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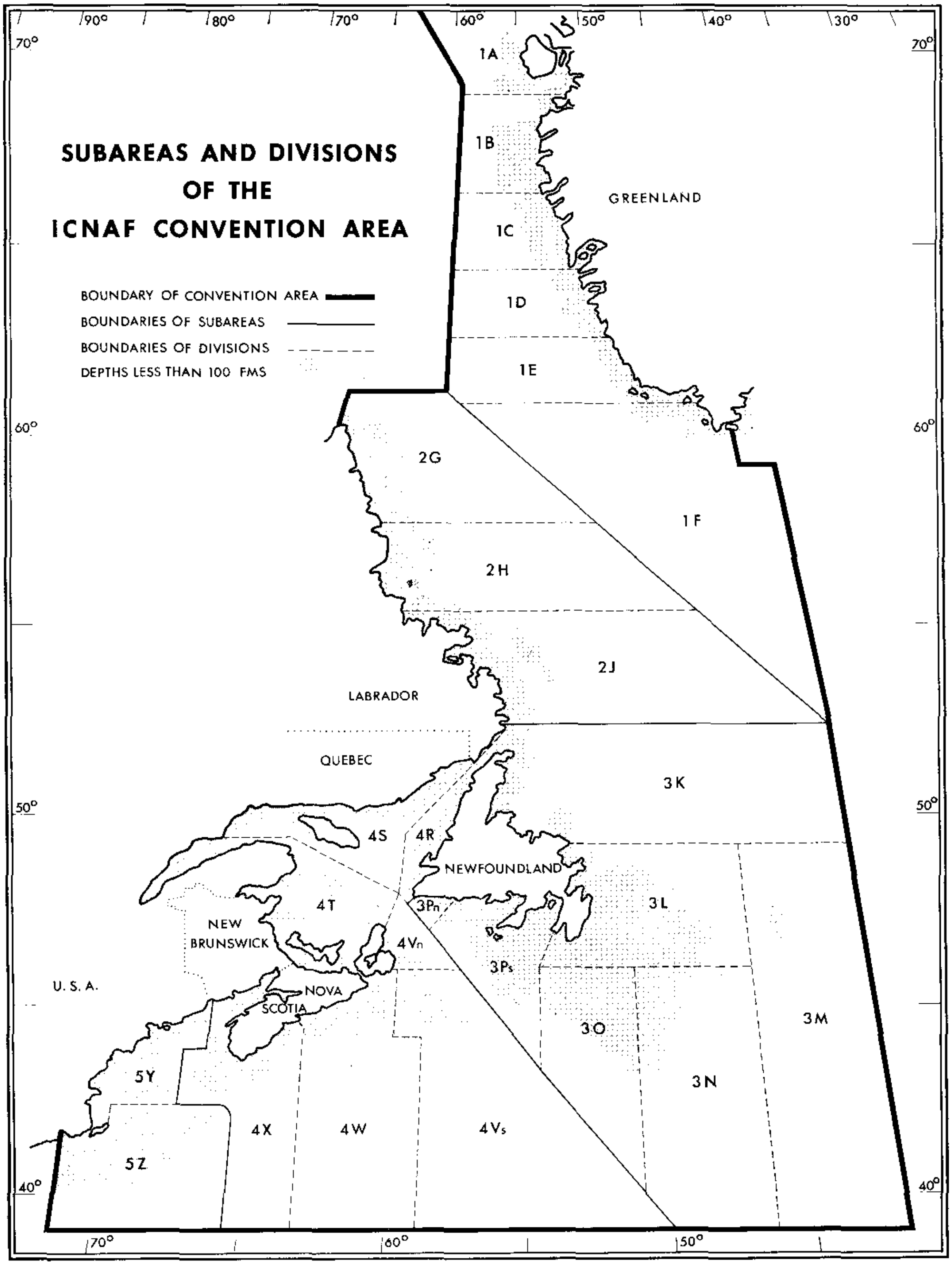

SUBAREAS AND DIVISIONS OF THE ICNAF CONVENTION AREA

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DEPTHS LESS THAN 100 FMS ⋯

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Atlantic Salmon from the Labrador Sea and off West Greenland, Taken During *A. T. Cameron* Cruise, July – August 1965

BY WILFRED TEMPLEMAN[1]

Abstract

In 18 surface drift-net sets made from 12 July to 24 August 1965 by the *A. T. Cameron*, 39 Atlantic Salmon were caught; 6 were taken over oceanic depths in the Labrador Sea from 18 to 20 July; 13 were taken on the West Greenland banks, almost all over the shallower water, from 5 to 16 August; 2 were taken over deep water west of Cape Desolation on 21 August; the largest catch, 13 in one set, was made over oceanic depths west of Cape Farewell on 21 and 22 August; and 5 were taken over oceanic depths in the Labrador Sea on 22 and 23 August.

A few of the salmon appeared to be travelling in pairs or in small schools of three. They were caught near the surface, 97% in the upper 8 ft (2.4 m).

Sixty-one per cent of the salmon had 2 years of river life and the numbers with 2, 3, 4, 5, and 6 years of river life were 23, 7, 4, 2, and 2. Thirty-six of 38 salmon had 1+ sea years, two having 2+ sea years. West Greenland and Labrador Sea salmon in our small samples had river ages too low for purely Canadian random samples and too high for samples entirely from Britain and Ireland.

Sex ratios were 14 M:24 F. All males were very immature but one 2+ sea-year female from the Labrador Sea on 19–20 July could possibly but not necessarily have been maturing to spawn in the same year.

Salmon from the West Greenland banks had more food in their stomachs and had greater girths and weights at the same lengths than salmon from west of Cape Farewell and Cape Desolation.

Of the meristic characters, vertebral counts, at least, are worth following further for possible use in locating the home areas of the West Greenland fish.

Food was principally larval Arctic squid, *Gonatus fabricii*, in the Labrador Sea and launce with some capelin on the West Greenland banks. Secondary foods over deep water were paralepids and Greenland halibut fry.

There were indications that the percentage of salmon possessing tapeworms, *Eubothrium crassum*, may increase with length of river life and that the presence of this parasite may be worth following for area of origin of West Greenland salmon.

Data from the literature on salmon migrations in the western Atlantic and on smolt ages in North American and European rivers are reviewed.

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

Introduction

Beaugé (1931) reported that in the French otter-trawl fishery on Store Hellefiske Bank in 1930, from 10 August it was advantageous to fish for cod in the shallowest water possible on the bottom at 25–30 m. He says that the salmon abounded and that the trawl took a great number with the cod. (The month was not stated but in his notes he also mentioned September and fishing in the channel between the banks and the coast.)

Jensen (1939, 1948), Nielsen (1961), Saunders et al. (1965), Hansen (1965), Saunders (MS, 1965) and others have written on the fishery for Atlantic salmon, *Salmo salar* Linnaeus, (in this paper usually referred to as salmon) in West Greenland. In recent years this fishery has risen rapidly reaching an exported quantity of 1,386 metric tons of gutted head-on fish in 1964. West Greenland salmon landings fell to a little over half this quantity in 1965, apparently due to decreasing effort resulting from lower prices and a greater abundance of cod inshore. Also in 1965 a Faroese and a Norwegian vessel engaged with some success in drift-netting for salmon outside the territorial waters of West Greenland (Anon., 1966).

Inshore salmon landings in West Greenland are from August to December but almost all from September to November. Commercial fishing has been carried on from Cape Farewell to Disko Bay. The greatest West Greenland landings in 1964 were in ICNAF Statistical Divisions 1B-1E.

The fishery depends almost entirely on salmon of European and Canadian origin as judged by returns of 64 tagged salmon between 1956–64 Of these, 23 were tagged, either as smolts or as spawning or spent salmon, in Canadian rivers, 2 in United States rivers and 39 in rivers in Europe. An additional 30 tagged salmon, 13 from Canada, 2 from Ireland and 15 from England and Scotland were reported from West Greenland in 1965 (Hansen, MS, 1966). Only very small numbers of salmon, insignificant in relation to the commercial fishery, and of longer river life than most salmon of the commercial fishery, are native to the small river Kapisigdlit in Godthaab Fjord, the only Greenland river in which salmon are known to spawn.

During a cruise of the *A. T. Cameron* to West Greenland 10 July–25 August 1965, with groundfish research as the chief objective and with the author as Scientist-in-Charge, some researches were conducted on Atlantic salmon distribution and biology. Since salmon research was not the main object of the cruise only relatively small amounts of gear were used and sets were made only when other work permitted.

Materials and Methods

The salmon forming the basis of this paper were taken in gill nets set at the surface over oceanic depths at the mouth of the Labrador Sea, on the banks of West Greenland, and west of Cape Farewell and Cape Desolation. The nets were of Ulstron (polypropylene), multifilament 3-ply, No. 12 for the 5-inch (127-mm) mesh and No. 15 for the 5¼-and 5½-inch (133-and 140-mm) mesh and made by W. J. Knox Ltd., Kilbirnie, Scotland. A herring net of 2¾-inch (70-mm) mesh and a mackerel net of 3¼-inch (83-mm) mesh were also used. These were of synthetic materials of unknown identity.

The nets in each set were set free of the ship as one string of drift nets with a large marker buoy at one end set in the direction of the current movement and a smaller one at the other. The greatest number of nets was 13. A 4.8 mm diameter polypropylene rope was attached to the headrope at the ends of each net. The nets were set during the dark period of the night or part of this period and hauled at dawn.

Some Japanese salmon longline gear, obtained from the Fisheries Research Board of Canada, Nanaimo Biological Station, British Columbia, was also used close to the surface in two sets. The hooks were baited half with salted anchovies and half with Newfoundland squid, *Illex illecebrosus*. This gear was set at dawn and hauled several hours later.

The salmon were weighed, measured, and examined in detail for copepod and other parasites, for food in the stomachs, etc. in the fresh condition on board ship. The salmon were evidently exhausted and had usually lost large quantities of scales and often had bad net mark injuries. A number of the liveliest were placed in tanks immediately after being taken on board but did not survive.

A few body proportions were done on fresh specimens at sea. The total length, snout to mid-fork of the caudal fin, and the greatest lengths were taken to the nearest millimetre on an accurate measuring board. For greatest lengths the upper and lower lobes of the caudal fin were in turn extended directly backward. The head length was taken with calipers from the tip of the snout to the most posterior extension of the bony left operculum. The pectoral length was measured from its anterior dorsal base to the tip of the longest ray of the left pectoral. Girths were measured with a plastic tape 2.0 cm wide. The opercular girth was taken

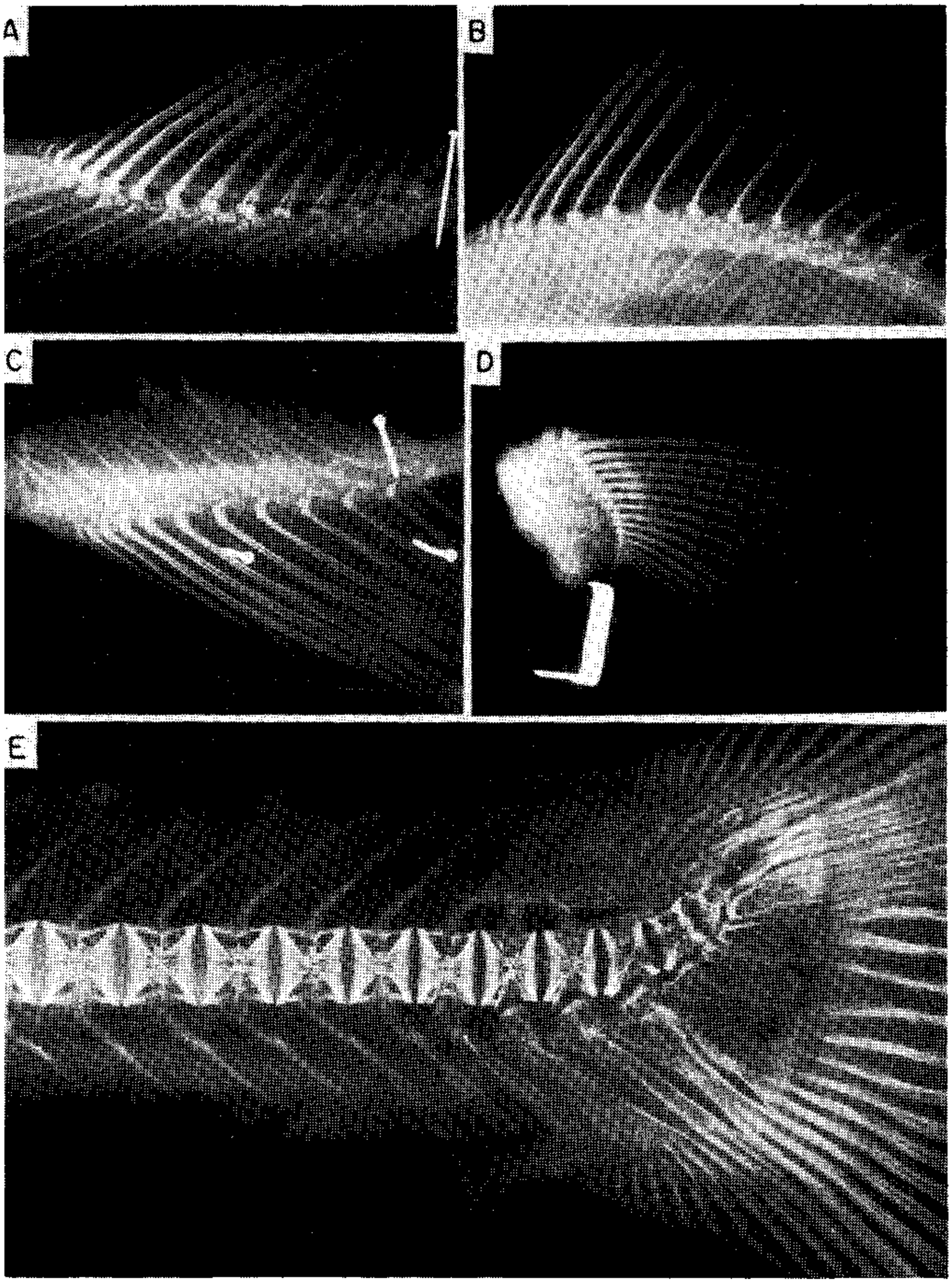

Fig. 1. Radiographs of: (**A**) dorsal fin normal (15 rays); (**B**) dorsal fin (15 rays + a small rounded bone, not counted, in front of first fin ray); (**C**) anal fin (12 rays); (**D**) pectoral fin (14 rays); (**E**) vertebral column showing the posterior 11 vertebrae (+ half of the 12th vertebra from the posterior end) and the hypurals and rays of the caudal fin.

with the anterior edge of the tape touching the posterior tip of the operculum. For the maximum girth the posterior edge of the tape touched the anterior base of the dorsal fin. Other positions were checked and it was indicated that this measurement gave the maximum girth. The girth where the net mesh caught the fish was taken half way between the ventral and dorsal net scars in the usual situation where the net scar was oblique and usually farther posterior dorsally than ventrally.

Meristic studies were carried out at the Biological Station, the fin-ray counts being made from radiographs and the vertebral column cleaned and the vertebrae counted directly (Fig. 1). In counting the fin-rays the methods of Fukuhara *et al.* (1962) were used. In the dorsal and anal fins all rays including rudimentary rays were counted. As found by the above authors for *Oncorhynchus nerka* a small rather rounded bone, not elongated as in the rudimentary rays, was occasionally present anterior to the first obvious rudimentary ray in the dorsal fin. This was not counted. The last split rays of the dorsal and anal coming from the same base were counted as one. The gill rakers of the first, left gill arch were counted including the rudimentary rakers. The raker in the bend of the arch was included with the lower limb.

The vertebral number included all centra from the first vertebra to and including the urostylar half vertebra as a vertebra, following the method of Vladykov (1954, fig. 3) for *Salmo salar* (Fig. 1). Fused vertebrae which were present in only two fish, each with two vertebrae fused, were treated as whole vertebrae, each part being counted as one vertebra. (This was done because of the small amount of material. With larger numbers these vertebral columns with fused vertebrae would not have been used.)

Results

Fishing localities and catches

Eighteen surface drift-net sets were made at night between 12 July – 24 August (Fig. 2, Table 1), north of Flemish Cap, in the mouth of the Labrador Sea, along the West Greenland banks and west of Cape Desolation and Cape Farewell.

Thirty-nine salmon were caught (Fig. 2, Table 2) 6 over oceanic depths in the Labrador Sea on 18–20 July, 13 on the West Greenland banks, almost all over the shallower water, 2 over deep water west of Cape Desolation, the largest catch, 13 in one set, over oceanic depths west of Cape Farewell, and 5 over oceanic depths in the Labrador Sea 22–23 August. In a set farther southward and westward in the Labrador Sea on 23–24 August no salmon were caught. Also no salmon were caught in the set north of Flemish Cap. In relation to the amount of gear used and the time fishing the largest two catches were obtained in the Labrador Sea on 18–19 July and west of Cape Farewell on 21–22 August at temperatures of 8.5° to 8.6°C in the upper 25 m. Salmon, however, were apparently not distributed entirely by temperature as no salmon were obtained at similarly high temperatures at Flemish Cap on 12 July (this, however, was a short set) and in the southern Labrador Sea off Hamilton Inlet Bank on 23–24 August. Over the West Greenland banks, salmon were taken in localities with temperatures of 3.0° to 5.5°C in the upper 5 m and where temperatures at 25 m were 1.5° to 5.5°C. Upper layer temperatures in the West Greenland fishing area close to the coast declined from north to south and two salmon were caught off Cape Desolation in temperatures of 2.3°C at the surface to 1.0°C at 25 m.

Other fishing trials

All the salmon mentioned above were caught in nets with stretched mesh sizes of 127–140 mm. Also in each set an additional mackerel net of 83-mm mesh was used, 62 m long and 4.9 m deep and in sets A–D, a herring net of 70-mm mesh, 32 m long and 4.0–7.9 m deep was used. No salmon were caught in these small meshed nets.

Also, in the same localities and dates in which sets A and C were taken (Table 1, 2) Japanese salmon longline gear baited with anchovies and squid was used at dawn at the surface. Ten lines (490 hooks with gangings about 0.9 m long) were used in locality A and 20 lines (740 hooks) in locality C and no salmon were caught although three salmon were caught in gill nets in locality C. In the Labrador Sea more than 100 fulmar petrels (*Fulmarus glacialis*) were taken on the squid baits, but none on the anchovy baits.

Location of salmon in net

On each of two occasions (Table 3) three salmon were meshed in the net with the individuals only 2 ft (0.6 m) apart. On two other occasions a pair of salmon was meshed 6 ft (1.8 m)

TABLE 1. Position of salmon surface drift-net sets, gear used and time of sets by the *A. T. Cameron* 12 July–24 August 1965. (2¾ and 3¼ inch, 70 and 83 mm, gill nets are not included in this table. All nets included are 5–5½ inch, 127–140 mm, mesh.)

Gill net set	Date 1965	Locality	Position		No. of linear m of gill nets used	No. of square m of gill nets used	Greenland standard time			No. minutes between setting and beginning of haul	Distance from nearest coast in nautical miles
			Lat. N	Long. W			Beginning of set	Beginning of haul	End of haul		
A	12 July	North of Flemish Cap	48°28′	44°56′	260	670	0105	0235	0250	90	330
B	18–19 July	Labrador Sea	55°44′	47°15′	260	670	2142	0050	0250	188	265
C	19–20 July	Labrador Sea	55°45′	47°14′	600	2,380	2235	0315	0342	280	265
D	5 Aug.	N peak Store Hellefiske Bank	68°00′	54°49′	600	2,380	0115	0350	0450	155	27
E	5–6 Aug.	N peak Store Hellefiske Bank	67°30′	54°22′	860	3,670	2250	0310	0410	260	15
F	6–7 Aug.	Store Hellefiske Bank	66°49′30″	54°25′30″	860	3,670	2320	0410	0530	290	20
G	7–8 Aug.	W slope Store Hellefiske Bank	66°00′	56°56′	860	3,670	2240	0400	0500	320	80
H	9 Aug.	W slope Lille Hellefiske Bank	64°58′	54°38′	940	4,090	2400	0635	0800	395	60
I	9–10 Aug.	Banana Bank	64°30′	53°13′	940	4,090	2225	0400	0512	335	30
J	12–13 Aug.	Fylla Bank	63°45′30″	52°24′00″	940	4,090	2230	0420	0530	350	25
K	14–15 Aug.	Fylla Bank	63°36′	52°42′	940	4,090	2155	0430	0520	395	33
L	15–16 Aug.	Fiskenaes Bank	63°22′	51°58′	940	4,090	2257	0430	0530	333	20
M	17–18 Aug.	Dana Bank	62°47′	51°27′	940	4,090	2250	0425	0550	335	30
N	18–19 Aug.	Dana Bank	62°54′30″	51°35′	940	4,090	2355	0340	0510	225	25
O	21 Aug.	W of Cape Desolation	60°40′	49°17′	940	4,090	0040	0430	0600	230	32
P	21–22 Aug.	W of Cape Farewell	59°56′	49°29′	940	4,090	2302	0435	0537	333	65
Q	22–23 Aug.	Labrador Sea	56°42′30″	50°21′	940	4,090	2303	0445	0620	342	256
R	23–24 Aug.	Labrador Sea off Hamilton Inlet	53°55′	51°12′	940	4,090	2257	0505	0607	368	160

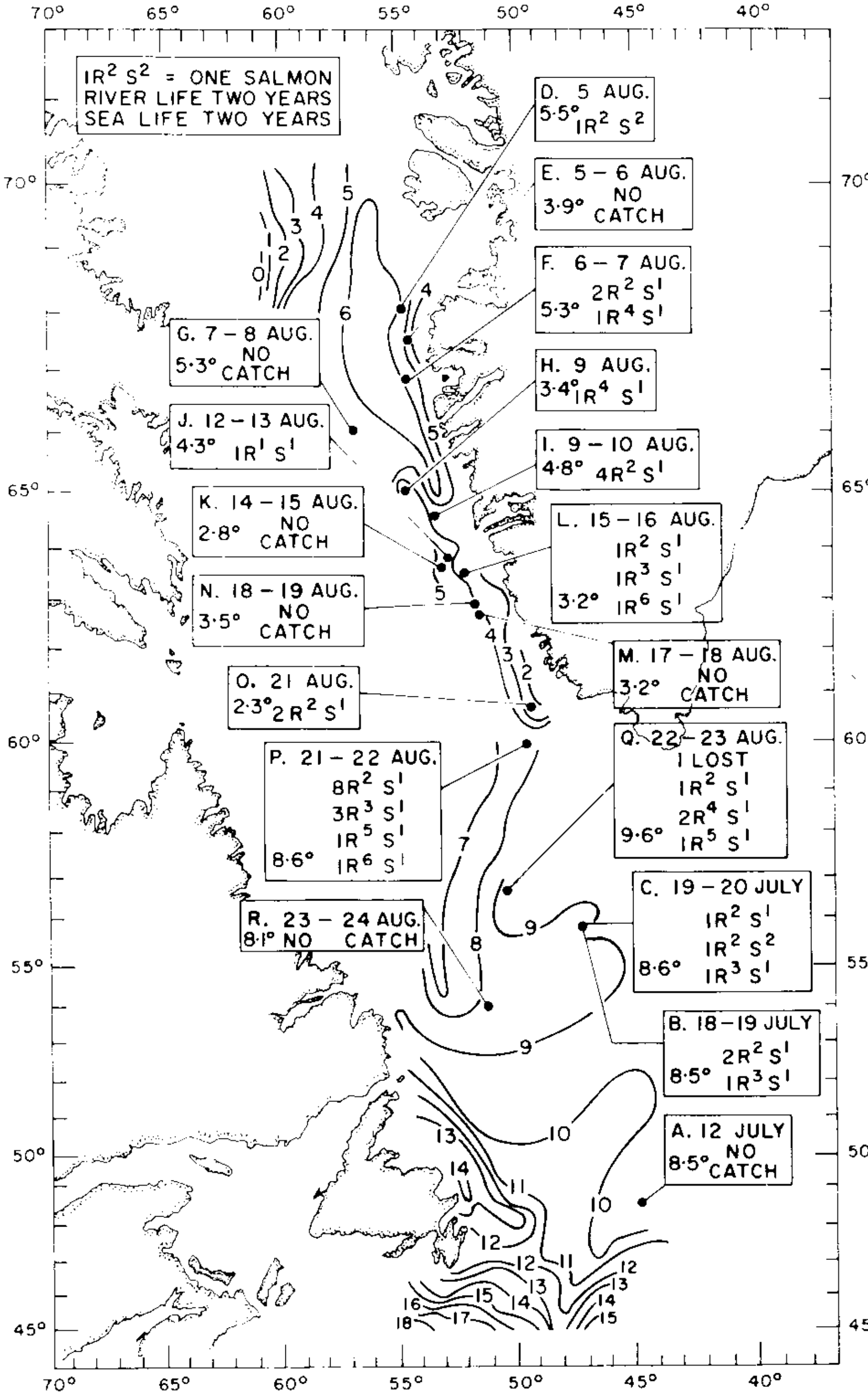

Fig. 2. Numbers of Atlantic salmon caught in surface drift nets in night sets by the *A. T. Cameron*, 12 July–24 August 1965 at the locations, dates, surface temperatures (°C), and river and sea ages indicated. (Temperatures were taken at the end and sometimes at the beginning of the set. The set positions are located in the middle of the set. There was sometimes considerable drifting, usually in a north-south direction. Hence the surface temperatures recorded for the set are sometimes out of position in relation to the general cruise isotherm picture on which the sets are superimposed.)

TABLE 2. Numbers of salmon and other animals, and relative numbers of salmon caught in surface drift-net sets at and above various temperatures by the *A. T. Cameron*, 12 July–24 August 1965.

Gill-net set	Date 1965	Locality	Depth at position (m)	Temperature (°C)					No. of salmon caught	Total wt. of salmon caught kg	Est. no. of salmon caught fishing 940 linear m for 350 min	Other animals caught
				Surface	5 m	25 m	50 m	100 m				
A	12 July	N of Flemish Cap	730	8.5	8.5	8.2	5.0	4.2	0	0	0	...
B	18–19 July	Labrador Sea	3,290	8.5	8.5	8.5	6.0	4.2	3	5.3	20	...
C	19–20 July	Labrador Sea	3,290–3,480	8.6	8.5	8.5	6.0	4.2	3	11.7	6	1 spiny dogfish, 1.9 kg
D	5 Aug.	N peak Store Hellefiske Bank	24	5.5	5.5	5.5	...	...	1	5.4	4	...
E	5–6 Aug.	N peak Store Hellefiske Bank	37–46	3.9	...	...	...	...	0	0	0	1 common lumpfish, 0.3 kg 2 common porpoises, 94 kg
F	6–7 Aug.	Store Hellefiske Bank	27–31	5.3	5.2	5.2	...	...	3	9.4	4	36 cod, 76 kg 1 common lumpfish, 2.6 kg
G	7–8 Aug.	W slope Store Hellefiske Bank	650	5.3	5.5	4.0	3.0	3.2	0	0	0	...
H	9 Aug.	W slope Lille Hellefiske Bank	310	3.4	3.3	3.2	1.8	2.1	1	2.7	1	...
I	9–10 Aug.	Banana Bank	46	4.8	4.8	2.5	...	...	4	12.2	4	10 cod, 20 kg
J	12–13 Aug.	Fylla Bank	35	4.3	4.0	3.0	...	...	1	3.5	1	3 cod, 15 kg 33 Brunnich's murres (*Uria lomvia*) 1 greater shearwater (*Puffinus gravis*)
K	14-15 Aug.	Fylla Bank	350	2.8	2.5	1.7	1.8	2.2	0	0	0	...
L	15–16 Aug.	Fiskenaes Bank	53–62	3.2	3.0	1.5	1.5	...	3	9.0	3	10 *Uria lomvia* 1 *Puffinus gravis*
M	17–18 Aug.	Dana Bank	62–71	3.2	3.2	1.8	1.6	...	0	0	0	1 common porpoise, 43 kg
N	18–19 Aug.	Dana Bank	64	3.5	3.5	1.6	2.5	3.6	0	0	0	2 common lumpfish, 2.7 kg
O	21 Aug.	Off Cape Desolation	2,200–2,560	2.3	2.3	1.0	3.0	4.8	2	6.4	3	...
P	21–22 Aug.	W of Cape Farewell	3,200	8.6	8.6	8.5	6.8	5.8	13	37.4	14	...
Q	22–23 Aug.	Labrador Sea	3,660	9.6	9.6	9.3	5.6	4.2	5	15.4	5	1 porbeagle, 104 kg
R	23–24 Aug.	Labrador Sea off Hamilton Inlet Bank	2,930	8.1	8.1	7.7	6.0	4.3	0	0	0	1 porbeagle lost during hauling ca. 110 kg

apart and on two other occasions pairs were 25 ft (7.6 m) and 30 ft (9.1 m) apart. In at least the first four occasions the salmon could have been travelling in schools of three or two.

Salmon were caught near the surface, 62% within the first 2 ft (0.6 m) from the surface, 90% in the first 5 ft (1.5 m), 97% in the first 8 ft (2.4 m) and all above 11 ft (3.4 m) (Table 4). The use of some nets only 7½ and 10 ft (2.3 and 3.1 m) deep would not change these figures very much. No salmon at all were caught in the 7½-ft (2.3-m) nets and only one salmon (at 11 ft, 3.4 m) was caught below 8 ft (2.4 m) in the 16½-ft (5.0-m) nets.

TABLE 3. Distances apart in feet of individual salmon pairs in gill nets. (The figures show the number of spaces of 2, 3, etc. feet between individual salmon pairs and the numbers in parentheses show the numbers of salmon. Thus 2(3), 2(4) show 2 spaces of the distance indicated at the left in the table, in the first instance 2 spaces between 3 salmon in a group and in the second 2 separate spaces between 4 salmon in 2 groups of 2. 1 ft = 0.305 m.)

Distances apart of individual pairs	Numbers of spaces and (salmon)								
	Set locations as in Table 1 with 2 or more salmon								
	B	C	F	I	L	O	P	Q	Total
ft									
1	...	...	...	...	...	...	...	...	...
2	2(3)	...	...	2(3)	...	...	...	...	4(6)
3	...	...	...	...	...	...	...	...	...
4	...	...	...	...	...	...	...	...	...
5	...	...	...	...	...	...	...	...	...
6	...	...	...	...	...	...	2(4)	...	2(4)
21-30	...	1(2)	...	...	...	...	1(2)	...	2(4)
31-40	...	...	...	...	...	...	...	...	...
41-60	...	...	...	...	...	...	...	...	...
61-80	...	...	...	...	...	...	2(4)	...	2(4)
81-120	...	...	...	...	...	...	...	1(2)	1(2)
121-200	...	...	...	...	...	...	2(4)	...	2(4)
201-300	...	...	...	...	...	...	3(6)	1(2)	4(8)
301-600	...	...	...	...	1(2)	1(2)	1(2)	...	3(6)
601-1,000	...	1(2)	1(2)	...	...	...	...	2(4)	4(8)
1,001-1,500	...	...	...	1(2)	...	...	1(2)	...	2(4)
1,501-2,000	...	...	1(2)	...	...	...	...	...	1(2)
2,001-2,500	...	...	...	...	1(2)	...	...	...	1(2)

Age and length

Most of the salmon (61%) had 2 years river life (Table 5). The percentage with 2 years river life increased from the Labrador Sea which could be expected to be mainly or entirely Canadian salmon, (50%) to the West Greenland banks which could be expected to be a mixture of European and Canadian salmon and the area west of Cape Farewell and off Cape Desolation which could be expected to have a higher percentage of European salmon, (69 and 60% respectively). A somewhat higher percentage with a 2-year-old river life might have been expected off Cape Farewell, but the small numbers involved can only give indications of the trend. River ages ranged from 2 to 6 years and the numbers with 2, 3, 4, 5, and 6 years of river life were: 23, 7, 4, 2, and 2.

