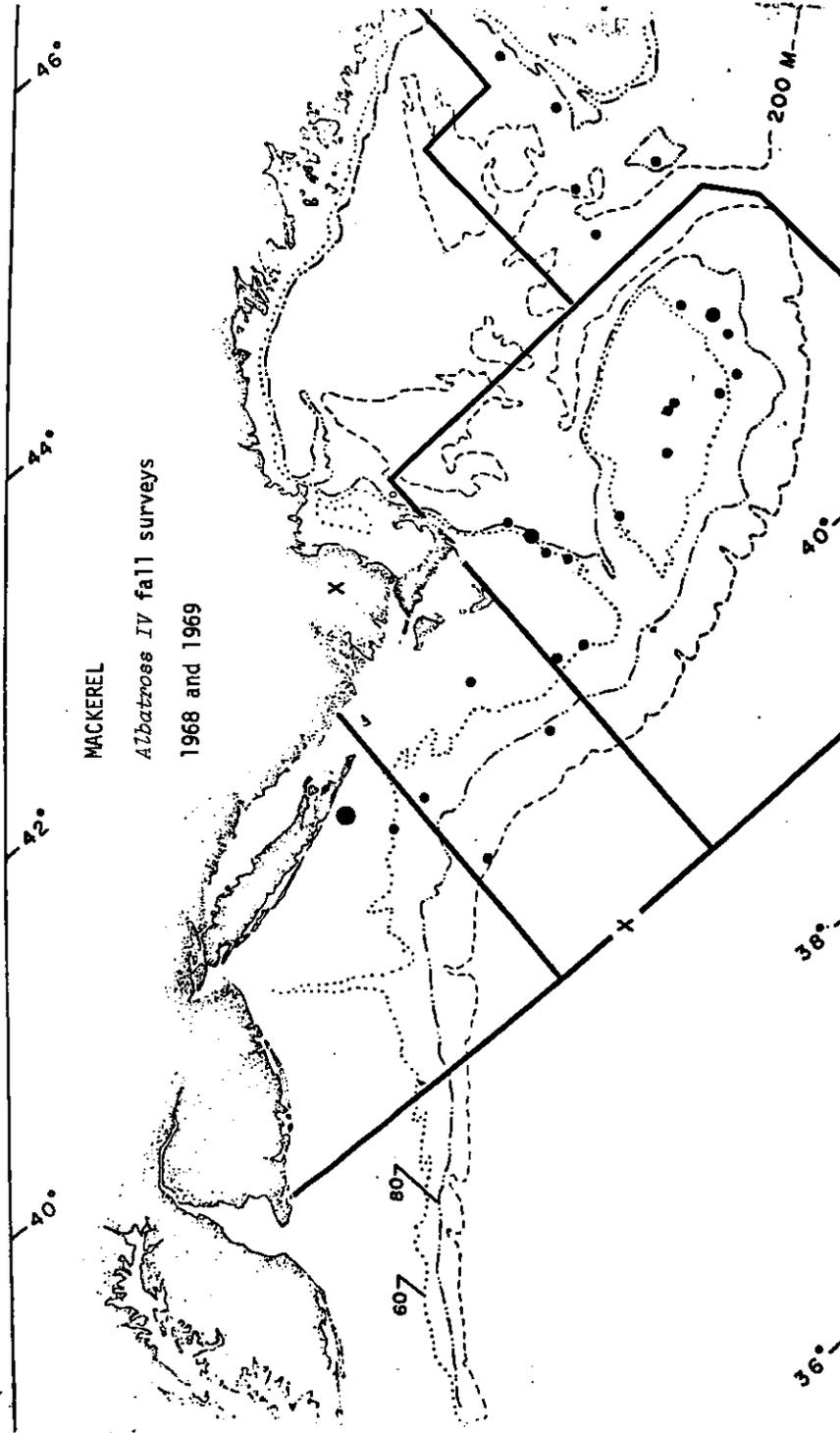


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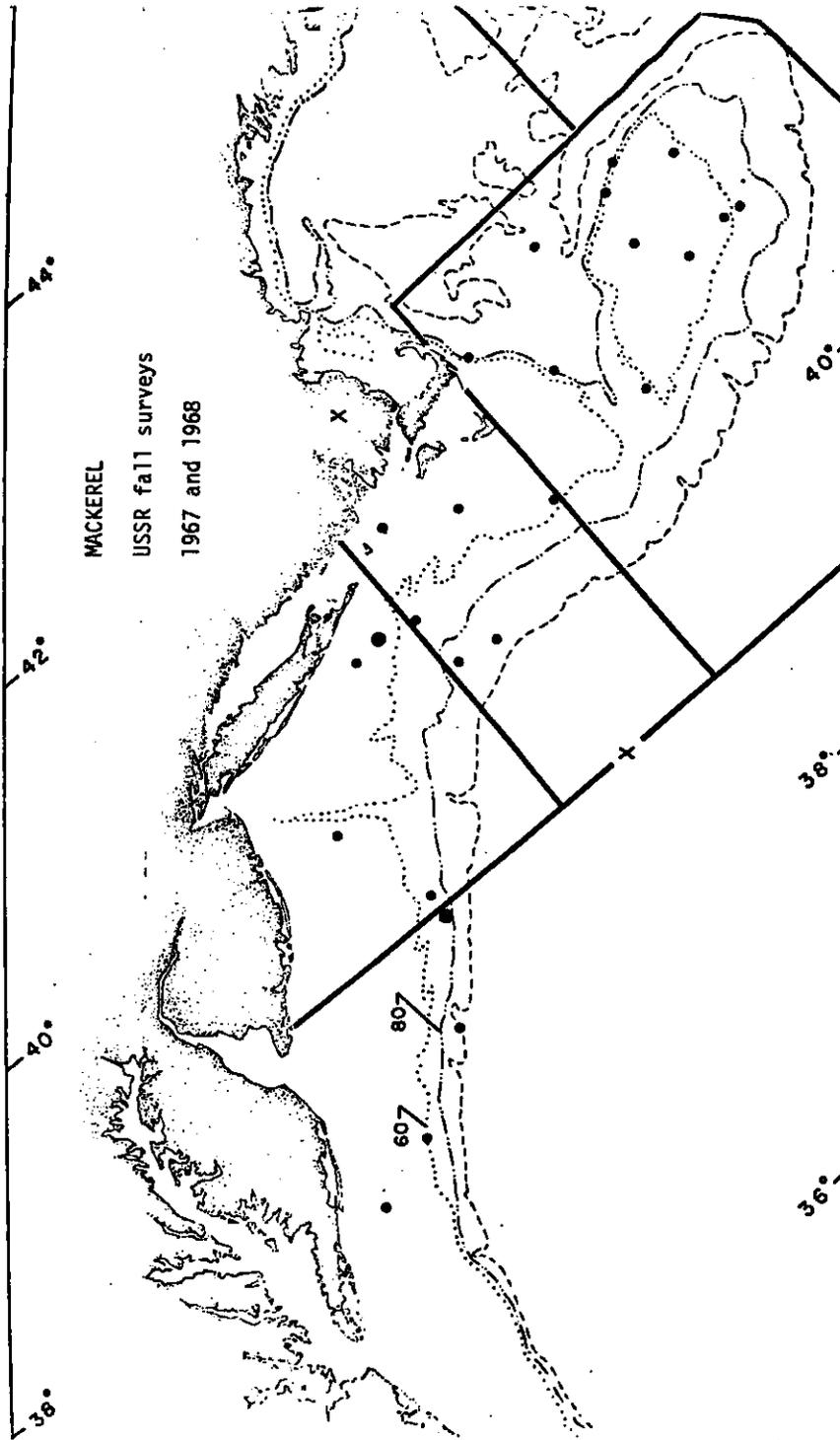


Chart 27.

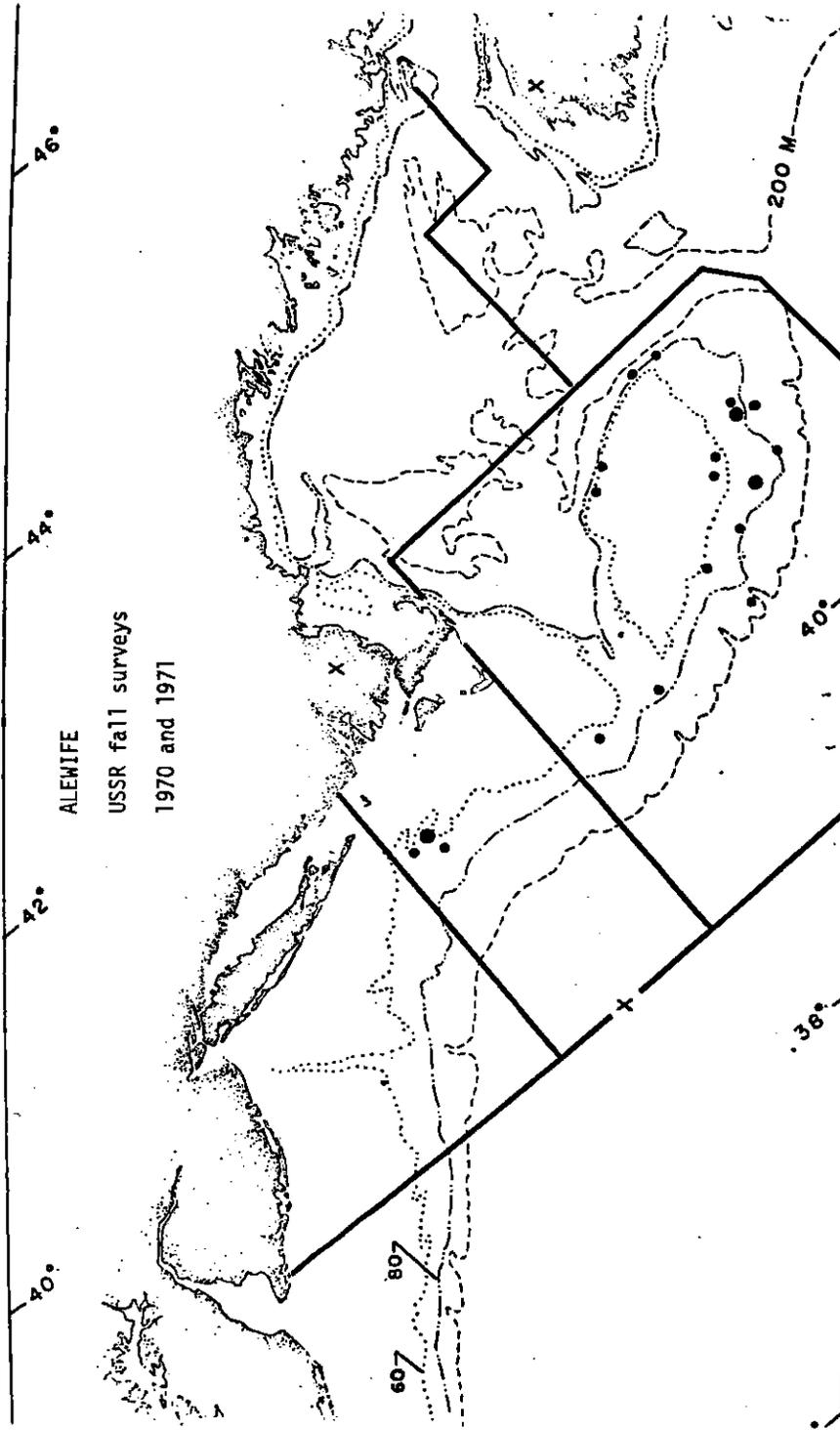


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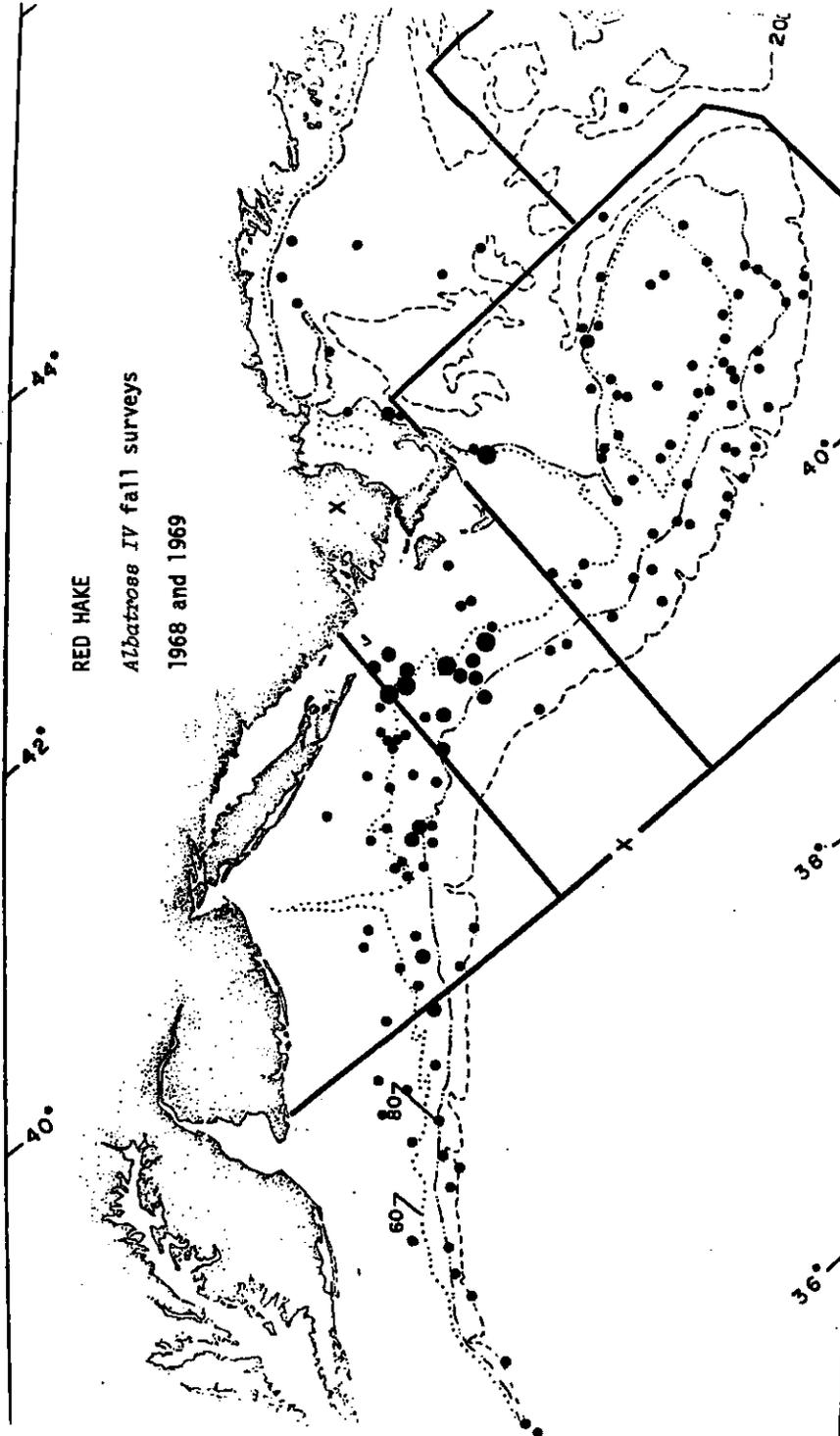


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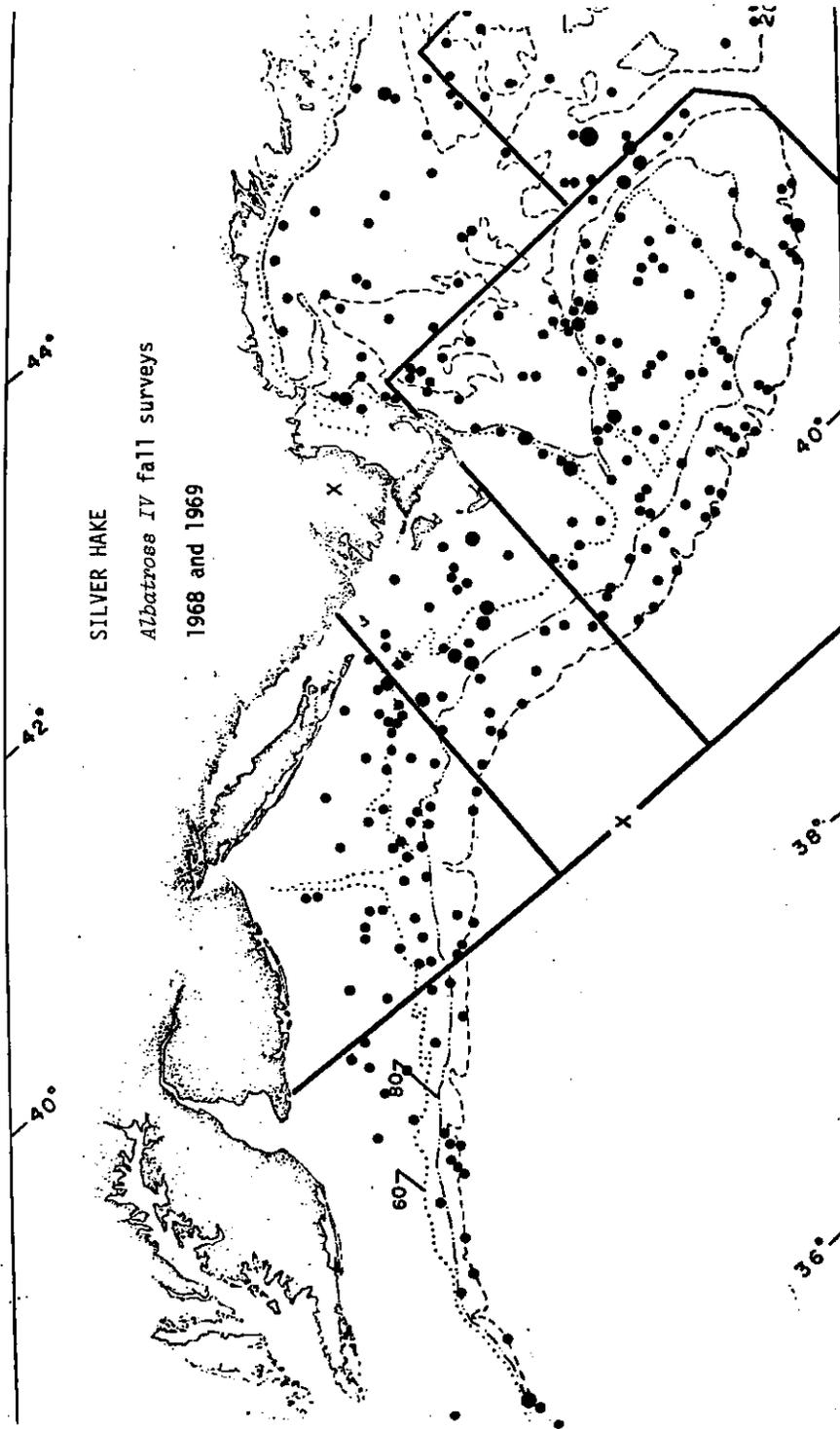


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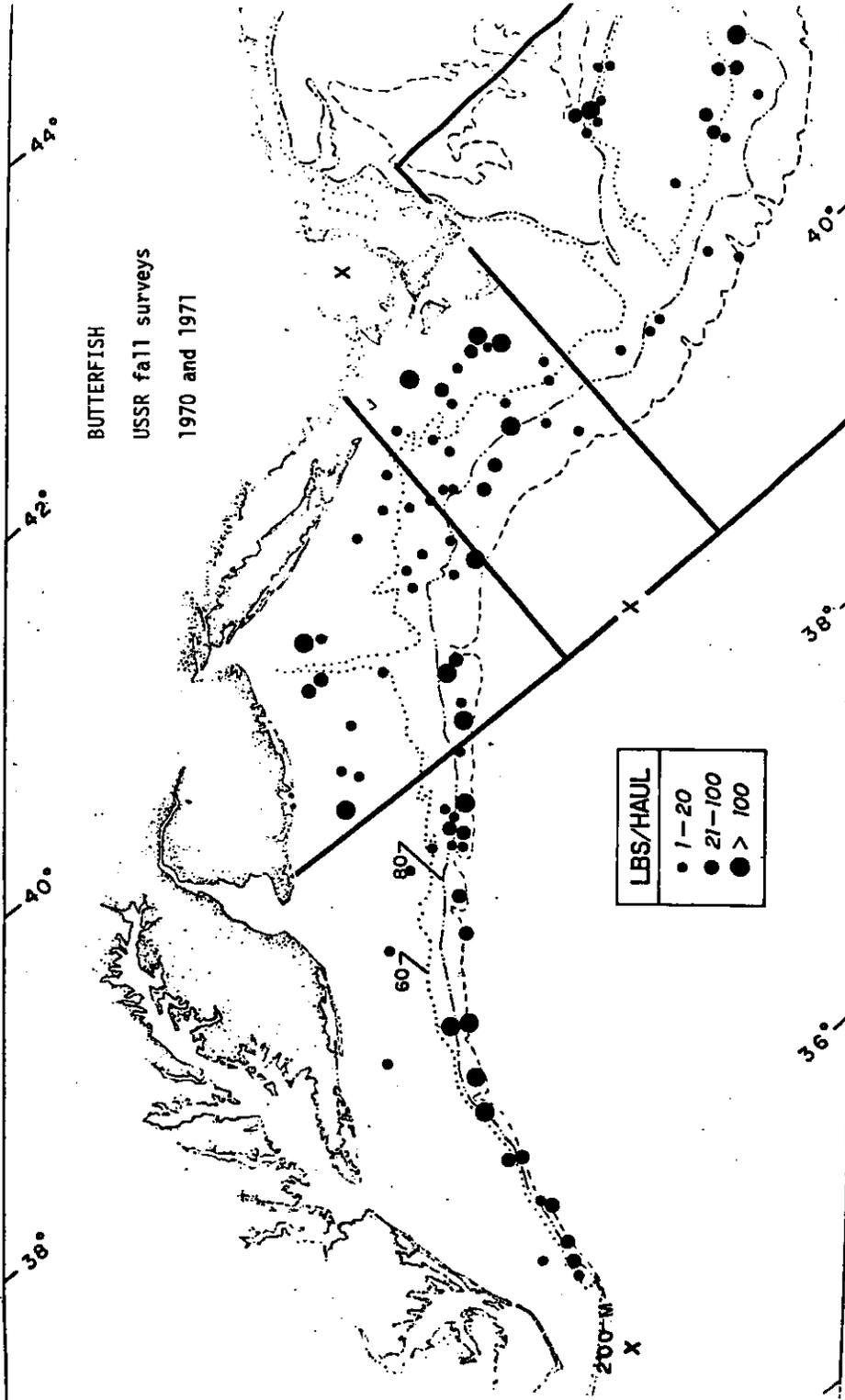


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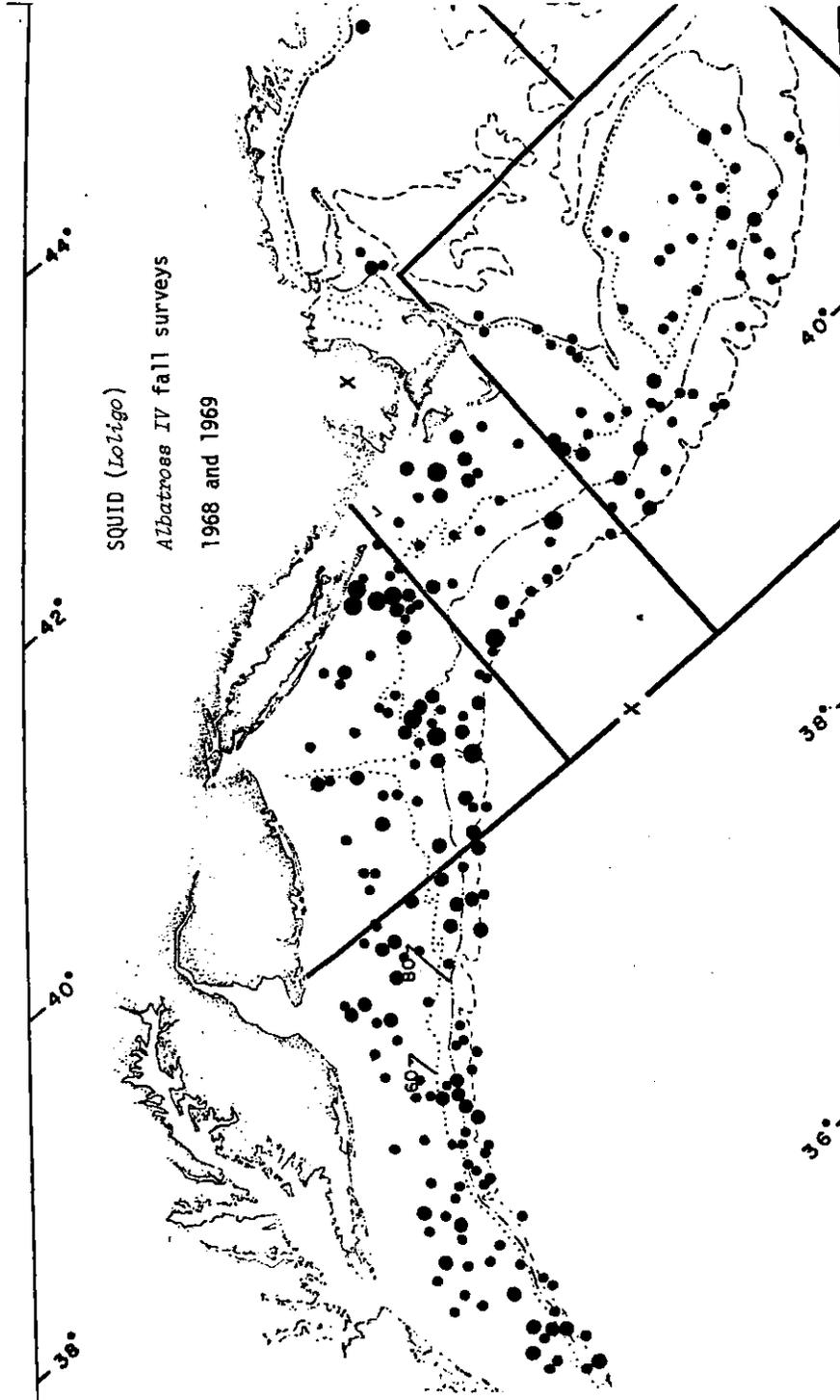


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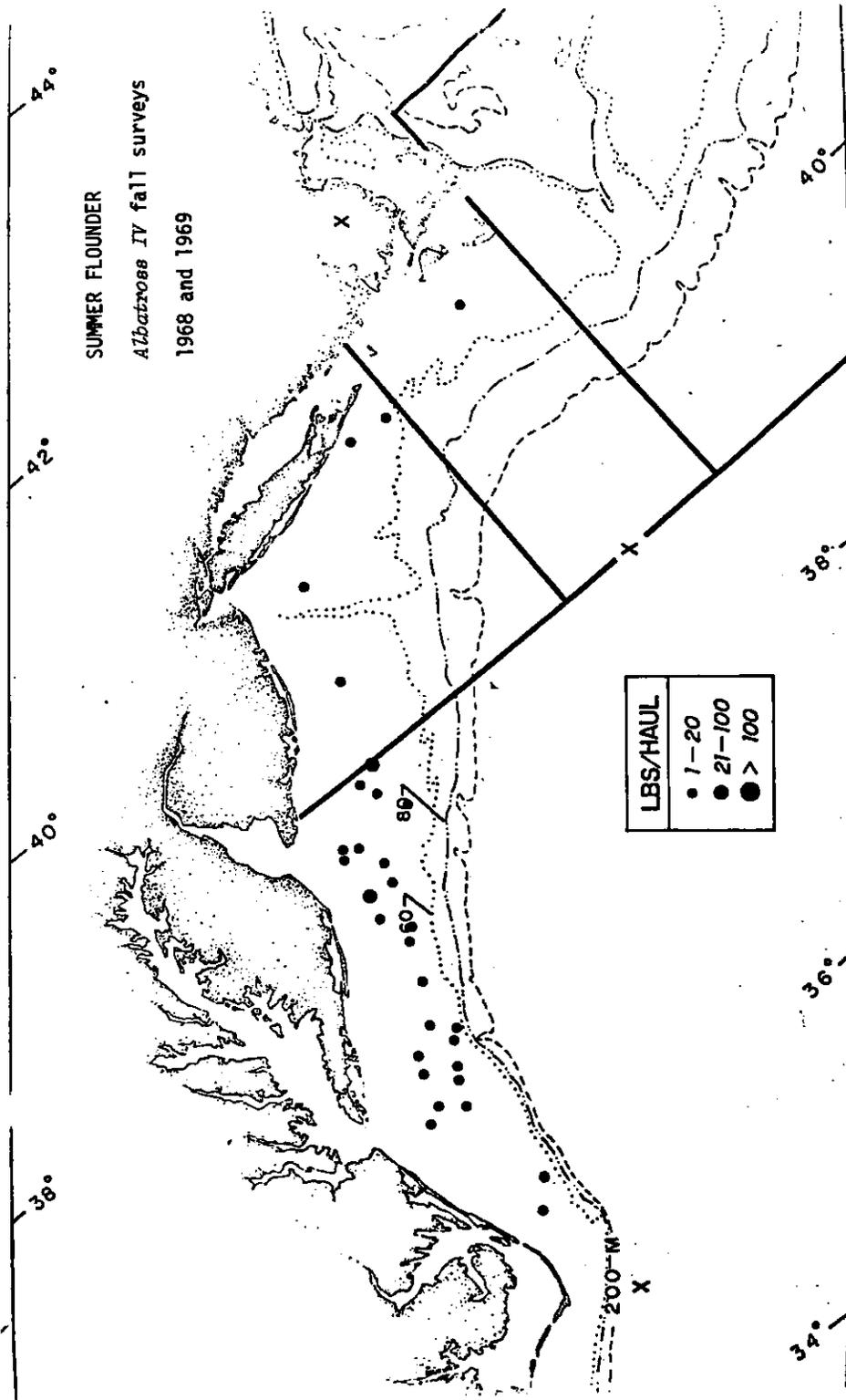


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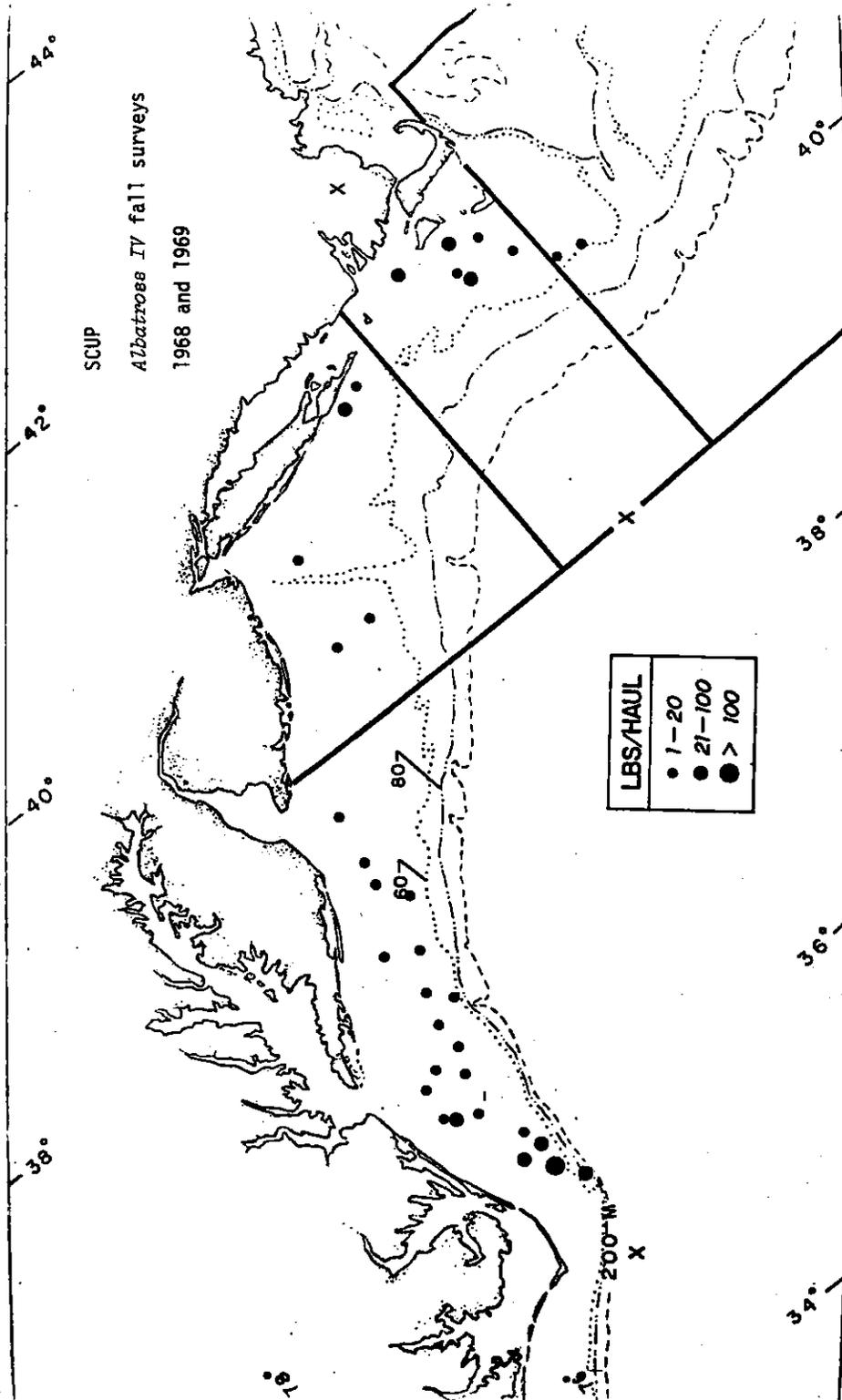


Chart 34.

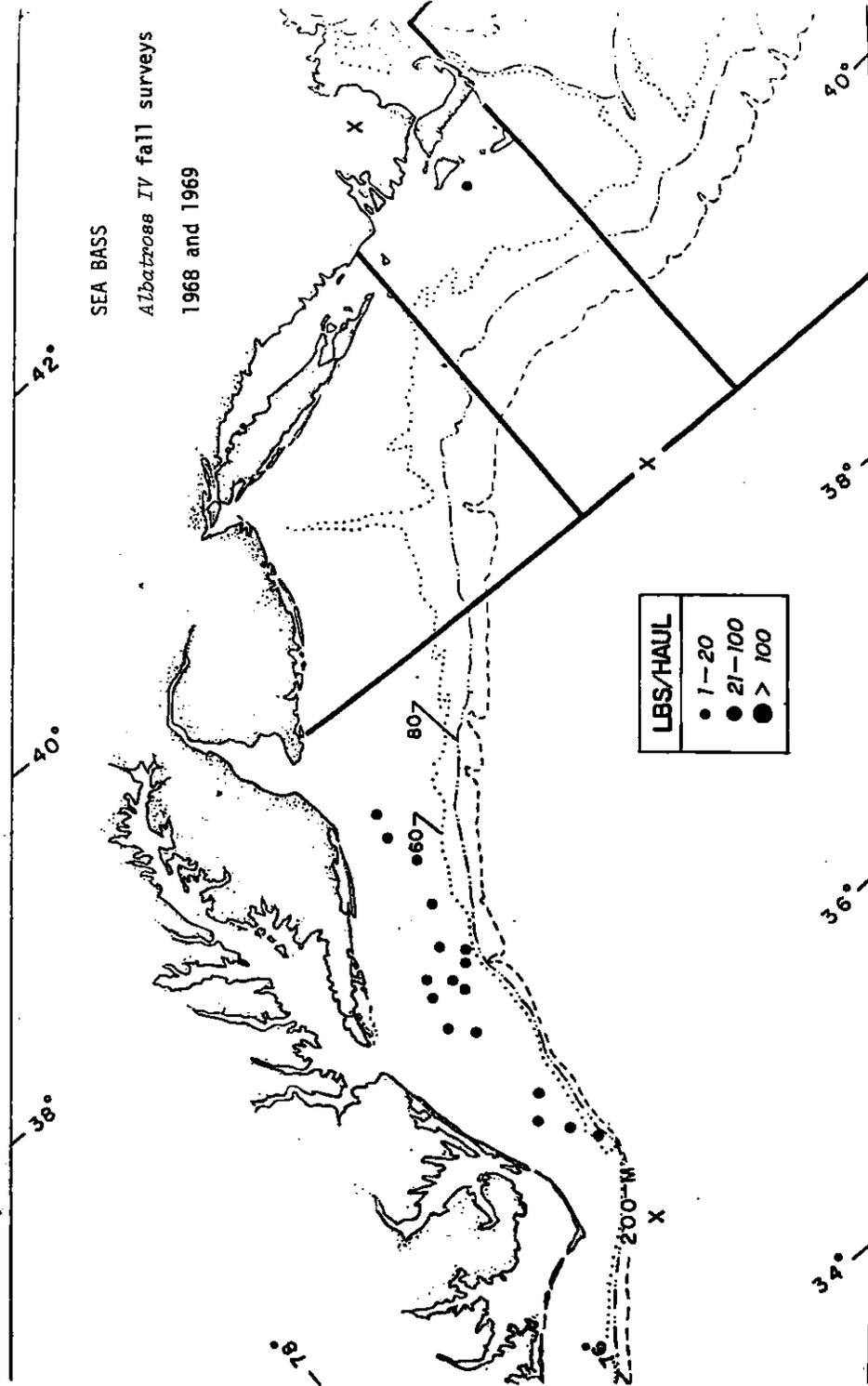


Chart 35.

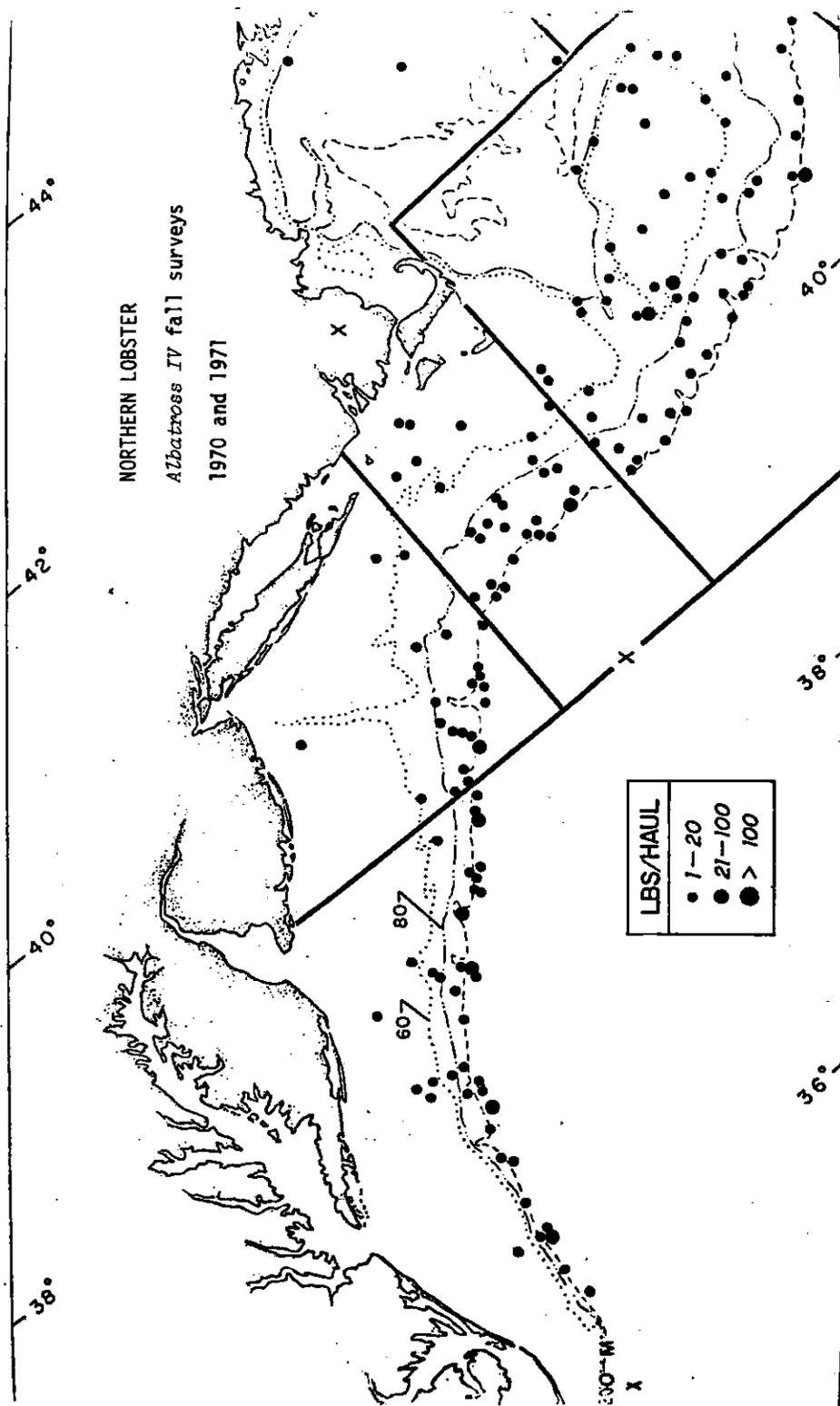


Chart 36.