Thirty-six (and probably 37) of the fish were in their second year at sea (1+ sea years) and two were in their third year at sea (2+ sea years). Fork lengths of the 1+ sea-year salmon (Table 5) ranged from 54 to 73 cm with the peak at 65–69 cm, and those of the 2+ sea-year salmon were 80 and 86 cm. The 1+ sea-year salmon from the Labrador Sea in the 18–20 July period were a little smaller than those from the West Greenland banks and from the Cape Farewell-Cape Desolation localities.

TABLE 4. Vertical location of salmon in nets in surface drift-net fishing by the *A. T. Cameron*, 18 July–23 August 1965. (1 ft = 0.305 m)

Depths of salmon in net from sea surface	Labrador Sea			W Greenland banks			Off C. Desolation and C. Farewell			Total			
	7½-ft nets	10-ft nets	16½-ft nets	7½-ft nets	10-ft nets	16½-ft nets	7½-ft nets	10-ft nets	16½-ft nets	7½-ft nets	10-ft nets	16½-ft nets	Total
ft													
0	...	...	...	...	...	...	...	...	...	...	...	...	...
1	...	1	3	...	1	2	...	...	7	...	2	12	14
2	...	...	2	...	2	2	...	1	3	...	3	7	10
3	...	...	1	...	...	2	...	...	2	...	...	5	5
4	...	...	...	...	...	...	...	1	...	...	1	...	1
5	...	3	1	...	1	...	...	...	...	...	4	1	5
6	...	...	...	...	...	...	...	...	...	...	...	...	...
7	...	...	...	...	...	...	...	...	...	...	...	...	...
8	...	...	...	...	...	3	...	...	...	...	...	3	3
9	...	...	...	...	...	...	...	...	...	...	...	...	...
10	...	...	...	...	...	...	...	...	...	...	...	...	...
11	...	...	...	...	...	...	...	...	1	...	...	1	1
12	...	...	...	...	...	...	...	...	...	...	...	...	...
13	...	...	...	...	...	...	...	...	...	...	...	...	...
14	...	...	...	...	...	...	...	...	...	...	...	...	...
15	...	...	...	...	...	...	...	...	...	...	...	...	...
16	...	...	...	...	...	...	...	...	...	...	...	...	...
Total	0	4	7	0	4	9	0	2	13	0	10	29	39
Total thousand linear feet × no. hours set	8	4	18	32	17	119	5	3	21	45	24	158	...

TABLE 5. Numbers, river and sea ages and lengths of Atlantic salmon caught at Labrador Sea and West Greenland locations, 18 July–23 August 1965.

Gill-net set	Date 1965	Locality	No. of salmon at river ages (years)					No. of salmon at sea ages (years)		No. salmon at lengths, snout to mid fork, cm								Total
										1 + sea year					2 + sea year			
			2	3	4	5	6	1+	2+	50–54	55–59	60–64	65–69	70–74	75–79	80–84	85–89	
B	18–19 July	Labrador Sea	2	1	...	...	...	3	...	1	...	2	...	...	...	...	...	3
C	19–20 July	Labrador Sea	2	1	...	...	...	2	1	...	1	...	1	...	...	...	1	3
D	5 Aug.	N peak Store Hellefiske Bank	1	...	...	...	...	...	1	...	...	...	...	...	...	1	...	1
F	6–7 Aug.	Store Hellefiske Bank	2	...	1	...	...	3	...	...	...	1	1	1	...	...	...	3
H	9 Aug.	W slope Lille Hellefiske Bank	...	...	1	...	...	1	...	...	...	...	1	...	...	...	...	1
I	9–10 Aug.	Banana Bank	4	...	...	...	...	4	...	...	...	...	3	1	...	...	...	4
J	12–13 Aug.	Fylla Bank	1	...	...	...	...	1	...	...	...	...	...	1	...	...	...	1
L	15–16 Aug.	Fiskenaes Bank	1	1	...	...	1	3	...	...	...	1	2	...	...	...	...	3
O	21 Aug.	W of Cape Desolation	2	...	...	...	...	2	...	...	...	...	1	1	...	...	...	2
P	21–22 Aug.	W of Cape Farewell	7	4	...	1	1	13	...	...	1	4	5	3	...	...	...	13
Q	22–23 Aug.	Labrador Sea	1	...	2	1	...	4	...	...	1	...	2	1	...	...	...	4
B, C, & Q	18–20 July 22–23 Aug.	Labrador Sea	5	2	2	1	...	9	1	1	2	2	3	1	...	...	1	10
D L	5–16 Aug.	W Greenland banks	9	1	2	...	1	12	1	...	...	2	7	3	...	1	...	13
O & P	21–22 Aug.	W of Cape Farewell and of Cape Desolation	9	4	...	1	1	15	...	...	1	4	6	4	...	...	...	15
Total	18 July 23 Aug.		23	7	4	2	2	36	2	1	3	8	16	8	...	1	1	38

Length-weight

Whole weights (Fig. 3) at the same lengths were greater in the salmon from the West Greenland banks (5–16 August) and from the Labrador Sea (22–23 August) than from the Labrador Sea (18–19 July) or from west of Cape Farewell and Cape Desolation (21–22 August). The same is true for gutted weight but the differences between areas are not as great and for both whole and gutted weights there are exceptional individuals which do not agree with the majority.

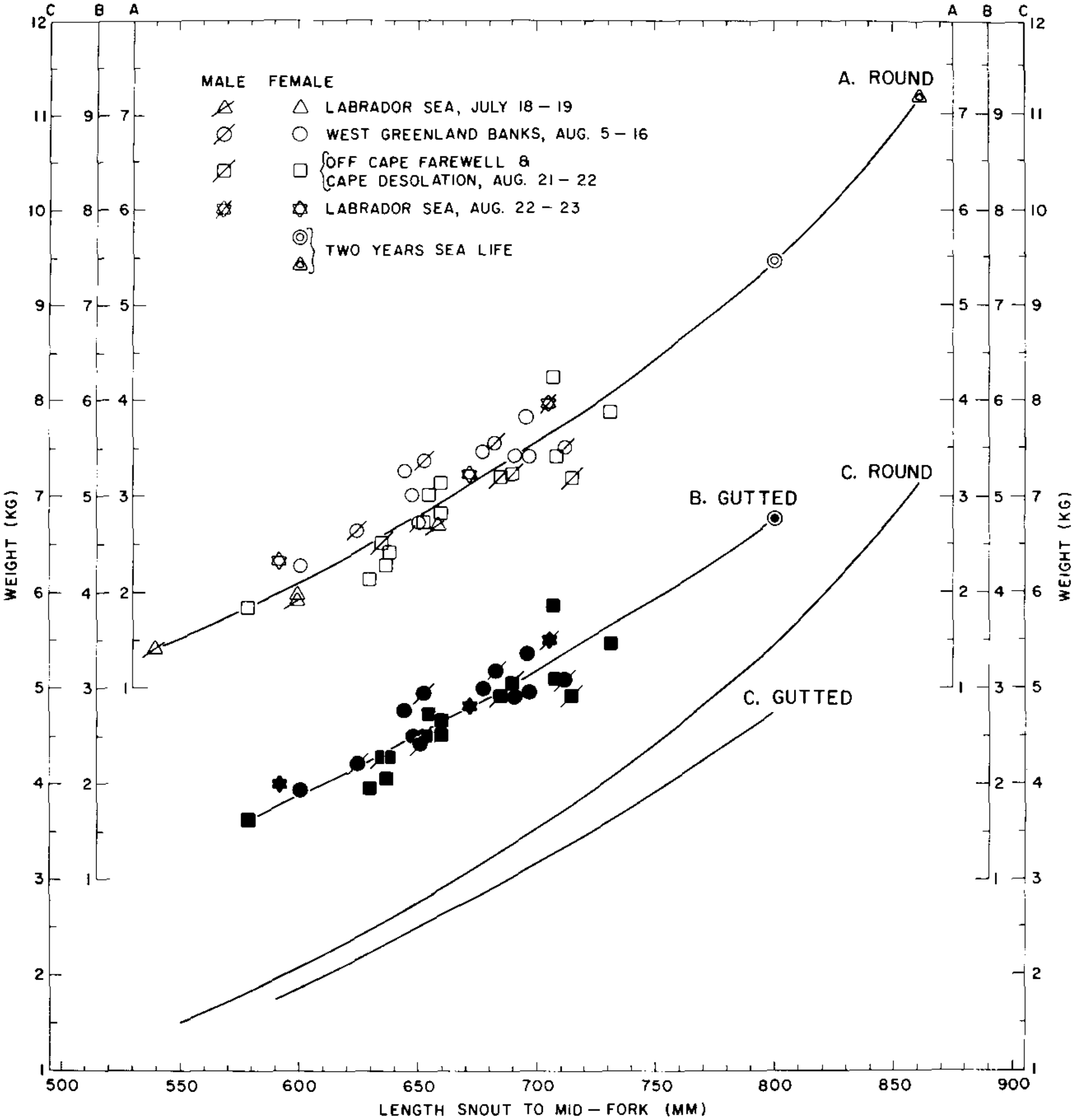

Fig. 3. Length-weight relationships of Atlantic salmon from Labrador Sea and West Greenland areas, 12 July–23 August 1965.

Allowing for differences between areas, there is no good evidence, in these small numbers, of weight differences between the sexes.

Average whole weights (Fig. 3) rose from 2.0 kg at 593 mm to 4.0 kg at 728 mm fork length. Weights were too few, the variation between times and areas too great and the range of sizes too small to justify the application of weight formulae.

Gutted weights for salmon of 57–64(8), 65–69(14), 70–73(8), and 80 cm (1) fork lengths

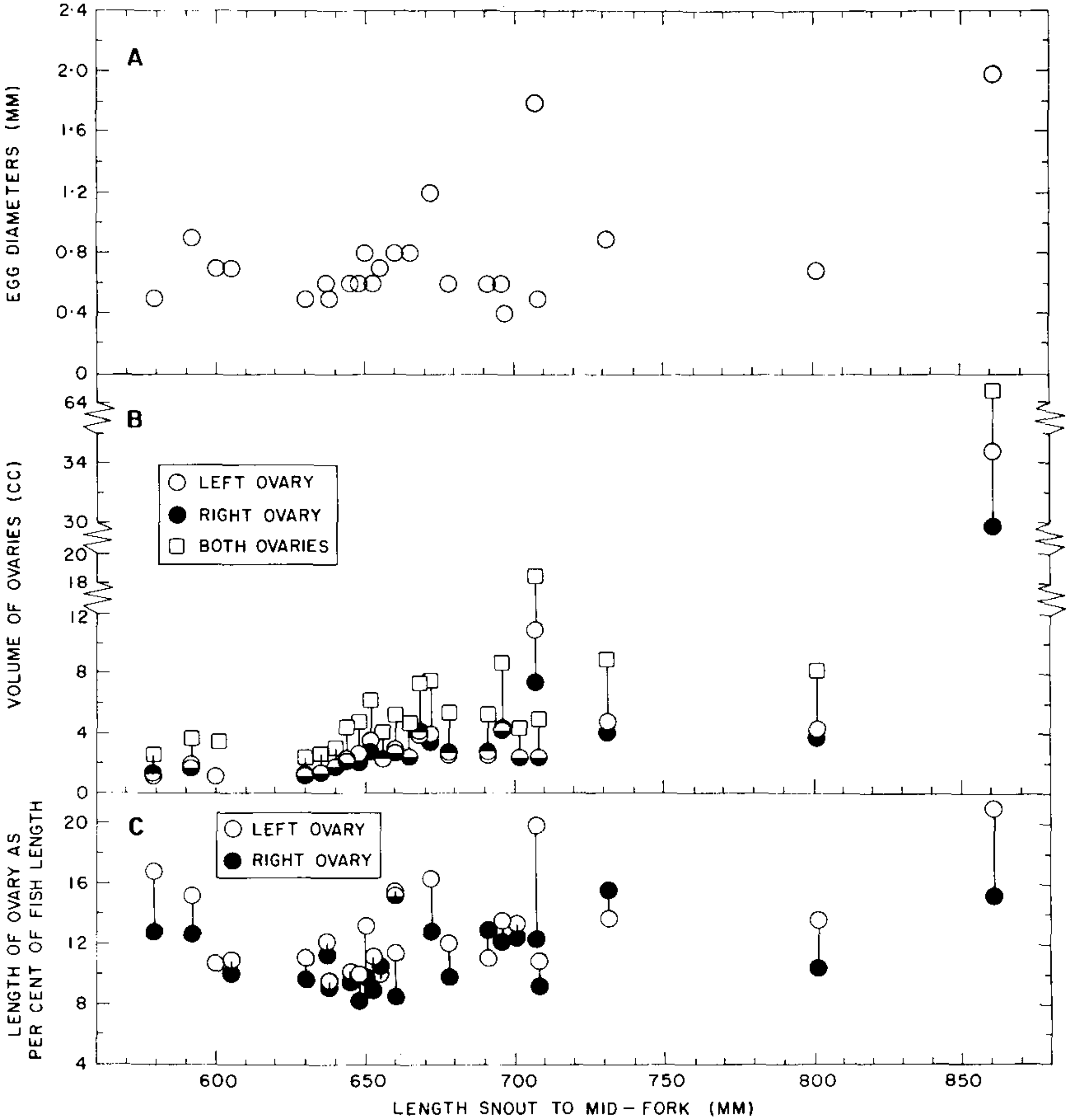

Fig. 4. Egg diameters, and lengths and volumes of ovaries of Atlantic salmon of various lengths taken in the Labrador Sea and off West Greenland, 12 July–23 August 1965.

were 89, 88, 89, and 88% (average 88.7% for 31 fish) of whole weights.

Sex ratio and stage of sexual maturity

Sex ratios in the 1+ sea group were: Labrador Sea, 5 M:4 F; West Greenland banks, 5 M:7 F; Cape Farewell and Cape Desolation, 4 M:11 F; total 14 M:22 F. The two 2+ sea-year fish, one from the Labrador Sea and the other from the north peak of Store Hellefiske Bank, were both females.

All males were in an immature condition with small and very thin pink testes ranging in width from 4 to 8 mm. All females were in immature condition, the egg diameter of all but two ranging from 0.4 to 0.9 mm (except one 1.2 mm) and the total volume of both orange-yellow ovaries from 2.5 to 9.0 cc (Fig. 4). One 2+ sea-year 861-mm female, taken in the Labrador Sea 19–20 July, had an egg diameter of 2.0 mm and a volume of both ovaries of 65 cc. Also, a 1+ sea-year 707-mm female, taken west of Cape Farewell on 21–22 August had an egg diameter of 1.8 mm and a volume of both ovaries of 18.5 cc.

The left ovary was the longer in 21 of 24 individuals. In three fish the right ovary was the longer. In the smaller ovaries the volumes of the left and right ovary did not differ as much as the lengths, the left being often only a little greater or equal in volume. In the two fish with the best developed ovaries, however, the left ovary had a definitely greater volume (Fig. 4).

Meristic characters

The numbers were too few to reveal small differences in meristic characters or to make a study of the significance of differences worth while. There are, however, indications of differences which are worth testing on larger numbers of fish (Table 6). Vertebral numbers may be highest in the Labrador Sea group and lowest in the salmon from west of Cape Farewell and Cape Desolation. There is little consistent trend in the differences between meristic characters of salmon with 2–3 years of river life and those with 4–6 years of river life. The greatest differences in this regard are in the pectoral and anal fin-ray numbers, on the average lower in fish with 2–3 years of river life, but numbers are small.

In addition to the characters shown in Table 6, pelvic fin-rays were counted but showed little variation. In 10 fish from the Labrador Sea, 13 from the West Greenland banks, and 15 from off Cape Farewell and Cape Desolation, all had 9 pelvic fin-rays except 2 from the Cape Farewell-Cape Desolation area, which had 8 and 10 rays.

Body proportions

A few measurements were made on each salmon to find out whether or not there were readily observable body-proportion differences between the salmon of the various areas.

Greatest length. In 33 salmon, the greatest length to the posterior tip of the upper lobe of the caudal fin was greater in 22 (6 males and 16 females), the lower lobe greater in 10 (5 males and 5 females) and in one male both lobes were equal. In the cases where the upper lobe was greater, it was on the average 3.6 mm greater than the lower lobe, and in the cases where the lower lobe was greater it was on the average 2.3 mm greater than the upper lobe. By this measurement (Fig. 5) there was no very good separation between areas although more of the West Greenland bank than of Labrador Sea fish were above the median line. With increase in length there appears to be a slight decrease in the greatest length relative to fork length.

Head length. This measurement does not appear to be useful in separating individuals from the various regions examined. On the small numbers examined here, the head lengths of the males are on the average greater than those of females of the same length (Fig. 5).

Pectoral length. There is no clear separation in pectoral length between areas (Fig. 5) and the pectoral length decreases slightly in relative length with increase in fish length.

Girth. Neglecting the 2-year-sea-life fish, above 800 mm in length, for which there are too few records to draw any conclusions, girth (especially the greatest girth) was greater in the salmon from the West Greenland banks and from late August in the Labrador Sea than in the salmon from west of Cape Farewell and Cape Desolation and in July in the Labrador Sea. There are again individual exceptions but the general picture is clear (Fig. 6C, D).

TABLE 6. Meristic characters of Atlantic salmon from the Labrador Sea and West Greenland, 18 July–23 August 1965.

Years river life:	2–3				4–6				Total 2–6			
Vertebral numbers:	59	60	61		59	60	61		59	60	61	
Labrador Sea	1	6	...		...	2	1		1	8	1	
W Greenland banks	4	5	...		2	1	...		6	6	...	
W of Cape Farewell and W of Cape Desolation	8	4	1		1	1	...		9	5	1	
Total	13	15	1		3	4	1		16	19	2	
Dorsal fin-rays:	14	15	16		14	15	16		14	15	16	
Labrador Sea	2	2	3		...	3	...		2	5	3	
W Greenland banks	1	7	2		1	1	1		2	8	3	
W of Cape Farewell and W of Cape Desolation	3	8	2		...	2	...		3	10	2	
Total	6	17	7		1	6	1		7	23	8	
Anal fin-rays:	11	12	13		11	12	13		11	12	13	
Labrador Sea	3	3	1		...	2	1		3	5	2	
W Greenland banks	1	7	2		...	3	...		1	10	2	
W of Cape Farewell and W of Cape Desolation	4	7	2		...	1	1		4	8	3	
Total	8	17	5		...	6	2		8	23	7	
Pectoral fin-rays:	12	13	14	15	12	13	14	15	12	13	14	15
Labrador Sea	...	1	6	...	...	...	3	...	...	1	9	...
W Greenland banks	...	3	5	2	...	...	3	...	...	3	8	2
W of Cape Farewell and W of Cape Desolation	1	5	6	1	...	...	1	1	1	5	7	2
Total	1	9	17	3	...	...	7	1	1	9	24	4

TABLE 6. (continued)

Years river life:	2–3								4-6						Total 2–6							
Gill rakers on first arch:	17	18	19	20	21	22	23	24	18	19	20	21	22	23	17	18	19	20	21	22	23	24
Labrador Sea	...	...	...	...	5	1	1	...	...	1	1	...	...	...	...	...	1	1	5	1	1	...
W Greenland banks	...	1	...	3	1	2	1	2	...	...	...	2	1	...	...	1	...	3	3	3	1	2
W of Cape Farewell and W of Cape Desolation	1	...	1	2	4	4	1	...	...	1	1	...	...	...	1	...	2	3	4	4	1	...
Total	1	1	1	5	10	7	3	2	...	2	2	2	1	...	1	1	3	7	12	8	3	2

Gill rakers lower limb, first arch:	10	11	12	13	14	11	12	13	10	11	12	13	14
Labrador Sea	...	...	1	6	...	1	1	...	...	1	2	6	...
W Greenland banks	...	1	3	3	3	...	1	2	...	1	4	5	3
W of Cape Farewell and W of Cape Desolation	1	1	2	9	...	1	1	...	1	2	3	9	...
Total	1	2	6	18	3	2	3	2	1	4	9	20	3

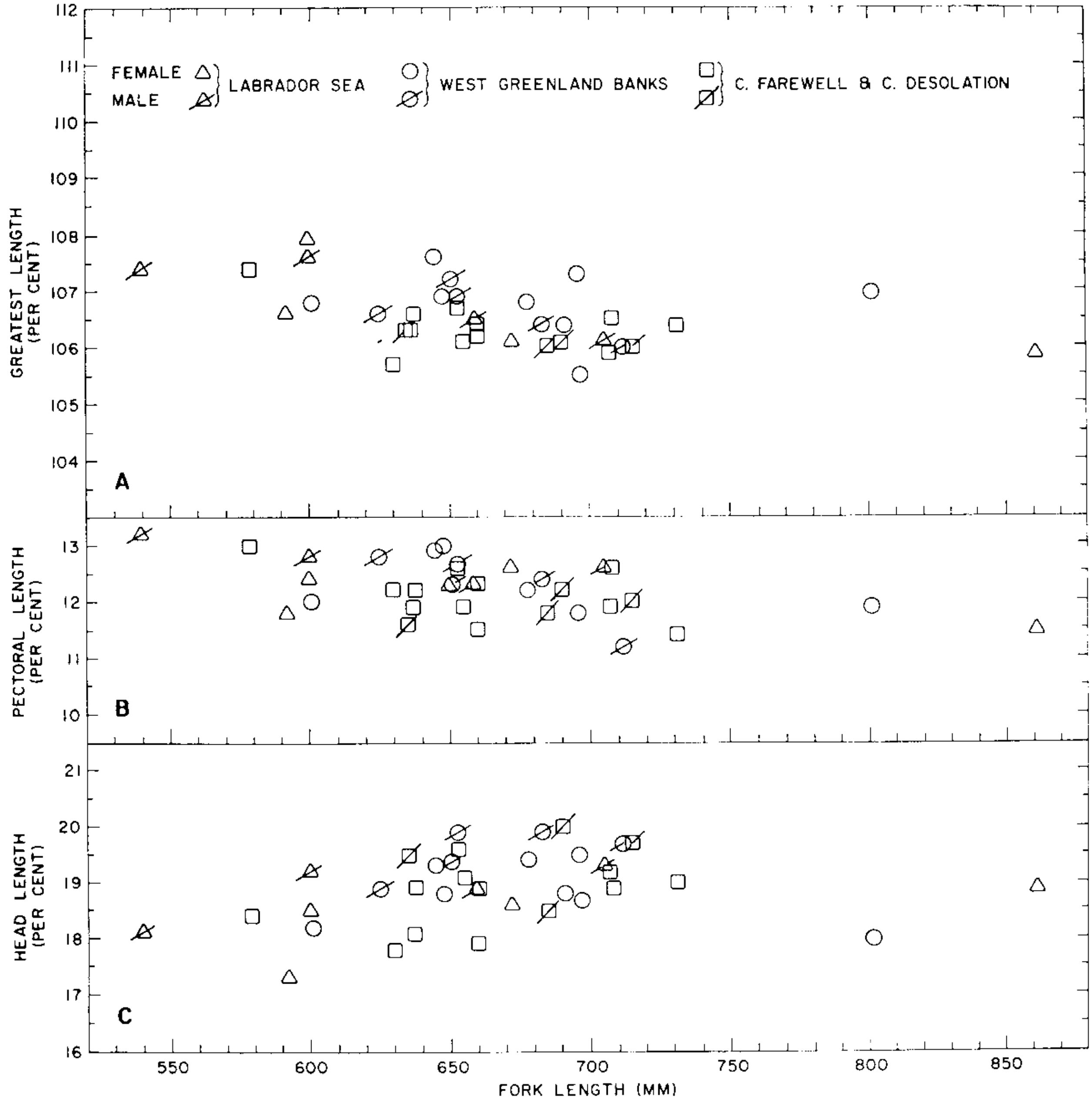

Fig. 5. Head, pectoral and greatest lengths relative to the total length to the end of the mid-fork of the caudal fin for Atlantic salmon taken in the Labrador Sea and off West Greenland, 12 July–23 August 1965.

For the 5–5½-inch (127–140-mm) nets used, a few of the smaller salmon were gilled in the position of their greatest girth (Fig. 6B), and some had a greatest girth less than the circumference of 5½-inch (140-mm) meshes (Fig. 6A). Thus some of the smaller salmon may have escaped by passing or struggling through the 140-mm meshes and still more might have escaped through a 6-inch (152-mm) mesh (Fig. 6A).

Food

In the Labrador Sea over oceanic depths the small salmon were feeding principally on small

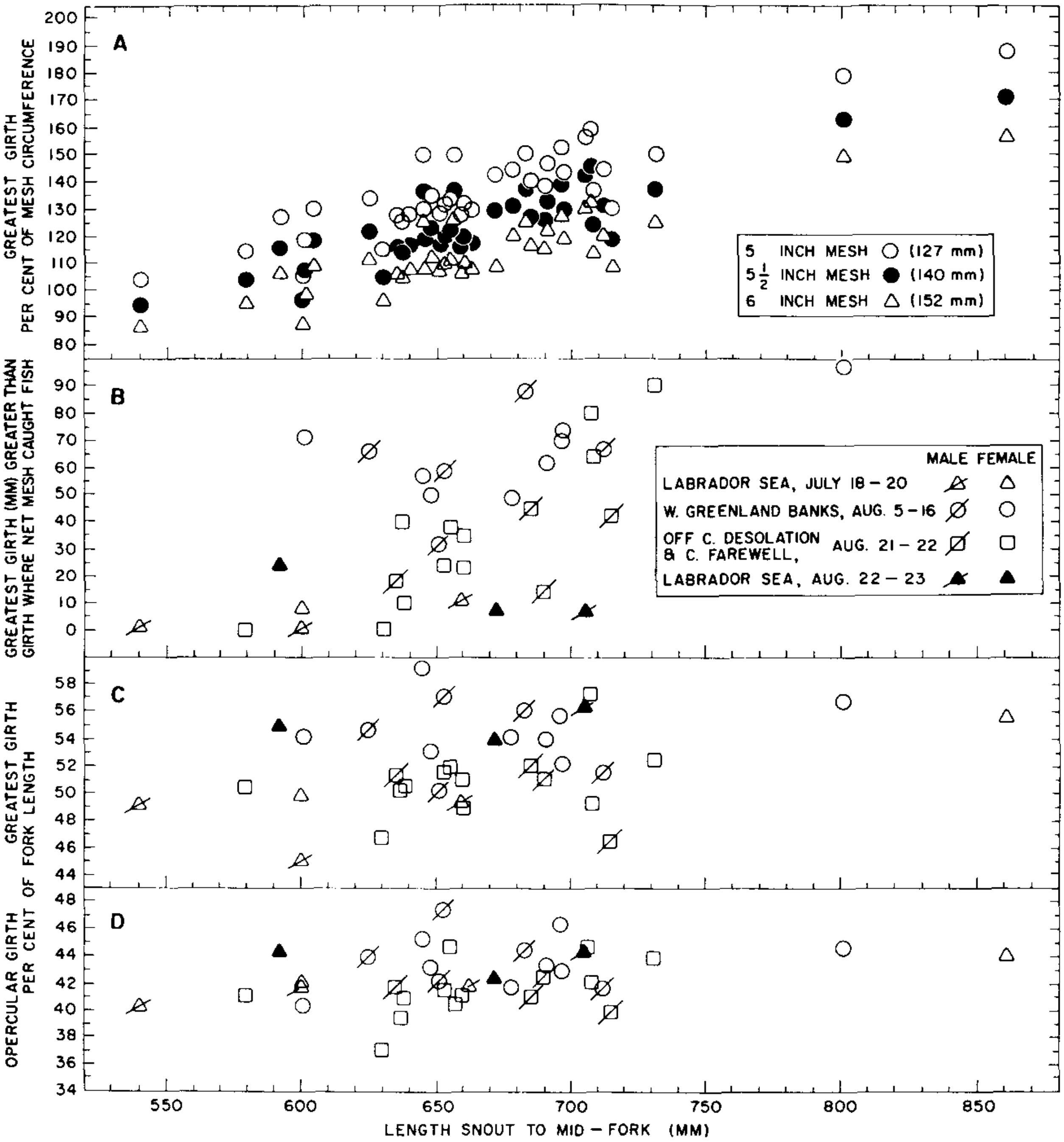

Fig. 6. Length-girth relationships for Atlantic salmon taken in the Labrador Sea and off West Greenland, 12 July–23 August 1965.

Arctic squid, *Gonatus fabricii*. One large 2+ sea-year fish had 18 adult *Notolepis rissoi krøyeri*. One salmon was feeding on large Greenland halibut fry (Table 7).

On the West Greenland banks the food was principally launce and secondarily capelin while off Cape Farewell and Cape Desolation over very deep water the main food was again *Gonatus*

TABLE 7. Stomach contents of Atlantic salmon, Labrador Sea and West Greenland, 18 July–23 August 1965 (Numbers of food individuals in parentheses.)

	Labrador Sea		West Greenland banks	W of C. Farewell and C. Desolation
Date 1965:	18–20 July	22–23 Aug.	5–16 Aug.	21–22 Aug.
Depth to bottom (m):	3290–3480	3660	24–649	2196–3203
No. salmon stomachs with contents				
Empty	1	...	1	8
Arctic squid (*Gonatus fabricii*)	4	4	...	4
Octopus	1	...	...	...
Pelagic amphipods (*Parathemisto*)	...	...	...	1
Launce (*Ammodytes*)	...	...	11	...
Capelin (*Mallotus villosus*)	...	...	5	...
Notolepis rissoi krφyeri	1	...	...	...
Greenland halibut fry (*Reinhardtius hippoglossoides*)	...	1	...	1
Fish (herring type)	...	...	...	3
Fish (unidentified)	...	...	...	1
Total quantity, (cc) (No. of individuals)				
Squid (*Gonatus fabricii*)	65.7 (29)	41.0 (26)	...	16.0 (8)
Octopus	0.2 (1)	...	...	...
Pelagic amphipods (*Parathemisto*)	...	...	...	0.05
Launce (*Ammodytes*)	...	...	604.0 (48)	...
Capelin (*Mallotus villosus*)	...	...	83.0 (18)	...
Notolepis rissoi krφyeri	280.0 (18)	...	...	...
Greenland halibut fry (*Reinhardtius hippoglossoides*)	...	19.0 (9)	...	4.0 (4)
Fish (herring type)	...	...	...	2.9
Fish (unidentified)	...	...	...	5.0
Total food, (cc):	345.9	60.0	687.0	27.95
Total salmon stomachs examined, (No.):	6	4	13	15
Total weight of salmon whose stomachs were examined, (kg):	17.4	12.2	43.8	43.8
Total food (cc) per kg of salmon weight:	19.9	4.9	15.9	0.6
Total food per kg of salmon weight Labrador Sea 18–20 July, omitting the one salmon (7.2 kg) containing *Notolepis*, (cc):	6.5	...	...	...

fabricii and the remaining food was fish including Greenland halibut fry.