25. Factors affecting estimates of relative catchabilities of fishing units in ICNAF Subarea 5 and Statistical Area 6¹

by W.H. Lenarz
National Marine Fisheries Service
Southwest Fisheries Center, LaJolla, California, USA

and

B.E. Brown
National Marine Fisheries Service
Northeast Fisheries Center, Woods Hole, Massachusetts, USA

INTRODUCTION

At the ICNAF Special Meeting of Experts on Effort Limitation in March 1973, it was recommended that Member Countries examine the "magnitude of the error associated with the factors involved in setting a fishing effort regulation". As one approach to this problem, analyses of variance studies were used to investigate the effects of year, month, species and area factors, in addition to country and gear-tonnage categories in estimating relative catchabilities. This procedure makes possible the calculation of the reduction in total variation of relative catchabilities accounted for by the various factors in the linear model used.

METHODS

Data base. Nominal landings and effort for designated main species (or species group) sought categories are reported by countries fishing in Subarea 5 and Statistical Area 6 (Fig. 1). These data are published in Table 4 of the ICNAF *Statistical Bulletin*. Landings from Subdiv. 5Ze, 5Zw and Div. 6A of finfish only, but excluding catches by fixed gear and of the large pelagic fishes (i.e. tuna, billfish), menhaden, and sharks (other than dogfish), in 1970 and 1971 were used in this study. In instances where no "main species sought" category was indicated, or where landings were attributed to a "mixed" fishery, the monthly landings by gear were assigned to one of the "species caught" categories of Table 4 on a basis of simple plurality (ICNAF, 1973). All reported landings were thus grouped by species or species group fisheries.

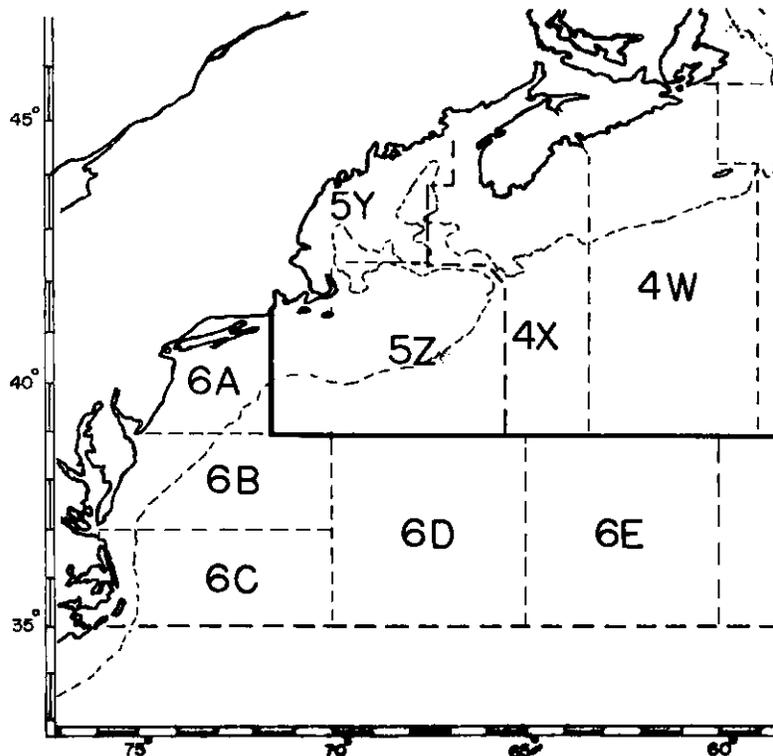


Fig. 1. Map of the southern part of the ICNAF Area and Statistical Area 6.

¹ Submitted to the 1973 Annual Meeting of ICNAF as ICNAF Res.Doc. 73/18.

Summary totals by month and area for species fisheries were made to obtain two data sets, one containing yearly totals for each area, country, gear-tonnage class and one for 1971 data only containing monthly totals over all species for each area, country and gear-tonnage class category.

The following model was used for the analyses:

$$y'_{i'j'k'\ell'm} = \exp \left[N + \sum_{i=1}^I X_{1im} B_{1i} + \sum_{j=1}^J X_{2jm} B_{2j} + \sum_{k=1}^K X_{3km} B_{3k} + \sum_{\ell=1}^L X_{4\ell m} B_{4\ell} + e_{i'j'k'\ell'm} \right] \quad \dots (1)$$

= catch per unit effort (CPUE) of the m^{th} observation at the $i' - j' - k' - \ell'$ level such that $1 < i' < I, 1 < j' < J, 1 < k' < K, 1 < \ell' < L$;

where

N = overall mean ;

B_{1i} = i^{th} level of nation factor, $\sum_{i=1}^I B_{1i} = 0$;

B_{2j} = j^{th} level of gear factor, $\sum_{j=1}^J B_{2j} = 0$;

B_{3k} = k^{th} level of area factor, $\sum_{k=1}^K B_{3k} = 0$;

$B_{4\ell}$ = ℓ^{th} level of month factor, $\sum_{\ell=1}^L B_{4\ell} = 0$;

$$X_{np} = \begin{cases} (i', & \text{when } n = 1) & \text{or} \\ 1, & \text{if } p = (j', & \text{when } n = 2) & \text{or} \\ & (k', & \text{when } n = 3) & \text{or} \\ & (\ell', & \text{when } n = 4) & \text{or} \\ 0, & \text{otherwise} & ; \end{cases}$$

and

$e_{i'j'k'\ell'm}$ = error term of the m^{th} observation at the $i'j'k'\ell'$ level, and is assumed to be independent of $i, j, k,$ and $\ell,$ and has a $N(0, \sigma^2)$ distribution.

The \log_e transform of (1) is an example of the general linear hypothesis model (Pheng, 1967) and, specifically, is a four-way analysis of variance model with the implicit assumption that all interaction terms are insignificant. The nature of the data results in many cells with no observations and thus the design is unbalanced, and the standard procedures developed for fitting balanced designs do not apply. The following procedure was used to estimate the parameters of the model and to test their significance. Using matrix notation the log transform of (1) becomes

$$X\beta = Y + E \quad , \quad \dots (2)$$

where

$$Y = \begin{pmatrix} \log y'_{11111} \dots \log y'_{IJKL1} \\ \vdots \\ \log y'_{1111m} \dots \log y'_{IJKLm} \end{pmatrix} ;$$

$$E = \begin{pmatrix} e_{11111} \dots e_{IJKL1} \\ \vdots \\ e_{1111m} \dots e_{IJKLm} \end{pmatrix} ;$$

$$X = (1 : X_1 : X_2 : X_3 : X_4) \quad ;$$

$$X_n = \begin{pmatrix} X_{n11} & \dots & X_{nI1} \\ \vdots & & \vdots \\ X_{nIm} & \dots & X_{nIm} \end{pmatrix} \quad ;$$

$$\beta = \begin{pmatrix} N \\ B_{11} \\ \vdots \\ B_{1I} \\ \vdots \\ B_{41} \\ \vdots \\ B_{4L} \end{pmatrix} \quad \dots (3)$$

The estimate of β is obtained by multiplying (2) by X' , the transpose of X , and then by, $(X'X)^{-1}$, the inverse of $X'X$, yielding

$$\hat{\beta} = (X'X)^{-1} X'Y \quad \dots (4)$$

(σ^2) is estimated by

$$\hat{\sigma}^2 = (Y'Y - \hat{\beta}'X'Y) / (M - (I + J + K + L) + 3) \quad \dots (5)$$

where M is the sample size.

Additional notation is required to describe the calculation of sums of squares of the effects of the model.

$$\text{Let } Z_n = (1 : X_1 : X_2 : \dots X_4) \quad ,$$

where

$$n = \text{factor of interest, } 1 < n < 4,$$

and

$$X_n = \begin{pmatrix} 0 \dots 0 \\ \vdots \\ \vdots \\ 0 \dots 0 \end{pmatrix} \quad .$$

Also, let

$$\beta_n = \begin{pmatrix} N \\ B_{11} \\ \vdots \\ B_{1I} \\ \vdots \\ B_{4L} \end{pmatrix} \quad ,$$

where N is the overall mean,

and

$$B_{np} = \begin{pmatrix} 0 \\ \cdot \\ \cdot \\ \cdot \\ 0 \end{pmatrix} \text{ for all } p.$$

(X_n) and B_{np} are then deleted from their respective matrices under the hypothesis that there is no n^{th} effect. The estimates of sums of squares are given by

<u>Effect</u>	<u>Degrees of Freedom</u>	<u>Sums of Squares</u>
Country	I - 1	$\beta_1'X_1Y - \beta_1'Z_1'Y$
Gear	J - 1	$\beta_2'X_2Y - \beta_2'Z_2'Y$
Area	K - 1	$\beta_3'X_3Y - \beta_3'Z_3'Y$
Month	L - 1	$\beta_4'X_4Y - \beta_4'Z_4'Y$
Error	M - (I + J + K + L) + 3	$Y'Y - \beta'X'Y$

... (6)

An estimate of the log of relative catchability is obtained by

$$R'_{ijkl} = \hat{B}_{1i} + \hat{B}_{2j} + \hat{B}_{3k} + \hat{B}_{4l} - B_{1s_1} - B_{2s_j} - B_{3s_k} - B_{4s_l}, \quad \dots (7)$$

where

R'_{ijkl} = log relative catchability for the i^{th} nation, j^{th} gear, k^{th} area, and l^{th} month or species ;

s_i = value of i for the standard gear

\cdot :
 \cdot :
 \cdot :

s_l = value of l for the standard gear.

An estimate of the variance of R'_{ijkl} is given by

$$V(\hat{R}'_{ijkl}) = \hat{\sigma}^2(L'(X'X)^{-1}L) \quad \dots (8)$$

where

$$L = \begin{pmatrix} 0 \\ \cdot \\ \cdot \\ \cdot \\ \hat{B}_{1s_1} \\ 0 \\ \cdot \\ \cdot \\ \cdot \\ \hat{B}_{1i} \\ 0 \\ \cdot \\ \cdot \\ \cdot \\ -\hat{B}_{4s_l} \\ 0 \\ \cdot \\ \cdot \\ \cdot \\ \hat{B}_{4l} \end{pmatrix}$$

Approximate 95% confidence limits about R'_{ijkl} are given by

$$R'_{ijkl} \pm 2\sigma = R'_{ijkl} \pm 2(V(R'_{ijkl}))^{1/2}$$

The antilog of R'_{ijkl} is an estimate of relative catchability. These estimates tend to be biased downward for large values because of the log transformation. The estimates of the confidence limits about R_{ijkl} present a reasonably accurate view of the magnitude of the confidence limits about an unbiased estimate of relative fishing power. It should be noted that because of the unbalanced nature of the design, estimates of R_{ijkl} for combinations of $i, j, k,$ and l not present in the data are tenuous.

A second model was included in this study. The l and k factors, namely month and area, were substituted by a species factor and a year factor, and a year \times gear interaction term was included in the analysis of variance. The sum of squares table for this model is identical to (6), except for the error term which is split into an interaction term plus a new error term. Then two terms can be written as

$$\sum_{ijklm} (y_{..kl} - y_{..k.} - y_{...l} + y_{.....})^2, \quad \dots (9)$$

and

$$(Y'Y - \beta'X'Y - \sum_{ijklm} (y_{..kl} - y_{..k.} - y_{...l} + y_{.....})^2)$$

which sums to the error term of the previous model. The former sum in (9) has $(K - 1)(L - 1)$ degrees of freedom, while the latter sum has $(m + 3 - (I + J + K + L) - (K - 1)(L - 1))$ degrees of freedom.

RESULTS AND DISCUSSION

The first analysis concerned itself with area, month, country and gear-tonnage class factors. The total catch (of all species) and effort in 1971 within the blocks of data defined by these factors was used as the dependent variable (excluding the segments discussed above).

The results of this analysis of variance indicate that all main factor effects were significant, except areas (Table 1). An area-month interaction might be expected to be significant, but examination of this and other interactions are not apt to be meaningful because of the unbalanced nature of the data.

Table 1. Analysis of variance of 1971 catch-per-effort data in ICNAF Subdiv. 52e, 52w, and Div. 6A.

Source	Degrees of freedom	Sums of squares	Mean squares	F
Country	8	30.21	3.78	13.48**
Gear-tonnage class	13	185.75	14.29	51.00**
Area	2	0.34	0.17	0.61
Month	11	6.93	0.63	2.25*
Error	374	104.79	0.28	

* Significant at 95% level of confidence

** Significant at 99% level of confidence

The model explains about 68% of the variation of log catch-per-effort in ICNAF Subdiv. 52e, 52w, and Div. 6A for 1971. The country factor accounts for 9%, gear 57%, and month only 2%. This result suggests that not too much is to be gained by including other factors in the model.

The 95% confidence limits about individual relative catchabilities are within about 30% of the estimates. The 68% confidence limits would be approximately \pm one standard deviation and, in general, would be within about 20% of the estimates, i.e., the component of variation is about this much.

The second analysis of variance included year, species, country, and gear-tonnage class factors (otter trawlers only). Data for 1970 and 1971 were used with the basic variable being the sum of catch and effort

for each month over strata within the blocks. A year × gear interaction was included. The results (Table 2) again suggest that the latter two factors account for the largest portion of the variation in log catch-per-effort. The species effect was also significant but the year and year × gear effects were not. It is encouraging that the year × gear term is not significant because this suggests that the gears have remained the same between 1970-1971 in relation to each other and thus might be expected to do so in the future. While the species factor is significant, it only accounts for about 2% of the deviations from the model, while the country factor accounts for 14% and the gear-tonnage class factor for 29%. The model accounted for 46% of the total variance. Conclusions drawn from the second analyses, where only 46% of the overall variation is accounted for, should be very qualified.

Table 2. Analysis of variance of 1970-1971 catch-per-effort data in ICNAF Subdiv. 5Ze, 5Zw and Div. 6A.

Source	Degrees of freedom	Sums of squares	Mean squares	F
Country	7	102.37	14.62	34.13**
Gear-tonnage class	9	200.98	22.33	52.23**
Year	1	0.35	0.35	0.81
Species	6	12.16	2.03	4.73**
Year Gear	9	6.01	0.67	1.56
Error	887	380.10	0.43	

** Significant at 99% level of confidence

The conclusions from this study indicate that, for the purpose of standardizing fishing effort units, the most critical factor is that due to vessel gear-tonnage class category; the country factor is also important. Month and species are factors of lesser importance. The latter two were not considered together in the same analysis and it is possible that the monthly factor may, in part, be a result of shifts to different species, i.e., they may interact to produce a significant effect for some combinations. The absolute magnitude of monthly deviations from the overall (averaged over areas) does not appear great and much of the variation appears due to very few months (Table 3).

Table 3. Relative catchabilities averaged over areas by gear and country.

Month	Otter Trawler Side							Otter Trawler Stern						
	0-50	51-150	151-500		501-900		0-50	51-150	151-500	501-900	901-1800			
	USA	USA	USA	Canada	USSR	USSR	Poland	USA	USA	USA	Canada	Poland	FRG	Japan
Jan	0.65	0.99	0.60		0.82	1.03	0.99	2.15	0.69	1.13		4.16	5.45	
Feb	0.43	0.66	0.40		0.52	0.77	0.65	1.48	0.45	0.75	0.75	2.75		
Mar	0.48	0.73	0.44		0.59	0.77	0.74	1.67	0.52	0.84	0.84	3.09		1.38
Apr	0.49	0.76	0.45		0.61	0.80	0.73	1.65	0.52	0.86		3.07		
May	0.48	0.73	0.44	0.61	0.58	0.77	0.70	1.66	0.52	0.83	0.83	2.96		
Jun	0.54	0.82	0.50	0.69	0.63	0.85	0.79	1.86	0.57	0.93	0.93	3.32		
Jul	0.43	0.67	0.40	0.56	0.53	0.69	0.63	1.50	0.45	0.75	0.76	2.64		
Aug	0.38	0.57	0.35	0.48	0.46	0.61	0.55	1.25	0.40	0.65	0.65	2.28	3.06	
Sep	0.45	0.68	0.40	0.57	0.55	0.72	0.65	1.54	0.48	0.77	0.76	2.70	3.63	
Oct	0.40	0.61	0.37	0.51	0.48	0.62	0.59	1.32	0.43	0.69	0.69	2.32	3.24	
Nov	0.41	0.63	0.38	0.53	0.50	0.66	0.61	1.43	0.43	0.72	0.72	2.55	3.36	
Dec	0.43	0.67	0.39	0.56	0.53	0.70	0.64	1.50	0.53	0.76	0.76	2.68	3.45	

Table 3. continued

Month	Otter Trawler Stern						Purse Seine	Pair Trawl
	Over 1800						151-500	151-500
	USSR	Poland	FRG	Rom- ania	Japan	Bul- garia	USSR	Spain
Jan	5.03	4.78	6.18	0	0	0	0	0
Feb	3.32	0	0	0	0	0	1.59	1.68
Mar	3.74	3.55	0	1.66	1.60	0	0	1.95
Apr	3.85	3.53	0	1.67	1.65	0	0	0
May	3.71	3.40	0	1.67	1.60	0	1.73	1.94
Jun	4.08	3.85	0	1.81	1.79	3.44	1.94	2.17
Jul	3.30	3.11	4.07	1.44	1.49	2.78	1.57	1.76
Aug	2.93	2.69	3.52	1.24	1.26	2.40	0	1.48
Sep	3.48	3.19	4.18	1.47	1.50	2.85	0	1.75
Oct	3.03	0	3.73	1.31	1.34	2.55	0	1.57
Nov	3.19	2.95	3.86	1.39	0	2.67	0	1.67
Dec	3.37	3.15	4.08	1.44	0	2.86	0	0

In 14 and 15 cases where there were observations in January, that month had the highest relative catchability. The extent to which these single high values influence the range is illustrated by examining the ratio of the difference between the upper extreme value and the next highest value to the range (Table 4). For these cases, where there were at least four monthly observations, the average ratio was 44% (Table 4). Thus, unless fleets are capable of extreme concentration of fishing effort, little would be gained by regulating fishing effort using monthly standardization coefficients.

Table 4. Effects of extreme values on ranges of monthly relative catchabilities.

Gear category	Tonnage	Country	Highest value minus next highest value
Otter trawler side	0-50	USA	.41
	51-150	USA	.40
	150-500	USA	.40
	150-500	Canada	.33
	150-500	USSR	.53
	501-900	USSR	.43
	501-900	Poland	.44
Otter trawler stern	0-50	USA	.32
	51-150	USA	.41
	151-500	USA	.42
	501-900	Canada	.32
	901-1800	Poland	.45
	901-1800	Fed.Rep. Germany	.76
	1800+	USSR	.45
	1800+	Poland	.44
1800+	Fed.Rep. Germany	.75	
1800+	Romania	.24	

continued

Table 4. continued

Gear category	Tonnage	Country	Highest value minus next highest value
Otter trawler stern (continued)	1800+	Japan	.26
	1800+	Bulgaria	.56
Purse seine	151-500	USSR	.57
Pair trawl	151-500	Spain	.32
Average			.44

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26. Effect of by-catch on the management of mixed species fisheries in Subarea 5 and Statistical Area 6¹

by B.E. Brown, J.A. Brennan, E.G. Heyerdahl and R.C. Hennemuth
National Marine Fisheries Service
Northeast Fisheries Center, Woods Hole, Massachusetts

INTRODUCTION

The control of fishing mortality by means of individual species catch quotas is very difficult to accomplish whenever a significant proportion of the fishing mortality on any given species is generated as a result of the incidental catch or by-catch of that species in fisheries directed toward other species. In 1973 the catch of all major species in ICNAF Subarea 5 and Statistical Area 6 (Fig. 1) is regulated by national quotas and the estimated by-catch of the major directed fisheries is large. Under these circumstances, attempting to catch the entire quota of a given species by means of a directed fishery for that species may cause the total catch to exceed the allowable catch because of the associated by-catch of that species in the other fisheries.

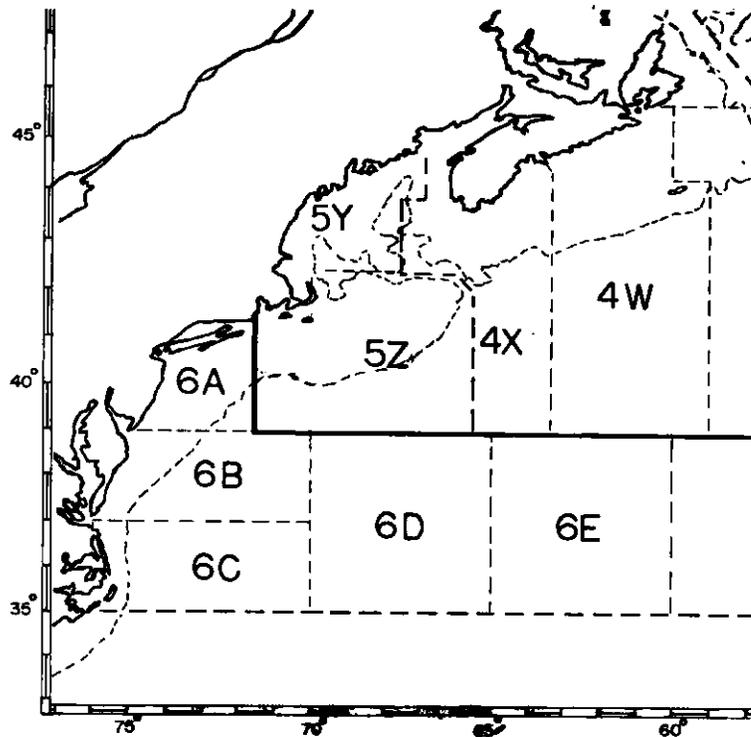


Fig. 1. Map of the southern part of the ICNAF Area and Statistical Area 6.

ICNAF modified its regulatory measures several times in an attempt to account for by-catches of species under quota restrictions. The initial haddock quota regulations (Subarea 5 and Div. 4X) stated that the directed fishery should cease whenever the accumulated catch (directed catch plus by-catch) reported to ICNAF bi-weekly reached 80% of the quota, anticipating in advance that the catch after closure (a by-catch by definition) would be 20% of the quota. When the yellowtail was added to the list of species under quota, the closure procedures were changed. The Assessments Subcommittee of STACRES first estimated the expected monthly by-catch after closure of directed fisheries. The decision to cease directed fishing was then made when the accumulated total catch reported to ICNAF on a bi-weekly basis plus the expected by-catch during the remainder of the year equalled the quota. With the introduction of national quota allocations in 1972 the procedure again changed, requiring each country to control its directed fishery so that the sum of its directed catch and the estimated by-catches would not exceed its quota allocation.

¹ Submitted to the 1973 Annual Meeting of ICNAF as ICNAF Res.Doc. 73/99.

In spite of the initiation of the above procedures to include by-catches in the ICNAF quota management structure, abundance indices for major fish stocks of interest in Subarea 5 and Statistical Area 6 continue to show a decline (Brown, *et al.*, 1973). The concern is thus raised that the magnitude of the by-catch in such a mixed fishery and its effects on management need to be closely examined. This is particularly important in a multifaceted fishery where competing elements exist for harvesting the same resource with some having a directed fishery and others utilizing the by-catch. In addition, the Assessments Subcommittee estimated in January 1973 (ICNAF, 1973a) that the fishing effort generated as by-catch was between 24 and 51% of the total effort expended by the major fisheries with an overall total of 33% in 1971. They also concluded that the effort in 1971 was 20-30% greater than the MSY (maximum sustainable yield) effort. This paper examines the collective relationship that existed in 1971 between the catch and by-catch of the major fish stocks, and simulates through direct expansion of the data and linear programming techniques a range of catches that could be expected to occur in 1973 under the current quota regime.

MATERIALS AND METHODS

Data base

Nominal landings and effort for designated main species (or species group) sought categories are submitted annually by almost all countries fishing in Subarea 5 and Statistical Area 6. These data are published annually in Table 4 of the ICNAF *Statistical Bulletin*. The 1971 data (ICNAF, 1972a) were selected as the base from which the proportions of by-catch and directed catch were estimated. The nominal catches do not include fish caught and discarded at sea.

The 1971 nominal catch and effort (days fished) for finfish only were summarized over months for each of the "main species sought" categories reported in Table 4 of the *Statistical Bulletin*. Catches made with fixed gear as well as catches of menhaden, halibut, and large pelagic fishes, i.e., tuna, billfish, and sharks (other than dogfish) were excluded. In instances where no "main species sought" category was indicated or where landings were attributed to a "mixed" fishery, the monthly landings were assigned to "species sought" categories according to the species which formed a simple plurality (ICNAF, 1973a). The term "fishery" as used in this document refers to the vessels and associated catch in these "main species sought" categories. The term "species" refers to both individual species and species groups. All reported landings were thus identified by two factors: species and fisheries. Such tabulations were prepared for all participating nations.

The quota restraints or total allowable catches (TAC) needed to simulate the 1973 fishery were derived from several different sources. The proposed 1973 national quota allocations for Member Countries in Subarea 5 and Statistical Area 6 (ICNAF, 1972b) were used for cod, redfish, silver hake, flounder (other flounder plus yellowtail quotas), and herring. For haddock the TAC was apportioned between countries on the basis of the 1971 haddock catches. The TAC of the category "other pelagic fish" was obtained by adding 12,000 tons to the ICNAF mackerel quota (based on the ratio of mackerel catch to the "other pelagic fish" catch in 1971). For non-member countries and for Member Countries without a national quota, the 1971 nominal landings were used to establish a quota for those species for which a TAC was proposed. Finally, for all unregulated species ("other groundfish" and "other fish"), the 1971 national nominal landings were again used as the quota. In this paper, the catch limitations described above will all be referred to as "quotas".

Analytical methods

In order to estimate the effects of by-catch on 1973 catches, the following simulation procedures were used. For each country, the catch of each species in a fishery in 1971 was first expressed as a percentage of the total catch (column total) for that species (CH Percent in Appendix I, Tables 1-11). These percentages were used to distribute 1973 "quotas" for each species over all fisheries to obtain an "estimated" 1973 catch for each country.

Secondly, within each fishery the 1971 catch of each species was expressed as a proportion of the catch of the main species sought (CH Ratio (R) in Appendix I, Tables 1 through 11). This computation showed the by-catch as a proportion of the main species sought catch in a given fishery. By applying these proportions to the estimated 1973 directed catch of the identifying species for each fishery as computed above, the "expected" by-catch of associated species was obtained for each fishery for each country. In other words, the expected by-catch is related to the estimated main species sought catch and not to the total catch.

Totals of the estimated and expected catches (Tables 1 and 2) were obtained by summing the appropriate values over all countries. The overall species by-catch ratios were then recomputed from the totals as described above (Table 2). The differences (Table 3) between the "estimated" catches given in Table 1 and the "expected" catches given in Table 2 indicate fishery-species interactions, the dependence of species on fisheries, that cause problems in managing multi-species fisheries by species quotas (ICNAF, 1973b). In other words, the differences represent an effect which has not been anticipated when setting regulations. Appendix I, Tables 12-19, give the differences between the estimated and expected catches for each country. A negative difference means the catch would exceed the quota.

Table 1. Simulation of 1973 "estimated" catch (EstCh) based on 1971 fishing patterns summed over countries considering national allocations, but considering each species independently distributed over fisheries (catches in '000 tons).

Species sought	Species caught									
	Cod	Haddock	Redfish	Silver hake	Flounder	Other groundfish	Herring	Other pelagic ¹	Other fish	Total
Cod	15.7	1.5	0.4	1.3	1.0	2.0	-	0.1	0.1	22.1
Haddock	7.7	2.1	0.9	0.1	2.1	2.9	-	-	-	15.8
Redfish	1.7	0.1	18.4	0.9	0.5	1.0	-	-	-	22.6
Silver hake	3.1	0.4	1.2	99.3	3.4	14.2	8.5	15.7	10.5	156.3
Flounder	10.2	1.4	3.1	6.6	36.5	5.8	0.3	4.1	0.4	68.4
Other groundfish	2.3	0.3	0.3	10.0	2.9	28.4	3.0	4.3	3.8	55.3
Herring	1.4	0.2	1.6	16.0	1.0	4.9	158.0	34.2	12.8	230.1
Other pelagic	0.5	-	3.6	12.3	1.6	10.0	21.3	398.9	36.4	484.6
Other fish	0.1	-	-	10.0	0.7	11.0	1.4	4.8	24.9	52.9
Total EstCh	42.7	6.0	29.5	156.5	49.7	80.2	192.5	462.1	88.9	1,108.1
"Quota" (1973) ²	45.0	6.0	30.0	170.0	51.0	80.0	175.0	462.0	89.0	1,108.0

¹ 97.5% mackerel

² Estimated catch differs from quota when unallocated portion of quota differs from appropriate 1971 catch

Table 2. Simulation of 1973 "expected" catch (ExpCh) based on 1971 fishing patterns summed over countries considering national allocations, but considering each species independently distributed over fisheries. Catches in '000 tons and expressed as a ratio (R) of by-catch to main species sought within fisheries. See text for explanation.

Species sought		Species caught									
		Cod	Haddock	Redfish	Silver hake	Flounder	Other groundfish	Herring	Other pelagic ¹	Other fish	Total
Cod	ExpCh	15.7	3.0	0.4	0.4	1.3	2.6	-	-	0.1	23.6
	R	1.000	0.191	0.025	0.025	0.083	0.166	-	-	0.006	
Haddock	ExpCh	2.9	2.1	0.3	-	0.9	1.4	-	-	-	7.6
	R	1.381	1.000	0.143	-	0.429	0.667	-	-	-	
Redfish	ExpCh	1.3	0.5	18.4	0.3	0.7	1.5	0.1	-	-	22.8
	R	0.071	0.027	1.000	0.016	0.038	0.082	0.005	-	-	
Silver hake	ExpCh	5.1	2.2	2.7	99.3	11.6	20.9	21.9	15.4	12.3	191.4
	R	0.051	0.022	0.027	1.000	0.117	0.210	0.221	0.155	0.124	
Flounder	ExpCh	8.6	3.2	2.2	1.9	36.5	6.4	0.4	0.5	0.4	60.1
	R	0.236	0.088	0.060	0.052	1.000	0.175	0.011	0.014	0.011	
Other groundfish	ExpCh	1.5	0.5	0.1	6.6	3.1	28.4	3.4	3.0	3.8	50.4
	R	0.053	0.018	0.004	0.232	0.109	1.000	0.120	0.106	0.134	
Herring	ExpCh	0.6	0.2	0.8	5.7	1.0	3.8	158.0	17.8	8.6	196.5
	R	0.004	0.001	0.005	0.036	0.006	0.024	1.000	0.113	0.054	
Other pelagic	ExpCh	0.2	0.3	0.4	13.8	5.5	11.3	39.1	398.9	45.8	515.3
	R	0.001	0.001	0.001	0.035	0.014	0.028	0.098	1.000	0.115	
Other fish	ExpCh	0.1	-	-	8.8	1.4	9.9	2.5	3.6	24.9	51.2
	R	0.004	-	-	0.353	0.056	0.398	0.100	0.145	1.000	
Total ExpCh		36.0	12.0	25.3	136.8	62.0	86.2	225.4	439.2	95.9	1,118.9
Quota (1973)		45.0	6.0	30.0	170.0	51.0	80.0	175.0	462.0	88.3	1,107.4

¹ 97.5% mackerel

Table 3. Differences between estimated 1973 catch and expected 1973 by-catch (catches in '000 tons).

Species sought	Species caught								
	Cod	Haddock	Redfish	Silver hake	Flounder	Other groundfish	Herring	Other pelagic ¹	Other fish
Cod	-	-1.5	0.0	0.9	-0.3	-0.6	0.0	0.1	0.0
Haddock	4.8	-	0.6	0.1	1.2	1.5	0.0	0.0	0.0
Redfish	0.4	-0.4	-	0.6	-0.2	-0.5	0.1	0.0	0.0
Silver hake	-2.0	-1.8	-1.5	-	-8.2	-6.7	-13.4	0.3	-1.8
Flounder	1.6	-1.8	0.9	4.7	-	-0.6	-0.1	3.6	0.0
Other groundfish	0.8	-0.2	0.2	3.4	-0.2	-	-0.4	1.3	0.0
Herring	0.8	0.0	0.8	10.3	0.0	1.1	-	16.4	4.2
Other pelagic	0.3	-0.3	3.2	-1.5	-3.9	-1.3	-17.8	-	-9.4
Other fish	0.0	0.0	0.0	1.2	-0.7	1.1	-1.1	1.2	-
Total	6.7	-6.0	4.2	19.7	-12.3	-6.0	-32.7	22.9	-7.0

¹ 97.5% mackerel

Two other simulations of 1973 patterns of catches were examined. In the first, the entire 1973 TAC for each species was assumed to be taken by its directed fishery. The associated by-catch within each fishery was then estimated using the proportions (R) given in Table 2. In the second, the effects on catches of certain objectives and restraints were analyzed using linear programming techniques which are described in detail in Appendix II.

RESULTS AND DISCUSSION

Maximum extent of by-catch effect

The rationale behind the setting of species quotas is based on control of species as opposed to fisheries. The amount of by-catch in our model is a function of the catch of the target species. An estimate of the maximum effect of by-catch on species catches in an open-ended (no total limit on the sum of all species) species-quota system can be obtained by assuming the 1973 "species quotas" are taken completely in directed fisheries. This is the implied situation from the standpoint of fishery control by species-quota regulations.

The by-catch associated with these catches is calculated using the (R) values from Table 2. The by-catch in this situation causes the total catch to exceed the total "quota" by about 50% (Table 4). All species are significantly overfished relative to the 1973 "quotas". Excesses are particularly high for haddock (328%), other groundfish (139%), other fish (107%), flounder (95%), cod (82%), and herring (58%). In all of the above species, the by-catch is greater than 50% of the directed catch. It is obvious from this illustration that since many of the 1973 "quotas" are equal to or greater than 1971 catches, fishery management in ICNAF in 1973 has to be concerned as much, if not more, with controlling the by-catch as with controlling the directed catch of the target species in the fishery itself.

Estimations of by-catch in 1973 based on 1971 fishing patterns

Table 3 gives the deviations between the estimated and expected by-catches in 1973, that will occur if the directed catch is the same proportion of the total catch as observed in 1971. There are significant deviations for some species in nearly every fishery. The silver hake fishery appears to cause the greatest amount of mortality on other species, with the by-catch in that fishery exceeding expected values for all species except other pelagics, and being particularly significant for haddock, flounder, other groundfish, and herring relative to their specific "quotas". The cod and flounder fisheries have a major impact on the haddock quota, while the other pelagic fishery impinges on flounder and herring quotas. The deviations for individual countries are presented in Appendix I, Tables 12-19.

This analysis clearly illustrates that the 1973 quota regulations dictate major changes in fishing practices if quotas are to be met. It is realized, of course, that the actual by-catch will fluctuate with

changes in species density even under constant fishing pressures. However, in general, the relative mortalities generated would have a constant relationship to the units of effort expended.

Table 4. Simulated 1973 catches assuming "quotas" are taken in the respective main species sought fisheries. Simulation based on 1971 fishing patterns (catches in '000 tons). See text for explanation.

Species sought	Species caught									
	Cod	Haddock	Redfish	Silver hake	Flounder	Other groundfish	Herring	Other pelagic	Other fish	Total
Cod	45.0	8.6	1.1	1.1	3.7	7.5	< 0.1	< 0.1	0.3	67.3
Haddock	8.3	6.0	0.9	< 0.1	2.6	4.0	-	< 0.1	-	21.8
Redfish	2.1	0.8	30.0	0.5	1.1	2.5	0.2	< 0.1	< 0.1	37.2
Silver hake	8.7	3.7	4.6	170.0	19.9	35.7	37.6	26.4	21.1	327.7
Flounder	12.0	4.5	3.1	2.7	51.0	8.9	0.6	0.7	0.6	84.1
Other groundfish	4.2	1.4	0.3	18.6	8.7	80.0	9.6	8.5	10.7	142.0
Herring	0.7	0.2	0.9	6.3	1.1	4.2	175.0	19.8	9.5	217.7
Other pelagic	0.5	0.5	0.5	16.2	6.5	12.9	45.3	462.0	53.1	597.5
Other fish	0.4	< 0.1	< 0.1	31.4	5.0	35.4	8.9	12.9	89.0	183.0
Total	81.9	25.7	41.4	246.8	99.6	191.1	277.2	530.3	184.0	1,678.0
Quota	45.0	6.0	30.0	170.0	51.0	80.0	175.0	462.0	89.0	1,108.0

The 1973 "quotas", as determined in this paper, include catches which are unallocated in the official 1973 regulations, but which in reality can be expected to occur. The effect of this can be ascertained by summing the deviations in Table 3 over fisheries for each species (column totals) and adding to these totals the difference between the 1973 "quota" used in this paper (refer to method section), and the actual legal quota (if any). This computation shows that for haddock (100%), flounder (22%), other groundfish (8%), herring (29%), and other fish (8%), quotas would be exceeded (by the percentages given in brackets), while for cod (20%), redfish (16%), silver hake (20%), and other pelagics (5%), catches would be under the quota by the percent indicated. This under-achievement could result in the expansion of effort in the directed fisheries for these species, in order for countries to achieve their allotted legal quota, thus causing an accompanying increase in by-catch for those species already over-harvested.

Linear programming solutions to by-catch problem

It is clear from Table 2 that by reducing the quota of certain directed fisheries and thus reducing by-catch, the problem of exceeding certain quotas could be mitigated, for example, reducing the directed catch of cod would lessen the total amount of haddock caught. There are, however, innumerable possible solutions to this general problem. For example, the herring quota could be met by adjusting the directed fisheries for herring, for other pelagic fishes, or for silver hake, in any one of several possible alternatives such as: eliminate the silver hake fishery, cut the mackerel fishery in half, and reduce the directed herring catch by 28,000 metric tons; or eliminate the other pelagic fishery, reduce the silver hake fishery by half, and cut back the directed herring fishery by 26,000 tons; and so on. Linear programming offers a rational approach to solving this problem.

One solution which maximizes total catch without allowing any species quota to be exceeded, although it does permit directed fisheries for species or species group catch to go to zero, is given in Table 5. The resultant total catch of 1,068,000 tons is a reduction of 40,000 tons from the original total allowable catch (Table 1). However, the directed fisheries for cod and haddock are eliminated, and those for herring, other fish, and flounder are only 62, 52, and 38% of the original values (Table 1). These species groups are of primary interest to the coastal fisheries.

In order to obtain a solution that preserves some semblance of a directed fishery for the coastal state, additional minimum constraints (Table 6) were established for both the directed and total catches. These constraints were arbitrarily derived to serve as an example and do not fully meet the coastal fishery needs as reflected in previous years' catches. Also, the directed fishery catches have been adjusted sufficiently below 1973 US quotas to eliminate internal US by-catch conflicts.

Table 5. Linear programming simulation of 1973 catches maximizing total catch ('000 tons).

Species sought	Total allowable catch constraint	Directed catch	Total catch
Cod	45	0	14
Haddock	6	0	6
Redfish	30	24	30
Silver hake	170	140	170
Flounder	51	14	42
Other groundfish	80	27	80
Herring	175	98	175
Other pelagic	462	424	462
Other fish	89	13	89
Total	1,108		1,068

Table 6. Linear programming simulation of 1973 catches maximizing total catch considering nation allocations and preserving portion to the US directed fishery (catches in '000 tons).

Species sought	Total allowable catch constraint	Directed catch	Total catch
Cod	45	8	19
Haddock	6	0	6
Redfish	30	19	22
Silver hake	170	3	40
Flounder	51	33	46
Other groundfish	80	23.5	59
Herring	175	125	175
Other pelagic	462	440.5	462
Other fish	89	27	89
Total	1,108		918

Additional constraints for coastal state fisheries

	Directed	Total
Cod	≥ 8	= 19.4
Haddock	≥ 0	= 5.0
Redfish	≥ 19	= 22.0
Silver hake	≥ 3	= 9.0
Flounder	≥ 33	= 38.7
Other groundfish	≥ 9	= 19.4
Herring	≥ 23	= 25.1
Other pelagic	≥ 9	= 10.0
Other fish	≥ 3	= 4.5

The solution to this second case is presented in Table 6. The total catch is now reduced by 190,000 tons, the directed fishery for haddock eliminated, and that for silver hake virtually eliminated. The directed fisheries for cod and herring are reduced substantially, and the total catches for cod, redfish, silver hake, flounder and other groundfish are lower than allocated for 1973. This indicates the gross inadequacy of regulation by species quotas alone to achieve conservation goals or to provide for the needs of the coastal fleet.

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APPENDIX I

Table 1. 1971 nominal landings for Canada (ICNAF Subarea 5 and Statistical Area 6), expressed as percentages of species catch distribution over fisheries (CH Percent) and ratios of by-catch to main species sought within fisheries (CH Ratio). See text for explanation.