Feeding was a little better on the West Greenland banks than in the Labrador Sea and very much better if the one salmon with the large amount of *Notolepis* is omitted. Feeding off Cape Farewell and Cape Desolation was very poor. In all areas most of the food in the stomachs was relatively freshly taken and in good condition with little digestion.

Parasites

Lepeophtheirus salmonis. This external marine copepod was absent in only 5 of the 38 salmon examined: on 3 out of 6 salmon from the Labrador Sea, 18–20 July and on 2 of 3 salmon from Store Hellefiske Bank on 6–7 August. Numbers of *Lepeophtheirus* present per fish ranged from 0 to 8 (average 2.7) on 6 salmon from the Labrador Sea, 18–20 July; 0 to 19 (average 5.2) on 13 salmon from the West Greenland banks, 5–16 August; 1 to 21 (average 6.2) on 15 salmon from west of Cape Farewell and Cape Desolation, 21–22 August; and 3 to 18 (average 7.5) on 4 salmon from the Labrador Sea, 22–23 August. The numbers remaining on the fish are very likely minimal since hauling in these drift nets on a large vessel resulted in rough treatment of the salmon and there may be little significance in the averages or the absence of these parasites.

These parasites were mostly females with long egg sacs. The young in the egg sacs were sometimes well developed and nauplii with three pairs of appendages were observed in the eggs of the egg sacs of some females.

Total lengths of random female *Lepeophtheirus* to the end of the caudal rami, not including setae were: 13.3–16.0 mm (average 15.0 mm) in 14 of these copepods from the Labrador Sea, 19–20 July; 13.6–16.3 mm (average 15.1 mm) in 5 copepods from Store Hellefiske Bank, 5 August; and 13.5–16.2 mm (average 15.2 mm) in 9 copepods from west of Cape Farewell, 22 August.

Total lengths including unbroken egg sacs were: 44–49 mm (average 47 mm), for six females from the Labrador Sea, 19–20 July; 39–53 mm (average 45 mm) for four females from Store Hellefiske Bank, 5 August; and 25–65 mm (average 45 mm) for six females from west of Cape Farewell, 22 August. Thus there were no considerable differences in size of these copepods in the areas examined.

Two males from the Labrador Sea 20 July were 6.4 and 7.3 mm in total length.

The females from the different areas were compared generally though not in complete detail and no differences were apparent. Ten females and one male from the Labrador Sea (19–20 July), five females from Store Hellefiske Bank (5 August) and nine females from west of Cape Farewell (22 August) were examined for the presence or absence of a small spine on the second segment of the fourth leg (Gurney, 1933; White, 1940; Margolis, 1958). Only in one female from the Labrador Sea was this spine absent, although until one becomes familiar with its appearance and situation it is difficult to distinguish.

Salmincola salmonea. The gills of all salmon were examined for this species but none of these parasites were observed.

Eubothrium crassum. Tapeworms, some identified by Dr L. Margolis as *Eubothrium crassum*, were found in 60% of 10 salmon from the Labrador Sea, 15% of 13 salmon from the West Greenland banks, and in 27% of 15 salmon from over oceanic depths west of Cape Farewell and Cape Desolation. These tapeworms were large and often numerous, filling the pyloric caeca and projecting into the intestine.

In the totals for the whole area there are indications, in spite of the small numbers of fish examined, that the relative number of salmon infected with tapeworms increases with the number of years of river life (Table 8).

Anisakis sp. Larval nematodes encysted in flat circular coils on the surface (almost always the ventral surface) of the liver, were identified by Dr L. Margolis as *Anisakis* sp. These nematodes on the surface of the liver were present in 56% of 9 salmon from the Labrador Sea (range 0–2, average 0.8 nematodes), in 54% of 13 salmon from the West Greenland banks (range 0–6, average 1.2 nematodes), and in 73% of 15 salmon from over very deep water west of Cape Farewell and Cape Desolation (range 0–12, average 2.2 nematodes).

Gall-bladder parasites. The gall bladders of these salmon were examined by Dr Z. Kabata who reported that no infection or parasites were found.

Discussion and Conclusions

Salmon location and migration

The experimental fishing carried out by the *A. T. Cameron* in July–August 1965 indicates that in both of these months there are salmon populations in the southern mid-mouth of the Labrador Sea, that in August there are some

TABLE 8. Relationship of presence of tapeworms in pyloric caeca and intestine to area and to years of river life in salmon taken by the *A. T. Cameron*, 18 July–23 August 1965.

	Labrador Sea		W Greenland banks		W of Cape Farewell and Cape Desolation		Total			
	Number of salmon		Number of salmon		Number of salmon		Number of salmon			%
Years river life	With tapeworms	Without tapeworms	With tapeworms	Without tapeworms	With tapeworms	Without tapeworms	With tapeworms	Without tapeworms	Total fish	with tape-worms
2	3	2	0	9	2	7	5	18	23	22
3	1	1	0	1	1	3	2	5	7	29
4	1	1	1	1	...	...	2	2	4	50
5	1	0	...	...	0	1	1	1	2	50
6	...	...	1	0	1	0	2	0	2	100
Total	6	4	2	11	4	11	12	26	38	32

salmon in the shallow water of the West Greenland banks and that salmon were also numerous over oceanic depths west of the coastal banks off Cape Farewell. In the latter location and in the Labrador Sea the largest catches per net occurred at temperatures between 8.5° and 8.6°C. There were some indications of differences between salmon of these three areas.

Outward and return migrations, Canada

Saunders *et al.* (1965) and Hansen (1965) have reported the capture in West Greenland of salmon marked as smolts, returning adults or kelts from North America, mainly Canada, and Europe. The Canadian tagged salmon were mainly from the Miramichi River of the southern part of the Gulf of St. Lawrence, but also some from Margaree River in the eastern Gulf of St. Lawrence, from Quebec rivers of the Gulf of St. Lawrence and Newfoundland rivers at the entrance to the Gulf and on the northeast coast.

The larger numbers from the Miramichi River are related to the relatively large number of smolts tagged in this river in the recent years during which the fast increasing fishery for salmon has occurred at West Greenland.

In order to reach the northern eddy system between West Greenland and Labrador and the continental slope north of the Grand Bank and Flemish Cap the mainland Canadian salmon and those of the south coast of Newfoundland could pass through the Strait of Belle Isle across the Labrador Shelf directly into the system or could leave the Gulf of St. Lawrence through the southwestern entrance, Cabot Strait, and passing over the Newfoundland banks or around the slopes of these banks migrate eastward and northward into the system. The distant migrations from the Atlantic salmon kelt tagging in the Margaree River of the southeastern Gulf of St. Lawrence (Huntsman, 1938) could be interpreted as migration in the first year after spawning to the northern eddy system off the Labrador coast, at least in some cases through the Strait of Belle Isle. In the following year much of the return migration is by way of the east coast of Newfoundland.

While there is no published information on outward migration routes of smolts after reaching the sea, there is information on the latter part of the return pre-spawning journey after the salmon strike the Canadian coast.

Belding and Préfontaine (1938) showed that salmon tagged (11 May–14 June 1937) in the drift-net fishery off Port-aux-Basques on the northern side of Cabot Strait were mainly caught in the following percentages by area: on the west coast of Newfoundland (26), in the Miramichi area of the Gulf of St. Lawrence (25), in Bay Chaleur (11), on the western part of the North Shore of the Gulf of St. Lawrence (11), on the western part of the south coast of Newfoundland (8), in the Cape Breton and northern Nova Scotia areas of the Gulf of St. Lawrence (6) and around the Gaspé Peninsula (5). One salmon went, presumably through the Gulf, to southern Labrador.

Salmon tagged at St. Anthony near the northeastern tip of Newfoundland between 10 June and 13 July 1938 (Belding and Préfontaine, 1961) were recaptured in the following percentages: in southern Labrador (39), on the north shore of the Gulf of St. Lawrence north of 50°N, on the northern side of the Strait of Belle Isle and on the west coast of Newfoundland from Bay of Islands to just north of Bonne Bay (34), in the tagging area near St. Anthony (12), and south of St. Anthony in Hare Bay and White Bay (12). One salmon (3%) was taken in Miramichi Bay but due to the high rate of travel (24 miles per day if a Strait of Belle Isle entrance is assumed compared with a mean daily rate of 14 miles for all salmon caught in the Gulf) it is uncertain whether this salmon entered the Gulf through the Strait of Belle Isle or on the longer route through Cabot Strait. This speed of 24 miles per day, however, is slower than the rates of travel of some of the fastest migrating salmon tagged at Bonavista (Blair, 1956) and hence the salmon could have migrated by the shortest route, through the Strait of Belle Isle. It is reasonably certain that most of the remainder of these St. Anthony tagged salmon entered the Gulf through the Strait of Belle Isle.

Kerswill (1955) and Elson and Kerswill (1955) from smolt marking in 1955 in the Miramichi River of the Gulf of St. Lawrence and the Pollett River at the head of the Bay of Fundy showed that large numbers of these fish were recaptured, on their return migration as grilse and salmon, on the east coast of Newfoundland and some off southern Labrador. The 15 returns from Labrador (southern) were entirely from the more distant Pollett River. There were some recaptures on the south and west coast of Newfoundland and off Cape Breton Island. Some of the Pollett River and estuary fish were caught in the Miramichi drift-net fishery but not in the Miramichi River. The fish apparently returned to their home rivers and were not caught in other rivers. Only one recapture (of a Pollett fish) was made on the outer (eastern) coast of Nova Scotia. These data like those for fin-clipping experiments generally suffer somewhat from the lack of a complete coverage of the fishing area and the lack of returns from areas not covered in the sampling.

Kerswill's (1955, fig. 1) and Table 9 derived from this figure show that the Pollett salmon strike the coast of Newfoundland and Labrador more northerly than the Miramichi salmon, also that at least many of them enter and circulate in the Gulf of St. Lawrence and leave it on their way south by passing around Cape Breton Island. There is relatively little evidence that many Miramichi salmon enter the Gulf by passing near the coast of Cape Breton Island, but the results of Belding and Préfontaine's (1938) tagging showed that many pass inward near the north side of Cabot Strait. In order to make a real comparison with the numbers of salmon caught in the Miramichi drift-net fishery the catch around Newfoundland should be increased by almost four times since less than a quarter of the landed catch from the Newfoundland area was examined whereas all salmon landed from the Miramichi drift-net fishery were examined for marks. The Gulf of St. Lawrence Miramichi salmon and Bay of Fundy Pollett salmon evidently winter mainly east or north of Newfoundland and not east of Nova Scotia.

TABLE 9. Captures on return migration of salmon (including grilse) from 48,000 smolts marked in the Miramichi River and 25,000 in the Pollett River in 1951 (from Kerswill, 1955).

Locality of recapture as salmon (or grilse)	Total recaptures	Miramichi smolts	Pollett smolts
	no.	%	%
Labrador (Strait of Belle Isle northward)	15	0	100
Northeast coast Nfld. Notre Dame Bay and vicinity	50	68	32
East coast Nfld. Bonavista to Conception Bays	155	80	20
South coast Nfld.	2	0	100
West coast Nfld.	9	89	11
Chaleur Bay	7	86	14
Miramichi River	172	100	0
Miramichi, shore nets	293	96	4
Miramichi, drift nets	200	92	9
Cape Breton	21	10	90
Outer coast Nova Scotia	1	0	100
Bay of Fundy	6	0	100
Pollett River and vicinity	4	0	100

Blair (1956) from tagging of returning salmon and grilse at Bonavista on the east coast of Newfoundland reported that 39% of the tagged salmon and 7% of the tagged grilse recaptures were from the Canadian mainland, especially near and in rivers of the southern part of the Gulf of St. Lawrence. Additionally many others appear to have been captured in Newfoundland while on their way to the Gulf of St. Lawrence. From the tagging locality salmon and grilse proceeded both north and south and it is difficult to know what track into the Gulf was taken. One would assume that migration to the southern part of the Gulf should be southward and westward at this time as coastal northern areas are often covered with ice in May and early June.

All of Belding and Préfontaine's (1938) drift-net salmon tagged off Port aux Basques were 2 and 3 sea-year fish and were taken between 11 May and 14 June. Blair's (1956) salmon and grilse at Bonavista were tagged from 8 to 28 June. Thus all of Belding and Préfontaine's salmon were tagged earlier than the date when any of Blair's fish were likely to reach Port aux Basques. Belding and Préfontaine's fish were thus the earlier run and presumably on the average larger fish and some of them were captured on the northern part of the Gaspé Peninsula, in the St. Lawrence Estuary and on the north shore of the Gulf whereas apart from those going to the Newfoundland west coast none of Blair's salmon and only one of his grilse, entering the Gulf was caught north of Bay Chaleur.

Blair (1957*a*, 1957*b*) reported on salmon tagged at Francis Hr. Bight and at Cape Charles, both on the southern part of the Labrador coast immediately north of the Strait of Belle Isle. Twenty salmon were recaptured on the Labrador coast as far south as the northern part of the Strait of Belle Isle and as far north as Hamilton Inlet. Two fish (grilse) passed through the Strait of Belle Isle to the northern part of the west coast of Newfoundland.

The spring run of salmon on the east coast of Newfoundland begins each year in the St. John's area between mid-May and June. The run comes in progressively later to the northward, only a few days later at Bonavista than at St. John's and from 6 to 11 June in Notre Dame Bay and White Bay (Lindsay and Thompson, 1932). In Blair's (1956) salmon tagging at Bonavista in 1940 from 8 to 28 June, the main run of salmon was over early in this period. Blair reports the main run of grilse in this area to be between 10 June and 15 July with the peak around 30 June. Belding and Préfontaine (1961) say that the peak of the salmon run at St. Anthony in 1938 occurred about 24 June.

Blair (1957*b*) says for Cape Charles in southern Labrador that the usual time of the salmon run is 5 June–15 July with the peak around 25 June and that the grilse run is several weeks later, 1–31 July with the peak around 15 July. For Francis Hr. Bight, Labrador, a little north of Cape Charles, Blair (1957*a*) reports the salmon run from about 10 June to 31 July with the peak around 30 June and the grilse run from 1 July to 15 August, with the peak around 20 July.

In 1937 (Belding and Préfontaine, 1938) the salmon run in the drift-net fishery (large-mesh, 6¾–7 inches, 171–178 mm) off Port aux Basques, Newfoundland had already begun by the week of 4–10 May with the peak of the run between 25 May and 7 June and the fishery ending 15–21 June. The main run in the Miramichi drift-net fishery was almost 3 weeks later, 15 June–5 July. However, part of the apparent timing of this peak run is probably due to the relative amount of effort for drift-netting at various periods since Elson and Kerswill (1955) say that about the middle of May a run of large salmon enters the Miramichi River, followed in mid-June by a larger run of grilse.

On the North Shore of the Gulf of St. Lawrence (Belding and Préfontaine, 1961), in the western portion the peak of the salmon run is later from west to east, from about 20 June in the Moisie to Pointe-de-Mons section, to about 26 June in the Natashquan to Romaine section. On the eastern portion on the other hand the peak is later from east to west ranging from 27 June at Blanc Sablon near the Strait of Belle Isle to 15 July at Washicoutai in the west. Thus, as concluded by Belding and Préfontaine (1961), the dates for the peak of the run in the southern part of the Gulf of St. Lawrence and on the western part of the Quebec North Shore agree with the indicated migration of salmon through Cabot Strait. Also, the dates for the peak of the run on the eastern part of the Quebec North Shore agree with the indicated migration directions of the St. Anthony tagging and the movement of salmon inward through the Strait of Belle Isle.

In addition to the spring and early summer runs of salmon and grilse there is on the east coast of Newfoundland a winter run of smaller numbers of salmon. This is described by Lindsay and Thompson (1932) as beginning in the St. John's and neighbouring areas in the latter part of November to early December and continuing to the latter part of December with some salmon taken in 1931 at the head of Trinity Bay in the second week of January.

In recent years the continuing fishery for this winter run has been farther northward at Twillingate in Notre Dame Bay with some west of Twillingate as far as La Scie (Ronayne, 1953; Anon., 1955). These salmon are larger and fatter than the usual spring run, the average of 98 fish being 6.0 kg, 44% being over 6.8 kg. In 1952 the winter catch at Twillingate was about

2,950 kg or about 490 salmon. These salmon are not maturing for spawning in the year that they are caught and tagging of a small number has resulted in captures during the following year in the Gulf of St. Lawrence at Miramichi Bay, New Brunswick, in Bay Chaleur and at Seven Islands on the western part of the Quebec North Shore. Also one of these tagged salmon was taken on the southwest coast of Newfoundland and another in the Saint John River of the Bay of Fundy. Nine Atlantic salmon kelts tagged in the Annapolis River of southwestern Nova Scotia (Huntsman, 1938) were taken in the following autumn on the east coast of Newfoundland. The returning spawners return to this river in the second year after the spawning year. There is some evidence also of an autumn run of salmon to the southern Labrador area from about mid-September to mid-October.

At Twillingate, it is reported that the winter run is present and has been fished from the first of November (also reported present by mid-October) to the middle of January. (The January fishery is now prevented by law.) The anchored gill nets are set at the surface and the salmon are reported by fishermen to be caught higher in the net in the winter than in the summer fishery and that the colder the weather (and presumably the water) the higher they are in the net.

For the Twillingate area, the St. John's Daily News 23 November 1946 reported in Twillingate Notes dated 9 November that quite a few salmon had been netted during the last week or so. The St. John's Evening Telegram 24 December 1948, stated that for some years past there had been a run of large salmon each fall in the coastal areas of St. John's East and Twillingate, but in the present year they have been reported from other areas between Cape John and Seal Cove in White Bay where up to 14 salmon per haul were secured weighing between 4.5 and 16 kg and averaging between 9 and 11 kg. These salmon were fatter than the summer run and were very red fleshed. They make their appearance in the Twillingate area in November and about 2 weeks later in the St. John's area.

For the Avalon Peninsula coast south of St. John's, the St. John's Evening Telegram reported on 13 December 1913 that fishermen from the South Shore were daily bringing fresh salmon to town and again on 25 November 1915 that salmon were fairly plentiful along the southern shore between Bay Bulls and Cape Broyle and that one fisherman had brought 10 large salmon to St. John's on 24 November.

In the Evening Telegram of 13 February 1917, it was stated that a fisherman from Heart's Ease, Trinity Bay arrived in St. John's on 13 February with 20 fresh salmon. One weighed 18.6 kg and was 94 cm long and three others together weighed 50 kg. The appearance of these salmon on the Newfoundland and possibly the Labrador coast is therefore somewhat comparable with the West Greenland salmon but a somewhat later run of fish, on the average larger than those at West Greenland. They probably occur all along the coasts of southern Labrador and eastern Newfoundland, apparently striking in earlier to the north but are not fished for in most areas because of their rather small numbers at any one place and time and the exposed nature of the coast and of the rough seas of late autumn and early winter.

In the Newfoundland area (Templeman, 1966), in the late spring and summer run most salmon are caught in the northern areas of southern Labrador and the northeast coast from the northern entrance to the Strait of Belle Isle to Cape St. John and the northeast and east coast areas of Notre Dame Bay to Bonavista and Trinity Bays. They are caught in moderate numbers in Conception Bay and on the eastern coast of the Avalon Peninsula but the main run seems to bypass the eastern bays of the south coast. Landings increase again along the western part of the south coast of Newfoundland and in St. George's Bay. Apart from St. George's Bay the west coast landings are not large.

Lindsay and Thompson (1932) found that salmon landed from the more southern areas, Bonavista and the Avalon Peninsula, grew faster at sea than salmon from St. Anthony in northern Newfoundland and at Battle Harbour in southern Labrador. These more southern salmon are therefore likely to spend their sea life at higher temperatures or in areas of a greater food supply or both than do the northern fish.

Northward movement of salmon similar to that of other fishes

Alm (1958) says that in the Baltic, salmon are sensitive to water temperatures higher than 11° to 12°C and that when the surface water temperatures exceed this value they seek deeper water. In the Northwest Atlantic many of the larger salmon, at least from the more southern warmer areas, proceed northward in summer. Salmon spend much time in the surface layers and this movement northward will bring them into considerably lower temperatures, from 15° to 18°C or more in mid-summer in the southern part of the Gulf of St. Lawrence to 8°C or lower in the Labrador Sea and still lower as the coast of West Greenland is approached. There is as yet no indication that the smaller salmon destined to return to the river as grilse make this long northward migration. These northward migrations of salmon are similar to those of the spiny dogfish, *Squalus acanthias* (Templeman, 1944, 1954) and bluefin tuna, *Thunnus thynnus*, of the western Atlantic (Templeman, 1966) which come from farther southward than the salmon. They do not reach as far northward as the salmon but in the case of the tuna do reach the Newfoundland area from the Caribbean and in that of the spiny dogfish reach eastern Newfoundland and southern Labrador. In each case only the larger fish make the northward journey and they return southward to spawn and extrude young.

Ocean currents and eddies, and salmon

If the salmon are moving northward toward cooler water some will pass northward through the Strait of Belle Isle. Others taking a more eastern route will avoid the Gulf Stream water and keeping to the westward fringe of the North Atlantic drift finally reach the large and rather weak eddy system or systems between the northern Grand Bank and Labrador, southern Greenland and West Iceland. This anti-clockwise eddy system is produced by the frictional movements

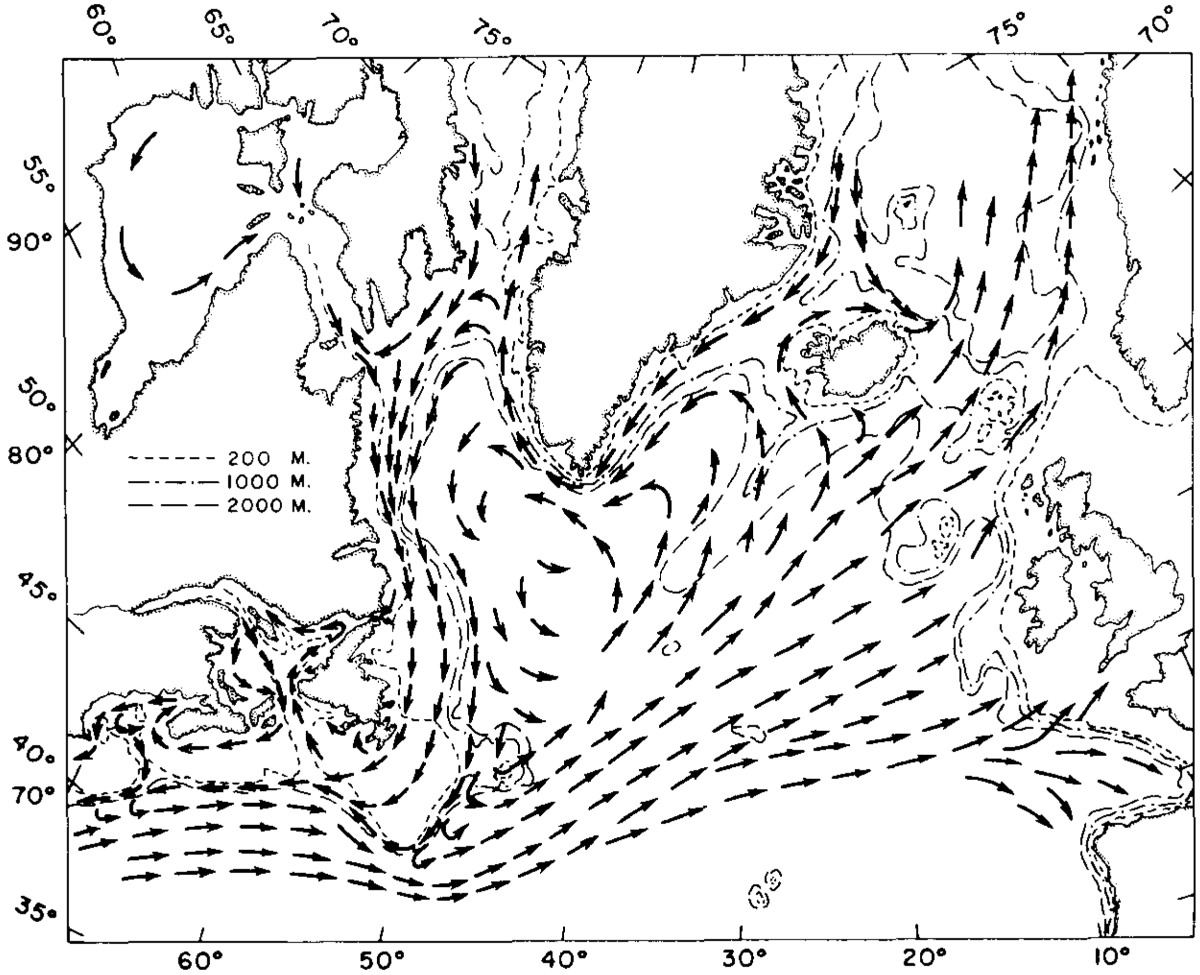

Fig. 7. General directions of flow of main surface current systems in the northern part of the North Atlantic.

of the western fringe of the North Atlantic Current, the Irminger and West Greenland Currents and the Labrador Current. The pattern of the system is aided by the coastal shelf and deep water configuration of the Reykjanes Ridge, the southern border of the Denmark Strait Ridge, the coastal shelf of South Greenland, the southern border of the Davis Strait Ridge, the continental shelf of Labrador and Newfoundland, and the northern edge of the Grand Bank and Flemish Cap (Fig. 7).

In this eddy system there are evidently conditions suitable for the maintenance of fish populations. Redfish larvae are abundant and pelagic redfish populations exist (Tåning, 1949; Templeman, 1959; Hansen and Andersen, 1961; Henderson, 1962; Henderson and Jones, 1964; Zakharov, 1964; Magnússon *et al.*, 1965). There is evidently a large population of the Arctic squid, *Gonatus fabricii*, whose larvae are abundant in the surface layers in summer and provide food for the salmon. Paralepids are present and from our recent investigations in March 1966, also lantern fishes and other pelagic fishes. From the eddy, salmon can move into the West Greenland Current or into the Labrador Current to the Labrador or Newfoundland coasts. In the eddy they can find suitable temperatures for survival and feeding near the surface over winter.

Enemies while in the northern eddy systems and at West Greenland

The salmon is a large, fast and powerful fish apparently spending much of its time in the surface layers and is vulnerable only to large fishes and mammals living in this habitat. During the summer some large porbeagles are in the area since on the *A. T. Cameron* Greenland cruise two large porbeagles were caught at the mouth of the Labrador Sea. Other animals large and fast enough to catch salmon and swimming over these eddy systems in spring are the harp and hood seals. Killer whales also may be salmon predators and minke whales (Sergeant, 1963) to a small extent. The porbeagle which I examined from the area had eaten two large *mentella* redfish from the pelagic school and there is no evidence regarding whether the various mammals which inhabit the area significantly prey on salmon or whether the redfish and smaller fishes are so much more abundant that these are the main sources of food. In the colder waters of the outer coasts and of the fjords of West Greenland and in the Labrador Current, if the salmon are forced deeply enough by cold surface water the Greenland shark could feed on them but these sharks are probably usually deeper than the salmon range. However, in 1951 a salmon was found in the stomach of a Greenland shark in Umanak Fjord (Hansen and Hermann, 1953). Also, Dr Paul Hansen (5 September 1966) has informed me that on 2 October 1930 he examined a Greenland shark caught by longline at 220 m depth near Frederikshåb, which had two salmon in its stomach. Greenland sharks are becoming much more plentiful in this area since the fishery for this shark for its liver has ceased. Dr Hansen also writes that two porbeagles were taken in West Greenland in September 1964 and that one of them (total length 2.2 m, taken in a salmon gill net in Ikertoq Fjord) had the remains of Atlantic salmon in its stomach.

In the records of salmon caught at sea (Balmain and Shearer, 1956) salmon were found in shark stomachs on five occasions. On two occasions 1 salmon was found in the stomach, but in the other three shark stomachs 3, 8, and 10 salmon were found indicating that the salmon were travelling in a school at sea and that the shark could readily capture them. The species of the shark is not mentioned but Menzies (1931) for the same records reports 3 salmon in the stomach of a shark about 3 m long, 8 salmon in the stomach of a shark 4.7 m long, and 10 salmon, 4.5–5.4 kg, in the stomach of a shark 7.6 m long.

Age and length

The percentage of 2-year river-life fish in our small sample is slightly greater than that of Hansen (1957) on a much larger sample of salmon from the West Greenland coastal area but is lower for 3-year-olds and higher at greater ages (Table 10). Hansen's (1956) earlier age readings on West Greenland salmon had shown only small numbers of 2-year-olds but larger numbers of 3- and 4-year-olds (Table 10). For the present paper we shall neglect these age readings in our discussion, assuming that the later readings are more indicative of the present situation.

The fact that all but 2 of 38 salmon were 1+ sea-year salmon, the potential spawners at 2+ sea-years, and that no 0+ sea-year fish, the potential grilse spawners, were caught in spite of using some small-meshed nets agrees with the findings of Hansen (1957, 1965) and with the general principle in northward migration of pelagic fishes that the larger fish migrate farther northward than the smaller fish. Only two 2+ sea-year fish were caught. This 2:36 may represent the ratios of older fish present, but very likely the mesh sizes used, 127–140 mm, were not large enough to hold the larger fish securely, especially under the rough conditions of hauling. The largest 2+ sea-year fish was feebly secured by the part of the head anterior to the opercula.

North American rivers (Table 10) typically produce 3-year or older smolts with only a small proportion of 2-year-olds and with 1-year-olds being very exceptional. In the Bay of Fundy and in Maine there is a predominance of 2-year-olds. Toward the north the percentage of older smolt ages increases, with a large percentage of 4- and 5-year-olds and some 6-year-olds and an occasional 7-year-old. Thompson (1935) reports and figures a salmon from the Hamilton Inlet region with a clear 8-year river life. In 1964, annual salmon landings as reported by ICNAF south of Subarea 1 were: Subarea 2, 440 tons; Subarea 3, 705 tons; Gulf of St. Lawrence north (4R, S), 238 tons; Gulf of St. Lawrence south (4T) 620 tons; east coast of Nova Scotia and Bay of Fundy, 115 tons. Landings of Atlantic salmon from the United States Atlantic rivers are negligible. From the map showing the distribution of the salmon catch in the Canadian Maritimes in 1930 in Huntsman (1931), and assuming the same present distribution, it is evident that only a very small proportion of the Canadian salmon landings are caught near the rivers at the head of the Bay of Fundy where 2-year smolts predominate. In the southern part of the Gulf of St. Lawrence, also, only a relatively small percentage of the salmon come from the Margaree area where a high proportion of 2-year smolt ages is reported for the coastal salmon, and most of the landings from the area off the Miramichi River and in Bay Chaleur where 3-year-old smolts predominate. The northern Gulf of St. Lawrence has few 2-year smolts. The reports by Menzies (1926), Macfarlane (1928) and Menzies and Macfarlane (1928*c*) of 34–56% 2-year-old and 61–39% 3-year-old smolts from the Moisie River of the northern Gulf are opposed to the reports by other authors of older smolts for this general area and to Belding's (1938) report of ca. 67% 3-year-old and ca. 33% 4-year-old smolts from the same river. In the Newfoundland-Labrador area most of the landings are from Labrador and the northeast coast of Newfoundland (Templeman, 1966) areas of high smolt ages.