Species sought		Species caught								
		Cod	Haddock	Redfish	Silver hake	Flounder	Other groundfish	Herring	Other pelagic	Other fish
Cod	CH Ratio (R)	1.000	0.352	0.020	0.000	0.060	0.196	0.000	0.000	0.000
	CH Percent	64.41	40.49	14.50	0.00	55.35	13.11	0.00	0.00	0.00
Haddock	CH Ratio (R)	0.582	1.000	0.115	0.000	0.063	0.219	0.000	0.000	0.000
	CH Percent	12.95	39.67	29.00	0.00	20.00	5.06	0.00	0.00	0.00
Redfish	CH Ratio (R)	0.318	0.218	1.000	0.000	0.091	0.282	0.000	0.000	0.000
	CH Percent	1.14	1.40	40.89	0.00	4.65	1.05	0.00	0.00	0.00
Other groundfish	CH Ratio (R)	0.276	0.133	0.018	0.000	0.018	1.000	0.000	0.000	0.000
	CH Percent	21.49	18.44	15.61	0.00	20.00	80.78	0.00	0.00	0.00
Herring	CH Ratio (R)	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000
	CH Percent	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00
Other fish	CH Ratio (R)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000
	CH Percent	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00

Table 2. 1971 nominal landings for Federal Republic of Germany (ICNAF Subarea 5 and Statistical Area 6), expressed as percentages of species catch distribution over fisheries (CH Percent) and ratios of by-catch to main species sought within fisheries (CH Ratio). See text for explanation.

Species sought		Species caught								
		Cod	Haddock	Redfish	Silver hake	Flounder	Other groundfish	Herring	Other pelagic	Other fish
Herring	CH Ratio (R)	0.000	0.000	0.000	0.000	0.000	0.011	1.000	0.022	0.000
	CH Percent	100.00	100.00	0.00	0.00	0.00	100.00	100.00	43.02	100.00
Other pelagic	CH Ratio (R)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000
	CH Percent	0.00	0.00	0.00	0.00	0.00	0.00	0.00	56.98	0.00

Table 3. 1971 nominal landings for Japan (ICNAF Subarea 5 and Statistical Area 6), expressed as percentages of species catch distribution over fisheries (CH Percent) and ratios of by-catch to main species sought within fisheries (CH Ratio). See text for explanation.

Species sought		Species caught								
		Cod	Haddock	Redfish	Silver hake	Flounder	Other groundfish	Herring	Other pelagic	Other fish
Herring	CH Ratio (R)	0.003	0.004	0.001	0.002	0.001	0.018	1.000	0.000	0.007
	CH Percent	87.50	100.00	50.00	10.53	25.00	2.90	99.67	0.03	0.34
Other pelagic	CH Ratio (R)	0.000	0.000	0.000	0.005	0.002	0.080	0.002	1.000	0.010
	CH Percent	0.00	0.00	0.00	44.74	75.00	19.61	0.29	97.59	0.73
Other fish	CH Ratio (R)	0.000	0.000	0.000	0.003	0.000	0.235	0.000	0.018	1.000
	CH Percent	12.50	0.00	50.00	44.74	0.00	77.49	0.04	2.39	98.93

Table 4. 1971 nominal landings for Poland (ICNAF Subarea 5 and Statistical Area 6), expressed as percentages of species catch distribution over fisheries (CH Percent) and ratios of by-catch to main species sought within fisheries (CH Ratio). See text for explanation.

Species sought		Species caught								
		Cod	Haddock	Redfish	Silver hake	Flounder	Other groundfish	Herring	Other pelagic	Other fish
Herring	CH Ratio (R)	0.002	0.000	0.000	0.000	0.000	0.002	1.000	0.222	0.107
	CH Percent	53.52	100.00	9.20	14.19	0.00	41.36	85.38	14.93	43.80
Other pelagic	CH Ratio (R)	0.001	0.000	0.001	0.001	0.000	0.002	0.132	1.000	0.104
	CH Percent	46.48	0.00	90.80	85.81	100.00	55.93	14.27	84.93	53.80
Other fish	CH Ratio (R)	0.000	0.000	0.000	0.000	0.000	0.018	0.708	0.355	1.000
	CH Percent	0.00	0.00	0.00	0.00	0.00	2.71	0.35	0.14	2.40

Table 5. 1971 nominal landings for Romania (ICNAF Subarea 5 and Statistical Area 6), expressed as percentages of species catch distribution over fisheries (CH Percent) and ratios of by-catch to main species sought within fisheries (CH Ratio). See text for explanation.

Species sought		Species caught								
		Cod	Haddock	Redfish	Silver hake	Flounder	Other groundfish	Herring	Other pelagic	Other fish
Silver hake	CH Ratio (R)	0.000	0.000	0.000	1.000	0.069	0.000	0.000	0.000	0.000
	CH Percent	0.00	0.00	0.00	6.71	0.38	0.00	0.00	0.00	0.00
Herring	CH Ratio (R)	0.000	0.321	0.000	0.000	0.437	0.020	1.000	0.553	1.088
	CH Percent	0.00	71.11	0.00	0.00	41.68	41.67	55.57	6.10	26.09
Other pelagic	CH Ratio (R)	0.001	0.015	0.000	0.095	0.071	0.003	0.094	1.000	0.362
	CH Percent	100.00	28.89	0.00	93.29	57.93	58.33	44.43	93.90	73.91

Table 6. 1971 nominal landings for Spain (ICNAF Subarea 5 and Statistical Area 6), expressed as percentages of species catch distribution over fisheries (CH Percent) and ratios of by-catch to main species sought within fisheries (CH Ratio). See text for explanation.

Species sought		Species caught								
		Cod	Haddock	Redfish	Silver hake	Flounder	Other groundfish	Herring	Other pelagic	Other fish
Cod	CH Ratio (R)	1.000	0.175	0.000	0.000	0.000	0.024	0.000	0.000	0.000
	CH Percent	100.00	100.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00

Table 7. 1971 nominal landings for USSR (ICNAF Subarea 5 and Statistical Area 6), expressed as percentages of species catch distribution over fisheries (CH Percent) and ratios of by-catch to main species sought within fisheries (CH Ratio). See text for explanation.

Species sought		Species caught								
		Cod	Haddock	Redfish	Silver hake	Flounder	Other groundfish	Herring	Other pelagic	Other fish
Silver hake	CH Ratio (R)	0.013	0.005	0.003	1.000	0.039	0.209	0.177	0.218	0.173
	CH Percent	58.82	81.02	5.24	67.36	29.73	27.64	12.98	9.97	24.91
Other groundfish	CH Ratio (R)	0.003	0.000	0.000	0.356	0.058	1.000	0.051	0.142	0.178
	CH Percent	3.39	0.27	0.00	5.70	10.39	31.43	0.89	1.54	6.09
Herring	CH Ratio (R)	0.006	0.000	0.012	0.120	0.006	0.037	1.000	0.153	0.056
	CH Percent	25.67	2.41	18.50	7.14	3.90	4.28	64.81	6.17	7.18
Other pelagic	CH Ratio (R)	0.001	0.000	0.025	0.089	0.031	0.066	0.147	1.000	0.117
	CH Percent	10.71	4.01	76.25	10.50	40.48	15.20	18.85	80.01	29.56
Other fish	CH Ratio (R)	0.001	0.003	0.000	0.617	0.092	0.725	0.150	0.225	1.000
	CH Percent	1.42	12.30	0.00	9.31	15.50	21.45	2.47	2.31	32.26

Table 8. 1971 nominal landings for USA (ICNAF Subarea 5 and Statistical Area 6), expressed as percentages of species catch distribution over fisheries (CH Percent) and ratios of by-catch to main species sought within fisheries (CH Ratio). See text for explanation.

Species sought		Species caught								
		Cod	Haddock	Redfish	Silver hake	Flounder	Other groundfish	Herring	Other pelagic	Other fish
Cod	CH Ratio (R)	1.000	0.132	0.043	0.060	0.146	0.259	0.003	0.002	0.010
	CH Percent	24.70	8.61	1.46	2.50	1.93	7.21	0.06	0.39	1.17
Haddock	CH Ratio (R)	1.492	1.000	0.143	0.007	0.489	0.740	0.000	0.001	0.000
	CH Percent	24.86	44.00	3.32	0.19	4.35	13.90	0.00	0.10	0.00
Redfish	CH Ratio (R)	0.073	0.025	1.000	0.018	0.036	0.083	0.005	0.000	0.001
	CH Percent	3.91	3.58	74.55	1.67	1.03	5.00	0.17	0.03	0.13
Silver hake	CH Ratio (R)	0.140	0.062	0.082	1.000	0.295	0.219	0.312	0.006	0.011
	CH Percent	4.89	5.71	3.97	58.86	5.49	8.58	7.86	1.60	1.88
Flounder	CH Ratio (R)	0.235	0.089	0.061	0.051	1.000	0.176	0.010	0.014	0.012
	CH Percent	35.18	35.08	12.65	12.89	79.94	29.72	1.07	15.29	8.41
Other groundfish	CH Ratio (R)	0.155	0.032	0.018	0.149	0.377	1.000	0.048	0.018	0.075
	CH Percent	4.35	2.37	0.69	7.05	5.64	31.56	0.97	3.59	10.09
Herring	CH Ratio (R)	0.014	0.002	0.019	0.078	0.022	0.028	1.000	0.008	0.002
	CH Percent	1.78	0.63	3.32	16.46	1.43	3.94	89.67	7.48	0.91
Other pelagic	CH Ratio (R)	0.005	0.000	0.000	0.020	0.011	0.003	0.029	1.000	0.011
	CH Percent	0.05	0.00	0.00	0.32	0.06	0.03	0.20	68.11	0.49
Other fish	CH Ratio (R)	0.019	0.001	0.001	0.002	0.017	0.003	0.000	0.030	1.000
	CH Percent	0.30	0.04	0.03	0.05	0.14	0.05	0.00	3.40	76.93

Table 9. 1971 nominal landings for German Democratic Republic (ICNAF Subarea 5 and Statistical Area 6), expressed as percentages of species catch distribution over fisheries (CH Percent) and ratios of by-catch to main species sought within fisheries (CH Ratio). See text for explanation.

Species sought		Species caught								
		Cod	Haddock	Redfish	Silver hake	Flounder	Other groundfish	Herring	Other pelagic	Other fish
Other groundfish	CH Ratio (R)	0.000	0.000	0.000	0.000	0.000	1.000	0.474	0.015	0.005
	CH Percent	0.00	0.00	100.00	0.00	0.00	67.16	10.90	0.10	0.24
Herring	CH Ratio (R)	0.000	0.000	0.000	0.000	0.000	0.086	1.000	0.140	0.067
	CH Percent	0.00	0.00	0.00	0.00	0.00	18.20	72.63	3.05	10.20
Other pelagic	CH Ratio (R)	0.000	0.000	0.000	0.000	0.000	0.016	0.050	1.000	0.108
	CH Percent	0.00	0.00	0.00	0.00	0.00	14.64	16.02	96.67	73.15
Other fish	CH Ratio (R)	0.000	0.000	0.000	0.000	0.000	0.000	0.057	0.077	1.000
	CH Percent	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.18	16.40

Table 10. 1971 nominal landings for Bulgaria (ICNAF Subarea 5 and Statistical Area 6), expressed as percentages of species catch distribution over fisheries (CH Percent) and ratios of by-catch to main species sought within fisheries (CH Ratio). See text for explanation.

Species sought		Species caught								
		Cod	Haddock	Redfish	Silver hake	Flounder	Other groundfish	Herring	Other pelagic	Other fish
Silver hake	CH Ratio (R)	0.007	0.010	0.000	1.000	0.023	0.027	0.752	0.523	0.299
	CH Percent	20.000	100.00	0.00	14.80	2.73	0.29	4.92	0.55	1.33
Other groundfish	CH Ratio (R)	0.000	0.000	0.000	0.579	0.033	1.000	0.075	0.761	0.791
	CH Percent	0.00	0.00	0.00	29.34	13.28	37.13	1.67	2.72	12.09
Herring	CH Ratio (R)	0.002	0.000	0.004	0.048	0.002	0.044	1.000	0.057	0.178
	CH Percent	60.00	0.00	86.67	8.29	3.13	5.61	76.75	0.70	9.31
Other pelagic	CH Ratio (R)	0.000	0.000	0.000	0.026	0.005	0.052	0.026	1.000	0.174
	CH Percent	20.00	0.00	13.33	35.75	49.61	51.40	15.71	95.66	71.06
Other fish	CH Ratio (R)	0.000	0.000	0.000	0.575	0.193	0.370	0.104	0.261	1.000
	CH Percent	0.00	0.00	0.00	11.82	31.25	5.57	0.94	0.38	6.20

Table 11. 1971 nominal landings for Cuba (ICNAF Subarea 5 and Statistical Area 6), expressed as percentages of species catch distribution over fisheries (CH Percent) and ratios of by-catch to main species sought within fisheries (CH Ratio). See text for explanation.

Species sought		Species caught								
		Cod	Haddock	Redfish	Silver hake	Flounder	Other groundfish	Herring	Other pelagic	Other fish
Other fish	CH Ratio (R)	0.000	0.000	0.000	0.358	0.000	0.000	0.000	0.196	1.000
	CH Percent	0.00	0.00	0.00	100.00	0.00	0.00	0.00	100.00	100.00

Table 12. Differences between estimated 1973 Canada catches and their expected 1973 by-catch ('000 tons).

Species sought	Species caught								
	Cod	Haddock	Redfish	Silver hake	Flounder	Other groundfish	Herring	Other pelagic	Other fish
Cod	0.0	-0.6	-0.1		-0.1	-0.1			
Haddock	0.3	0.0	0.1		0.1	0.1			
Redfish	-0.1	0.0	0.0		0.0	-0.1			
Other groundfish	0.3	-0.1	0.1		0.0	0.0			
Herring							0.0		
Other pelagic								0.0	
Total	0.5	-0.7	0.1	0.0	0.0	-0.1	0.0	0.0	

Table 13. Differences between estimated 1973 Federal Republic of Germany catches and their expected 1973 by-catch ('000 tons).

Species sought	Species caught								
	Cod	Haddock	Redfish	Silver hake	Flounder	Other groundfish	Herring	Other pelagic	Other fish
Herring	0.0	0.0				0.2	0.0	0.8	0.0
Total	0.0	0.0				0.2	0.0	0.8	0.0

Table 14. Differences between estimated 1973 Poland catches and their expected 1973 by-catch ('000 tons).

Species sought	Species caught								
	Cod	Haddock	Redfish	Silver hake	Flounder	Other groundfish	Herring	Other pelagic	Other fish
Herring	0.1					0.0	0.0	10.0	3.6
Other pelagic	0.1		0.0	0.0		0.0	-7.5	0.0	-1.6
Other fish						0.0	-0.3	-0.1	0.0
Total	0.2		0.0	0.0		0.0	-7.8	9.9	2.0

Table 15. Differences between estimated 1973 Romania catches and their expected 1973 by-catch ('000 tons).

Species sought	Species caught								
	Cod	Haddock	Redfish	Silver hake	Flounder	Other groundfish	Herring	Other pelagic	Other fish
Silver hake				0.0	0.0				
Herring		-0.1			-0.1	0.0	0.0	0.8	-0.3
Other pelagic	0.0	-0.3		-1.4	-1.0	-0.1	-1.2	0.0	-5.2
Total	0.0	-0.4		-1.4	-1.1	-0.1	-1.2	0.8	-5.5

Table 16. Differences between estimated 1973 Spain catches and their expected 1973 by-catch ('000 tons).

Species sought	Species caught								
	Cod	Haddock	Redfish	Silver hake	Flounder	Other groundfish	Herring	Other pelagic	Other fish
Cod	0.0	-0.3				0.0			
Total	0.0	-0.3				0.0			

Table 17. Differences between estimated 1973 USSR catches and their expected 1973 by-catch ('000 tons).

Species sought	Species caught								
	Cod	Haddock	Redfish	Silver hake	Flounder	Other groundfish	Herring	Other pelagic	Other fish
Silver hake	0.8	-0.1	0.0	0.0	-1.8	-1.8	-5.9	-0.2	-1.6
Other groundfish	0.1	0.0		0.7	-0.5	0.0	-0.3	0.3	0.0
Herring	0.5	0.0	0.4	3.6	-0.1	0.7	0.0	4.3	1.3
Other pelagic	0.2	0.0	0.4	0.2	-2.5	-0.9	-8.3	0.0	-1.7
Other fish	0.0	0.0	0.0	1.2	-0.7	0.0	-0.8	0.4	0.0
Total	1.6	-0.1	0.8	5.7	-5.6	-2.0	-15.3	4.8	-2.0

Table 18. Differences between estimated 1973 USA catches and their expected 1973 by-catch ('000 tons).

Species sought	Species caught								
	Cod	Haddock	Redfish	Silver hake	Flounder	Other groundfish	Herring	Other pelagic	Other fish
Cod	0.0	-0.6	0.1	0.9	-0.2	-0.5	0.0	0.1	0.0
Haddock	4.5	0.0	0.5	0.1	1.1	1.4		0.0	
Redfish	-0.2	-0.4	0.0	0.6	-0.2	-0.5	-0.1	0.0	0.0
Silver hake	-2.8	-1.7	-1.5	0.0	-6.4	-4.9	-7.5	0.2	-0.2
Flounder	1.6	-1.8	0.9	4.7	0.0	-0.6	-0.1	3.5	0.0
Other groundfish	0.4	-0.1	0.1	2.7	0.3	0.0	-0.1	0.8	0.0
Herring	0.2	0.1	0.4	6.7	0.2	0.2	0.0	1.8	0.0
Other pelagic	0.0			-0.2	-0.2	-0.1	-0.4	0.0	0.0
Other fish	0.0	0.0	0.0	0.0	0.0	0.0		0.8	0.0
Total	3.7	-4.5	0.5	15.5	-5.4	-5.0	-8.2	7.2	-0.2

Table 19. Differences between estimated 1973 Bulgaria catches and their expected 1973 by-catch ('000 tons).

Species sought	Species caught								
	Cod	Haddock	Redfish	Silver hake	Flounder	Other groundfish	Herring	Other pelagic	Other fish
Silver hake	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0
Other groundfish				0.0	0.0	0.0	0.0	0.1	0.0
Herring	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other pelagic	0.0		0.0	-0.1	-0.1	-0.2	-0.1	0.0	-0.7
Other fish				0.0	0.0	0.0	0.0	0.0	0.0
Total	0.0	0.0	0.0	-0.1	-0.1	-0.2	-0.1	0.1	-0.7

APPENDIX II

The linear programming model is a decision model for which the effectiveness of an allocation scheme distributed over several variables is measured by the maximum value of some linear function of those variables, when those variables are subject to linear constraints. The problem can be formulated as that of determining

$$X = (x_1, x_2, x_3, \dots, x_N) \quad \dots (1)$$

in the model
$$Z = \sum_{i=1}^N (c_i x_i) \quad \dots (2)$$

such that the constraints
$$\sum_{i=1}^N (a_{ij} \cdot x_i) \begin{matrix} < \\ (=) \\ > \end{matrix} b_j \quad j = 1, \dots, M, \quad \dots (3)$$

$$x_i \geq 0 \quad i = 1, \dots, N \quad \dots (4)$$

where a_{ij} , b_j and c_i are constants, and N and M are finite integers. In this model Z is maximized with respect to the variables x_i , and since minimizing Z is equivalent to maximizing the term,

$$\sum_{i=1}^N (-c_i x_i),$$

all optimization problems of the kind defined by equations (1) - (4) can be treated as maximization problems.