Salmon from the St. John River of the Bay of Fundy, which in the past has supported a fairly large salmon fishery near its mouth, are apparently not typically distant migrants but seem to remain close to or in the Bay of Fundy.

Compared with the small likelihood of a high percentage of salmon from Canada with a 2-year river life being found in northern waters, in England, Scotland, and Ireland the percentage of 2-year-old smolts is very high (Table 11). In the papers we have seen, a high percentage with a river life as great as 4–7 years is found only in northern Norway.

Canadian salmon landings in 1964 were about one-quarter as great as those of Europe. Most of the European salmon tags found in Greenland were from Great Britain and Ireland with landings twice as great as those of Canada and none from Norway with landings about the same as Canada's. Landings a little larger than those of Canada came from the Baltic area. Dr Börje Carlin of Sweden informed me in May 1966 that about 800,000 smolts, 50–100,000 per year have been marked in the Baltic area. None of these have been definitely recorded from West Greenland, but one has been recaptured in East Greenland and one from an unknown Greenland locality. Very few smolts have been marked in recent years from the west coast of Sweden at the entrance to the Baltic, but of these two have been recaptured in West Greenland.

The salmon caught on our Greenland cruise were so few that there is probably little significance in the small differences in percentages of fish with a 2-year river life (50, 69, and 60%) and in the percentages of 3- to 6-river-year fish between the three main areas considered: Labrador Sea, West Greenland banks, and west of Cape Farewell and Cape Desolation. The percentages of 2-river-year fish are, however, so high as to be well above the Canadian average, especially for the northern populations. It is possible that the movement toward the northern eddy systems and West Greenland is greater from the southern than from the northern populations of Canadian salmon. There is some evidence in favor of this from the smolt tagging of Kerswill (1955) and Elson and Kerswill (1955) from the Miramichi River of the Gulf of St. Lawrence and the Pollett

TABLE 10. Smolt ages in rivers and coastal regions of North America and West Greenland.

Rivers or coastal areas	Literature references	Smolt ages in years, %								Total fish examined	Year fish collected
		1	2	3	4	5	6	7	8		
Penobscot R. and vicinity, Maine[a]	Kendall, 1935	...	67	29	4	...	...	...	...	48	1915–19—?
St. John R., N.B., Fundy (drift net in estuary)[b]	Huntsman, 1931	...	72	28	0.5	...	...	...	...	192	1930
Pollett R., N.B., Fundy[c]	Elson, 1957	...	90–95	ca. 5–10	...	...	...	...	...	ca. 2,000	...
NE Margaree R., N.S., Gulf[c]	White, 1939	...	7	92	1	...	...	...	...	...	1938
Margaree R. (neighbouring coast), N.S., Gulf[d]	Huntsman, 1939	0.7	60	36	3	...	...	...	...	740	1935
Miramichi R., N.B., Gulf, estuary and adjacent sea[b]	Kerr, 1961	...	19	78	3	...	...	...	...	436	1929
" " " "[b]	Blair, 1935	...	15	78	7	0.2	...	...	...	1,557	1931
" " " Estuary drift net[b]	Belding & Préfontaine, 1939	...	23	66	10	0.5	...	...	...	3,179	1930–37
Bay Chaleur, N.B., Gulf. Commercial fishery[b]	" " " "	...	0.1	33	59	8	0.2	...	...	930	1931
Grand Cascapedia R., Bay Chaleur, Que., Gulf	Calderwood, 1928	...	6	59	34	1	...	...	...	182	1926
Seven Islands, Que., N Shore, Gulf. Coastal[b]	Belding & Préfontaine, 1961	...	0.7	50	45	4	0.1	...	...	695	1937
Moisie R., Que., N. Shore, Gulf[b]	Menzies, 1926	...	56	39	5	0.3	...	...	...	377	1922–23
" " " "[bf]	Menzies and Macfarlane,1928c	0.4	34	61	4	...	...	...	...	325	1923–24
" " " "[bf]	Macfarlane, 1928	...	47	50	3	0.1	...	...	...	883	1926–27
" " " "[e]	Belding, 1938	...	...	ca. 67	ca. 33	...	...	...	...	...	...
Nabisipi & Natashquan R., Que., N. Shore, Gulf. Estuary[b]	Belding & Préfontaine, 1961	...	0.8	26	62	11	...	...	...	239	1937
St. Augustin R., Que., N Shore, Gulf. Estuary[b]	" " " "	...	...	9	51	37	4	...	...	227	1937
St. Paul R., Que., N Shore, Gulf. Estuary[b]	" " " "	...	...	15	78	7	...	...	...	250	1937
Little Codroy R., Nfld. S entrance Gulf[b]	Murray, 1958	...	34	67	0.6	...	...	...	...	312	1954–55
W Nfld., Gulf. Probably mainly rivers[b]	Belding, 1937	...	7	57	30	5	0.3	...	...	350	1931–34
Bay of Islands, W Nfld., Gulf. Commercial[b]	Blair, 1965	...	2	42	52	4	0.1	...	...	891	1942
Humber R., W Nfld., Gulf. River angling[b]	" "	...	...	21	74	6	...	...	...	34	1942
Cape Ray—Cape Race, S coast Nfld. Rivers[b]	Lindsay & Thompson, 1932	...	7	63	27	3	...	...	...	147	1931
Cape Race—Bonavista, E Nfld. Coastal[b]	" " " "	...	13	51	31	5	...	...	...	354	1931
Cape Race--Bonavista Bay, E Nfld. Coastal[b]	Blair, 1943	...	7	39	38	14	2	...	...	1,099	1939
Notre Dame Bay, NE Nfld. Rivers[b]	Lindsay & Thompson, 1932	...	...	44	40	16	...	...	...	62	1931
" " " " Coastal[b]	Blair, 1943	...	3	29	52	14	2	0.6	...	178	1939
St. Anthony, NE Nfld. Coastal[b]	Lindsay & Thompson, 1932	...	5	29	46	17	2	...	...	3,161	1931
LaScie — St. Lunaire, NE Nfld. including St. Anthony area. Coastal[b]	Blair, 1943	...	0.5	19	39	35	6	0.5	...	577	1939
St. Anthony, NE Nfld. Coastal[b]	Belding & Préfontaine, 1961	...	3	25	56	16	0.5	...	...	380	1938
Battle Hr., S Labrador, Nfld. Coastal[b]	Lindsay & Thompson, 1932	...	...	7	50	36	6	...	...	193	1931
Cape St. Charles — Hamilton Inlet, S Labrador, Nfld. Coastal[b]	Blair, 1943	...	...	9	38	39	13	1	...	622	1939

TABLE 10. (continued)

Rivers or coastal areas	Literature references	Smolt ages in years, % 1	2	3	4	5	6	7	8	Total fish examined	Year fish collected
George R., Ungava Bay[c]	Power, personal communication Sept. 1966	...	...	...	8	21	54	16	2	200	1956
" " "[g]	" "	...	...	...	11	46	36	7	...	114	1956
Koksoak R., " "[c]	" "	...	...	...	11	75	14	...	...	104	1957, 1965
" " "[g]	" "	...	...	1	33	48	18	...	...	106	1957, 1965
Whale R., " "[e]	" "	...	...	...	9	63	24	4	0.3	300	1960
" " "[g]	" "	...	...	...	4	62	31	3	...	169	1960
Kapisigdlit R., W Greenland	Hansen & Hermann, 1953	...	...	...	43	52	5	...	...	...	...
" "	Hansen, 1956	...	...	2	42	50	6	...	...	111	1953–54
Sukkertoppen, W Greenland. Coastal[b]	" "	...	13	61	26	...	...	...	...	38	1954
" " " [b]	" "	...	13	52	29	6	...	...	...	129	1955
W Greenland. Coastal[b]	Hansen, 1957	...	57	34	8	0.6	...	...	...	154	1956
W Greenland banks and Labrador Sea[b]	Author	...	61	18	11	5	5	...	...	38	1965

[a] from adults and post smolts.
[b] from adults.
[c] from smolts.
[d] from adults, maiden fish only.
[e] estimated from parr.
[f] average of percentages.
[g] grilse and 2+ maiden salmon.
Fundy = Bay of Fundy.
Gulf = Gulf of St. Lawrence.

TABLE 11. Smolt ages in some European rivers and coastal regions.

Rivers or coastal areas	Literature references	Smolt ages in years, %							Total fish examined	Year fish collected
		1	2	3	4	5	6	7		
Avon R., Hampshire Co., S England[c]	Jones, 1950	90	9	0.6	...	...	...	...	353	1940
“ “ “ [b]	“ “	91	...	...	...	...	...	...	81	“
Itchen R., “ “ [b]	“ “	92	...	...	...	...	...	...	...	...
Wye R., SW England	Hutton, 1941	5	89	7	...	...	...	...	Very large no.	1908–39
Dee R., Cheshire Co., NW England[c]	Jones, 1949	6	90	4	...	...	...	...	347	1938–39
“ “ “ [b]	Jones, 1953	5	93	2	...	...	...	...	4,062	1937–51
Tyne R., NE England. Coastal[b]	Storrow, 1949	11	81	8	...	...	...	...	5,692	1927–46
Tees R., NE England[c]	Pentelow *et al.*, 1933	...	95	5	...	...	...	...	503	1930–31
British rivers other than the Dee[c]	Jones, 1949	13	81	6	...	...	...	...	542	1938–39
Durwent R., Cumberland Co., NW England[b]	Jones, 1950, 1951, 1953	2	96	3	...	...	...	...	2,194	1946–51
Tweed R., SE Scotland[b]	Menzies, 1923*b*; Macfarlane, 1933*a*, 1933*b*	6	92	3	...	...	...	...	5,057	1921–30
Forth R., SE Scotland[b]	Menzies, 1923*b*	0.7	90	9	...	...	...	...	134	1921
Dee R., E Scotland[b]	Menzies, 1922; Menzies & Macfarlane, 1924*b*, 1926*a*, 1927	0.9	81	18	0.3	0.01	...	...	10,834	1921–24
Ewe R., NW Scotland[b]	Nall, 1933	...	51	45	4	...	...	...	629	1923–31
Don R., NE Scotland[b]	Menzies, 1923*b*	1	62	37	...	...	...	...	280	1921
Spey R., NE Scotland[b]	Menzies, 1923*a*; Menzies & Macfarlane, 1924*a*, 1926*b*, 1928*a*, 1928*b*	0.2	70	29	0.5	0.01	...	...	10,729	1921–25
Findhorn R., NE Scotland[b]	Menzies, 1923*b*	1	92	7	...	...	...	...	255	1921
Thurso R., N Scotland[c]	Allen, 1944	3	90	7	...	...	...	...	1,513	1938
Grimersta R. system, Lewis. Outer Hebrides, Scotland[b]	Menzies, 1927	...	34	61	5	0.3	...	...	803	1925
Hope R. and Loch Hope, Sutherland Co., N Scotland[b]	Nall, 1927	...	56	42	1	...	...	...	186	1920–25
Ballisodare R., Eire. River, tidal portion[df]	Went, 1941*a*	21	78	1	...	...	...	...	1,090	1938–39
Owenduff R., Eire. Mainly river, some estuary[d]	Went, 1941*b*	0.2	94	6	0.3	...	...	...	1,101	1930–39
Waterville R., Eire. River[d]	Went and Barker, 1943	5	86	9	...	...	...	...	698	mainly 1941
Shannon R., Eire. River	Went, 1943	19	80	2	...	...	...	...	...	1927–28
“ “ “ [d]	“ “	12	83	5	0.2	...	...	...	1,250	1941
“ “ “ [df]	Went, 1946, 1950, 1953	16	79	5	0.03	...	...	...	7,039	1944–51
“ “ “ [df]	Twomey, 1957, 1966	19	79	2	...	...	...	...	8,946	1952–61
Moy R., Eire[bf]	Twomey, 1958	19	79	2	...	...	...	...	3,178	1954–56
Erne R., Eire[bf]	Twomey, 1961	11	85	4	...	...	...	...	...	1954–59
Nidelven R., S Norway[d]	Dannevig, 1949	1	49	46	4	...	...	...	...	1911–13

TABLE 11. (continued)

Rivers or coastal areas	Literature references	Smolt ages in years, % 1	2	3	4	5	6	7	Total fish examined	Year fish collected
" " [d]	" "	...	41	56	3	0.2	...	...	1,497	1922–39
Tovdalselven R., S Norway[df]	" "	...	32	64	5	...	...	...	...	1909–10
" " [d]	" "	0.3	32	66	2	...	...	...	375	1925–32
Arendal, S Norway[d]	" "	...	34	61	5	...	...	...	366	1925–31
Kristiansand, S Norway. Coastal[b]	Dahl, 1911	...	23	66	11	0.6	...	...	2,279	1908–09
Trondheim district, mid-W Norway. Coastal[b]	" "	...	11	71	17	0.9	...	...	682	"
E Finmarken, N Norway. Coastal[b]	" "	...	4	50	40	6	...	...	371	"
Repparfjord R., N Norway	Dymond, 1963	...	...	...	18	45	32	5	...	...
Torne, Kalix, Lule and Pite R. N Sweden, Gulf of Bothnia[bf]	Alm, 1928	...	6	58	36	0.6	...	...	285	...
Ume R., N Sweden, Gulf of Bothnia[bg]	" "	...	54	43	3	...	...	...	146	...
Mörrum R., 1916–23, S Sweden, Baltic[bf]	" "	6	82	12	...	...	...	...	994	1916–23
Oloron R., France (Adour R., Bay of Biscay)[c]	Jones, 1949	26	73	1	...	...	...	...	77	1947
" " " [c]	Vibert, 1950	58	42	0.2	...	...	...	...	492	1946–48
Baltic, Poland. Coastal & sea. Small[bf]	Dixon, 1931, 1934	...	...	48	37	16	...	...	170	1925–33
" " " " Large, drift-net[bf]	" " "	...	10	67	22	1	...	...	464	1928–33
" " " " " Large, lines[bf]	" " "	...	39	54	7	...	...	...	97	1928–33

[b] from adults.
[c] from smolts.
[d] from adults (maiden fish).
[f] average of percentages.
[g] south of Torne, Kalix, Lule, and Pite R.

River at the head of the Bay of Fundy in which all 15 returns for southern Labrador were from the Pollett River.

The high percentages of fish with a 2-year river life make it appear likely, however, that there is in the West Greenland and neighbouring areas a large quantity of European fish from the rivers of Great Britain and Ireland, but the 60–69% of 2-year-olds near West Greenland is lower than the usually reported 70 to over 90% in these rivers. Hence, although our information for these areas is not exhaustive, significant numbers of these West Greenland salmon, also, are presumably from Canada or from European areas with higher river ages than those of Great Britain and Ireland. The older 4, 5, and 6 river-year fish could come largely from the northern Canadian salmon rivers since it appears likely that the Norwegian area — the other source of fish with high river ages — probably does not contribute greatly to the West Greenland population. Hansen (1965) records no captures in Greenland of smolts or salmon tagged in Norway, but relatively few were tagged. The stock of native salmon from the West Greenland Kapisigdlit River is so small that it makes a negligible contribution to the fishery.

Length-weight

Hansen (1965) presents a length-weight curve for round fresh salmon taken off Fiskenaesset, 3 October 1964. Our lengths, however, were total lengths to the mid-fork of the caudal fin, whereas Hansen's lengths were greatest total lengths to the tip of the lower lobe of the caudal fin with this lobe extended back to its greatest length. From our data these lengths of Hansen's should be reduced by 6.0% (3.6 cm) at 60 cm, 5.7% (3.7 cm) at 65 cm, 5.6% (3.9, 4.2, and 4.5 cm) at 70, 75, and 80 cm to change them to fork lengths. With the lengths thus reduced Hansen's weight curve is 0.5 kg at 62 cm, 0.4 kg at 65 cm, 0.45 kg at 70 cm, and 0.5 kg at 75 cm, higher than our weight curve. This indicates that when ocean migration is complete, although coastal migration is presumably continuing, in the excellent feeding found near the coast the salmon become fatter, increasing considerably in weight relative to length. Above 731 mm, our weight curve is from only two fish. Dymond's (1963) salmon weight curve, again for only a small number of fish from North American and European literature sources, agrees with our curve at 620 mm and is slightly below our curve at 760 and 800 mm. The weight level of Lindsay and Thompson (1932) for a few Newfoundland salmon, presumably coastal, is so far above our curve at the smaller sizes (0.9 kg at 600 mm, 1.45 kg at 660 mm, 1.35 kg at 690 mm, and 0.9 kg at 750 mm, although agreeing reasonably well at 800–860 mm) that these coastal weights should be checked again. The fish may have been fatter or have had more food.

The greater weight of the salmon from the West Greenland banks in early August and from the Labrador Sea in late August than for the salmon west of Cape Farewell and Cape Desolation in late August and in the Labrador Sea in July is paralleled, as would be expected, by greater girths in the localities with greater weights. The amounts of food in the stomachs were also greatest on the West Greenland banks and least in the fish off Cape Farewell and Cape Desolation most of which had a thin appearance as though they were near the end of a long migration.

Sex ratio and stage of sexual maturity

The sex ratio 14 male:22 female agrees with the general predominance of females in 2 sea-year salmon.

The males were all definitely immature with no indication of development of the testes toward sexual maturity. Only two females showed much enlargement of the eggs or ovaries. For one of these, the 861 mm 2+ sea-year female taken in the Labrador Sea on 19–20 July with an egg diameter of 2.0 mm and ovarian volume of 65 cc, it is possible that it would have proceeded to a river to spawn in the same year. The 1+ sea-year female taken west of Cape Farewell on 21–22 August with an egg diameter of 1.8 mm is very unlikely to be spawning in the same year.

Meristic characters

It does not appear to be worthwhile to compare our dorsal and anal fin-ray and our vertebral counts for *Salmo salar* with those from most other investigators. Rounsefell (1962) has summarized the situation for North American Salmonidae including *Salmo salar* and notes that methods of counting both the anterior fin-rays including or excluding the hidden rays were highly variable and often not even described adequately. Vertebral counts also vary in relation to the most posterior elements counted and more often than not the method of counting was not adequately defined, nor the locality from which the fish were obtained.

Methods of taking gill-raker counts may be less variable but this cannot be certain. Our counts of gill rakers from the first arch on the left side (range 17–24, average 21.0 for 37 specimens) are higher than those of Kendall (1935) for the Penobscot River in Maine (17–21 for 65 specimens) and than those of McCrimmon (1949) from the Royal Ontario Museum (average 19.8 for 41 specimens), and considerably higher than those of Wilder (1947) from Canadian rivers of the Maritimes and Quebec (average 18.8, for 28 adult salmon) and from three Nova Scotian rivers (average 18.3 for 52 Atlantic salmon parr).

Gill-raker counts for the first gill arch and also for the lower limb which might be more accurate, are therefore worth following further. Pectoral rays should also generally be counted by the same methods. These are quite similar for Wilder's (1947) average 13.9 and for our collection, 13.8.

The importance of meristic information in determining the native river areas of West Greenland salmon can only be estimated when salmon parr or smolts or preferably salmon from North American and European river systems have been studied intensively for these characters in the same way as the Greenland salmon.

Food

The stomach contents, principally larval squid, *Gonatus fabricii*, in the Labrador Sea and launce with some capelin on the West Greenland banks, were apparently the most abundant food available near the surface. Secondary foods over deep water were paralepids and Greenland halibut fry. In the shallower parts of the West Greenland banks, except on the northern part of Store Hellefiske Bank, launce were very abundant and cod also were coming into the surface layers at night apparently to catch launce with some capelin. Hansen (1965) found the salmon, while close to the Greenland coast in autumn, to be eating mainly euphausiids and capelin with some launce. Thus the food changes when the salmon enter the coastal water.

Parasites

Margolis (1958) found that *Lepeophtheirus* from European Atlantic salmon, from Pacific salmon (genus *Oncorhynchus*) and from North American Atlantic salmon (from the literature) were the same species *Lepeophtheirus salmonis*. Kuitunen-Ekbaum (1933) studied the tapeworms from European and Canadian Atlantic salmon and concluded that these tapeworms were *Eubothrium crassum* showing no fundamental differences between areas.

As with meristic characters, research on the parasites of the salmon known to be native to the North American and European rivers will be necessary before parasites can be used to held separate these fish in the intermingled population at West Greenland. (See Margolis, 1965, for a summary of similar studies on Pacific salmons.) Our observations were only on the larger and more obvious parasites.

Rosen (1919) says that in Europe the procercoid stage of *Eubothrium crassum* occurs in *Cyclops strenuus* and *Cyclops serrulatus* and the plerocercoid stage in *Perca fluviatilis*.

There are indications in our observations that the percentage of salmon possessing tapeworms, *E. crassum*, may increase with the length of river life. This should be investigated further and if so it may be that tapeworms will be more frequent in the Canadian salmon. This is indicated also by the greater percentage of salmon (including also salmon of short river life)with tapeworms in the Labrador Sea closer to the Canadian area. Numbers of fish examined, however, are too small and the intangibles in the discussion too great for more than indications that the subject is worthy of further investigation.

Hoar (1939) found 95% of 203 adult salmon taken in the Margaree River area of the eastern Gulf of St. Lawrence between 14–26 June 1937 to be infested with tapeworms. After this date the average fell to 38% between 28 June–12 July. There was less feeding in this latter period and Hoar concluded that the tapeworms were dropped when the salmon ceased feeding. Presumably only the obvious proglottids were noticed and it is uncertain whether or not the heads were retained.

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Seasonal Population Dynamics of *Calanus finmarchicus* (Gunner) in the Northwestern Atlantic, 1958 - 61

BY E. V. VLADIMIRSKAYA[1]

Abstract

Analysis of data from 810 plankton samples taken at 194 stations in 1958-61 shows that *Calanus finmarchicus* is abundant in the Northwest Atlantic in subarctic and Labrador water masses. Its southern limit is the 10° C surface isotherm marking the northern edge of the northern Atlantic Current (100 specimens/m^2). The greatest abundance (up to 750,000 specimens/m^2) occurred during the spring months in the region of the Labrador Current. During all seasons *C. finmarchicus* was most abundant in the region of the Labrador Current over the north and northeastern edge of the Grand Banks of Newfoundland and in branches of the Current over the eastern part of the Bank.

Introduction

During the International Geophysical Year (IGY) and the year of International Geophysical Cooperation (IGC) a great amount of data on the composition and distribution of plankton in the North Atlantic was collected by Soviet workers. Based on the material collected the qualitative composition and distribution of biomass of food zooplankton was reported by Kusmorskaya (1959, 1960), Kanaeva (1960, 1962, 1963), Yashnov (1961, 1962) and Vladimirskaya (1962, 1964, 1965).

Analysis of the material shows that the food zooplankton consists mainly of boreal fauna of which *Calanus finmarchicus* (Gunner) is its main component. This paper presents a study of the seasonal distribution and time of reproduction of the species in the area investigated.

Materials and Methods

Samples of plankton collected during the IGY and the IGC from R/V *Michail Lomonosov* (Cruises II, IV, VII, and XI) and R/V *Sevastopol* (Cruise XIV) are analysed in this paper (Fig. 1).

Plankton was sampled with a small Juday net (diameter of opening, 36 cm) made of No. 38 silk gauze from standard horizontal layers starting from depths of 500 or 1,000 m upward. A total of 810 samples was obtained at 194 stations. All samples were examined for the number of eggs, nauplii, and males and females. All copepodite stages were counted individually.

Hydrological conditions in the area surveyed are determined by the interaction of warm Gulf Stream water and the cold water of the Labrador Current. Material collected by the R/V *Michail Lomonosov* in the autumn of 1958 (Cruise IV) enabled Mamaev (1960) to determine the boundaries of the different water masses in the central North Atlantic. The use of his chart and analysis of the hydrographical data obtained during Cruise II have enabled us to compile a similar chart for the spring of 1958 (Fig. 2). This chart is referred to in the present study of distribution of plankton.

The southern boundary of the mass distribution of *Calanus finmarchicus* in the area is, according to data obtained in March-April, 1958, the surface 10°C isotherm, i.e., the approximate boundary of the distribution of boreal fauna. South of the boundary *Calanus* occurs in negligible numbers and mainly at greater depths.

Spring

The spring pattern of *Calanus* distribution is shown from the data obtained in March-April 1958 and March 1960 (Fig. 3).

The greatest abundance of *Calanus* (350,000 - 750,000 specimens per square meter of the surface down along the water column, which for the purpose of convenience will be referred to in this paper as specimens/m^2) was observed on the northern and northeastern slopes of the Grand Banks of Newfoundland which are influenced by the cold Labrador water masses. The lowest values (500-2,500 specimens/m^2) were recorded on the northern edge of the North Atlantic Current.

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[1] All-Union Research Institute of Marine Fisheries and Oceanography (VNIRO), Moscow, USSR.

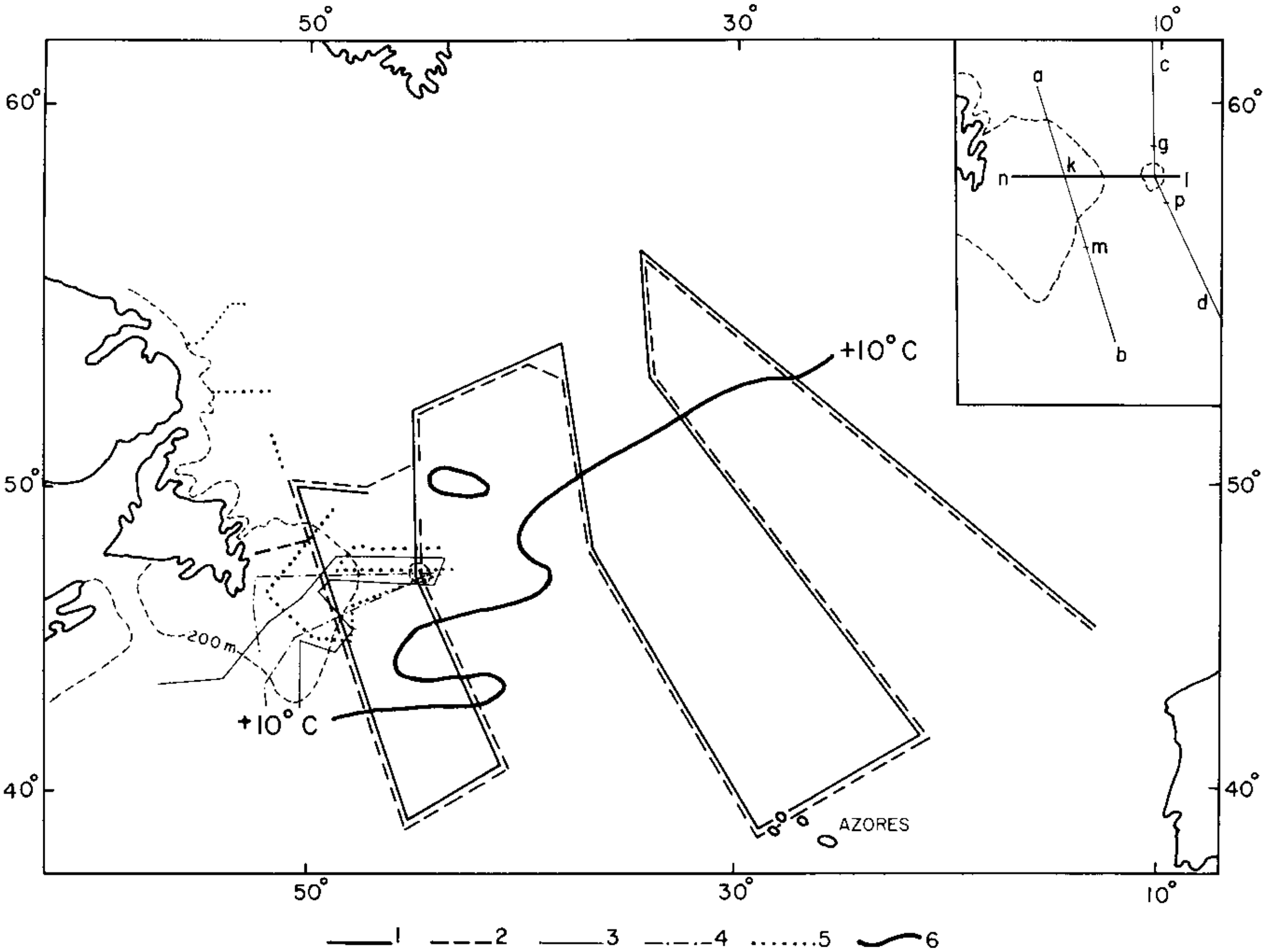

Fig. 1. Soviet cruises during IGY and IGC in the Northwest Atlantic, 1958-61.
(1) R/V *Michail Lomonosov*, Cruise II (6 April - 2 May 1958).
(2) " " " Cruise IV (18 October - 2 December 1958).
(3) " " " Cruise VII (17 - 31 March 1960).
(4) " " " Cruise XI (25 September - 7 October 1961).
(5) R/V *Sevastopol* Cruise XIV (7 July - 11 August 1959).
(6) 10° C isotherm (Cruise II).

East of 30°W long in the subtropical water masses and on the border of the habitat of *Calanus* in the North Atlantic Current, no reproduction of the species was observed in the second half of March. At that time *Calanus* inhabited mainly the 200–500 m layers. Females and males constituted 10–40% of the population and no eggs or nauplii were present. Sampling was carried out in the western area of the subarctic water masses in the second half of April which is believed to be the beginning of the biological spring in the area. Males and females constituted not less than half of the population, the counts showed 600 eggs/m³ and up to 240 nauplii/m³.

By contrast at the same latitude (55°N) but on the Labrador shelf, the breeding period of *Calanus* starts in late May or early June (Semenova, 1964).