A general procedure for determining a solution to equations (2) - (4) is to modify equation (3) so that all b_j are non-negative, i.e., multiply through by -1 where necessary. This transformation does not alter the problem. Another procedure that can be used is to convert system (3) to a system of equalities through the introduction of slack variables (for "less than" inequalities), and surplus variables (for "greater than" inequalities). For instance, if in the original system with N variables, the constraint

$$(a_{11}x_1 + a_{12}x_2) < b_1$$

were present, where x_1 and x_2 were to be non-negative, then the revised equation

$$a_{11}x_1 + a_{12}x_2 + x_{N+1} = b_1$$

is considered, where x_{N+1} is also to be non-negative. In this situation, the additional variable x_{N+1} can be thought of as accounting for the difference between $a_{11}x_1 + a_{12}x_2$ and b_1 , and will take on a positive or negative sign according to whether or not the original constraint was a "less than" or a "greater than" inequality. It can be proven that there is a one to one correspondence between the solutions $(x_1, x_2, \dots, x_N, x_{N+k})$ to a system containing k slack and surplus variables, and the corresponding solutions (x_1, x_2, \dots, x_N) to the original system (Hadley, 1963, p. 74). Further, the solution which maximizes the objective function in the altered system is the same one which maximizes the objective function of the original system (2). Thus, in trying to determine a solution for equations (2) - (4), it is sufficient to consider only the system

$$AX = B \quad \dots (5)$$

$$x_i \text{ non-negative } i = 1, \dots, N + k \quad \dots (6)$$

where the objective function (2) is to be maximized, and A is a matrix of coefficients a_{ij} defining the constraints, X is the vector of variables to be determined $X = (x_1, \dots, x_N, \dots, x_{N+k})$, and B is the vector of limiting values b_j . The system is as follows: for a system which initially had k_1 "less than" inequalities, k_2 "greater than" inequalities and k_3 equalities, where $M = k_1 + k_2 + k_3$, the corresponding system $AX = B$ is defined as follows:

$$A = \begin{pmatrix} a_{11} & a_{12} & \dots & a_{1N} & 1 & \dots & 0 & \dots & 0 \\ a_{21} & a_{22} & \dots & a_{2N} & 0 & 1 & \dots & 0 & \dots & 0 \\ \cdot & \cdot \\ \cdot & \cdot \\ a_{(k_1)1} & a_{(k_1)2} & \dots & a_{(k_1)N} & 0 & 0 & \dots & 1 & 0 & 0 & \dots & 0 \\ a_{(k_1+1)1} & a_{(k_1+1)2} & \dots & a_{(k_1+1)N} & 0 & 0 & \dots & 0 & -1 & 0 & \dots & 0 \\ a_{(k_1+2)1} & a_{(k_1+2)2} & \dots & a_{(k_1+2)N} & 0 & 0 & \dots & 0 & 0 & -1 & \dots & 0 \\ \cdot & \cdot \\ \cdot & \cdot \\ a_{(k_1+k_2)1} & a_{(k_1+k_2)2} & \dots & a_{(k_1+k_2)N} & 0 & 0 & \dots & 0 & 0 & 0 & \dots & -1 \\ a_{(k_1+k_2+1)1} & a_{(k_1+k_2+1)2} & \dots & a_{(k_1+k_2+1)N} & 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 \\ \cdot & \cdot \\ \cdot & \cdot \\ a_{M1} & a_{M2} & \dots & a_{MN} & 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 \end{pmatrix}$$

$$X^T = (x_1 \dots x_N, x_{N+1} \dots x_{N+k_1} \dots x_{N+k_2})$$

$$B^T = (b_1 \dots b_M)$$

Solutions to the systems addressed in this paper were derived using the Simplex algorithm (Hadley, 1963, p. 132 f), which has had a long history of usage in solving allocation problems. This algorithm provides an iterative method for exactly determining the vector X which maximizes the objective function (2). It considers only extreme points¹ in the set of all vectors, which satisfy the constraints in the system (5), invoking the principle that if a solution X exists which maximizes (2) and is finite, this solution occurs at an extreme point. The algorithm allows for the evaluation of the objective function successively at each extreme point, moving from any given point to the point giving the greatest increase in the objective function with the smallest change in X, and finally to the point which maximizes (2). For example, if the solution set can be envisaged as the area and perimeter of a rectangle, the extreme points of the solution set are the four corners of the rectangle. The Simplex algorithm starts with the vector X which corresponds to some corner, provides a method for determining which adjacent corner X' will generate the greatest increase in the objective function, and continues to "move" around the rectangle until the "maximizing corner" is found. Since there are only a finite number of extreme points, a solution (if one exists), will be found in a finite number of steps.

A Honeywell computer program, LINPRO, provided the solution to the systems addressed in this paper. The program used the two-phase method of solution. During the first phase, an augmented system,

$$AX + IX_a = B \quad , \quad \dots (7)$$

is considered, where X_a is a matrix of artificial variables added to give the system an initial solution, and I is the corresponding identity matrix. The Simplex algorithm is then used to maximize the objective function

$$Z^* = \sum_{j=1}^{N+k} c_j \cdot x_j + \sum_{j=1}^l (-1) \cdot x_{N+k+j} \quad \dots (8)$$

where l is the number of artificial variables added to the system, and again requiring that x be non-negative for all i's. If the final solution is defined other than,

¹ Formally, an extreme point x of the set S on the line is a point for which there exist no x₁ and x₂ also in S satisfying x = ax₁ + (1-a)x₂ for some 0 < a < 1.

$$x_{N+k+j} = 0 \quad \text{for } j = 1 \dots l \quad , \quad \dots (9)$$

then there is no solution to the system (2), (5) and (6) (and equivalently to systems (2) - (4)), since a solution to (7) will satisfy (5) only if $X_2 = 0$. The first phase thus determines whether or not the original system has a solution, before the system is actually analyzed. If the system (7) - (8) has (9) as its solution, the second phase of the two-phase method is initiated, and a direct solution to the system (2), (5) - (6) is sought using the Simplex algorithm. This procedure terminates in a finite number of steps, either with a solution or with an unbounded (and therefore unacceptable) objective function.

The linear programming model has had a short history of application to fisheries problems. Recently, Rothschild and Balsiger (1971) constructed such a model in order to allocate the catch of salmon among the days of the salmon run. In this application, the objective function to be maximized represented the total landings of the species. The constraints in the system included the cannery capacity for the species, and the adequate escapement of male and female fish.

The systems addressed in the present paper all had an objective function Z to be maximized which represented the total catch of all finfish in Subarea 5 and Statistical Area 6. The constraints in the systems were restrictions on the catches of the species, e.g. quotas on the catch of individual species, minimum acceptable values of catch of certain species, etc. The actual data base used in the analysis is given in Table 2 where, in line with equations (1) - (4),

$$X = (x_{11}, \dots, x_{99}) = (x_1, \dots, x_9) = \text{vector of directed catches } x_i.$$

$$X_{ij} = \text{catch of species } j \text{ in fishery } i.$$

$$a_{ij} = \frac{x_{ij}}{x_{i1}} = \frac{X_{ij}}{X_i} = \text{ratio of catches of species } i \text{ and } j \text{ taken in fishery } i$$

$$b_j = \text{limiting catch of species } j, \quad j = 1 \dots 10$$

$$c_i = \sum_{j=1}^9 a_{ij} = \sum_{j=1}^9 \frac{X_{ij}}{X_i} = \frac{1}{X_i} \cdot \sum_{j=1}^9 X_{ij} = \text{ratio of total catch of all species taken in fishery } i \text{ to catch of species } i.$$

From the above, it can be shown that the j^{th} constraint

$$a_{1j}x_1 + a_{2j}x_2 + \dots + a_{9j}x_9 = b_j \quad j = 1 \dots 10$$

represents the total catch of all species that can be taken in fishery j, when the system is restricted by a limit on the total catch of species j. Similarly, the objective function (2) represents the total catch of all species in all fisheries, as

$$Z = \sum_{i=1}^9 c_i x_i = \sum_{i=1}^9 \sum_{j=1}^{10} a_{ij} x_i = \sum_{i=1}^9 \sum_{j=1}^{10} x_{ij}$$

The output of the program LINPRO includes the vector X of directed catches of the species, along with the resultant total catches of the species, and the grand-total catch. Variations in the system were easily handled, and included additional minimal catch restrictions on selected species.

27. Fishing unit measures¹

by A.I. Treschev
VNIRO, Moscow, USSR

INTRODUCTION

The analysis of the system of fishing unit measures worked out in 1969 for trawl, purse seine and drift net fisheries (Treschev, 1970) showed that the system of measuring in which the same units are used for all fishing methods would have very great advantages. We have, therefore, attempted to work out and apply the same units of fishing power, fishing effort, efficiency and intensity for beach seine, set gillnet, longline and other gears used in the modern fishery, as was done for the three methods of fishing considered earlier. The value of the fishing power is the same for all fishing gears considered, i.e., the volume of water swept per unit of time.

FISHING POWER OF VARIOUS GEARS

All fishing gears may be divided into three groups: (i) gears whose fishing power is defined directly; (ii) gears whose fishing power is defined experimentally; and (iii) gears whose fishing power is defined by comparison of catches.

The first group, in addition to trawls, purse seines and drift nets, includes all dragged fishing gears. The characteristic feature of these gears is that the volume of water swept by them can be directly measured or estimated by their dimensions and the parameters of their fishing operation.

The second group includes the fishing gears within which the volume of the water swept depends considerably on the radius of action of the devices or factors employed for the attraction of fish to the fishing area. The attraction of fish to fishing gears by means of electric light has been studied intensively, and this method is now widely used in combination with lifting nets (veranda traps) and fish pumps. For different items of fishing and sources of electric light, the radius of the sphere of fish attraction is determined experimentally. Thus, for example, it was found that this radius at the sources of electric light used in the Caspian kilka fishery equals 20 m, and amounts to 25-35 m in the Far East saury fishery.

The fishing power of the fishing gears employed in conjunction with the devices for the attraction of fish in the fishing area, provided the radius of action of the attractive factor is known, can be defined by the product of the water volume contained in the sphere of attraction, by the coefficient of fishing continuity. The coefficient of the fishing continuity is assumed to be the relation of the time of action of the attractive factor in the course of a given fishing period (for example, a night) to the general duration of the period.

The third group comprises the fishing gears that, according to present knowledge, can neither be related to the first nor to the second group, because the actual volume of water swept by them has not, for some reason or another, yielded a precise definition. It is proposed to determine the fishing power of these gears in an indirect way, i.e., by comparing the catches made by these fishing gears with the catches taken by the other fishing gears for which the volume of water swept is known. Thus, for example, if the catch of a drift net is x , the volume of water swept per unit of time is V_x , and the catch by the same set single-walled gillnet when fishing the same items is y , then there are good reasons to believe that the unknown water volume (V_y) swept by a set gillnet is

$$V_y = \frac{yV_x}{x}$$

In other words, we assume that the fishing power of set gillnets will differ from the fishing power of drift nets so many times as the average catches of the former years are more or less than the latter gears.

It is evidently possible with this method to define not only the fishing power of the same type of fishing gears, as in the example above, but also of all other secondary fishing gears founded on different principles of fishing, for instance, nets in comparison with hooks, nets in comparison with traps, etc. It is only necessary to remember that in this case not the actual volume of the water swept is taken into consideration, but a certain conventional value is needed to express the fishing power of all fishing gears in commensurable units.

Examples of the estimation of the fishing power for fishing gears of the third group are given below.

¹ Submitted to the 1973 Meeting of ICNAF as ICNAF Res.Doc. 73/118.

Set gillnets

In order to determine fishing power of a set gillnet, we compare its catches with the catches of the same drift net; the annual catches in centners¹ per drift net in the USSR fishery (by years) are as follows:

1965	1966	1967	1968	1969	Average for 5 years
7.03	7.07	6.83	7.26	8.02	7.24

The average catch per set single-walled gillnet of the same dimensions (q_x) makes up 1.78 centners.

A drift net 30 m by 12 m per 1,000-m drift sweeps the volume of water (V_y) equal to:

$$V_y = 30 \times 12 \times 1,000 = 36,000 \text{ m}^3$$

Hence, the equivalent volume of water swept by a set gillnet (V_x) can be determined according to the formula:

$$V_x = \frac{q_x \times V_y}{q_y} = \frac{1.78 \times 36,000}{7.24} = 8,830$$

This volume equals approximately the cylinder volume, the base of which is a circle with a diameter equal to the length of the net and the height equal to its height, i.e.

$$V = \frac{\pi l^2 a}{4} = \frac{3.14 \times 30^2 \times 12}{4} = 8,478$$

Thus, proceeding from the ratio of catches, the following formula can be used for the definition of the fishing power of set gillnets:

$$v = \frac{\pi l^2 na}{4t} \dots (1)$$

where l = length (m); a = height (m); n = number of nets; t = time of fishing (days); and π = 3.1416.

Traps

In a number of cases, we can find examples of simultaneous application of traps and set gillnets when fishing the same items. Thus, for instance, in the Don area of the Azov Sea, set traps and set gillnets were used in the bass and bream fishery for a long period. The nets measure 20 m in length and 3 m in height. There are three categories of set traps, the length of a guiding wing being 30, 80 and 150 m, respectively, the average height being 3 m.

Both fishing gears are used annually at the same places and at the same time; in spring from 15 March to 20 April, and in autumn from 1 October to 20 December. In the years from 1946 to 1955, i.e., in the period of the most intensive use of these fishing gears in the Don area of the Azov Sea, the annual catches were:

- A. Per net, 20 x 3 m - 3 c¹
- B. Per trap (having a single heart), the length of the wing being 30 m - 20 c
- C. Per trap (having a single heart), the length of the wing being 80 m - 50 c
- D. Per trap (having two hearts), the length of the wing being 150 m - 160 c

¹ 1 centner (c) = 100 kg.

Provided that the lengths of orders of set gillnets are equal to the lengths of sea guiding wings of traps, the ratios of their catches are as follows:

$$\frac{B}{A} = \frac{20}{4.5} = 4.4; \quad \frac{C}{A} = \frac{50}{12} = 4.2; \quad \frac{D}{A} = \frac{160}{22.5} = 7.1$$

The volume of water swept, when estimated according to the formulas

$$V = \frac{\pi l^2 n a}{4} \quad (\text{for nets}), \text{ and} \quad V = \frac{\pi l^2 a}{4} \quad (\text{for traps}), \text{ comes to the following:}$$

$$\frac{B}{A} = \frac{2,120}{480} = 4.4; \quad \frac{C}{A} = \frac{15,072}{3,768} = 4.0; \quad \frac{D}{A} = \frac{52,987}{7,065} = 7.5$$

As is seen, the corresponding ratios of the catches and the volumes of water swept by traps and set gillnets are close to each other. Proceeding from this, we may assume that the fishing power of traps with a precision sufficient for practical estimations can be expressed by the following formula:

$$V (\text{trap}) = \frac{q (\text{trap}) \times V (\text{set gillnet})}{q (\text{set gillnet}) \times t} = \frac{\pi l^2 a}{4t} \quad \dots (2)$$

Hooked fishing gears

In the 1930's set gillnets and longlines were rather widely used in the cod fishery at the Murman coast of the Barents Sea. Until now, the fishery of spring spawning cod (skrei) in Norway has been made by set gillnets and hooked fishing gears (lines and longlines). In 1961, for example, 53.1% of the total catch of these fish were caught by nets, and 36.9% by hooked fishing gears. Recently, the specific weight of nets and hooks in the skrei fishery has decreased somewhat, but, nevertheless, these gears remain the essential ones up to the present time. Skrei catch per fisherman amounted to: 62.4 c by nets in 1959; 47.0 c by nets in 1961; 53.6 c by hooks in 1959; and 64.2 c by hooks in 1961.

According to previous data, the catch in 1969 per fisherman engaged in the line and longline fishery was approximately 5 centners higher than the catch taken in the net fishery. Thus, if we take an average of figures for several years, it appears that the catches per fisherman in net, line and longline fisheries, respectively, are about the same.

A Norwegian set gillnet for cod fishing is 28 m long, height in setting being 5 m. The fishing power of such a net is:

$$V (\text{set gillnet}) = \frac{\pi l^2 n a}{4} = \frac{3.14 \times 28^2 \times 1 \times 3}{4} = 1,846 \text{ m}^3$$

If we try to determine the fishing power of longlines, we suppose in the first instance that the distance between the hooks of longlines proceeding from their catchability has been properly selected. Then, each hook may be considered as a centre, and a gangling as a radius (R) of the water volume swept, i.e.,

$$V (\text{hook}) = \frac{4\pi R^3}{3} \quad \dots (3)$$

The length of ganglings in the Norwegian cod longlines (R) is 0.46 m. Substituting this value in the formula, we then see that one hook of such a longline has to sweep a volume of water equal to:

$$V (\text{hook}) = \frac{4\pi \times 0.46^3}{3} = 0.41 \text{ m}^3$$

Having divided the volume of water swept by one set gillnet by 0.41, we then get:

$$\frac{V (\text{set gillnet})}{V (\text{hook})} = \frac{1,840}{0.41} = 4,488$$

i.e., one net corresponds to approximately 4,500 hooks.

The Norwegian cod longline consists of 16,200 hooks and is served by five fishermen, and consequently, each fisherman serves 3,240 hooks. The number of nets per one fisherman averages 7.

At the same time, the catches per one fisherman in the net and hook fishery, as shown above, are approximately equal. This means that the radius of the spherical volume of water swept by one hook approximately is not equal to the length of the ganging, but somewhat longer.

Let us determine this radius on the assumption that the catches and the volumes of water swept remain the same, and at the same time taking into account the number of fishing gears served by one fisherman:

$$V (\text{set gillnet}) = V (\text{longlines})$$

hence,

$$7V (\text{set gillnet}) = \frac{4}{3} \pi R^3 = 3,240 \quad ,$$

or

$$R = \sqrt[3]{\frac{3 \times 7V (\text{set gillnet})}{4 \times 3,240}} \quad .$$

Then, using constant numerical values, we get:

$$R = \sqrt[3]{\frac{3 \times 1,846 \times 7}{4 \times 3.14 \times 3,240}} = 0.984 \text{ m} \quad .$$

Having placed the obtained value of R in formula (3), we find that one hook of longlines and lines in the skrei fishery sweeps a volume of water equal to:

$$V (\text{hook}) = \frac{4}{3} \pi R^3 = \frac{4}{3} (3.14 \times 0.9526) = 3.9882 \approx 4.0 \text{ m}^3 \quad .$$

Therefore, proceeding from the ratio of catches, one may assume that the fishing power of hooked fishing gears can be defined according to the following formula:

$$V (\text{hook}) = \frac{4}{3} \left(\frac{\pi R^3 n}{t} \right) \quad ,$$

where R = radius of the fishing sphere found by the above-mentioned method, and n = number of hooks.

In this estimation we used catches per fisherman. The task might obviously have been solved in a much simpler way if the direct data on catches per net, longline or hook had been available.

Since set gillnets are very widely distributed and easily accessible fishing gears, the determination of the fishing power of any coastal fishing gear by comparison of catches offers no difficulty. As to the reduction of fishing power in various kinds of fisheries to the common index, we shall not define the total fishing effort in the so-called 'mixed fishery', but also differentiate it according to the kind of fishery.

FISHING POWER, EFFORT, EFFICIENCY AND INTENSITY

As a result of dividing all fishing gears into three groups and expressing the fishing power by the above-mentioned methods, we managed to improve considerably the system of the units worked out in 1969 and to use it for all kinds of fisheries with no exception. A summary of the methods on the definition of the fishing power of different fishing gears is shown in Figs. 1, 2 and 3.

As a common unit for the fishing power for all fishing gears, the power at which 1,000,000 m³ of water is swept per unit of time is assumed. This value of the fishing power unit is based on the fishing power of the most widely used modern trawl (horizontal opening 37.5 m, vertical mouth 3.9 m, speed of trawling 4 knots, i.e., approximately 2 m per second) per hour of trawling (3,600 seconds), which is

$$37.5 \times 3.9 \times 2 \times 3,600 = 1,053,000 \approx 10^6 \text{ m}^3 \quad .$$

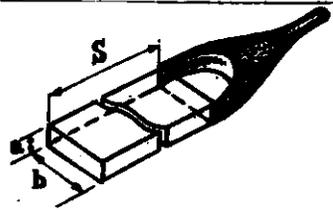
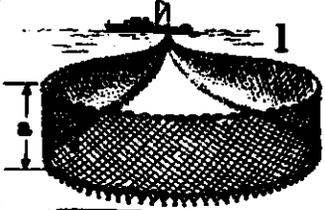
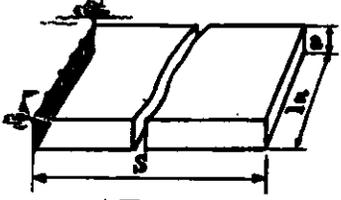
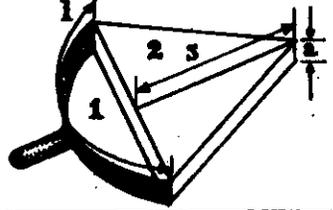
FISHING GEAR	DIAGRAM	FORMULA
TRAWLS		$V = abS$
PURSE SEINES		$V = \frac{l^2 a}{4\pi}$
DRIFT NETS		$V = a l n S$
DRAGGED FISHING GEARS		$1. V = \frac{a l^2}{\pi}$ $2. V = \frac{a l^2}{\pi} + \frac{a l S}{\pi}$

Fig. 1. The gears whose fishing power is defined directly.

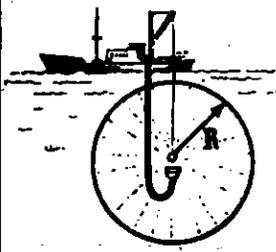
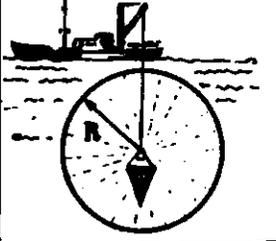
FISHING GEAR	FISHING POWER		DETERMINED PARAMETERS	
	DIAGRAM	FORMULA	Radius of attraction	Coefficient of fishing continuity
FISH PUMPS		$V = \frac{4}{3} \pi R^3$	R	$K = 1$
LIFTING NETS		$V = \frac{4}{3} \pi R R_1^3$	R_1	$K = \frac{t_1^*}{t}$ $R = R_1$

Fig. 2. The gears whose fishing power is defined experimentally. (* t and t_1 = the period of time during a day when the lamp is switched on and fish pumps and nets are respectively used).