On the southwestern and southeastern slopes of the Grand Bank the reproduction of *Calanus* commences in late February or March. In late March nauplii constituted 80–90% of the population (3,000–4,000 specimens/m³). Of the total

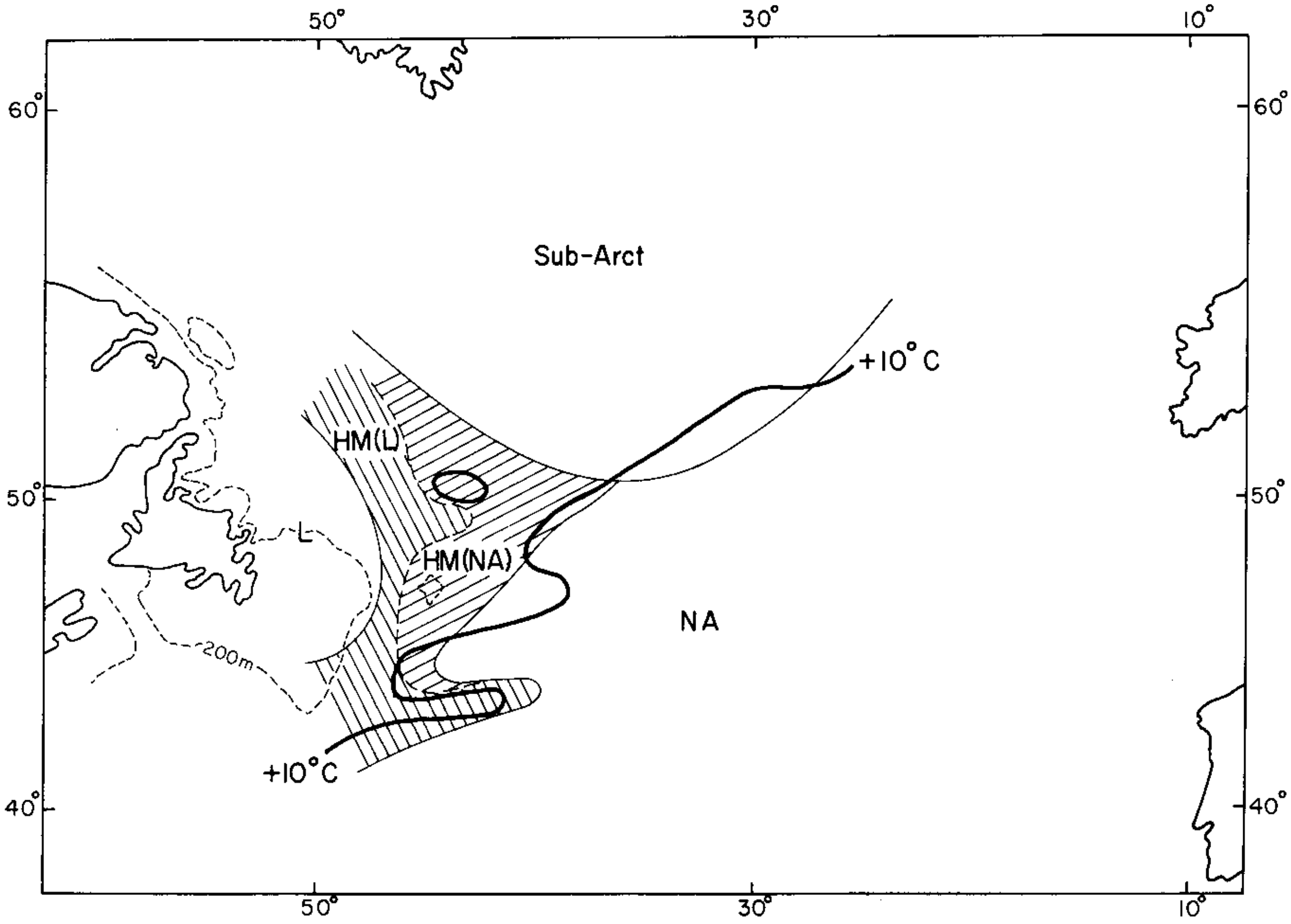

Fig. 2. Distribution of water masses in the Northwest Atlantic, spring 1958
L — Labrador water masses.
HM (L) — part of the zone of horizontal mixing influenced by Labrador current.
NA — North Atlantic water masses.
HM(NA) — part of the zone of horizontal mixing influenced by North Atlantic current.
Sub-Arct — Subarctic water masses.

numbers in the copepodite stages, 75% were in stages I–III.

Mass development of *Calanus* was observed along the whole eastern slope of the Grand Bank in April, males and females constituted less than 10% of all copepodite stages, stages I–III amounting to 80% (Fig. 4). Counts showed 1,200 eggs/m³ and 900 nauplii/m³. At the same time males and females were more abundant on the northeastern slope, but young copepodite stages were still rare. On the northern slope reproduction had just started, males and females averaged 82%, stages I–III only 4%, the counts showed 2,300 eggs/m³ and 320 nauplii/m³.

Section "a-b" (Fig. 1) extends northward from the North Atlantic Current area (Fig. 2, area NA) along the eastern part of the zone of horizontal mixing (Fig. 2, area HM (L)) where the effect of the Labrador Current is very pronounced. The northern half of the section was located in the Labrador water masses proper (Fig. 2, area L). A gradual movement of the biological spring from south to north was observed along the section. The Grand Bank shallows are distinctive in the general pattern due to their specific conditions.

However, the advent of biological spring does not depend only on latitude. At the same

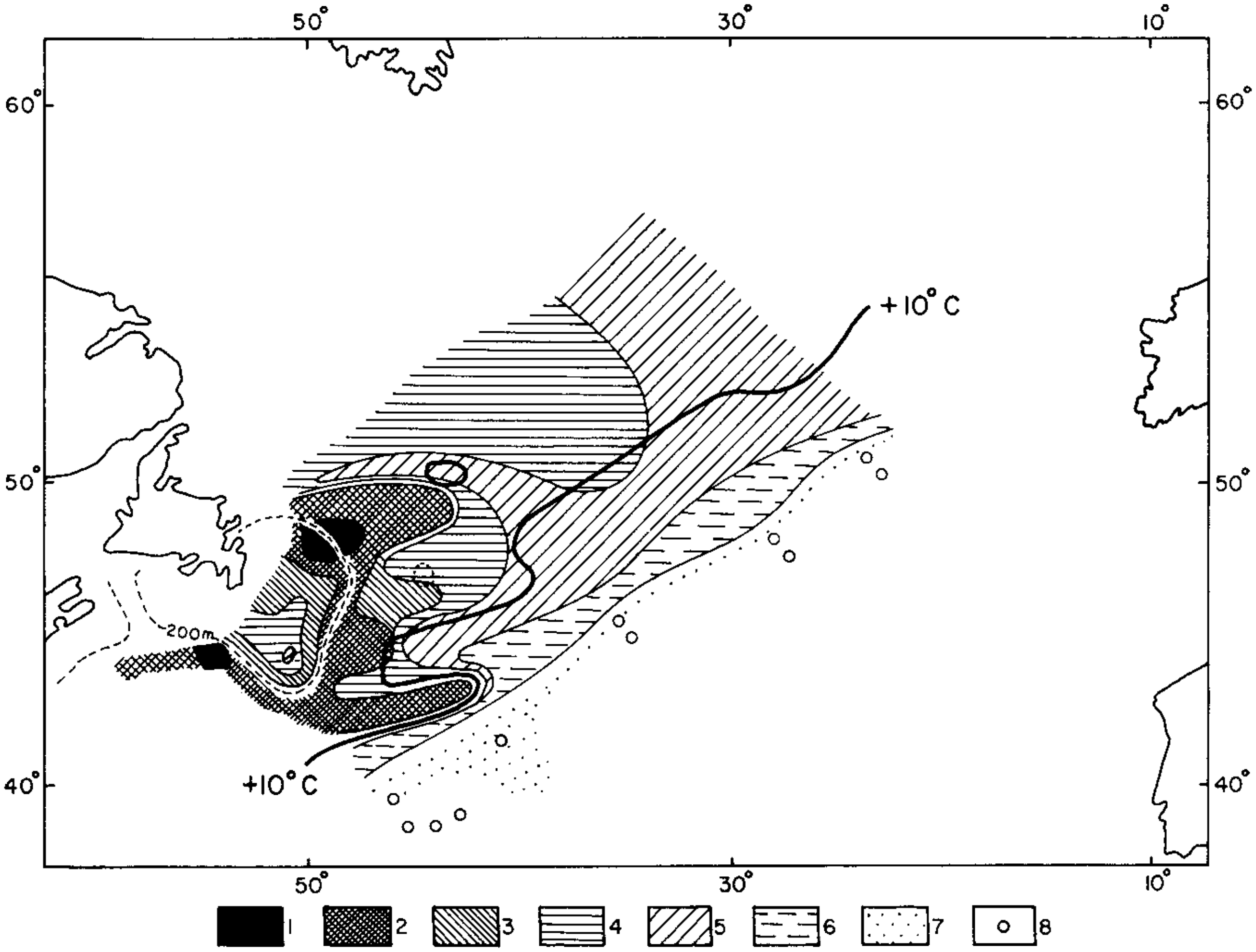

Fig. 3. Distribution of *Calanus finmarchicus* in spring (thousands of specimens per sq m); (1) more than 500; (2) 100–500; (3) 50–100; (4) 10–50; (5) 1–10; (6)0.1–1; (7) less than 0.1; (8) No occurrence.

latitudes the breeding of *Calanus* commences in places affected by different water masses at different times.

Along section "c–d" (Fig. 1) the intensive development of *Calanus* was observed only in two locations (Fig. 2, area HM(L)) where the waters of the Labrador Current intrude into the zone of horizontal mixing where they are strongly influenced by the North Atlantic Current. In the area of intrusions the young copepodite stages constituted about 50% of the all copepodite stages (Fig. 4) and the number of eggs increased 1,000–4,000/m³, whereas in the zone of horizontal mixing which is strongly influenced by the North Atlantic Current (Fig. 2, area HM(NA)) females were dominant and only 130–200 eggs/m³ were found. The population in the North Atlantic water mass proper (Fig. 2, area NA) consisted mainly of copepodite stage V; no eggs or nauplii were found.

The biological spring, and therefore other seasons do not arrive in different places at the same time. Evidence for this is available through observations made along the latitudinal section "k–l" crossing the shallow waters of the Grand Bank and Flemish Cap (Fig. 1, section "k–l"). This section extends westward from the zone of horizontal mixing influenced by the North Atlantic Current (Fig. 2, area HM (NA)) then crosses the Labrador Current zone (Fig. 2, area L) and terminates on the Grand Bank shallows.

Observations made in mid-April, 1958, and

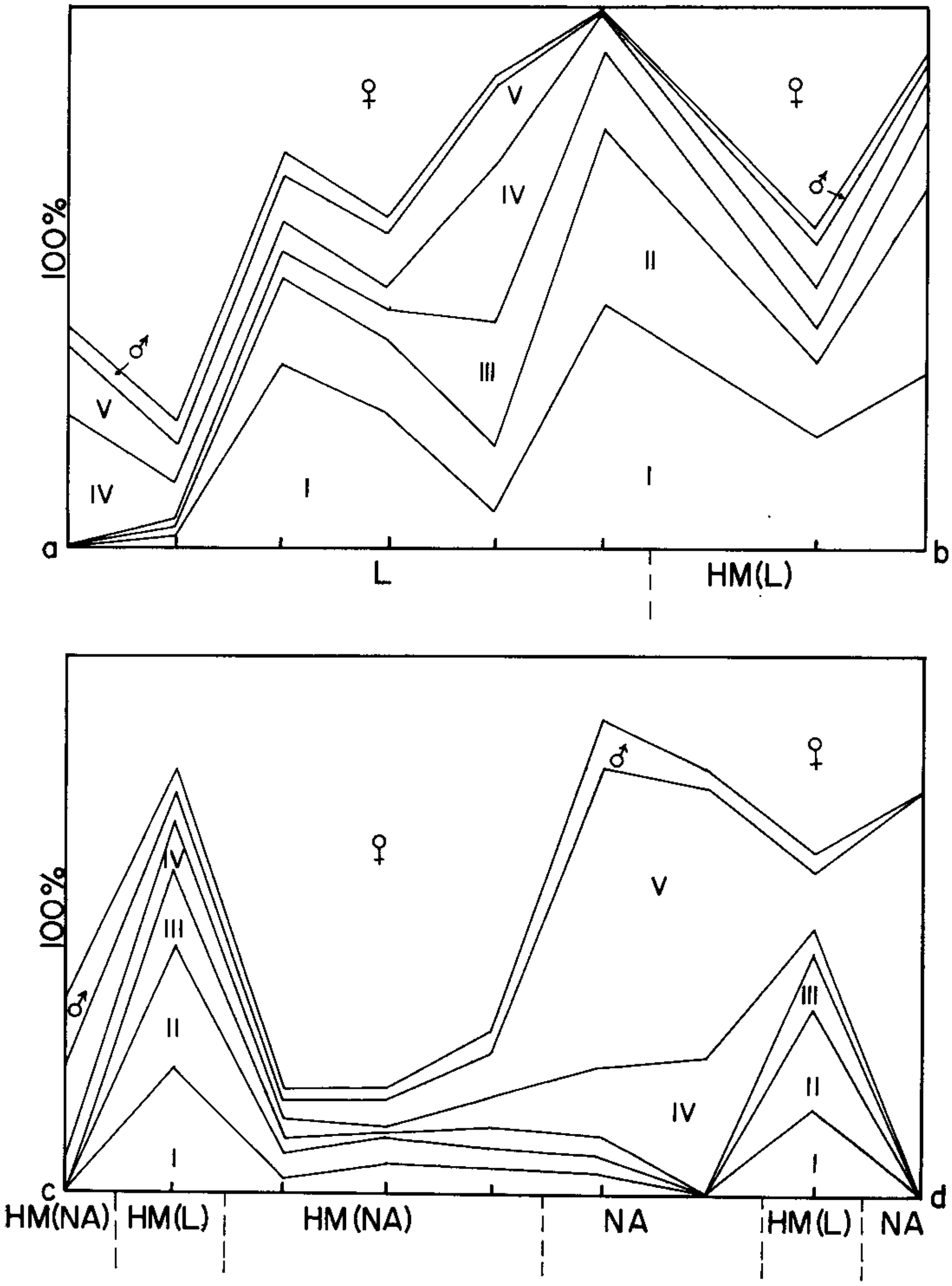

Fig. 4. Frequency of occurrence of copepodite stages of *Calanus finmarchicus*, spring 1958, Sections "a–b" and "c–d".

L — Labrador water masses.
HM(L) — part of the zone of horizontal mixing influenced by Labrador current.
NA — North Atlantic water masses.
HM(NA) — part of the zone of horizontal mixing influenced by North Atlantic current.
Sub-Arct — Subarctic water masses.

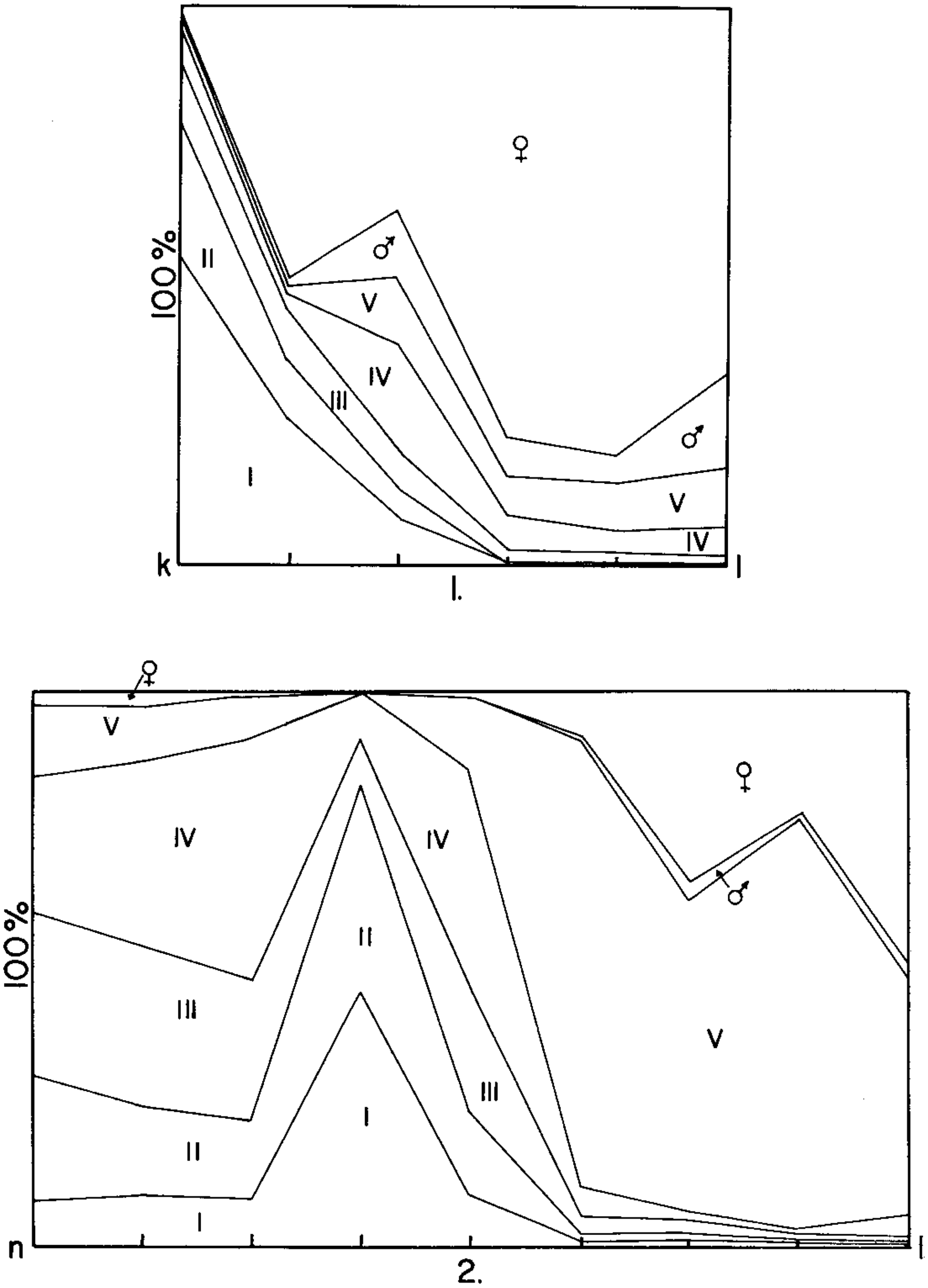

Fig. 5. Frequency of occurrence of copepodite stages of *Calanus finmarchicus* in different water masses. (1) spring 1960, Section "k – l"; (2) autumn 1961, Section "n – l".

in March, 1960, showed that the breeding season had just started in the central part of the Flemish Cap Bank and on its slopes (Fig. 5 (1)). Females and males constituted about 85% of the copepodite stages, but no stages of I and II occurred. The number of eggs of *Calanus* was insignificant, only 20–60/m³; nauplii were either absent or their numbers were 4–7 times lower than that of eggs.

Toward the Grand Bank shallows the composition of *Calanus* showed marked changes, viz, the number of males and females was considerably reduced and young copepodites occurred in ever-increasing numbers. In the region between the Grand Bank and Flemish Cap, in the zone influenced by the Labrador Current, the breeding season was very active and the number of eggs (2,400–3,500/m³) was 3 or 4 times greater than that of nauplii.

Observations revealed an opposite relation on the Grand Bank shallows: the number of eggs was small, only 200/m³, but the number of nauplii was 5 times as great. Copepodites stages I – III made up 91% of all stages with stage I amounting to over 50%. The distribution of *Calanus* is very peculiar in the area investigated. A small number of eggs occurred both in the central Grand Bank shallows and in the Flemish Cap area. However, in the shallows, the small egg number was associated with much heavier abundance of nauplii and dominance of young copepodite stages and in the Cap, as is shown above, males and females were dominant. This suggests that no eggs had yet appeared on the Grand Bank while there was no hatching yet on the Flemish Cap.

The intensive reproduction of *Calanus* follows the development of phytoplankton (Fig. 6).

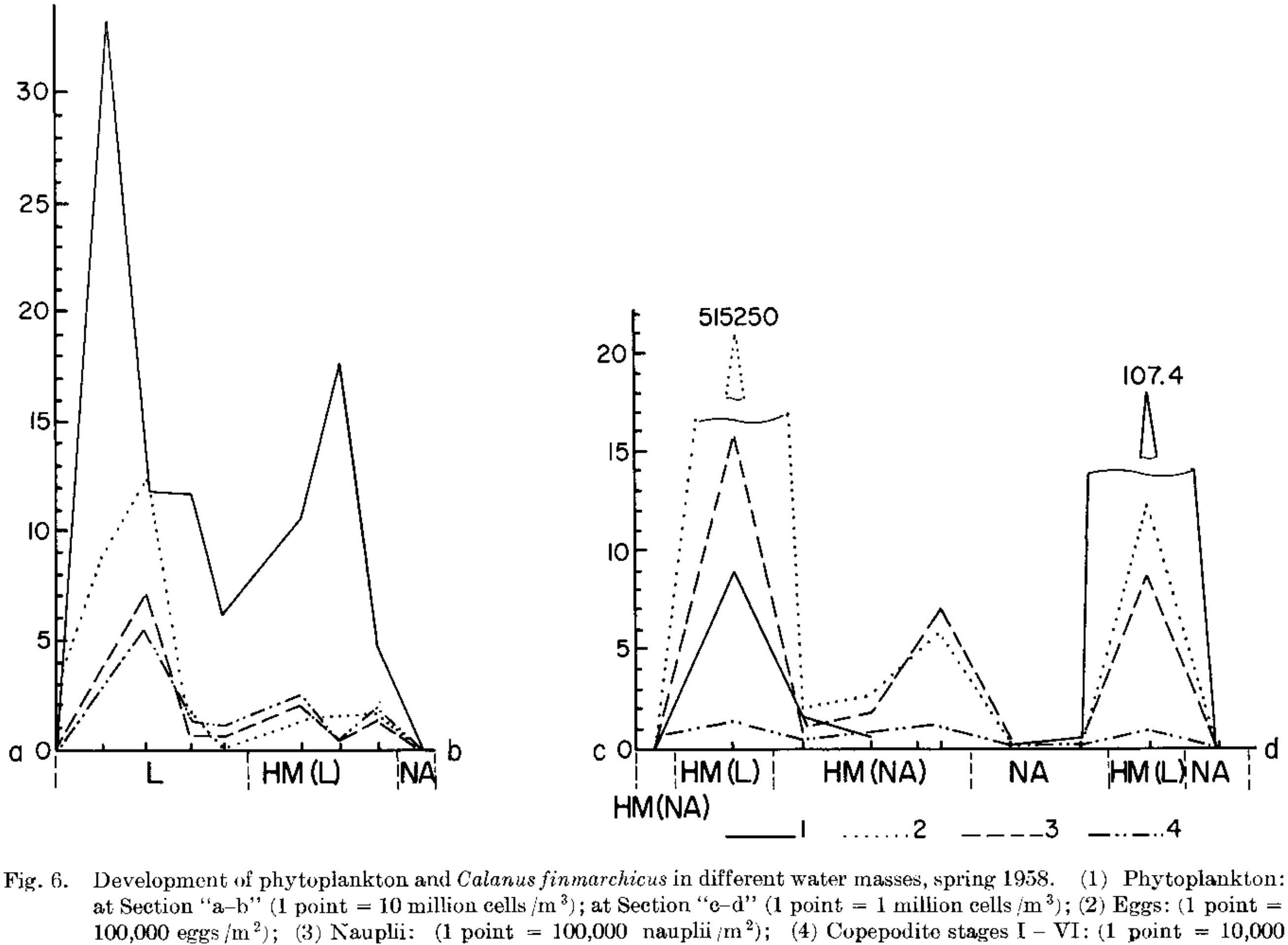

Fig. 6. Development of phytoplankton and *Calanus finmarchicus* in different water masses, spring 1958. (1) Phytoplankton: at Section "a–b" (1 point = 10 million cells/m³); at Section "c–d" (1 point = 1 million cells/m³); (2) Eggs: (1 point = 100,000 eggs/m²); (3) Nauplii: (1 point = 100,000 nauplii/m²); (4) Copepodite stages I – VI: (1 point = 10,000 specimens/m²).

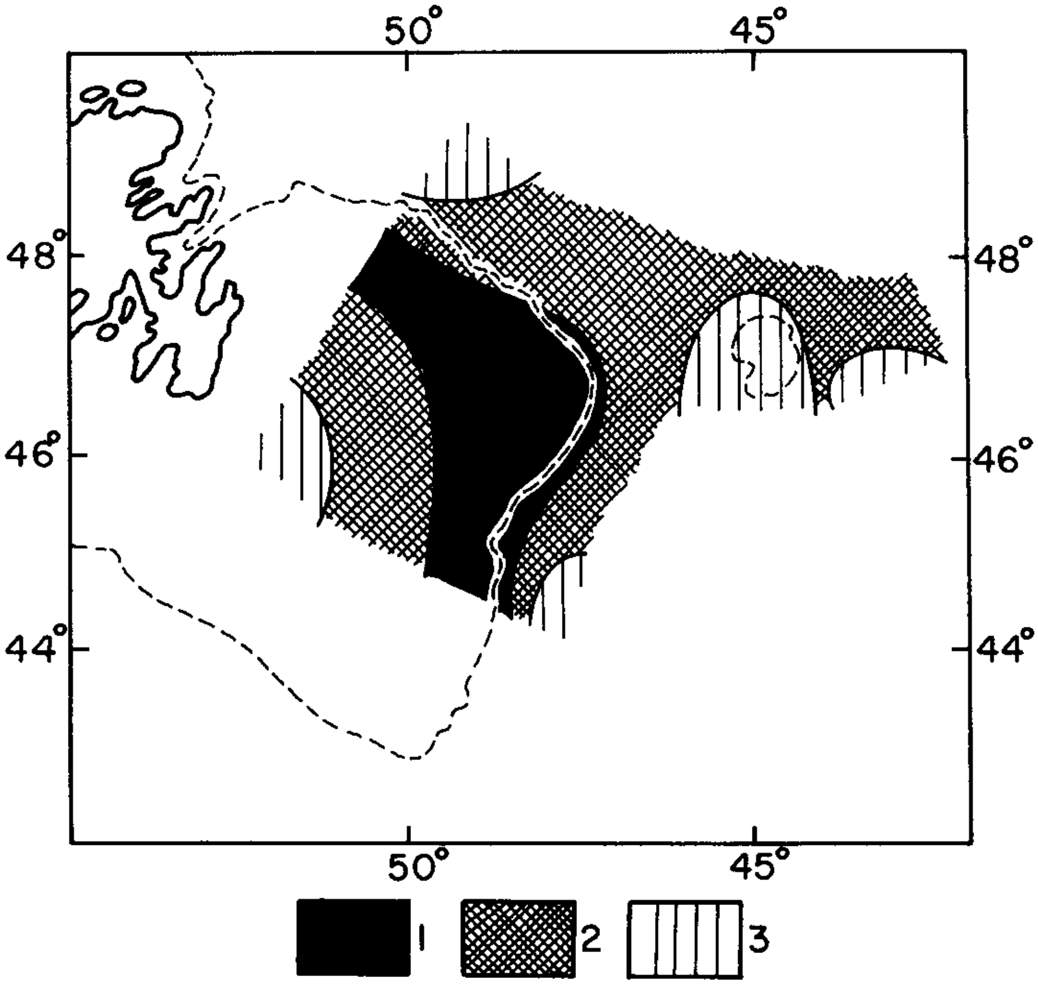

Fig. 7. Distribution of *Calanus finmarchicus*, summer 1959 (thousands of specimens per sq m): (1) over 500; (2) 100–500; (3) 10–100.

This figure is compiled from Movshan's (1962) data. The peak of development of phytoplankton in Labrador waters was always followed by most intensive reproduction of *Calanus*.

Summer

In July 1959 some zooplankton hauls were made mainly in the 0–50-m layer with a few hauls made in the 0–100-or 0–200-m layers.

Figure 7 shows that *Calanus* was observed to be most abundant in the 0–50-m layer (which is also true for spring) in the northeastern Grand Bank area influenced by the Labrador Current (500,000–700,000 specimens/m^2) and to the northeast of Flemish Cap (450,000 specimens/m^2).

Mass development of *Calanus* was observed on the Grand Bank. Eggs occurred in insignificant numbers while the number of nauplii amounted to 5,000–12,000/m^3. Of all the copepodites 75–98% were in stage I. To the north of Flemish Cap stages III–IV or II–IV were dominant (82–94%). Eggs and nauplii either were not present in the samples or occurred in negligible numbers (200–500 specimens/m^3). In the mixed waters of the North Atlantic Current (to the east of the Grand Bank and on the Flemish Cap shallow waters) the samples contained only 10–50 specimens/m^2 and not more than 100 eggs and nauplii/m^3. Stages IV and V made up 80–90% of all the copepodites in the area.

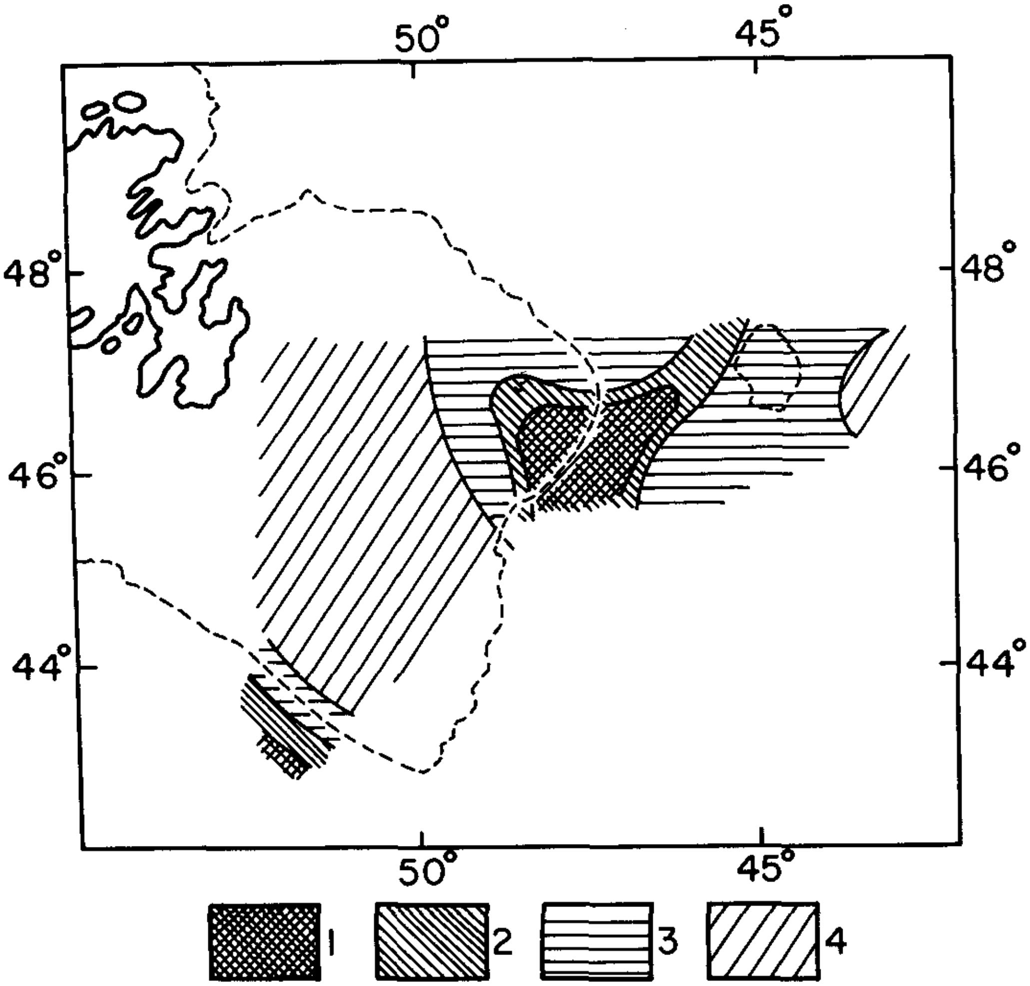

Fig. 8. Distribution of *Calanus finmarchicus*, autumn 1961 (thousands of specimens per sq m): (1) 100–500; (2) 50–100; (3) 10–50; (4) less than 10.

Autumn

Early Autumn

In early autumn (late September to early October 1961) the abundance of *Calanus* ranged from 100 to 320,000 specimens/m² (Fig. 8). The greatest abundance was observed in the vicinity of the eastern and southwestern slopes of the Grand Bank, 320,000 and 107,000 specimens/m² respectively. The lower values are specific for the southwestern part of the Grand Bank shallows (100–200 specimens/m²).

Similar to the spring observations water masses differed markedly from one another as to the composition of the population of *Calanus*. On the northern and northeastern edges of the Grand Bank shallows influenced by the Labrador water masses the population consisted in the main, of young forms. Near the southeastern slope and to the east of the Grand Bank, in the zone of horizontal mixing of water, the population turned to wintering.

In early October latitudinal section "n-l" was made. It resembled section "k-l" made in spring, but it was more extensive (Fig. 1)). On the northern edge of the Grand Bank shallows stages I–III constituted over 50% of all the copepodites (Fig. 5(2)), while nauplii occurred individually. The main stream of the Labrador Current passed along northeastern part of the Grand

Bank (middle part of the section). Copepodite stages I–III constituted 90%, the number of nauplii was over 200/m³. In the central part of the Flemish Cap and on its slopes, that is, in the North Atlantic Current waters, the young forms were represented in negligible numbers with stage V and females prevailing. The wintering stock (stages IV and V) accounted for 65–90% on the southwestern part of the Grand Bank shallows and near its southwestern slopes.

The population of *Calanus* inhabited largely the layers below 100 m. More than half of the population occurred in the off-bottom layer due to negative water temperatures of both on the southern and northern edges of the Grand Bank shallows. On Flemish Cap and its slopes almost all the population was below 100 m. In the areas of greater depths the majority of *Calanus* preferred the layers below 200 or even 500 m. Only young forms occurred on the upper layer.

Therefore, by early October 1961 *Calanus* had entered the wintering phase in almost all the areas investigated with the exception of the zone influenced by the Labrador water masses.

Late Autumn

In the autumn of 1958 (late October to early December), samples were taken at the same stations as in spring 1958 (Fig. 1). The greatest abundance of *Calanus* (100,000–150,000 specimens/m²) was observed in the area influenced

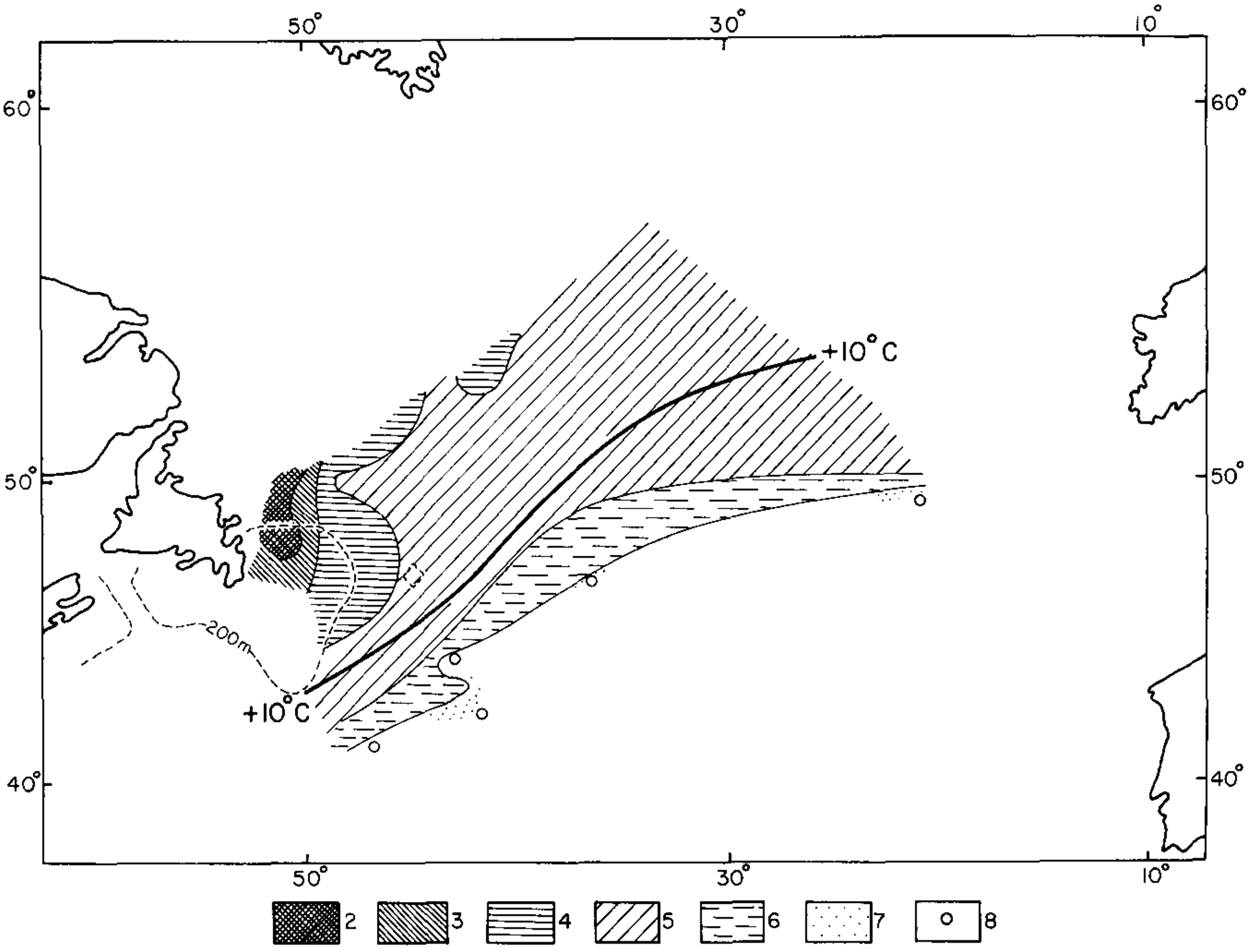

Fig. 9. Distribution of *Calanus finmarchicus*, late autumn 1958. (2) 100–500; (3) 50–100; (4) 10–50; (5) 1–10; (6) 0.1–1; (7) less than 0.1; (8) No occurrence.

by the Labrador water masses, viz: on the northern edge of the shallows and northern slope of the Grand Bank (Fig. 9), whereas the lower abundance, as in spring, was registered at the northern edge of the North Atlantic Current (40–300 specimens/m^2).

The high abundance of the population of *Calanus* in the Labrador waters can be explained, to a considerable extent, by the availability of young forms. The number of nauplii ranged from 9,000 to 12,000/m^3 and stages I–III amounted to 75% of all the copepodites (Fig. 10, section "a–m").

Extending southward the percentage of young forms decreases. Near the eastern slope of the Grand Bank (Fig. 10, section "g–p") a wintering population was discovered with copepodite stages IV and V amounting to 96%. This part of the section was in the zone of horizontal mixing. The composition of the population along the section varied with the changes in depth at which the bulk of *Calanus* occurred. Where the bulk of the population was represented the young forms (northern slope and northeastern shallows of the Grand Bank) concentrations of *Calanus* were found in the upper 50–m layer. In the zone of horizontal mixing the wintering stock was as low as 200 m. The same pattern is apparent for section "c–d" (Fig. 1). In autumn no sharp alternations of water masses were observed as compared to the spring of 1958. The abundance and ratios of age groups were relatively uniform along the section. Figure 10 (section "g–p") shows the ratios of age groups on Flemish Cap and its slopes. About 90% of the total copepodites were in stages IV and V. The bulk of *Calanus* occurred in the off-bottom layer on Flemish Cap and at depths of over 200 m on its slopes.

In the area influenced by the subarctic water masses the frequency of occurrence did not exceed 10,000 specimens/m^2. The population consisted mainly of stages IV and V and inhabited the layers below 200 m.

Along the northern edge of the North Atlantic Current, at the extremity of the habitat of *Calanus*, only about 100 specimens/m^2 occurred. Most of them were at stages IV and V and inhabited the layers below 200 m.

Therefore, the population of *Calanus* turns to wintering in the area investigated in October and leaves the upper layers, except in the area influenced by the Labrador water masses where a considerable number of copepodite stages I–III and even nauplii occurred until late November.

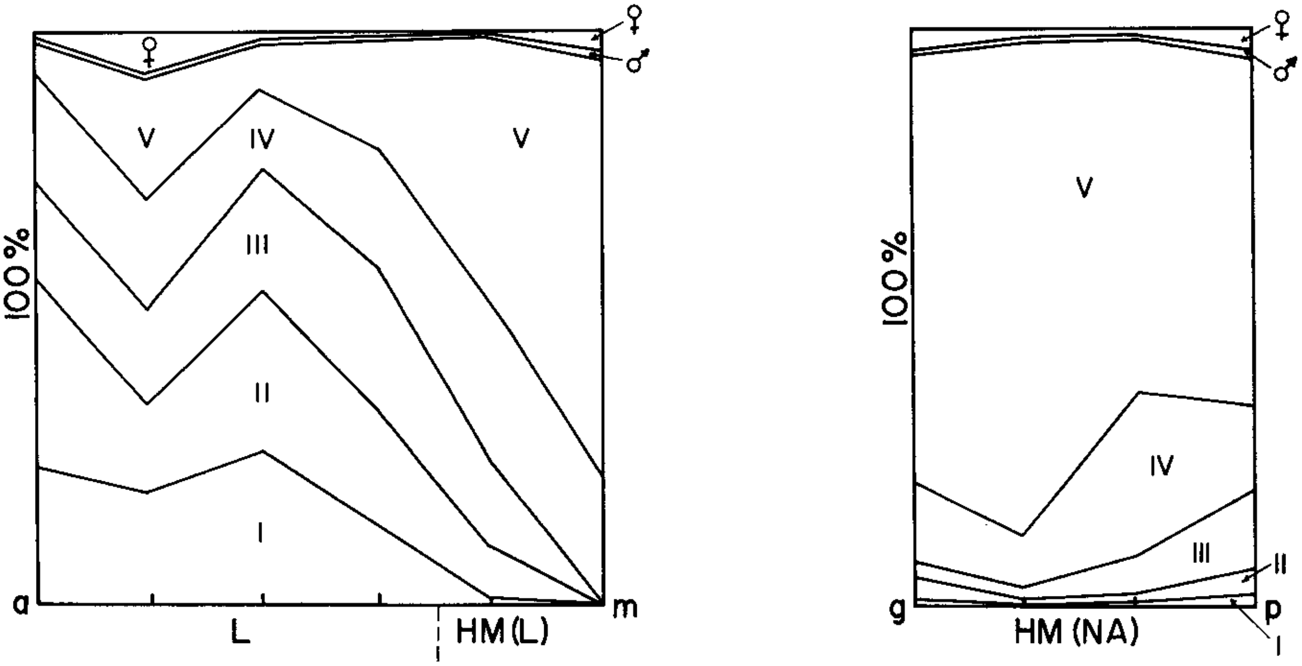

Fig. 10. Frequency of occurrence of copepodite stages of *Calanus finmarchicus*, autumn 1958, Sections "a–m" and "g–p".

Conclusions

From analysis of the data collected in 1958–61 the following conclusions are reached. In the Northwest Atlantic *Calanus finmarchicus* is distributed in the subarctic and Labrador water masses, an area characterized by boreal fauna. It is believed that the southern boundary of the habitat is the northern edge of the North Atlantic Current where the frequency of occurrence is not more than 100 specimens/m².

The greatest abundance (up to 750,000 specimens/m² including nauplii and copepodite stages I–VI) is observed in spring, that is in the period of mass development in the area influenced by the Labrador Current.

The spring breeding season for *Calanus* starts south of the Grand Bank and gradually extends northward in late February or early March. In the subarctic water masses at 55°N lat, breeding is observed in late April, on the Labrador Shelf in the waters of the Labrador Current it occurs in late May or early June.

Calanus starts reproducing at the same latitudes at different periods, depending on the peculiarities of the water masses it inhabits.

The development of the second generation is very likely to start on the Grand Bank in July and on Flemish Cap a little later. In early October the population turns to wintering throughout the area and sinks to lower layers.

To the northwest of the Grand Bank the second generation seems also to start developing in August, which explains the occurrence of young forms observed on the northern edge of the Grand Bank in October–November.

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Diurnal Variation in the Catches of American Plaice, *Hippoglossoides platessoides* Fabr., from the Grand Bank

BY T. K. PITT[1]

Abstract

Data on the catches at various time periods obtained from records of a group of commercial otter trawlers and also from a research cruise of the *A. T. Cameron* indicated that more American plaice, *Hippoglossoides platessoides*, were caught during daylight than at night. There was less diurnal variability in the catches from shallow depths (100 m) than from deeper water (155 m and up) for both research and commercial catch data.

The average size of American plaice caught during the daylight hours was greater than that of the night catches.

This species apparently moves away from the bottom at night and are thus less vulnerable to the otter trawl than during the daylight hours.

Introduction

A knowledge of the diurnal variation in the average size of the catches of commercial groundfish species is of interest to the fishing fleet since fishing activity can possibly be regulated in line with the periods of peak abundance. For fishery biologists, this knowledge is necessary when use is made of the catch per unit effort as an index of abundance of fish, especially in routine surveys by research ships where an area is surveyed by sampling at a number of fixed stations.

The largest commercial fishery for American plaice, *Hippoglossoides platessoides*, in the Northwest Atlantic occurs on the Grand Bank in those localities where the slope of the bank is in contact with the cold section of the Labrador Current (Fig. 1) in depths ranging approximately from 70 to 230 m.

In conversation with several fishing captains, they reported that the catches of plaice were less for night drags than those made during daylight hours. This report contains a study made from statistics of the commercial fleet and a limited amount of research vessel data.

Material and Methods

The captains of commercial trawlers operating from St. John's Newfoundland keep detailed records of locality, date, depth, time, and catch for individual sets. From the records for 1960–63, the average catch per hour for the different time periods as used in this paper, have been calculated.

In addition a cruise of the research ship *A. T. Cameron* provided additional information on the diurnal variation in the catches of American plaice. In October 1964 a total of 61 one-hour tows was made using the standard 41.5 otter trawl with the codend lined with nylon netting. Fishing was carried out at 100, 155, and 183 m on the eastern slope of the Grand Bank at about 45°N and 49°W (Fig. 1) and a tow was made every 3 hr.

For the commercial trawlers the data were tabulated by 2-hr periods and the records for April–September 1960–63, were used. Unfortunately the time of sunrise and sunset will vary, but it was necessary to combine records from these months to give sufficient data for the various combinations over a fairly short period of years when the size of the fishable population was probably fairly constant.

Results

The catches for both the research and commercial vessel data indicate a greater average catch during daylight than during the darkness period.

Comparison of day and night catches in relation to depth

The catches of American plaice from the 100 m sets of the *A. T. Cameron* varied less over the 24-hr period than did the catches from 155 and

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

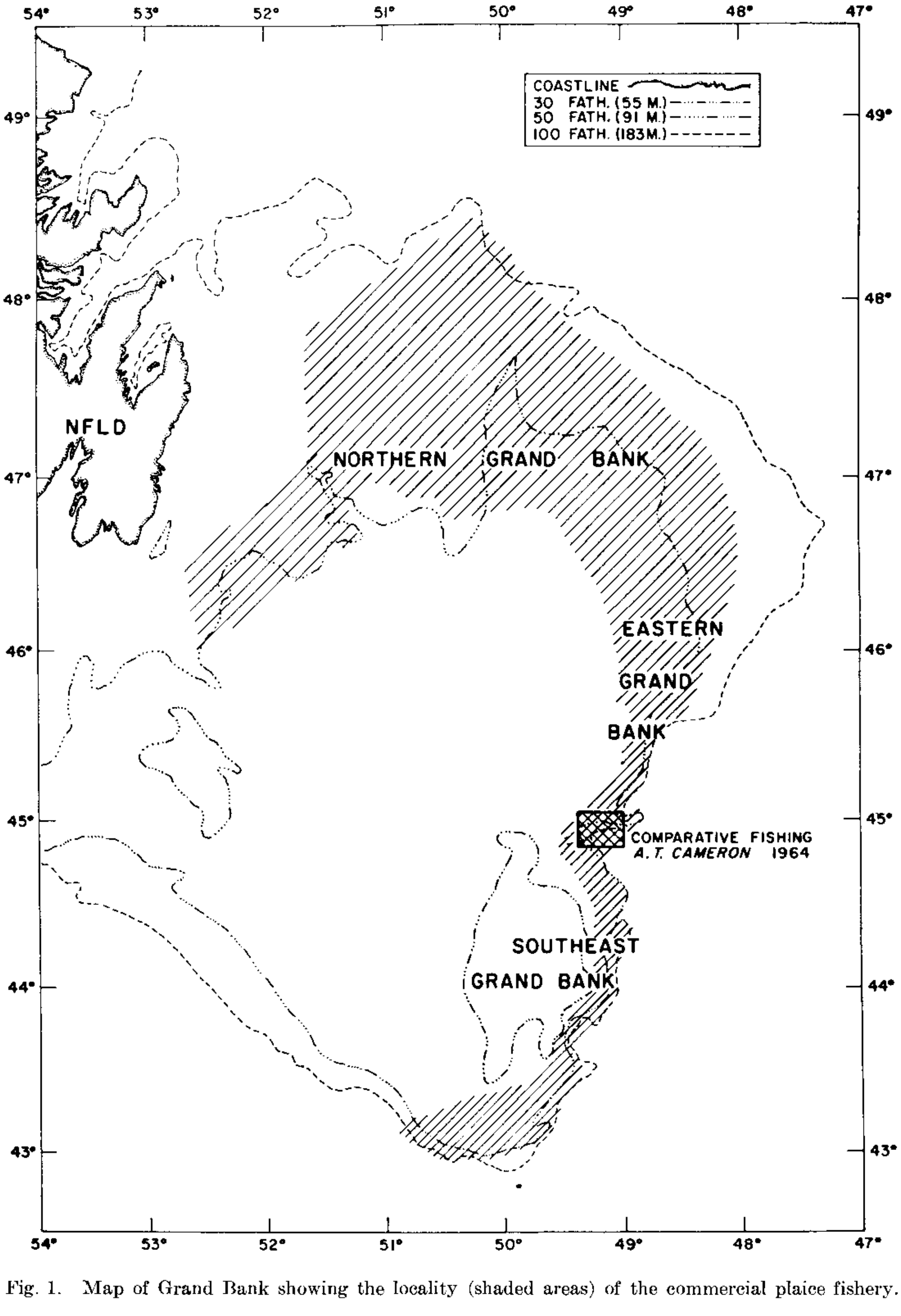

Fig. 1. Map of Grand Bank showing the locality (shaded areas) of the commercial plaice fishery.

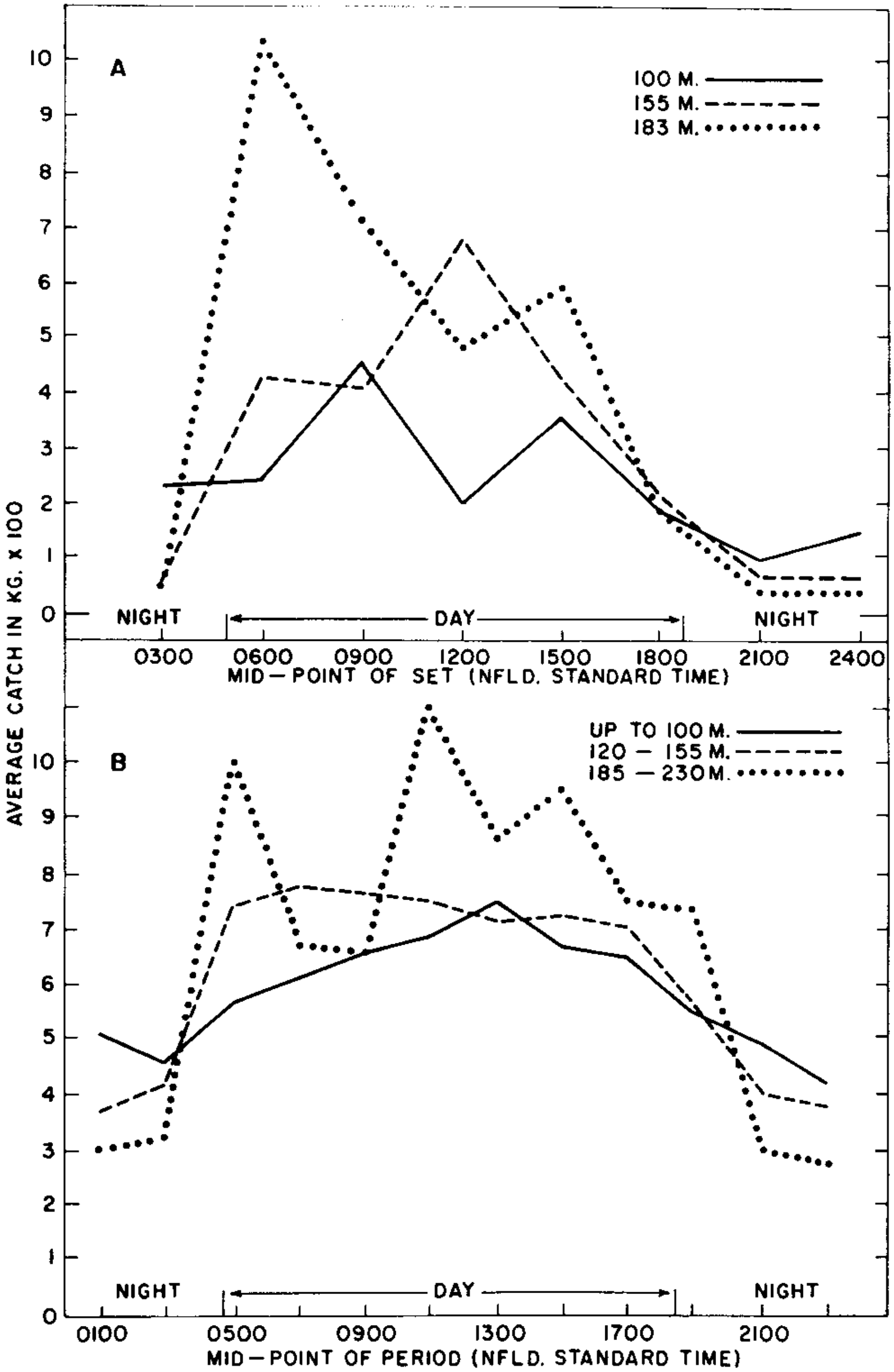

Fig. 2. (A) Average catch per hour for 24 hr fished by the *A. T. Cameron* at the three depths fished, and (B) Average catch per hour by selected commercial trawlers April-September 1960-63 over a 24-hr period for three depth ranges on the eastern slope of the Grand Bank (Fig. 1).

183 m (Fig. 2A). The 100 m catches ranged from an average of 93 kg per hour for a 2100-hr (night) catch to 466 kg per hour for one at 0900 hr (day). Compared to this the 183 m average catches ranged from 25 kg per hour for the midnight period to 1,025 kg per hour for the first daylight set (0600 hr).

For the commercial data a similar relationship was found (Fig. 2B) with the catches for the shallower depths having less variability over the 24-hr period than those from deeper water localities.

The commercial fishery for American plaice on the southeast part of the Grand Bank was in shallower water than for the other two areas (Table 1). For this area nearly 80% of the fishing was in depths of 110 m or less, whereas in the other two areas only 26–37% of the fishing was as shallow as this. Thus, the difference between average day and night catches was less variable than from the other two areas (Fig. 3).

TABLE 1. Percent of the effort of commercial trawlers at five depth ranges for three areas of the Grand Bank.

Depth range	Grand Bank Northeast	 East	 Southeast
m			
70 and under	nil	2.0	26.4
71–110	37.1	24.2	52.4
111–145	43.7	32.8	14.5
146–183	15.0	33.6	4.5
184 and over	4.2	7.4	2.2
Total no. sets	1,194	1,453	2,556

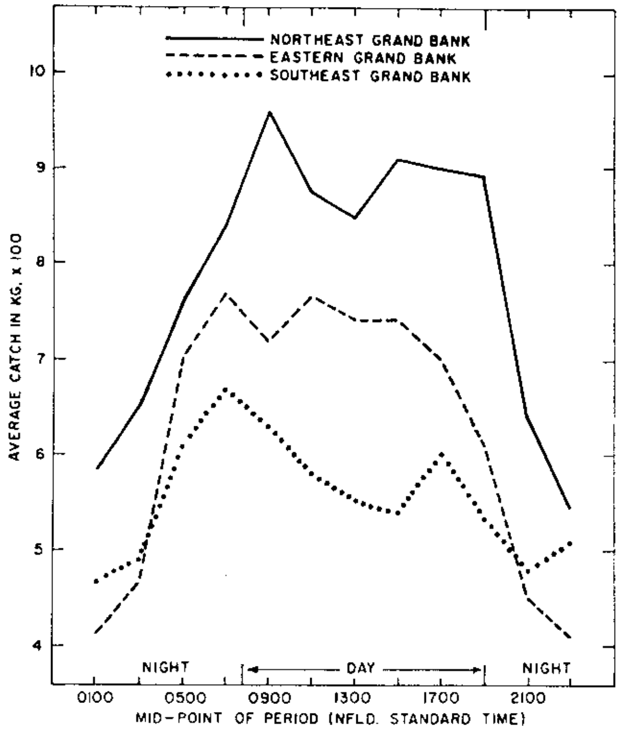

Fig. 3. Average catch per hour by selected commercial trawlers 1960–63 for three areas of the Grand Bank (Fig. 1) April–September.

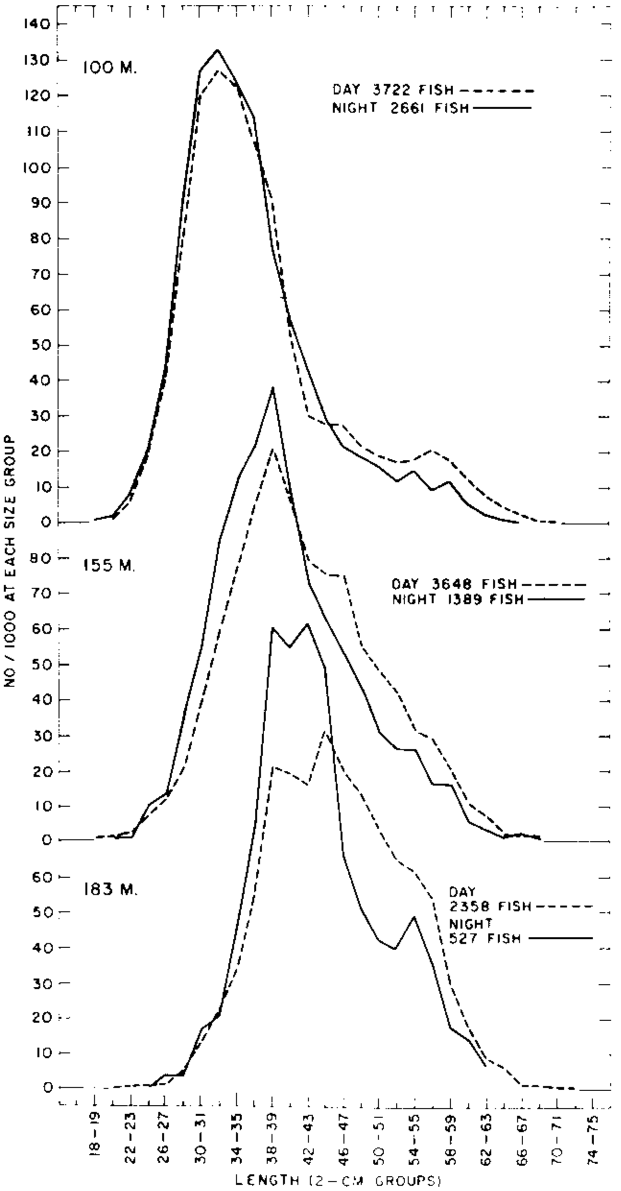

Fig. 4. Length frequencies of American plaice for day and night catches from 100, 155, and 183 m.

Comparison of sizes of plaice for day and night fishing

The average size of the American plaice from day catches was significiantly greater than those for the night catches (Fig. 4, Table 2). The average size of the plaice caught increased with depth and so also did the difference between the average day and night sizes, from 1.26 cm at 100 m to 2.18 cm at 183 m.

TABLE 2. Average size of American plaice for day and night catches — *A. T. Cameron* Cruise 93, October 1964.

Depth	Day	Night	Difference
m	*cm*	*cm*	*cm*
100	37.50±0.15	36.24±0.16	1.26
155	42.04±0.14	40.08±0.21	1.96
183	45.90±0.16	43.72±0.28	2.18

Discussion

Diurnal variation in the catches of commercial trawlers are well known. For flatfish there appears to be differences between species and for the same species from different localities. Jones (1954) for lemon sole, *Microstomus kitt*, and Parrish, Blaxter, and Hall (1964) with North Sea plaice, *Pleuronectes platessa*, and dab, *Hippoglossoides platessoides*, found that almost always the largest catches were at night. In contrast to this Woodhead (1960, 1964) with plaice, and Bagenal (1958) with witch, *Glyptocephalus cynoglossus*, and dab, for the Clyde area, report that the largest catches were during daylight hours. For the Northwest Atlantic Beamish (1966) found that American plaice were caught in larger numbers during daylight hours but the other flatfish: winter flounder, *Pseudopleuronectes americanus*; the greysole, *Glyptocephalus cynoglossus*; yellowtail, *Limanda ferruginea*, had the largest catches during the night.

The information as presented here from commercial trawler and research vessel data point definitely to a greater average catch during the daylight than during the darkness period (Fig. 3, 4).

Flatfish are usually considered to be bottom dwellers, but there are records to show that they do leave the bottom habitat and swim at shallow depths. North Sea plaice have been caught by mid-water trawls well above the sea-bed (Woodhead, 1960) and De Veen (1964) reports sole swimming at the surface near the Dutch coast. In 1958 a research ship operated by the St. John's Station of the Fisheries Research Board of Canada using a surface line trawl caught two American plaice at 9–18 m where the bottom depth was about 146 m.

Harder and Hempel (1954), Woodhead (1964), and De Groot (1964) in aquaria experiments with plaice and sole, showed that flatfish usually remained on the bottom partly covered with sand during bright sunlight and swam actively at all depths during the darkness period. However, De Groot (1964) shows that in light conditions similar to that of the natural habitat, during daylight, plaice move actively along the bottom.