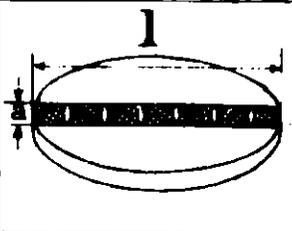
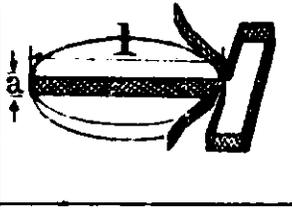
FISHING GEAR	FISHING POWER		
	DIAGRAM	FORMULA	BASIS
SET GILLNETS		$V = \frac{\pi l^2 n}{4} a$	$\frac{\pi l^2 n a}{4} \approx \frac{q_{s.n.} V_{d.n.}}{q}$
TRAPS		$V = \frac{\pi l^2}{4} a$	$\frac{\pi l^2 a}{4} \approx \frac{q_{tr.} V_{s.n.}}{q_{s.n.}}$
HOOKE FISHING GEARS		$V = \frac{4}{3} \pi R^3 n$	$\frac{4}{3} \pi R^3 n \approx \frac{\pi l^2 n a}{4}$

Fig. 3. The gears whose fishing power is defined by comparison of catches.

A unit of the fishing effort is the product of the fishing power and the time of fishing during a 24-hour period; the time of fishing in all cases is the period during which a fishing gear is actively fishing. For the different fishing gears this time is defined as follows:

- Trawls:
$$\frac{\text{number of hours trawling}}{24 \text{ hours}}$$
- Purse seines:
$$\frac{\text{time from the beginning of shooting till the end of pursing in hours} \times \text{number of shootings}}{24 \text{ hours}}$$
- Traps and other stationary fishing gears:
$$\text{number of full days fished}$$
- Drift fishing gears:
$$\frac{\text{number of drifts} \times \text{average duration of a drift (hour)}}{24 \text{ hours}}$$
- Fish pumps and lifting fishing gears applied with fish attracting devices to a fishing area:
$$\frac{\text{time of action of fish attracting devices per cycle (hour)} \times \text{number of fishing cycles}}{24 \text{ hours}}$$
- Other fishing gears:
$$\frac{\text{number of hours active fishing}}{24 \text{ hours}}$$

The fishing efficiency is the ratio of the catch for a period of fishing to the fishing effort for the same period. Hence, a unit of fishing efficiency would be expressed as follows:

$$\frac{\text{catch (tons)}}{10^6 \text{ m}^3}$$

If the catch is averaged over a sufficiently long period of time, the unit of fishing efficiency for

each class (group) of gear will accumulate all the peculiarities of the fishing process, including fish behaviour and the organization, technique and tactics of fishing. Unlike the measures currently used, such as catch per unit time, catch per unit tonnage, etc., which are not connected with the principle of fishing, the new measure of fishing efficiency will incorporate both the effect of fishing and the degree of perfection of the fishing technique. With unchanged fishing technique, the fishing power remains the same and the fishing efficiency of the gear will change proportionately with the changes in the stock. Considering that the fishing efficiency is based on actual catch data over a long period of time, it is also more accurate than other estimates arrived at theoretically on the basis of various assumptions concerning fish behaviour.

When changing (improving) the designs of fishing gears or the methods of their application, provided the fishing power remains constant, then the average efficiency for a rather long period of time will permit us to judge the efficiency of the innovations. Thus, such improvements in the trawl fishery, for example, as the use of cables, electric current, concentrating the fish in the trawl mouth, as well as the towing of a trawl from two vessels, the use of hydroacoustics, etc., do not relate to the means of increasing the fishing power, as was sometimes noticed in the past, but rather to the methods of increasing their efficiency.

When proceeding from fishing effort and fishing efficiency, it is possible to determine, for practical purposes and with a quite sufficient accuracy, the fishing intensity, differently called "the intensity of fishing".

So far, there has been no clear definition of the notion "the intensity of fishing", as well as of other fishing parameters. The fishing intensity was understood by some to be the ratio of the area swept to the area of the surface or the bottom of the water body (geometrical intensity of fishing), while others characterized the fishing intensity as being the number of vessels participating in the fishery, fishing gears, time, etc. The lack of an agreed viewpoint as to the understanding of such an important term as "the fishing intensity" creates great difficulties in the analyses of the fishing effect on the stocks, as well as in the solution of many operative problems of fishery regulations.

In the given system of units, fishing intensity means the ratio of the water volume swept to the general volume of area of distribution of the species fished. Therefore, the fishing intensity is a sizeless value.

For the species, on which fishing intensity is rather high, and for which the fishing areas are clearly restricted (for instance, flounders of all areas, the species fished on the Great Newfoundland Bank, cod off Lofoten Islands and Iceland, sea bass on the Kepyrov Bank, etc.), both values are commensurable, and there is no difficulty to determine the fishing intensity. For the species, on which the fishery is only slightly developed, and for which the areas of distribution are either unknown or too vast, it is still difficult to define the true fishing intensity by means of the above-mentioned method. The fishing intensity in these areas can be roughly expressed by the product of the fishing effort and the sizeless coefficient of catchability (in cases where the coefficient of the catchability of fishing gears is unknown). The value characterizing the fishing intensity will, in this case, be expressed in units of the fishing effort.

If the coefficient of the catchability of fishing gears is unknown and cannot be determined, the fishing intensity can be characterized by the product of the fishing effort and the dimensional value - fishing efficiency. This product is expressed in units of weight, i.e., is nothing more than a catch.

In order to characterize the fishing intensity of the fish dispersed over vast areas, the method of comparison of the actual catches with the value of the optimal catch may also be employed, provided that this value is known or can be defined. In this case, the fishing intensity, as in the case of the volumes relation, can be expressed by sizeless values.

In future, however, it is necessary, with the development of the fishery, to aim at using the only method for determination of the fishing intensity, namely, the true intensity of fishing, i.e., the relation of the water volume swept to the volume of the distribution of the fish.

When turning from the fishing indices (power, effort, efficiency, intensity) of certain fishing gears to the summary indices of the work of the fishing fleet and flotillas, the above units for measuring the fishing would be too small; therefore, in addition to the initial unit of the fishing power (10^6) and the units for measuring other parameters corresponding to it, it is advisable to have also units which are 10, 100 and 1,000 times as much (Table 1).

The general assessment of the fishing power becomes much simpler with such a selection of the units scale. For the full and uniform assessment of all kinds of fishery made by the various modern devices, the following data must be available:

Table 1. Scale of fishing unit measures.

Purpose	Name	Abbreviation	Dimension	Fraction of basic unit
Measure of fishing power	Promm	pm	$10^9 \text{ m}^3/24 \text{ hours}$	1
	Decipromm	dpm	$10^8 \text{ m}^3/24 \text{ hours}$	1:10
	Centipromm	cpm	$10^7 \text{ m}^3/24 \text{ hours}$	1:100
	Millipromm	mpm	$10^6 \text{ m}^3/24 \text{ hours}$	1:1,000
Measure of fishing effort	Promus	pu	10^9 m^3	1
	Decipromus	dpy	10^8 m^3	1:10
	Centipromus	cpy	10^7 m^3	1:100
	Millipromus	mpu	10^6 m^3	1:1,000
Measure of fishing efficiency	Promef	pe	$t/10^9 \text{ m}^3$	1
	Decipromef	dpe	$t/10^8 \text{ m}^3$	1:10
	Centipromef	cpe	$t/10^7 \text{ m}^3$	1:100
	Millipromef	mpe	$t/10^6 \text{ m}^3$	1:1,000
Measure of fishing intensity	Promin	pi		1
	Decipromin	dpi		1:10
	Centipromin	cpi		1:100
	Millipromin	mpi		1:1,000

(a) The fishing power of the fishing gears. For each fishing gear, the fishing power should be established by one of the above-mentioned methods and should be indicated with its name. Thus, "trap mpm - 7.2" would mean that the trap fishes $7.2 \times 10^6 \text{ m}^3$ water per 24 hours of continuous fishing.

(b) The number of fishing gears.

(c) The number of days fished. For trawl fishing gears, it is more convenient to carry out the collection of data in hours of trawling and then to convert to days.

For purse seines, drift fishing gears, and gears applied with the devices for attraction of fish to the fishing area, as well as for trawl gears, it is necessary to register the active working time of the fishing gears measured in hours in the boat logs. The summary number of fishing hours divided by 24 will characterize, in this case, the number of fishing days. For the stationary fishing gears, data on the number of days that the gears were in fishing operation are sufficient. For all other fishing gears, data on the time of active fishing per day will suffice.

(d) The catch. The catch for all fishing gears should be represented by species of fish in tons with an indication of the time and place to which this catch relates.

In order to facilitate the collection of data and to increase the precision of the fishery data, it would be advisable to have on board the fishing vessels automatic devices for the registration of the following parameters: (i) number of trawling hours; (ii) time of active operation of purse seines; (iii) duration and length of drifts of the vessels with fishing gears; and (iv) duration of the action of the fishing stimulators (light, electric current and so on). Such devices can apparently be very simple and cheap, and their application greatly increase the quality of the fishery data and bring it to a really scientific base. This, in turn, opens the possibility of the more concrete management of fishing effort in the fishery and creates the conditions for considerable simplification of the scientific fishery statistics and for the wider application of computing techniques.

SUMMARY

The obtaining of precise quantitative data from fisheries under modern conditions is very important for the study of the interrelation between the stock and the fishery. It is also of great importance for the elaboration of the theory of the optimal catch and for the solution of other scientific problems.

This method allows the determination in comparable units of the fishing power and other characteristics

of fishing in earlier years. The use of this method is of special interest as to the estimation of the dynamics of fishing efficiency in relation to the dynamics of fishing effort in the most important fishing areas.

An important advantage of the proposed system of units for measuring fishing lies in the fact that it may be used to provide the basis for the quantitative characteristics of the operation of a fleet in working out future plans on the basis of the rational exploitation of the stock and fishing technique.

The unification of fishing unit measures is at present equally important both for technical and for biological purposes.

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Fishery parameters assessment method

The International Council for the Exploration of the Sea (ICES), at its 60th Session, decided to hold in IJmuiden, Holland, 3 through 8 May 1973, a Meeting on Engineering Aspects of Fishing Gear, Vessels and Equipment and on Statistical Problems of Measuring Fishing Efforts. Among the Meeting's objectives, it is pointed out that

"in pursuance of the issues raised by S.A. Studenetsky (Doc.C.M. 1972/D:5) referring to A.I. Treschev, Doc.C.M. 1971/B:9, Dr A.I. Treschev be asked to submit to the Meeting of the Working Group a paper illustrating by means of worked examples referring to USSR fisheries the application of his proposed new method of measuring fishing effort, and that other countries evaluate the merits of the method applied to their own fisheries and report their findings to the Working Group".

ASSUMPTIONS IMPLIED IN THE PROPOSED METHOD

The method relies on the following basic assumptions:

Fishing gear capacity (power), W (in conjunction with a certain class of vessel, crew and equipment), is described by the water volume (V_s) fished per unit of time (T_1), i.e.,

$$W = \frac{V_s}{T_1}$$

where V_s is established for different gear classes by the methods indicated and is measured in volumetric units, s and T_1 is the time when a gear is in active (fishing) state and is measured in 24-hour periods and registered either in ship-log or by special-purpose instrumentation.

Fishing effort (U) is the product of the fishing gear capacity (W) multiplied by its active fishing time, for any period T_2

$$U = WT_2$$

Here the time T_2 is measured in the same units as are accepted for fishing capacity, i.e., 24-hour periods.

Fishery efficiency (E_f) is the catch (C) per unit of fishing effort, viz.

$$E_f = \frac{C}{U}$$

where C is the catch in metric tons, and U is the fishing effort in volumetric units.

Since the fishing effort in terms of the accepted measuring system represents:

$$U = \frac{V_s}{T_1} T_2$$

i.e., the volume of water fished, then the fishery efficiency indicates the catch per unit of the volume fished.

This indicator is essential because, the fishing effort being constant, it describes the productivity of fishing areas in the same way as the harvest per unit of agricultural land provides an index of land fertility in agriculture. Its changes give a measure of evaluating the validity of the quotas set out for catches and efforts.

Under mixed fishery, i.e., with the same object being fished by different gears, the application of the proposed method presents no problem because the fishing effort of different gear classes is measured in the same units and, therefore, may be analyzed and limited for all the gears and for each one in particular.

REPRESENTATIVITY OF METHOD

For the purpose of checking on the method's representativity, the correlation has been investigated

between the catch and the following parameters: volume of the water fished, the length and displacement of vessel and capacity of the main engine.

The degree of interrelation was assessed using correlation ratios, as determined by the formula

$$r_{y/x} = \sqrt{\frac{\sum_{j=1}^l m_j (\bar{y}_{x_j} - \bar{y})^2}{\frac{n}{\sum_{i=1}^n (y_i - \bar{y})^2}}} ; \quad \bar{y}_{x_j} = \frac{1}{m_j} \sum_{i=1}^{m_j} y_{ij}$$

- where
- l = the number of intervals in x
 - j = the ordinal numbers of the x intervals
 - x_j = midpoint of interval in x
 - \bar{y}_{x_j} = mean value of y in the x^{th} interval
 - m_j = number of points whose x coordinates (x_{ij}, y_{ij}) are found in the j^{th} interval.

The data used in the calculations were those of USSR fishermen in ICNAF Subareas 2, 3, 4, 5 and Statistical Area 6 of the Northwest Atlantic (Table 1). Because there was a marked difference in the fishing situation between Subareas 2 and 3, on the one hand, and Subareas 4, 5 and Statistical Area 6, on the other, all calculations were made in relative values, i.e., for every area the mean per-hour-catch with a bottom trawl of a BMRT-type vessel was assumed to be unity (OTST-7).

Table 1. Data used in calculation of correlation ratios.

Vessel displacement	Vessel length	Main engine capacity, HP	Fishing capacity $\left(\frac{m^3}{24 \text{ hr}} \times 10^9\right)$	Catch per hour in relative units
(x_1)	(x_1)	(x_1)	(x_1)	(y_1)
3800	84.7	2000	0.0958	1.21
3800	84.7	2000	0.0958	1.05
3800	84.7	2000	0.0173	1.00
3800	84.7	2000	0.0173	1.00
3362	82.2	2320	0.2570	1.95
3362	82.2	2320	0.2570	1.57
3362	82.2	2320	0.0162	0.98
3275	79.2	1340	0.0986	1.30
3275	79.2	1340	0.0152	0.90
3275	79.2	1340	0.0152	0.60
912	54.2	800	0.0352	0.74
912	54.2	800	0.0098	0.26
912	54.2	800	0.0098	0.23
737	50.8	540	0.0072	0.24
545	43.6	400	0.0068	0.21
545	43.6	400	0.0068	0.17

The results were as follows:

<u>Relations</u>	<u>Correlation ratio</u>
Catch per hour - total displacement	0.82
Catch per hour - vessel length	0.79
Catch per hour - main engine capacity	0.88
Catch per hour - fishing capacity	0.97

It follows from these data that the technical parameters of fishing vessels (length, displacement, H.P., etc.) are not related through close functional dependence to the results of the fishery. It is usually confirmed by the fact that the same vessels operating at the same time in the same area, subject to the type of trawl, show considerable variation in catch per hour (for data considered up to 300%). It indicates that the technical parameters of vessels, if applied as the assessment criteria of fishing effort, are not representative enough. The fact that the correlation ratio of catch per hour of trawling and fishing capacity is close to unity (0.97) points to their closest functional dependence.

This is one of the reasons why the author has selected this criterion as the initial value for measuring fishing effort. Besides, the volume fished as the chosen measure of fishing capacity, in comparison with all other methods, has the following advantages:

- 1) It enables the most accurate assessment of the effects of fishery on the stocks.
- 2) At a certain productivity of the fishing area (with an established optimal permissible catch per unit of water volume), it permits permanently to observe the relationship between the stocks and fishery which may serve as an important criterion to assess the validity of the quotas set for catches.
- 3) Where there has been a preliminary evaluation of the fishing capacity of the fishing gear, it will be easy to determine from only two indicators, namely, the number of gears and their time on active duty.
- 4) It is universal for all fishing gear classes.
- 5) It lends itself to accurate control and distribution between countries, areas and fishing gears.
- 6) In a mixed fishery, it enables one to obtain a differential assessment of fishing efficiency with respect to every particular species.
- 7) Because fishing capacity and fishing effort stand in no relation to the catch, but represent, in effect, no more than technical and operational parameters, no uncertainty is admitted to determining the latter's values, as being dependent on the patterns of fish distribution and behaviour, weather, etc.
- 8) It is no longer necessary to apply conventional values and calibrated gears, which always involve great errors because of large variations in the conditions of fishery, efficiency of fishing gears and equipment, and skill of the crew.

METHOD AS APPLIED TO STOCKS AND FISHERY ANALYSIS

The use of the method for stock and fishery analysis cannot be explained unless we have first defined the concept of "the intensity of fishery". The latter comprises two values:

(a) intensity of yield, and (b) intensity of fishing. Yield intensity (v) is the ratio of the catch of a certain species (N_c) to its stocks (N):

$$v = \frac{N_c}{N}$$

The fishing intensity (I) in this system of measuring fishery parameters is the ratio of the water volume fished (V_f) to the volume of the fishing area (V):

$$I = \frac{V_f}{V}$$

Under rational fishery, the fishing intensity should not only be known, but properly controlled. To do this, one may use the concept of relative fishing intensity.

Relative fishing intensity (J) is the ratio of the actual fishing intensity rate (I), as defined from fishery data, to its optimal value (I_{opt}) derived from the condition of the rational relationship between the stocks and the fishery, i.e., from the biologically determined value of the possible harvest per cubic kilometer of water volume in the given area:

$$J = \frac{I}{I_{opt}}$$

From this expression one can infer that with J less than unity, the fishing intensity is insufficient and should be enhanced, while J more than unity indicates that the fishing intensity has reached its limit and should be reduced accordingly.

METHOD AS APPLIED TO REGULATION PRACTICES

Let us assume that the fishing effort of country A in area n for the time t is equal to U_1 ; the fishing effort of country B in area n for the time t is equal to U_2 ; the fishing effort of country C in area n for the time t is equal to U_3 ; the total effort of these three countries is $\Sigma U = U_1 + U_2 + U_3$; and the countries' catch in the same area for the same time is ΣC ; then the catch per effort has the form:

$$\frac{\Sigma C}{\Sigma U}$$

Let us assume further that it has been found analytically that the given time period (one year, for example) is such that the summary value of the fishing effort in area n has been optimal, i.e., in full accordance with the stock; also that x tons of fish have been taken per unit of water volume fished (e.g. per one cubic kilometer), and finally that the general yield quota for a particular fish species (C , tons) is determined for the same area for the next year using stock assessment. As a result, the total quota of the effort in the given year may be defined as:

$$\frac{C}{x} = U \text{ kilometer}^3$$

The total quota of the effort can be allocated between the countries in the same proportions in which catch quotas are usually distributed, and it can be distributed with greater accuracy, i.e., proportionate with the actual fishing effort of every country, using the Swept Volume Method. The countries with less advanced fishing technology would receive a relatively higher quota of fishing effort per unit of the catch quota than the countries with advanced technology. This requires that each country should make preliminary estimates of the fishing capacity of her fishing gear, as provided in ICES C.M.1971/B:9, and enter these into the fishing gear certificates to be kept on board the ships. Whether or not the estimates are accurate can be verified at any time by the International Inspection for fishing gear parameters and operation mode. An example of the calculation of fishing capacity is shown in Table 2.

Table 2. Example of calculation of fishing capacity and annual fishing effort developed by a fleet (real data for a USSR fishing fleet, 1968).