The feeding habits of American plaice for the Grand Bank have not been studied in detail but it is known that those caught on this particular cruise of the *A. T. Cameron* on the eastern slope of the Grand Bank (Fig. 1) were feeding almost exclusively on sand launce, *Ammodytes dubius*. This species is known to make some vertical diurnal movements so that the activity of the American plaice could be related to these.

It is doubtful if the search for food can entirely account for the difference in day and night catches. Plaice from the Northeast Grand Bank generally feed on bottom forms such as mollusks, echinoderms, and polychaete worms, yet the same diurnal variations were noted in the average catch as for the other areas (eastern and southeastern Grand Bank, Fig. 3), where the diet consists primarily of capelin and launce.

Ellis (1956), in the Barents Sea, recorded compact shoals of cod in 183 m during daylight with dispersal at sunset to reform again at sunrise, and Beamish (1966) showed an echogram of American plaice indicating that they move off the bottom during the night. The behaviour of plaice, in the experiments with flatfish by Harder and Hempel (1954) and Woodhead (1964) referred to in a previous paragraph, can be considered a schooling behaviour so that when the flatfish are on the bottom during daylight hours they are more vulnerable to the otter trawl. The fish are disturbed by the footrope moving along the bottom and swept into the net whereas at night they tend to scatter vertically and are less likely to be caught in this type of gear.

No explanation can be offered for the fact that there was less variation between day and night catches from shallow than from deep water, but it is apparent that fish in deep water react to a greater degree to the change in light intensity than do those in a shallower environment.

Experimental fishing in areas where American plaice are feeding on bottom forms is needed as well as a detailed investigation of the feeding habits of this species.

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Natural Hemagglutinins in Marine Fishes

BY KENNETH B. CUMMING[1]

Abstract

A large number of serological crossmatches between 33 species of marine fishes indicated that the blood of many of them contains natural agglutinins. These normal bloods are potential serological reagents for racial studies in fishery work. One example is presented to show the heterogeneity of haddock erythrocytes by using the serum of winter flounder as the differentiating agent.

Introduction

Investigations of the identification of races of fishes have assumed new importance with the advent of serological and biochemical methods of population analysis (Parrish, 1964; Cushing 1964). Several reports review the history (Ridgway and Klontz, 1960), indicate the genetic significance (Sanders and Wright, 1962), and show the application (Sindermann, 1961) of serological techniques in fishery research.

Several techniques are known for distinguishing the red blood cells of one fish from those of another. Recently emphasis has been on techniques that use antisera obtained from closely related or even the same species of fish (Ridgway, 1962). This paper demonstrates the existence of many naturally occurring hemagglutinins in marine fishes which could serve as potential antisera for blood typing. As an example, the sera from winter flounder are used to indicate agglutination patterns in the red blood cells of haddock.

Methods

Fish were obtained from net hauls of the *Albatross IV* in the Gulf of Maine and by angling near Woods Hole.

Whole blood was taken from the heart with disposable syringes (5 and 10 ml). When red blood cells alone were required, a 1-% aqueous solution of the disodium salt of ethylene diamine tetraacetic acid (EDTA) (1 mg/ml of whole blood) was put in the syringe as an anticoagulant. The red cells were centrifuged down, washed three times with 1-% saline, diluted to a 10-% suspension, and then kept in a refrigerator at 4°C. Serum was extracted from blood samples that were taken without anticoagulant, and was frozen in storage vials at -20°C. Cells were not held longer than 1 week, and were usually tested within 2 days. Serum samples, on the other hand, were thawed as needed and refrozen.

Tests for agglutination were made by mixing a drop of suspended red cells with a drop of serum in one chamber of a disposable plastic agglutination tray which contains 96 chambers of a 2.5-ml capacity each. The trays were agitated by hand for 30 min at room temperature and then scored on the basis of degree of agglutination. The scores are expressed as: — (negative); + (a fine, sand-grain appearance); 1+, 2+, 3+, and 4+ (a single clump of cells surrounded by clear serum).

Absorptions were performed by mixing equal volumes of undiluted serum and packed cells in a small centrifuge tube and letting the tube stand for 30 min at room temperature. After separation from the cells by centrifugation, the absorbed serum was decanted and tested for completeness of absorption by mixing a drop of the serum with a drop of cell suspension. One absorption was usually sufficient to remove all the agglutinins which were specific for the absorbing cells. Some hemolysis was seen in most absorptions leaving the supernatant fluid redder than the usual straw color, but subsequent agglutinations were still readily visible in the test chambers.

Natural Fish Hemagglutinins

The general pattern of agglutinations for many of the crossmatches between 33 fish species, arranged according to the phyletic order of the American Fisheries Society (Bailey *et al.*, 1960), is presented in Table 1. All of the crossmatches

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[1] Bureau of Commercial Fisheries Biological Laboratory, Woods Hole, Massachusetts, USA.
Present Address: Bureau of Sport Fisheries and Wildlife, Blacksburg, Virginia, USA.

TABLE 1. Scoring for natural agglutinins in 33 species of marine fish. The scores contain three numbers per block of crossmatches: upper left — number of positive responses, upper right — sum of agglutination scores, and lower centre — number of crossmatches. A zero in place of the upper two numbers indicates no positive responses. Blanks indicate blocks in which no tests were made. The subscripts indicate that cells (c), sera (s), or both (b) may be differentiated by the given crossmatch.

		Sera														
	Cells	*Squalus acanthias* (spiny dogfish) 1	*Raja ocellata* (winter skate) 2	*Raja radiata* (thorny skate) 3	*Dasyatis centroura* (roughtail stingray) 4	*Brosme brosme* (cusk) 7	*Gadus morhua* (Atlantic cod) 8	*Melanogrammus aeglefinus* (haddock) 9	*Merluccius bilinearis* (silver hake) 10	*Pollachius virens* (pollock) 11	*Urophycis chuss* (squirrel hake) 12	*Centropristes striatus* (black sea bass) 13	*Roccus saxatilis* (striped bass) 14	*Pomatomus saltatrix* (bluefish) 15	*Stenotomus chrysops* (scup) 17	*Tautoga onitis* (tautog) 18
1.	*Squalus acanthias* (spiny dogfish)	0 25		9/9 25		0 25	0 25	0 25	0 25	0 25		1/1 25	0 25	0 25	0 25	
4.	*Dasyatis centroura* (roughtail stingray)				1/1 4											
5.	*Alosa sapidissima* (American shad)						4/9 5_s	5/19 5		2/8 5_s		0 5	0 5	1/1 5	0 5	2/2 5
6.	*Clupea harengus* (Atlantic herring)	0 10	0 25	0 25	0 25	0 10	7/4 25	2/1 25		0 25		0 25	0 25	0 25	0 25	14/16 25
7.	*Brosme brosme* (cusk)	1/1 10				0 10	0 5	0 5		0 5		1/1 5	4/3 5	0 5	0 5	0 5
8.	*Gadus morhua* (Atlantic cod)	7/9 25	0 25	4/9 25	0 20	8/20 25_b	0 25	0 25	19/59 25_b	6/13 25_s		0 25	6/7 25	8/8 25	3/3 25	4/4 25
9.	*Melanogrammus aeglefinus* (haddock)	0 25	0 25	0 25	0 25	0 25	0 25	0 25	0 25	0 50		12/43 37	0 37	0 25	2/3 50	0 25
10.	*Merluccius bilinearis* (silver hake)						0 25	3/5 50	0 25	0 21	0 25	5/20 5			4/3 5	
11.	*Pollachius virens* (pollock)	0 25	0 25	10/7 25	0 20	0 25	0 25	0 25		0 25		0 25	5/5 25	0 20	0 25	4/5 25
12.	*Urophycis chuss* (squirrel hake)	9/7 25				0 25	0 45	0 45	0 20	0 45			0 25		0 25	
13.	*Centropristes striatus* (black sea bass)						0 25	0 25	5/5 25			0 25	19/53 25	2/2 25	0 25	15/58 25_s
14.	*Roccus saxatilis* (striped bass)	4/2 25	0 25	0 25	0 20	0 25	0 40	2/1 40	15/13 40	0 25		15/60 15	0 25	10/5 25	5/4 38	6/18 34_s
15.	*Pomatomus saltatrix* (bluefish)	20/12 25	10/17 15	0 25	0 20	0 20	0 25	4/2 25	0 25	0 25		0 25	18/41 25_s	3/3 25	10/6 25	25/38 25
16.	*Selar crumenophthalmus* (bigeye scad)	10/9 25	20/64 25_s	0 25	3/2 20	10/9 25	0 25	10/10 25		0 25		23/52 25_s	0 25	5/4 25	0 25	7/5 25
17.	*Stenotomus chrysops* (scup)	17/9 25	5/8 20_s	5/4 25	0 20	0 25	54/80 125_s	0 25	0 25	0 25		25/99 25	10/40 25_s	5/3 25	0 50	11/36 25_s
18.	*Tautoga onitis* (tautog)	0 25	0 15	0 25	0 20	0 25	0 25	0 25	0 25	0 25		25/49 25	2/5 25	13/8 25	0 25	0 25
19.	*Sarda sarda* (Atlantic bonito)	5/4 25	13/27 50_s	0 25	7/6 30	6/4 50	0 25	0 25	5/5 25	11/7 25	0 20		0 25		17/13 48	
20.	*Scomber scombrus* (Atlantic mackerel)	4/3 20	15/14 15	0 25	7/4 20	0 25	0 25	0 25	0 20	0 25		0 25	2/1 25	1/1 25	0 25	16/21 25_s
21.	*Scomberomorus cavalla* (king mackerel)	3/3 10	6/9 6	2/1 10	8/13 12	2/4 30	0 10	0 10	0 10	2/2 10	0 8		0 10		0 10	
23.	*Prionotus evolans* (striped searobin)	20/26 25	6/3 20	1/1 25	10/8 20	0 25	0 25	0 25	0 25	0 25		0 25	25/82 25	24/39 25_s	0 25	25/100 25
24.	*Myoxocephalus octodecemspinosus* (longhorn sculpin)	0 25					0 25	5/5 41	6/6 25	10/15 16	5/5 25		3/3 25		0 20	
26.	*Macrozoarces americanus* (ocean pout)	0 25					0 25	0 25	0 25				0 25		0 25	
27.	*Paralichthys dentatus* (summer flounder)															
29.	*Hippoglossoides platessoides* (American plaice)						0 15	0 15		0 15						
30	*Limanda ferruginea* (yellowtail flounder)															
31.	*Pseudopleuronectes americanus* (winter flounder)	0 25	15/10 45	31/55 50_b	5/20 20_s	0 25	17/15 110	0 25	0 25	0 25		0 25	5/3 25	4/5 25	15/12 25	8/14 25
32.	*Alutera schoepfi* (orange filefish)	18/23 25_s	5/10 15	8/5 25	15/43 20_s	5/3 25	0 25	0 25	0 25	0 25	0 20		0 25		6/3 25	
33.	*Lophius americanus* (goosefish)	3/2 20	10/22 15_c	2/1 16	0 15	0 20	7/20 15_c	0 15		0 15		0 5	5/9 5	0 5	3/2 5	5/11 5

TABLE 1. (continued)

Sera															
Sarda sarda (Atlantic bonito) 19	*Scomber scombrus* (Atlantic mackerel) 20	*Scomberomorus cavalla* (king mackerel) 21	*Sebastes marinus* (redfish) 22	*Prionotus evolans* (striped searobin) 23	*Myoxocephalus octodecemspinosus* (longhorn sculpin) 24	*Anarhichas lupus* (Atlantic wolffish) 25	*Macrozoarces americanus* (ocean pout) 26	*Paralichthys dentatus* (summer flounder) 27	*Glyptocephalus cynoglossus* (witch flounder) 28	*Hippoglossoides platessoides* (American plaice) 29	*Limanda ferruginea* (yellowtail flounder) 30	*Pseudopleuronectes americanus* (winter flounder) 31	*Aluterа schoepfi* (orange filefish) 32	*Lophius americanus* (goosefish) 33	Cells
$\frac{0}{25}$	$\frac{0}{25}$	$\frac{0}{10}$		$\frac{0}{25}$	$\frac{1/2}{25}$	$\frac{3/5}{25}$	$\frac{4/3}{25}$			$\frac{3/4}{25}$	$\frac{0}{15}$	$\frac{3/2}{25}$	$\frac{25/100}{25}$	$\frac{0}{25}$	1. *Squalus acanthias* (spiny dogfish)
$\frac{8/21}{10_s}$		$\frac{2/8}{4_s}$													4. *Dasyatis centroura* (roughtail stingray)
$\frac{0}{5}$		$\frac{0}{3}$		$\frac{0}{5}$	$\frac{0}{5}$		$\frac{0}{5}$	$\frac{0}{3}$		$\frac{0}{5}$	$\frac{2/7}{5_s}$	$\frac{0}{5}$		$\frac{0}{5}$	5. *Alosa sapidissima* (American shad)
$\frac{0}{25}$		$\frac{0}{10}$			$\frac{0}{34}$	$\frac{0}{10}$	$\frac{0}{30}$	$\frac{0}{25}$		$\frac{0}{25}$	$\frac{0}{25}$	$\frac{0}{25}$	$\frac{3/3}{25}$	$\frac{0}{26}$	6. *Clupea harengus* (Atlantic herring)
$\frac{0}{5}$		$\frac{0}{3}$		$\frac{0}{10}$	$\frac{0}{10}$	$\frac{0}{10}$	$\frac{2/3}{10}$	$\frac{0}{3}$		$\frac{0}{5}$	$\frac{0}{5}$	$\frac{0}{5}$		$\frac{0}{10}$	7. *Brosme brosme* (cusk)
$\frac{0}{25}$	$\frac{4/14}{25_b}$	$\frac{0}{10}$	$\frac{12/22}{25_b}$	$\frac{9/13}{20}$	$\frac{0}{20}$	$\frac{5/12}{25_s}$	$\frac{17/35}{25}$	$\frac{2/5}{25_b}$	$\frac{20/54}{25}$	$\frac{11/7}{25_c}$	$\frac{6/17}{25_s}$	$\frac{9/5}{25}$	$\frac{14/24}{25_b}$	$\frac{1/1}{25}$	8. *Gadus morhua* (Atlantic cod)
$\frac{0}{25}$	$\frac{0}{15}$	$\frac{0}{10}$	$\frac{10/23}{25_s}$	$\frac{0}{20}$	$\frac{0}{25}$	$\frac{5/20}{25_s}$	$\frac{0}{25}$	$\frac{0}{25}$	$\frac{0}{25}$	$\frac{0}{20}$	$\frac{10/40}{25_s}$	$\frac{14/23}{25_b}$	$\frac{0}{25}$	$\frac{0}{10}$	9. *Melanogrammus aeglefinus* (haddock)
					$\frac{15/42}{25_c}$		$\frac{3/2}{5}$					$\frac{15/55}{25_s}$		$\frac{5/20}{10_s}$	10. *Merluccius bilinearis* (silver hake)
$\frac{0}{25}$	$\frac{0}{20}$	$\frac{0}{10}$	$\frac{8/6}{24}$	$\frac{0}{20}$	$\frac{5/3}{20}$	$\frac{4/8}{25}$	$\frac{17/39}{25}$	$\frac{5/3}{25}$	$\frac{17/40}{25_c}$	$\frac{9/6}{25}$	$\frac{10/34}{25_s}$	$\frac{0}{25}$	$\frac{13/11}{25}$	$\frac{0}{25}$	11. *Pollachius virens* (pollock)
			$\frac{19/69}{25_b}$		$\frac{0}{25}$					$\frac{0}{25}$		$\frac{5/6}{25}$		$\frac{1/1}{20}$	12. *Urophycis chuss* (squirrel hake)
					$\frac{0}{25}$		$\frac{13/17}{25_s}$					$\frac{25/77}{25}$		$\frac{0}{10}$	13. *Centropristes striatus* (black sea bass)
$\frac{0}{25}$	$\frac{0}{25}$	$\frac{0}{10}$		$\frac{0}{25}$	$\frac{0}{40}$	$\frac{0}{25}$	$\frac{0}{40}$	$\frac{12/8}{25}$		$\frac{0}{25}$	$\frac{0}{25}$	$\frac{9/14}{40_s}$	$\frac{0}{25}$	$\frac{0}{28}$	14. *Roccus saxatilis* (striped bass)
$\frac{0}{25}$	$\frac{5/5}{25}$	$\frac{0}{10}$		$\frac{8/4}{25}$	$\frac{0}{25}$	$\frac{0}{25}$	$\frac{0}{25}$	$\frac{0}{15}$		$\frac{0}{25}$	$\frac{0}{15}$	$\frac{17/51}{25_s}$	$\frac{24/25}{25}$	$\frac{0}{25}$	15. *Pomatomus saltatrix* (bluefish)
$\frac{23/68}{25_s}$		$\frac{0}{10}$	$\frac{0}{25}$	$\frac{5/3}{15}$	$\frac{0}{25}$	$\frac{4/3}{20}$	$\frac{5/3}{25}$	$\frac{0}{25}$		$\frac{0}{25}$	$\frac{0}{25}$	$\frac{6/6}{25}$	$\frac{14/45}{25_s}$	$\frac{25/100}{25}$	16. *Selar crumenophthalmus* (bigeye scad)
$\frac{1/1}{25}$	$\frac{0}{25}$	$\frac{0}{10}$	$\frac{0}{20}$	$\frac{0}{25}$	$\frac{8/10}{25}$	$\frac{0}{25}$	$\frac{22/70}{25_b}$	$\frac{5/3}{25}$	$\frac{2/2}{15}$	$\frac{0}{25}$	$\frac{13/30}{25_s}$	$\frac{63/100}{125_b}$	$\frac{20/20}{25}$	$\frac{0}{35}$	17. *Stenotomus chrysops* (scup)
$\frac{2/1}{25}$	$\frac{0}{25}$	$\frac{0}{10}$		$\frac{0}{25}$	$\frac{0}{25}$	$\frac{0}{25}$	$\frac{0}{25}$			$\frac{0}{20}$	$\frac{0}{15}$	$\frac{0}{25}$	$\frac{5/5}{25}$	$\frac{0}{35}$	18. *Tautoga onitis* (tautog)
$\frac{0}{95}$		$\frac{0}{10}$	$\frac{6/3}{25}$	$\frac{0}{15}$	$\frac{5/3}{25}$	$\frac{0}{25}$	$\frac{6/14}{25_s}$	$\frac{4/3}{25}$		$\frac{0}{25}$	$\frac{0}{15}$	$\frac{5/3}{25}$		$\frac{0}{40}$	19. *Sarda sarda* (Atlantic bonito)
$\frac{0}{25}$	$\frac{4/4}{25}$	$\frac{0}{10}$	$\frac{0}{25}$	$\frac{0}{25}$	$\frac{0}{25}$	$\frac{0}{25}$	$\frac{0}{25}$			$\frac{0}{25}$	$\frac{0}{15}$	$\frac{13/15}{50_c}$	$\frac{15/23}{25_b}$	$\frac{11/25}{25_s}$	20. *Scomber scombrus* (Atlantic mackerel
$\frac{0}{10}$	$\frac{3/2}{10}$	$\frac{0}{4}$		$\frac{0}{6}$	$\frac{0}{8}$	$\frac{0}{10}$	$\frac{0}{10}$	$\frac{2/2}{10}$		$\frac{0}{10}$	$\frac{1/1}{6}$	$\frac{0}{10}$		$\frac{2/8}{10_s}$	21. *Scomberomorus cavalla* (king mackerel)
$\frac{5/5}{15}$	$\frac{15/26}{25}$	$\frac{10/23}{10}$		$\frac{0}{20}$	$\frac{0}{25}$	$\frac{3/2}{20}$	$\frac{6/4}{25}$	$\frac{3/3}{25}$		$\frac{0}{25}$	$\frac{11/11}{25}$	$\frac{5/4}{25}$	$\frac{6/4}{25}$	$\frac{0}{25}$	23. *Prionotus evolans* (striped searobin
					$\frac{0}{25}$			$\frac{0}{25}$		$\frac{0}{25}$		$\frac{18/36}{25_c}$		$\frac{4/13}{35_b}$	24. *Myoxocephalus octodecemspinosus* (longhorn sculpin)
					$\frac{0}{25}$		$\frac{0}{25}$			$\frac{2/1}{25}$	$\frac{0}{20}$	$\frac{10/17}{25_s}$		$\frac{0}{25}$	26. *Macrozoarces americanus* (ocean pout)
								$\frac{0}{25}$	$\frac{0}{15}$	$\frac{0}{25}$	$\frac{0}{25}$	$\frac{6/9}{25_b}$			27. *Paralichthys dentatus* (summer flounder)
$\frac{0}{20}$	$\frac{0}{20}$	$\frac{0}{8}$						$\frac{0}{20}$	$\frac{4/2}{16}$	$\frac{0}{20}$	$\frac{0}{20}$	$\frac{0}{20}$			29. *Hippoglossoides platessoides* (American plaice)
							$\frac{2/3}{16}$	$\frac{1/1}{25}$	$\frac{0}{25}$	$\frac{0}{25}$	$\frac{0}{10}$	$\frac{0}{25}$			30. *Limanda ferruginea* (yellowtail flounder)
$\frac{6/4}{25}$	$\frac{16/61}{85_b}$		$\frac{0}{20}$	$\frac{0}{25}$	$\frac{0}{25}$	$\frac{0}{25}$	$\frac{0}{25}$	$\frac{0}{25}$		$\frac{0}{25}$	$\frac{0}{25}$	$\frac{0}{144}$	$\frac{0}{25}$	$\frac{0}{25}$	31. *Pseudopleuronectes americanus* (winter flounder)
$\frac{6/9}{25}$	$\frac{0}{10}$	$\frac{4/4}{10}$		$\frac{0}{15}$	$\frac{0}{15}$	$\frac{0}{25}$	$\frac{22/23}{25}$	$\frac{0}{25}$		$\frac{0}{25}$	$\frac{0}{15}$	$\frac{0}{25}$	$\frac{0}{25}$	$\frac{0}{25}$	32. *Aluterа schoepfi* (orange filefish)
$\frac{0}{5}$		$\frac{1/1}{3}$			$\frac{0}{10}$		$\frac{3/3}{10}$	$\frac{0}{9}$		$\frac{0}{15}$	$\frac{0}{15}$	$\frac{2/3}{15}$	$\frac{0}{15}$	$\frac{0}{10}$	33. *Lophius americanus* (goosefish)

TABLE 2. Examples of agglutination patterns for the cells of Atlantic mackerel and Atlantic cod with sera of other species.

		Sera																								
		Bonito					American plaice					Witch flounder					Wolffish					Redfish				
	Samples	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
	1	—	—	—	—	—	+	+	—	—	+	4+	4+	2+	4+	4+	—	2+	—	—	—	4+	—	+	3+	—
Atlantic	2	—	—	—	—	—	+	+	+	—	2+	4+	4+	2+	4+	4+	—	2+	—	—	—	4+	1+	+	3+	—
cod	3	—	—	—	—	—	—	—	—	—	—	2+	1+	—	1+	1+	—	4+	—	—	—	—	4+	+	—	—
cells	4	—	—	—	—	—	+	+	—	—	—	2+	3+	1+	3+	2+	—	2+	—	—	—	—	—	+	—	—
	5	—	—	—	—	—	+	+	—	—	—	2+	—	—	—	—	—	2+	—	—	—	—	—	+	+	—

		Sera																								
		American plaice					Winter skate					Winter flounder					Goosefish					Orange filefish				
		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
	1	—	—	—	—	—	1+	1+	+	no	sera	1+	1+	+	1+	1+	—	—	—	+	4+	4+	1+	4+	—	—
Atlantic	2	—	—	—	—	—	1+	1+	1+	"	"	—	—	—	—	—	—	—	—	1+	4+	1+	—	1+	—	—
mackerel	3	—	—	—	—	—	1+	1+	+	"	"	4+	1+	+	1+	1+	—	—	—	1+	4+	—	—	+	+	—
cells	4	—	—	—	—	—	1+	1+	1+	"	"	1+	1+	+	—	—	—	—	—	1+	4+	1+	4+	2+	1+	1+
	5	—	—	—	—	—	1+	1+	1+	"	"	—	—	—	—	—	—	+	—	1+	4+	+	+	1+	—	—

of the cells of one species against the sera of a second species is here termed a "block." The 570 blocks tested included about 13,000 individual crossmatches. The average agglutination reaction was 2+ or stronger in at least half of the crossmatches in 29 of the blocks. In five blocks all crosses reacted 4+. The sera of black sea bass (13) and winter flounder (31) stand out as active agglutinators. A few of the strong reactions tested were active at a saline dilution of 1:16; most had titers of 1:4 or 1:8.

Seven blocks of Table 1 differentiate between the cells of individuals, 39 blocks differentiate between the sera and 15 blocks differentiate both. Even though the differentiation between sera of individuals by the use of fish cells has not been extensively applied in fishery work, this technique holds promise. Once the antigens of erythrocytes of some species are known, they can be employed (just as human cell types have been) to identify agglutinins in fish sera (Cushing, 1952; Suzuki and Morio, 1960).

Studies in which fish heteroagglutinins were used have been reported in several previous papers. Heteroagglutinins were demonstrated in marine fish by Noguchi (1903) and in freshwater fish by Toth (1932). Cushing and Durall (1957) crossed the cells and sera of channel catfish, *Ictalurus p. punctatus*, with brown bullhead, *Ictalurus n. nebulosus;* they reported that serum samples of individual channel catfish differentiated cells of brown bullheads. Brown bullhead serum reacted strongly with cells of sockeye salmon, *Oncorhynchus nerka*, but was not useful in differentiating fish from different areas (Ridgway, Cushing, and Durall, 1958). Natural hemagglutinins in the sera of kurokajiki, *Eumakaira nigra*, and shirokajiki, *Marlina marlina*, differentiate cells of bigeye tuna, *Parathunnus mebachi*, and cells of yellowfin tuna, *Neothunnus macropters*, (Suzuki and Morio, 1960; Suzuki, 1961, 1962). Finally, Sindermann and Honey (1964) showed that sera of winter skate, *Raja ocellata*, can differentiate cells of Atlantic herring, *Clupea harengus.*

Roughtail stingray (species 4 in Table 1), blue fish (15), and Atlantic mackerel (20), have natural isoagglutinins which react only when undiluted. Natural isoagglutinins have been found previously in eight species (Suyehiro, 1949; Cushing, 1956; Cushing, and Durall, 1957; Sindermann, and Mairs, 1961; Suzuki, 1961; and Sindermann, and Honey, 1964). They have been used only in catfish, spiny dogfish, and winter skate for blood group analysis where the titer permitted further work (Cushing and Durall, 1957; Sindermann and Mairs, 1961; Sindermann and Honey, 1964).

Species interactions tend to be less within a family than between families. Interactions were few within the cod, mackerel, and flounder families, but were numerous and strong among the several families represented by species 13-18 in Table 1.

Specific examples of the reactions for differentiating cells or sera or both are given in Table 2. Cells of Atlantic mackerel and Atlantic cod (five samples each) were crossed with the sera of the designated species. The sera of Atlantic bonito and American plaice did not react with the cells of Atlantic cod and Atlantic mackerel, respectively. Therefore, an insufficient titer or even absence of specific agglutinins make these sera unsatisfactory for differentiating between samples of the cells tested.

Sera of American plaice and winter skate contain agglutinins for Atlantic cod and Atlantic mackerel cells, repectively. Because of the weakness of reaction, there is doubt that the difference between a negative and weak positive reaction is significant. On the other hand, no question exists about the difference between a 4+ and a negative reaction. For this reason, a differential reaction is arbitrarily defined as a group of tests which show at least one 4+ reaction and one negative reaction in a row or column. With this definition in mind, the sera of some species such as witch flounder and winter flounder can be said to differentiate between cell samples of Atlantic cod and Atlantic mackerel, respectively. Similarly, the cell samples of Atlantic cod and Atlantic mackerel can be used to differentiate between serum samples of Atlantic wolffish and goosefish, respectively. Finally, both the cell and serum samples in some crossmatches of species can be used to differentiate each other as in Atlantic cod cells and redfish sera or Atlantic mackerel cells and orange filefish sera. In the few cases in which every crossmatch in the block reacted 4+, no tests were made to see if a differential reaction occurred after dilution of the sera.

Haddock Erythrocyte Antigens Detected by Fish Agglutinins

From the data in Table 1, winter flounder serum was selected as a promising source of reagent for differentiating individual haddock. Samples of red cells from 16 haddock caught near Chatham, Massachusetts, were tested against the pooled serum of several winter flounder from Great Harbor, Woods Hole. The cells of all haddock tested clumped positively and strongly. Next, the pooled serum was absorbed with the cells from individual haddock and then tested for remaining agglutinins (Table 3). The 11 distinct patterns of cell agglutination that occurred demonstrated the heterogeneity of haddock erythrocytes. Similar results were recorded by Suzuki and Morio (1960) when they absorbed the serum of one kurokajiki with the cells from five individual bigeye tuna, and by Suzuki (1961) when he absorbed the sera of two kurokajiki with cells from seven individual yellowfin tuna.

TABLE 3. Results of absorbing pooled winter flounder serum with erythrocytes of 16 individual haddock.

		Pooled winter flounder serum absorbed with haddock cells																
	Samples	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Pattern of agglutination
	1	—	—	3 +	—	2 +	—	—	—	—	—	—	3 +	—	—	—	+	1
	2	—	—	3 +	—	—	—	—	—	—	—	—	4 +	—	—	—	—	2
	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3
	4	—	—	1 +	—	—	—	—	—	—	—	—	2 +	—	—	—	—	2
	5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3
	6	—	—	2 +	—	—	—	—	—	—	—	—	—	—	—	—	—	4
Haddock	7	—	—	2 +	—	—	—	—	—	—	—	—	2 +	—	—	—	—	2
cells	8	—	—	2 +	—	2 +	—	2 +	—	—	—	—	2 +	—	—	—	—	5
	9	—	—	2 +	3 +	2 +	—	2 +	—	—	—	—	—	—	—	—	—	6
	10	—	—	3 +	—	—	—	2 +	—	—	—	—	—	—	—	—	—	7
	11	—	—	3 +	2 +	3 +	—	3 +	—	—	—	—	—	—	—	—	—	6
	12	—	—	—	—	2 +	—	2 +	—	—	—	—	—	—	—	—	—	8
	13	—	—	1 +	—	—	—	—	—	—	—	—	2 +	—		—	—	2
	14	—	—	3 +	—	—	—	3 +	1 +	—	—	—	3 +	—		—	—	9
	15	—	—	4 +	—	—	—	2 +	—	—	—	—	4 +	—	—	—	—	10
	16	—	—	3 +	—	2 +	—	2 +	—	—	—	—	—	—	—	—	—	11

No further testing was done with pooled serum because the concentration of agglutinins decreased with time. Whereas freshly pooled serum of winter flounder gave a titer of 1:8, the titer decreased daily until even the undiluted serum did not react with haddock cells on the fourth day. Ridgway (personal communication) suggested that soluble isoagglutinogens may have neutralized the agglutinins. Another explanation may be that proteolytic enzymes caused the decrease in titer.