Vessel type	Trawl	Trawl opening area ¹	Trawl coverage per hour	Fishing capacity of gear	Hours of trawling per annum	Fishing effort of vessel	Number of vessels	Fishing capacity of fleet	Fleet's fishing effort
		(m ²)	(m)	$\left[\frac{10^9 m^3}{24 \text{ hr}}\right]$		(10 ⁹ m ³)		$\left[\frac{10^9 m^3}{24 \text{ hr}}\right]$	(10 ⁹ m ³)
OTST-7 ²	PR 396	200	7,400	0.03552	2,446	3.619	16	0.568	57,904
OTST-7 ²	BMRT 352	150	7,400	0.02664	2,300	2.552	83	2.211	211,816
OTSI-5 ²	RT 25	94	5,926	0.01337	2,000	1.114	180	2.407	200,520
OTSI-4 ²	SRT 23	66	5,926	0.00939	540	0.211	189	1.175	39,879
Total								6.361	510,119

¹ Trawl opening area for vessels:
 PR - 43 m × 4.6 m = 200 m²
 BMRT - 37.5 m × 3.9 m = 150 m²
 RT - 24.7 m × 3.8 m = 94 m²
 SRT - 17.5 m × 3.8 m = 66 m²

² OTSI = otter trawler with side trawling
 OTST = otter trawler with stern trawling
 4 = 151-500 tons
 5 = 501-900 tons
 7 = over 1,800 tons

CONTROL AND STATISTICS

Control of fishing effort, by use of the Swept Volume Method, would be undertaken mainly on a national basis. Each country, as it directs its vessels, should supply its vessels with an assignment specifying the value of fishing effort within the bounds of the limit it has established. The captains would be required to register in the ship logs the actual operation time of a fishing gear and note at the end of each day the amount of fishing effort applied. An international inspector, as he pays a routine call to the ship, compares the fishing effort limit issued for the ship with the total amount of fishing effort as of a certain date.

In order to make it impossible for any particular country to issue more limits than it is entitled to issuing, the limit cards are to carry a stamp of the Fishery Control Commission (Convention) for the given area.

For the purpose of more exact control of the fishing effort consumption in the future, use can be made of elementary instruments to record on a sealed film the time of gears' operation in the fishing mode (for example, the time when a trawl is at stopper). The list of the necessary instruments is given in ICES C.M.1971/B:9.

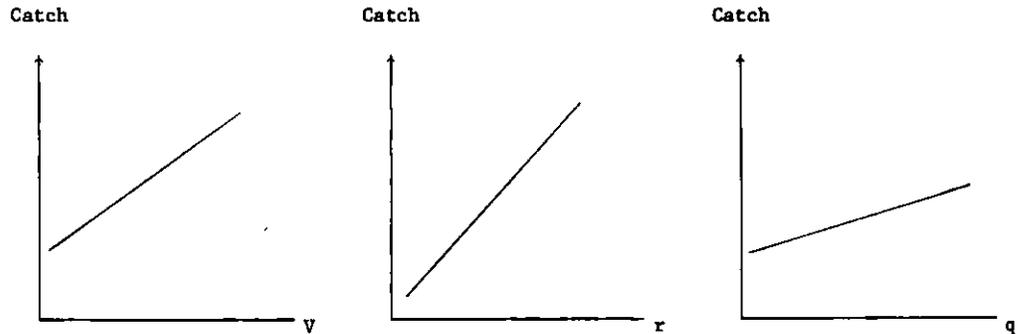
Application of the Swept Volume Method of fishery parameter evaluation will cause only minor changes in the statistics, such as are being currently submitted by countries to the various Commissions. Thus, in Table 4 (Statistics of fishing effort and nominal catch by division, month, gear and country) of the ICNAF *Statistical Bulletin*, under the heading "gear", besides the type of gear, there must be an indication of the latter's fishing capacity in promms, i.e., in the units equal to $10^3 \text{m}^3/24 \text{ hr}$. Thus, instead of "OTST", there should be "OTST - 035" where 035 signifies that a given gear as applied from a given ship during 24 hours of continued fishery is capable of fishing a water volume of $0.035 \times 10^9 \text{m}^3$.

The column "days fished" should contain data on the time of the active gear operation over a year. The column "hours fished" is to be ruled out. All other statistics shall be presented in the same form as before.

Engineering aspects of Swept Volume Method (SVM)

Definition parameters of fishery

Fishing effectivity (E) depends on three factors: (a) the volume swept by the fishing gear (V); (b) the degree of fish finding (r); and (c) the catchability of the fishing gear (q): $E = f_1(V, r, q)$.



(a) The Swept Volume Method (SVM) depends on the square of the mouth of the gear opening (S), the speed of the vessel (v), and the fishing time (t). In other words, $V = f_2(S, v, t)$.

From another viewpoint, $V = f_3(HP, \frac{B}{L} \lambda, K_w)$

where

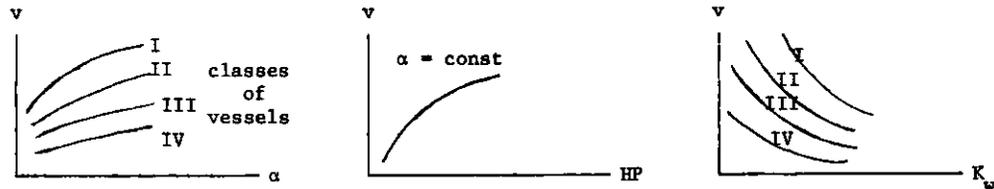
HP = horse power of engine;

$\frac{B}{L} \lambda = \alpha$, which includes hydrodynamic data (B is breadth of vessel, L is overall length of vessel, and λ is coefficient which depends on shape of the vessel, propeller and gear);

and

K_w = coefficient which characterizes the influence of weather (this can be the Beaufort scale of the sea state).

Studies of these parameters would yield relationships as illustrated in the following diagram:



A knowledge of these relationships would enable us to know the influence of these parameters on fishing efficiency.

(b) The degree of fish finding (r) may be represented by $r = \frac{N_v}{N_{fa}}$

where

N_v = the number of fish found in the fishing area (i.e., in the swept volume);

and

N_{fa} = the total number of fish in the area during the fishing time.

(c) The catchability of fishing gear (q) may be represented by $q = \frac{N_c}{N_v}$ which is the ratio of the number of fish in the catch to the number of fish in the swept volume.

The term "Gross Tonnage" is not given in this analysis because it has no direct influence on the fishing efficiency. When we find a connection between gross tonnage and catch, it means that gross tonnage is proportional to HP and speed of the vessel.

This brief analysis indicates the various components that should be included in the determination of fishing efficiency, as distinct from data currently collected (days on grounds, gross tonnage, standard gear, etc.).

The Swept Volume Method is much more representative because it includes all of the real influent factors and it can be determined very simply.

**SECTION J
DISCARDS**

28. Summary of information on discards and industrial fish for the year 1971¹

by the Assistant Executive Secretary

DISCARDS

Table 1 is a summary of information of quantities of fish discarded at sea from data submitted on ICNAF Statistics Form 4 by Canada (N), France (M), Germany (FR), Iceland, Japan, Poland, Portugal, Spain and USA. Denmark (G) reported that no fish was discarded at sea by trawlers; Canada (M), Norway and UK reported that no data were available, and no submissions were received from Bulgaria, Denmark (F), France (SP), Romania and USSR. The discard data are compared with nominal catch statistics of finfish given in Table 5 of ICNAF Statistical Bulletin Vol. 21 for the year 1971. It is thus assumed that the data reported on Statistics Form 4 pertain to the nominal catch data reported on Statlant 21B forms.

France (M) reported discards for cod, haddock, redfish and flounders in Subareas 1 to 4, Portugal for cod and "others" in Subareas 1 to 4, Spain for cod, haddock and "others" in Subareas 1 to 5, Japan for silver hake and "others" in Subareas 3 to 6, and Germany (FR) for the principal species and a "mixed" category in Subareas 1 to 6. Canada (N), in reporting discard information for certain "main species" and "gear and tonnage class" groupings in Subareas 3 and 4, listed discards (mostly zero entries) for some commercial species, and, while it is normal practice to discard all or nearly all of such species as silver hake, argentines, sculpins, lumpfish, anglers, eelpouts, skates, etc., no indication of the quantities of these species discarded was given. Although Poland has a significant fishery in Subareas 2 and 3, information on discards were supplied for cod, redfish and "others" in Subareas 5 and 6 only. USA provided data on discards of yellowtail only in Subarea 5.

The available data for the ICNAF Statistical Area (SA 1-6) indicate that discards of cod, haddock and redfish were small (1-2%), whereas discards of flounders and "others" were 8% and 4% respectively, the former mostly yellowtails in Subarea 5.

INDUSTRIAL FISH

Table 2 is a summary of information on quantities of fish converted to fish meal at sea from data submitted on Statistics Form 4 by Germany (FR), Portugal, Poland and USSR, and these data are shown in relation to nominal catch statistics of finfish for 1971.

Germany (FR) reported industrial fish by principal species and a "mixed" category in Subareas 1 to 6, Portugal for cod and "others" in Subareas 1 to 4, Poland for herring and mackerel in Subareas 5 and 6, and USSR by species in Subareas 1 to 5. All of the USSR data of fish converted into fish meal consisted of species which belong to the ICNAF Groups of "Other Groundfish" and "Other Fish".

For the ICNAF Statistical Area (SA 1-6) the available data indicate that negligible quantities of cod, haddock, redfish and flounders were converted into fish meal at sea, but that 16% of "other fish", mostly in Subareas 4, 5 and 6, were classed as industrial.

From Table 2 it is noted that Germany (FR) and Portugal reported quantities of industrial fish which exceed the nominal catches, and these are indicated by the symbol "*". Notes for the completion of Statlant 21A and 21B Forms indicate that quantities converted to fish meal should be included in the nominal catches. Such does not appear to be the case when industrial fish catches exceed nominal catches. Discrepancies of this kind have on several occasions in the past been brought to the attention of Member Countries.

ABBREVIATIONS AND SYMBOLS USED IN THE TABLES

<u>Country</u>	<u>Species</u>	<u>Tonnage Class</u>
Can (M) = Canada (Maritimes and Quebec)	Red = redfish	7 = over 1800
Can (N) = Canada (Newfoundland)	Flo = flounders	6 = 901-1800
Fr (M) = France (Metropolitan)	Her = herring	5 = 501-900
Ger (FR) = Germany, Federal Republic	Mix = mixed	4 = 151-500
Port = Portugal	Mac = mackerel	3 = 51-150
USSR = Union of Socialist Soviet Republics	SH = silver hake	2 = 0-50
USA = United States of America	OF = other fish	

<u>Symbols</u>	<u>Gear</u>	<u>Source of Information</u>
- = magnitude indicated to be less than one-half the unit used	OT = otter trawl	Log = logbook
? = quantities discarded or turned into fish meal might be included in quantities shown under "others"	OTSI = otter trawl, side	Int = port interview
	OTST = otter trawl, stern	Cap = captains' reports
	PT = pair trawl	Obs = observer on vessel

¹ Submitted to the 1973 Annual Meeting of ICNAF as ICNAF Summ.Doc. 73/8.

Table 1. Summary of information on quantities of finfish (metric tons) discarded at sea in relation to nominal catch for the year 1971.

Sub-area	Main Species	Country	Gear and Tonnage Class	COD		HADDOCK		REDFISH		FLOUNDERS		OTHERS		Source Sampling Information (%)				
				Nominal Catch	Dis-cards (%)	Nominal Catch	Dis-cards (%)	Nominal Catch	Dis-cards (%)	Nominal Catch	Dis-cards (%)	Nominal Catch	Dis-cards (%)		Nominal Catch	Dis-cards (%)		
1	Cod	Fr(M) Ger(FR) Port " "	OTSI 6	4108	42	1	-	-	28	100	-	?	4	?	Cap 100			
			OT 5-7	40916	37	-	1	-	2023	57	3	16	33	15	Cap 100			
			OTSI 6	577	-	-	-	-	-	?	-	-	-	-	?	Cap 100		
			OTST 7 PT 4	728 22086	- 3	- -	- 64	4 4	6 6	?	?	587	?	-	185	Log 100 Log 78		
Total Reported			68415	82	-	65	4	2023	85	4	603	-	196	218	52			
Total All Countries			121180		77			2756			3827		13069					
2	Cod	Fr(M) " Ger(FR) Port " Spain "	OTSI 6	1750	193	10	-	-	22	100	-	?	-	?	Cap 100			
			OTST 6	4159	37	1	-	-	55	100	-	?	6	?	Cap 100			
			OT 6-7	19680	63	-	-	-	67	7	9	-	-	37	15	Cap 100		
			OTSI 6 OTST 7 OT 6 PT 4	18788 15506 5245 367	3 61 46 ?	- - 1 ?	- - 100 ?	- - ?	- ?	?	?	?	-	-	?	Log 100 Log 84 Log 78		
Total Reported			65495	403	1	110	1	67	84	56	-	213	138	39				
Total All Countries			163221		110			6634			14045		62138					
3	Cod	Can(N) " Fr(M) " Ger(FR) Ice Port " Spain " Can(N) " Can(N) " Japan	OTSI 4	1494	-	-	91	-	254	-	-	208	-	60	Log 25			
			OTSI 5	10738	-	-	430	?	181	?	-	4058	-	403	Log 1			
			OTSI 6	11672	233	2	13	1	7	456	100	-	-	75	?	Cap 100		
			OTST 6	3568	42	1	-	1	100	48	100	-	-	17	?	Cap 100		
			OT 6-7	12154	27	-	-	-	-	46	5	10	75	-	66	?	Cap 100	
			OTSI 6	72	5	6	-	-	-	209	3	1	2	-	1	1	10 Mix	
			OTSI 6	52632	8	-	-	-	-	-	?	-	-	-	-	9	50 Shark	
			OTST 7	17797	38	-	-	-	-	-	?	-	-	-	-	7	100 Mix	
			OT 6	17813	28	-	-	51	2	4	?	-	173	-	333	667	67 Mix	
			PT 4	151645	823	1	3140	76	2	?	?	?	271	?	451	2939	87 Mix	
			OTSI 4	1313	-	-	42	-	-	-	18315	-	-	438	-	289	?	Log 84
			OTSI 3	16	-	-	-	-	-	-	322	24	7	13	-	4	?	Log 8
			OTSI 4	355	-	-	7	-	-	-	56	-	-	4372	-	23	?	Log 69
			OTSI 5	8000	-	-	82	-	-	-	126	-	-	54918	1029	2	?	Log 15
OTST 7	9	-	-	-	-	-	-	7634	?	?	2	-	524	1	Log 2			
Total Reported			289278	1204	-	3856	80	27180	536	2	64530	1069	2	3806	3624	49		
Total All Countries			513717		5076			102400			163962		165320					

Table 1. Continued.

Sub-area	Main Species	Country	Gear and Tonnage Class	COD		HADDOCK		REDFISH		FLOUNDERS		OTHERS		Source Sampling Information (%)			
				Nominal Catch	Dis-Rate (%)												
4	Cod	Can(N)	OTSI 4	3820	-	72	-	554	-	466	-	.95	?	Mix	Log 15		
		"	OTST 5	10738	45	430	-	181	-	4058	-	403	?	Mix	Log 3		
	Fr(M)	OTSI 6	18502	935	5	81	1	449	100	-	16	100	13	?	Mix	Cap 100	
		"	OTST 6	6481	41	1	-	-	85	100	-	-	17	1	1	Mix	Cap 100
	Port	OTSI 6	12506	1	-	-	-	-	-	-	-	-	-	-	-	Log 100	
		"	OTST 7	4782	13	-	-	-	-	-	-	-	-	-	-	Log 100	
	Spain	OT 6	13152	29	-	81	5	?	?	?	?	47	117	71	Mix	Log 84	
		PT 4	36261	16	-	3094	40	?	?	?	?	715	608	46	Mix	Log 78	
	Had	Can(N)	9	OTSI 4	-	-	10	-	4	-	-	-	6	?	Mix	Log 100	
		Can(N)	1313	OTSI 4	-	-	42	-	18315	-	438	-	289	?	Mix	Log 16	
	Flo	Can(N)	20	OTSI 4	-	-	1	-	3	-	92	-	-	?	Mix	Log 30	
		Ger(FR)	-	OT 6-7	-	-	-	-	-	-	-	-	70	-	Mix	Cap 100	
	Mix	Japan	6	OTST 7	-	-	1	-	1164	?	1	?	4270	6	Mix	Cap 100	
		Total Reported	107590	1080	1	3812	46	1	20221	534	3	5055	16	-	-	-	
Total All Countries				221953		31449		141787		56476		564394		11			
5	Cod	Spain	PT 4	7619	1	1336	16	-	?	-	?	184	64	26	Mix	Log 78	
		USA	OT 2-4	4400	?	1775	?	-	?	20069	6400	24	1787	?	Mix	Obs 1	
	Her	Ger(FR)	OT 6-7	-	-	3	-	-	-	-	-	57584	7637	12	Her	Cap 100	
		Poland	OTSI 5	106	9	8	-	5	100	-	-	23693	16	-	Mix	Obs 33	
	Mac	"	OTST 6	-	-	-	-	-	-	-	-	33953	10	-	Mix	Obs 33	
		"	OTST 7	49	-	1	-	-	19	-	2	-	65801	26	-	Mix	Obs 33
	Mix	Japan	OTST 7	20	?	10	?	-	4	?	8	8	10515	420	4	Mix	Cap 100
		"	OTST 6	-	-	-	-	-	-	-	1	-	119	59	33	Mac	Cap 100
	Total Reported				12194	10	3125	16	88	5	5	20080	6408	24	4	-	
	Total All Countries				35357		12168		20034		45950		193636	8232	4	-	
	6	Her	Ger(FR)	OT 6-7	-	-	-	-	-	-	-	-	1621	-	-	Cap 100	
			Poland	OTSI 5	76	11	13	-	5	100	-	-	21886	16	-	Mix	Obs 33
		Mac	"	OTST 6	3	-	-	-	3	-	-	-	29449	20	-	Mix	Obs 33
			"	OTST 7	22	?	-	-	-	-	-	-	44739	26	-	Mix	Obs 33
Mix		Japan	OTST 6	-	-	-	-	-	-	-	7	?	380	421	53	Mac	Cap 100
		"	OTST 7	-	-	-	-	-	-	-	28	?	6170	783	11	Mac	Cap 100
Total Reported				101	11	-	-	3	5	62	35	?	104245	1266	1		
Total All Countries				484		8		3		12860		603943					
Total Reported				543073	2790	10968	147	49582	1249	2	90303	7493	8	4	-		
Total All Countries				1055912		48888		273614		297120		2038630					

Table 2. Summary of information on quantities of fish converted to fish meal at sea in relation to nominal catch for the year 1971.

Sub-area	Main Species	Country	Gear and Tonnage Class	COD		HADDOCK		REDFISH		FLOUNDERS		OTHERS		Source Sampling Information (%)
				Nominal Catch	Dis- cards (%)									
1	Cod	Ger(FR)	OT 5-7	40916	723	2	1	2023	67	3	16	192	237	Cap
		Port	OTST 7	728	11	2	-	-	-	-	-	-	-	Log
	Mix	USSR	All	59	-	-	-	13	-	-	737	4153	355	NS
2	Cod	Ger(FR)	OT 6-7	19680	778	4	-	67	33	49	-	207	252	Cap
		Port	OTSI 6	18788	33	-	-	-	-	-	-	-	4	Log
		"	OTST 7	15506	455	3	-	-	-	-	-	-	43	Log
	Mix	USSR	All	61562	-	-	-	5919	-	-	10026	58619	8618	NS
3	Cod	Ger(FR)	OT 6-7	12154	248	2	-	46	25	54	75	66	54	Cap
		Port	OTSI 6	52632	68	-	-	-	-	-	-	25	25	Log
		"	OTST 7	17797	538	3	-	-	-	-	-	333	333	Log
	Mix	USSR	All	44262	-	-	479	71246	-	-	50402	31921	5199	NS
4	Her	Ger(FR)	OT 6-7	-	-	-	-	-	-	-	-	70	-	Cap
		Port	OTSI 6	12506	31	-	-	-	-	-	-	-	-	Log
		"	OTST 7	4782	46	1	-	-	-	-	-	-	38	Log
	Mix	USSR	All	4843	-	-	572	20591	-	-	20051	216790	49853	NS
5	Her	Ger(FR)	OT 6-7	-	-	-	3	-	25	*	-	57584	2618	Cap
		Poland	OTSI 5	106	-	-	-	-	-	-	-	23893	883	Obs
		"	OTST 6	-	-	-	-	19	-	-	-	33953	2199	Obs
		"	OTST 7	49	-	-	1	65	-	-	2	65801	17318	Obs
	Mix	USSR	All	1270	-	-	374	3394	-	-	6767	274476	31414	NS
6	Mac	Ger(FR)	OT 6-7	-	-	-	-	-	-	-	-	1621	-	Cap
		Poland	OTSI 5	76	-	-	-	-	-	-	-	21886	899	Obs
		"	OTST 6	3	-	-	-	3	-	-	-	29449	2408	Obs
		"	OTST 7	22	-	-	-	-	-	-	-	44739	19135	Obs
ALL	Total Reported			307741	2931	1	1430	103386	150	-	88076	865220	141885	
	Total All Countries			1055912			48888	273614			297120	2038630		

* Industrial fish catch exceeds nominal catch.