Even though the sera from several individuals may not be pooled, an alternative way of obtaining a large volume of blood is to bleed the same fish repeatedly. As much as 37 ml of whole blood (15.6 ml sera) have been obtained by intra-cardiac punctures from one adult scup in 4 weeks by bleeding about 1 ml per day. One drop of sera occupies approximately .02 ml; thus, as many as 50 tests per ml could be made. Agglutination tests have been made in capillary tubes for other experiments associated with this work with as reliable results as the tray method, yet requiring only one fourth the volume of sera.

Fifteen ml of whole blood have been obtained from one winter flounder in 3 weeks by bleeding 2½ml every 4 days and 15 ml from one striped bass in 2½ weeks by bleeding 3 ml every 4 days. No experiments were conducted to follow any titer level in these fish that were bled repeatedly.

Potential Value of the Natural Agglutinins of Fish

The present results can not be used to reflect any phyletic relationship because of the large number of unique blood systems that probably are involved. The indication of decreased agglutination within families suggests that a search for natural antisera would be best made between remote families. These reactions, however, may be associated more with genus or family specificity than with intraspecific differences.

The results of heteroagglutination indicate more agglutination variability in the serum of a species than in the cells. Toth (1932) made a similar observation in crossing *Rhodeus* cells with *Cyprinus* sera.

Pooling the sera of several individuals should be avoided at present but may be done later when sera from compatible individuals are found. However, individuals of a given species that are moderately large (1/2 kg or larger) could be used as live donors.

The titers of the natural fish agglutinins discovered in this study are not high. Isoimmunization experiments, however, have been successfully performed previously (Hildemann, 1956; Ridgway, 1962), and in other phases of this study (unpublished results) to produce a high titer of isoantibody. This technique may lead to wider use of isoagglutinins for racial separation.

Summary

1) Many hetero-hemagglutinins and a few isohemagglutinins were found to exist naturally in the blood of 33 species of fish.
2) There is no apparent relation between frequency or pattern of agglutination and phyletic order, although positive responses tend to be fewer within families than between families.
3) The titer of most agglutinations indicated activity only at the undiluted level, but some were still active at a saline dilution of 1:16.
4) Intraspecific variation in haddock erythrocytes was shown by the use of absorbed serum of winter flounder.
5) The normal sera of marine fish contain many agglutinins and may be valuable sources of blood-typing reagents.

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Effect of Offshore Fishing on the Inshore Labrador Cod Fishery

BY A. W. MAY[1]

Abstract

Recent trends in the offshore and inshore Labrador cod fisheries are described. Offshore fishing began in the early 1950's and landings reached an average level of over 200 thousand tons annually during 1961–64. Inshore landings declined from the mid-1940's to 1956, with a subsequent increase to an average level of over 20,000 tons annually during 1961–64. Catch per unit effort has increased in the offshore fishery, but has markedly declined inshore, apparently as a result of the increased offshore landings. Recent estimates of various population parameters suggest that the present fishing intensity may be at or beyond that giving maximum sustained yield.

Introduction

The Labrador coast is known to have been fished by French vessels at least as early as the early 1700's (Black, 1960). These were replaced by English vessels during the late 1700's and the latter replaced by vessels based in Newfoundland in the early 1800's. By this time a shore-based fishery was also established. The fishery grew rapidly until the early 1900's and three categories of fishermen were recognized:

1) Livyers — resident fishermen;
2) Stationers — those who came from Newfoundland each summer and operated from shore bases;
3) Floaters — Newfoundland fishermen who operated from fishing schooners.

Each group fished from small open boats, the schooners being used only for storage of the catch and accommodation. No catch statistics are available for this early period, but on the basis of figures given by Black (1960) for number of ships in the floater fishery, catches must have been substantial even by recent standards. By 1908 the number of schooners fishing along the coast had reached 1,400. Catch per ship in the 1940's was of the order of 200 tons (metric, round fresh) annually. On this basis the total annual catch in the early 1900's must have approached 300 thousand tons.

For economic reasons the inshore fisheries experienced a rapid decline to the mid-1950's, particularly the floater fishery which disappeared in 1955. There has since been a gradual buildup, with a tripling of the catch from 1956 to 1965, and a minor revival of the floater fishery (59 vessels in 1965). This has been accompanied by the development of a large European offshore fishery beginning about 1952, reaching a peak of 246 thousand tons in 1961, and increasing to 305 thousand tons in 1965.

Cod from the Labrador area are part of a stock complex extending from northern Labrador to the northern Grand Bank (Templeman, 1962). Spawning occurs in spring in deep water far offshore and is followed by a post-spawning shoreward migration (Templeman and May, 1965). The cod are fished for a few months in summer in the coastal fisheries, and for the remainder of the year by the offshore fleets. The present study examines the effects on the inshore Labrador fishery of the recent large expansion in offshore fishing.

Development of the Offshore Fishery

Offshore fishing first began in the early 1950's, and reached a level of almost one-quarter million tons annually in 1961 and 1962, or 10 times the amount taken in the inshore fishery in those years (Fig. 1). Between 1954–61 the fishery as a whole increased twelvefold. Offshore landings fell below 200 thousand tons in 1963 and 1964, but increased to 305 thousand tons in 1965. From 1960 to 1964 15–20% of the annual Northwest Atlantic cod catch has come from Labrador (Fig. 1).

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

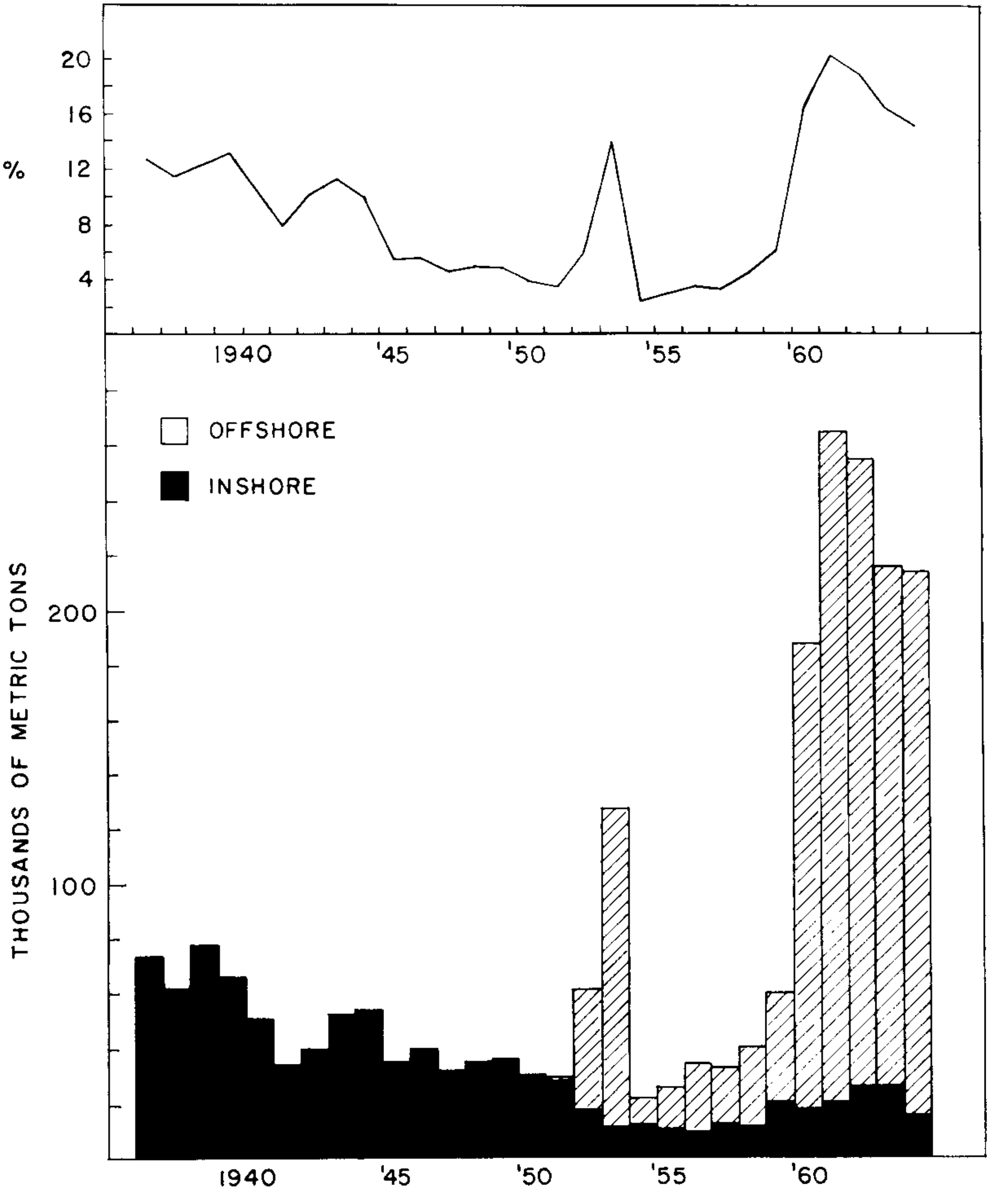

Fig. 1. **Top.** Relative contribution of cod landings from Labrador to total cod landings for the ICNAF area. **Bottom.** Inshore and offshore Subarea 2 landings, 1936–64.

In the past the inshore fishery was carried on along the entire coast. Recently only the southern one-third of the coast (Division 2J) has been fished to any great extent. The offshore fishery also is almost entirely based on Hamilton Inlet Bank, directly east of the southern part of the coast. Therefore more than 90% of the annual cod catch is taken in Division 2J (Fig. 2A). Virtually all the offshore catch is taken by France, Portugal, Spain, and the USSR (Fig. 2B).

The offshore fishery originally developed (1954–58) as a relatively small autumn fishery. A spring fishery began in 1959 and fishing was extended throughout the year. The autumn fishery increased and the new spring fishery quickly reached major proportions (Fig. 3). The

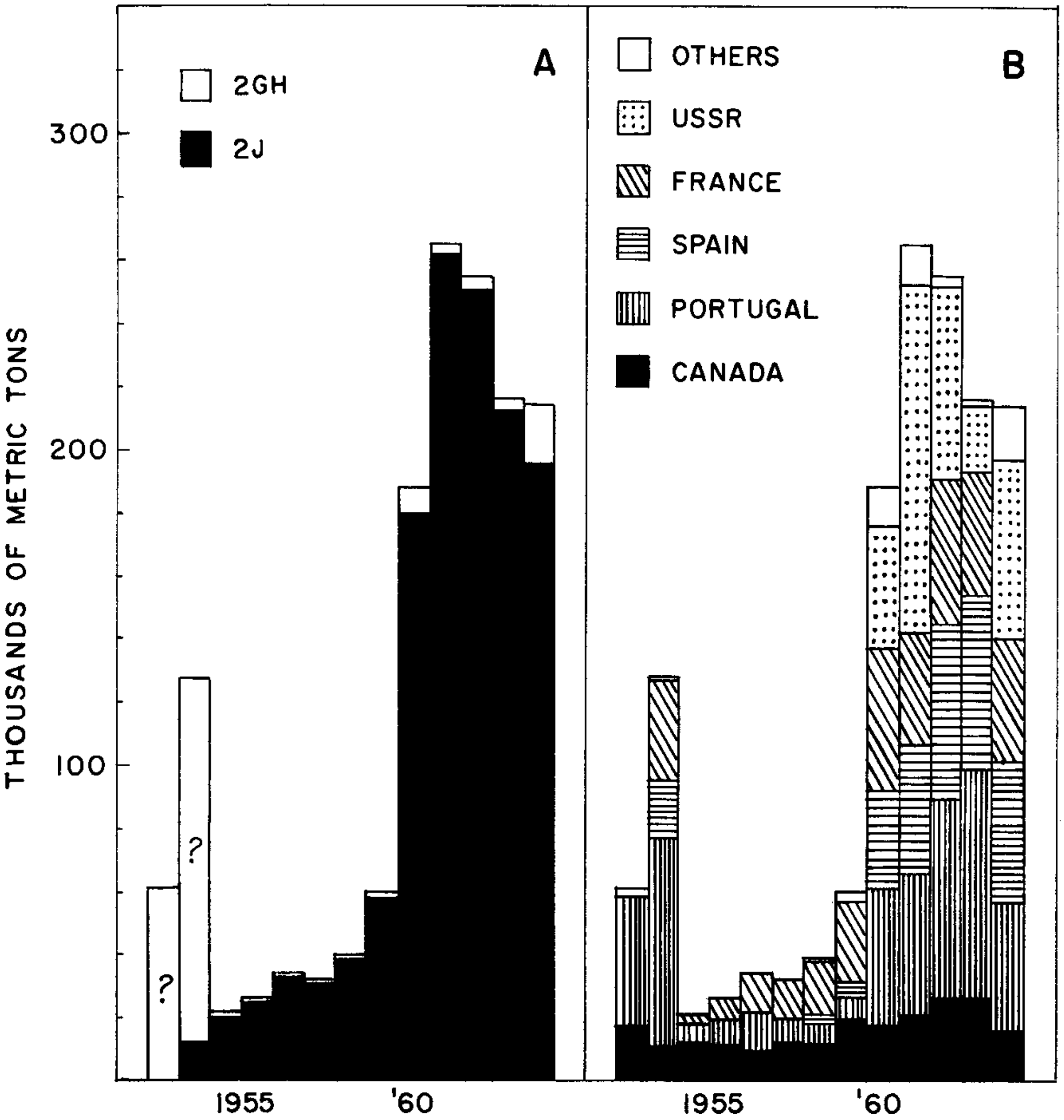

Fig. 2. Subarea 2 cod landings by ICNAF Division (A) and country (B), 1952–64.

latter appears to be based largely on spawning and post-spawning concentrations on the southeastern edge of Hamilton Inlet Bank. By June the concentrations break up and begin to move inshore where they are fished in July and August, when the offshore fishery is at a minimum (Fig. 3). The autumn offshore fishery builds up as fish move away from shore toward the spawning area. Trawl landings per effort declined from 1954 to 1958, but increased from about 1 ton per hour in 1958 to over 2 tons per hour in 1962 as a result of development of the spring fishery (Hodder, 1965).

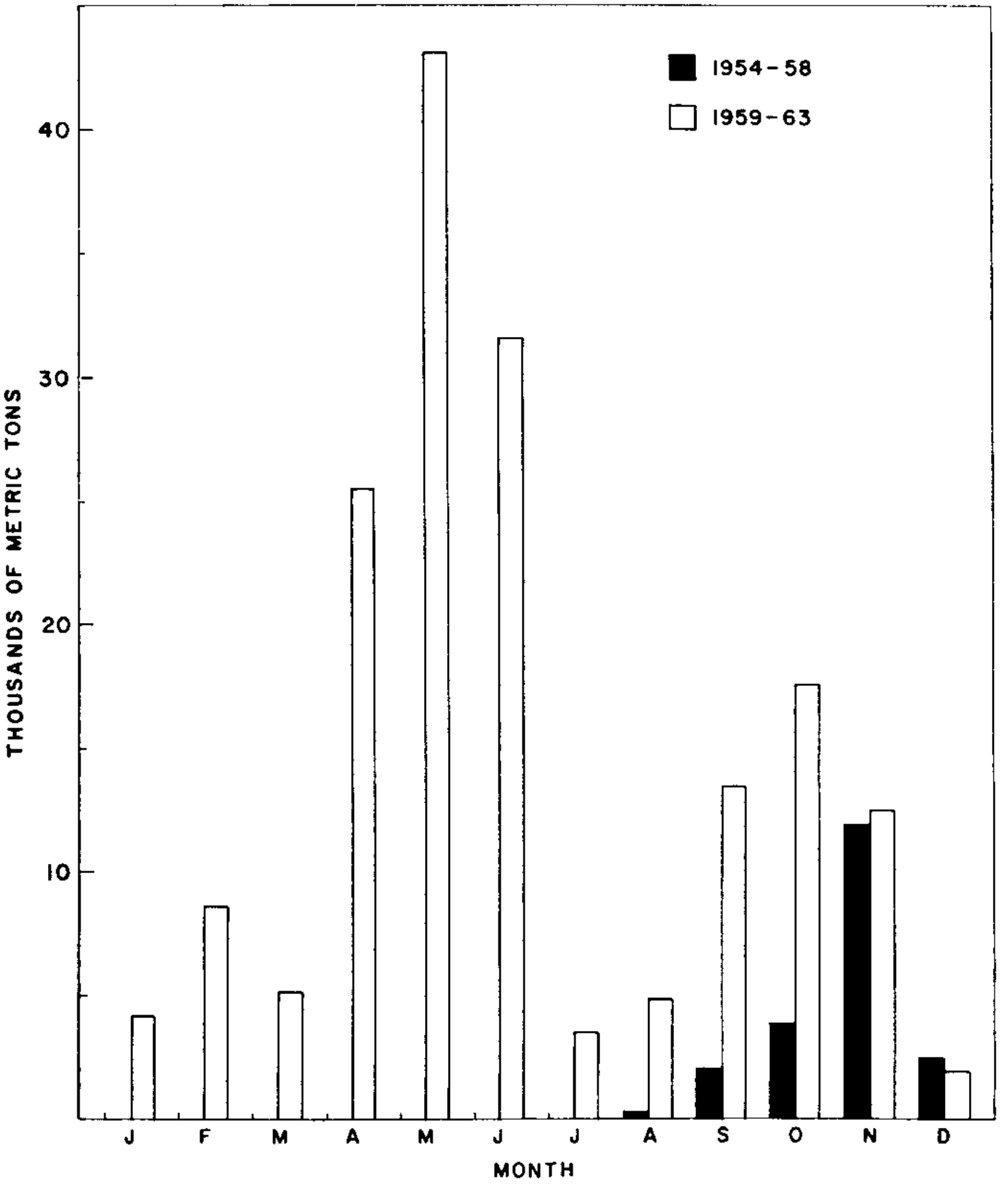

Fig. 3. Monthly landings from the offshore fishery in Division 2J averaged for 1954–58 and 1959–63.

Trends in Inshore Catch and Effort

In view of the recent large expansion of the offshore fishery, and the fact that it operates on the same stock of fish later fished inshore, it is of interest to examine inshore catches in relation to effort expended to determine whether the large offshore fishery is having any effect. Unfortunately it is difficult to get a good measure of effort in the inshore fishery. At least four gears of varying efficiency are in use (codtrap, jigger, longline, and gillnet) and the fishery is effectively decentralized. The catch of each fishing crew (often by several gears) is salted and disposed of at the end of the season. The greater part of the catch is probably taken by codtraps but actual quantities taken by each gear are unknown. However, numbers of men employed in fishing are known from the 1930's onward. Catch per man is not a good measure of effort since it does not take into account varying fishing practices and changes in fishing efficiency over the years. However if shore-based and ship-based fishermen are treated separately such changes may be regarded as minimal in Labrador over the period considered.

Statistics of the inshore fishery were obtained from the Annual Reports of the Newfoundland Fisheries Board from 1937 to 1948, and from files of the Canada Department of Fisheries (at St. John's, Newfoundland) after 1948. Data for shore-based and ship-based fishermen are separable. Shore-based fishermen here include both those resident on the coast and summer migrants from the island of Newfoundland, and for convenience are labelled together as stationers. Unfortunately the data are not directly comparable over the whole period. The area covered from 1937 to 1953 included the North Shore of the Strait of Belle Isle (part of Division 4R) as well as the coast of Labrador proper. The effect is not serious as recent statistics indicate that landings from the former area account for less than 15% of the total. However, the early figures are reported as "equivalents, light salted dry cure" in quintals (1 quintal = 112 lb.). Most cod production from this area is "heavy salted wet cure". Conversion factors from one to the other have altered over the years and it is not certain which of several was used from 1937 to 1953. For rough comparability with recent data the landings in equivalent light salted dry quintals were converted to metric tons, round fresh weight, by applying the following modern standard conversions:

1) quintals to pounds...... × 112;
2) light salted dry to round fresh............... × 4.88;
3) pounds to metric tons.. $\times \frac{1}{2{,}204.6}$.

Since cod from the Quebec North Shore and the Strait of Belle Isle belong to a different stock than those fished along the Labrador coast (Templeman, 1962) it is desirable to separate statistics of the two fisheries. Landings have been reported separately since 1954 (ICNAF Statistical Bulletins, Vols. 3–14), and these were used in analysis of the fishery from that time.

Numbers of fishermen and total landings declined sharply during the early years of the Second World War (Fig. 4). There was a brief recovery in 1943 and 1944 as the number of stationers increased, with a coincident increase in catch per man of both floaters and stationers. The number of floaters remained about the same during the mid-forties—while stationers increased, but low catches per man from 1945 to 1947, and decreasing numbers of men after 1946 resulted in an overall downward trend in landings from 1945 to 1953. There is a general correspondence in the trends in catch per man of floaters and stationers. The low periods of 1940–41 and 1945–47 may be indicative of declined stock abundance, or simply lessened availability to the inshore fishery because of anomalies in fish distribution due to hydrographic conditions.

The 1954–64 period must be considered separately for reasons previously outlined. Thus the high levels of catch per man in the mid-fifties are not directly comparable with earlier data because of different area coverage and probable differences in conversion factors to round fresh landings. Landings and numbers of men reached their lowest levels in 1956 (Fig. 4). The floater fishery temporarily disappeared. Numbers of floaters were so low during the period 1954–59 (less than 50 men) that figures for catch per man have no meaning. The number of stationers has doubled since 1959 but their landings exhibit a downward trend from that time. Increased total landings in 1962 and 1963 were due to renewed participation in the fishery by floaters. The very pronounced decline in catch per man of stationers since 1959 and floaters since 1961 coincides exactly with the period of great increase in offshore fishing (Fig. 1).

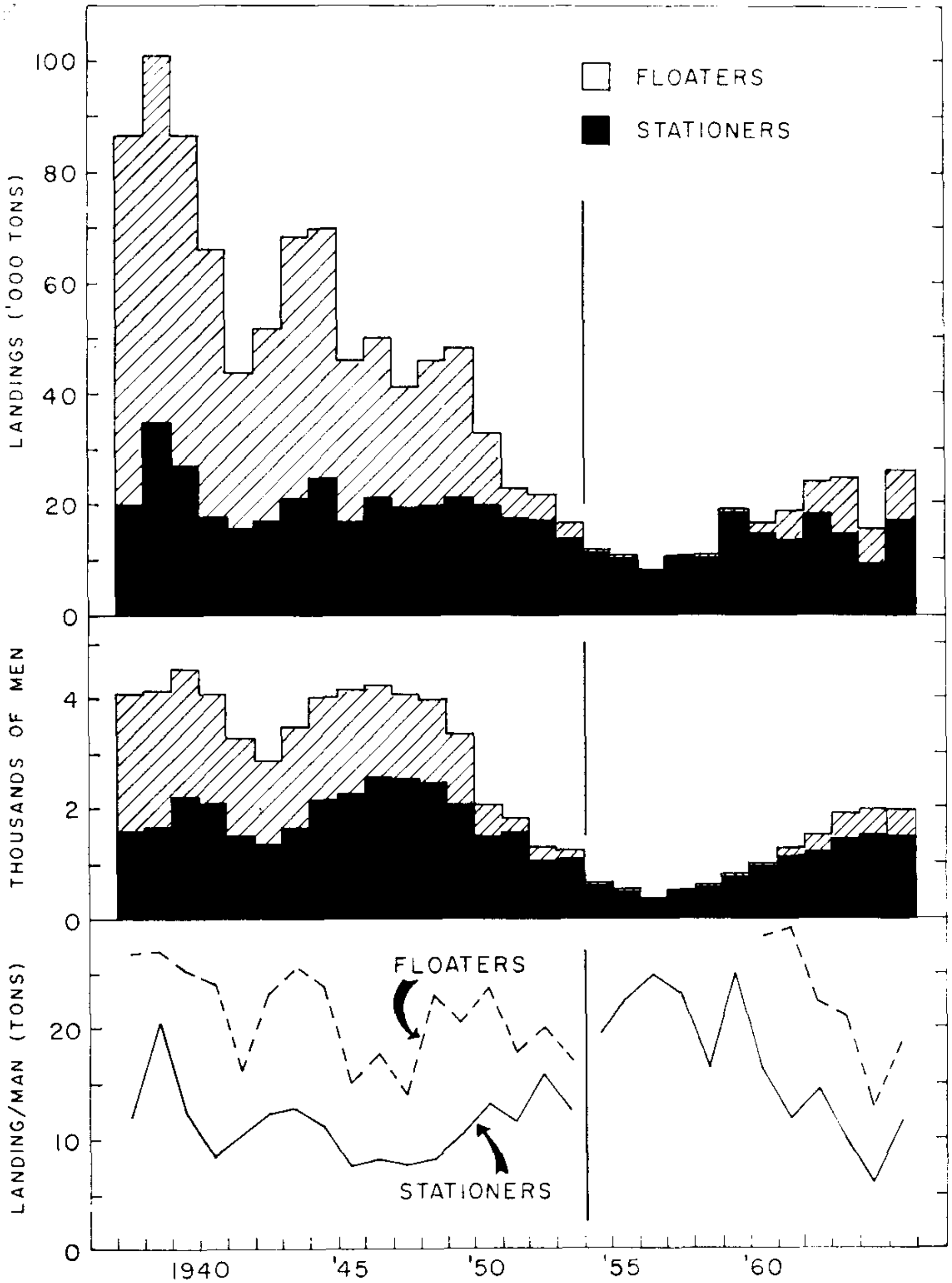

Fig. 4. Landings, effort, and landing per unit effort in the inshore fishery, 1937–65.

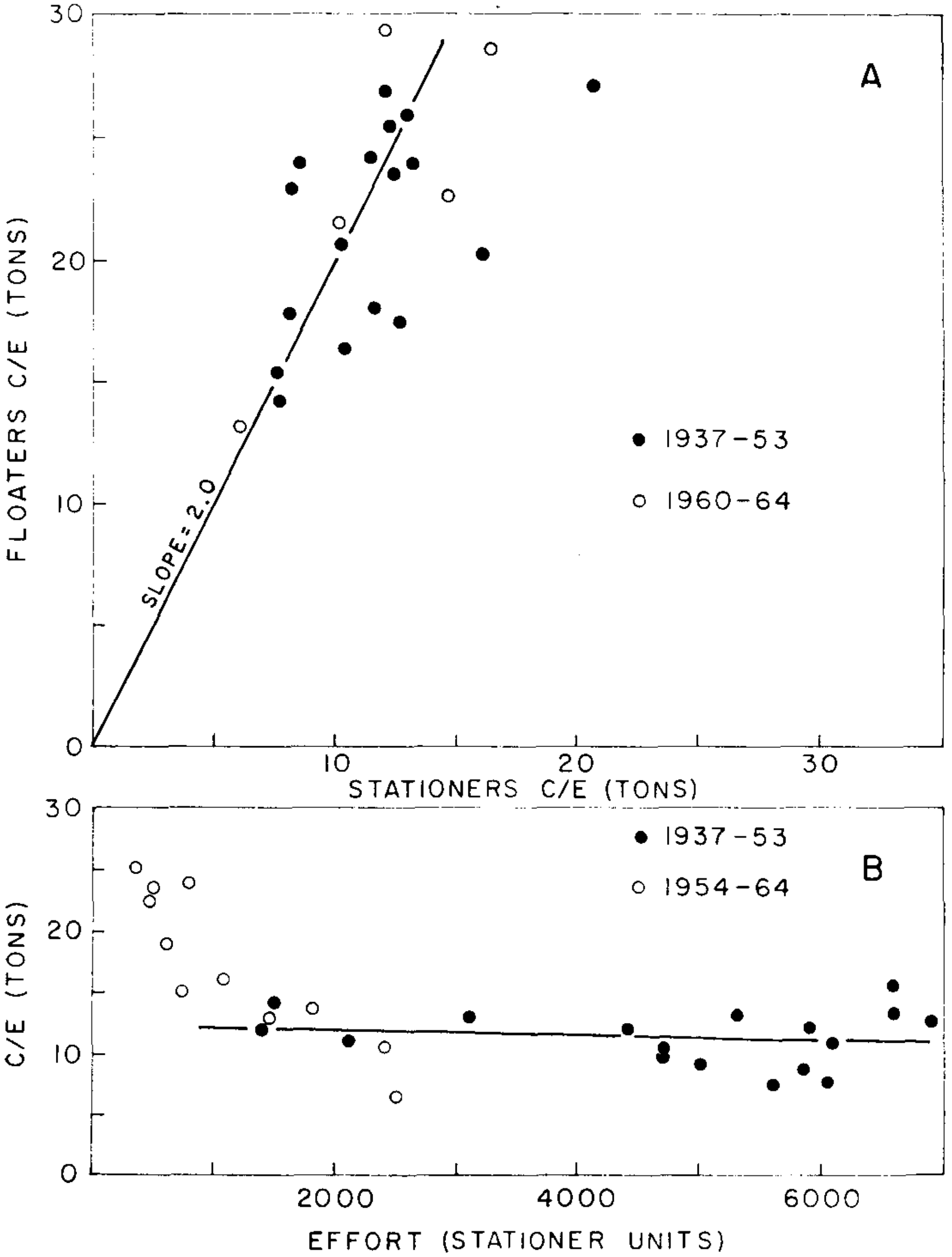

Fig. 5. (**A**) Relation between catch per man of floaters and stationers. (**B**) Catch per unit effort versus effort in the inshore Labrador cod fishery.

Discussion and Conclusions

It was previously noted that some of the variation in catch per man was possibly due to variations in availability to the inshore fishing areas. Thus catch per man was abnormally low in 1958, but cod catches and catch per unit effort were low in this year throughout the Newfoundland and Labrador Areas (Hodder, 1965). This has been considered to be due to unusually warm temperatures and lack of cold water barriers, allowing cod to be less concentrated and thus less easily fished than normally (Hodder, 1965). A difference in availability, rather than a decline in abundance, is indicated.

On the other hand increased fishing will result in proportional increases in catch only as long as there are reserves of stock to draw from. At higher effort levels catch per unit effort will decline due to a real decline in stock abundance as a result of fishing. Prior to 1951 the inshore fishery alone was responsible for removals from the available stock (Fig. 1). Using catch per unit effort as a relative measure of abundance the data were examined to determine the relation of effort to catch per effort for this period. It is obvious (Fig. 4) that numbers of men cannot be used directly as a measure of effort since floaters fish more efficiently, probably due to their greater mobility and extensive use of traps rather than less efficient gears. A plot of catch per floater against catch per stationer (Fig. 5A) revealed that floaters were on the average twice as efficient. Total effort was thus estimated in stationer units by applying this factor, i.e.

Total effort (stationer units) = number of stationers + 2 (number of floaters).

Dividing these values into annual catch gave catch per stationer unit for each year. A plot of catch per stationer unit against number of units (Fig. 5B) showed no significant correlation for the period 1937–53 ($r = -0.16$, $.50 > P > .40$). It may be concluded that even at the highest levels of effort during this period the inshore fishery had little or no effect on overall stock abundance, and that variations in abundance were due to "natural" causes.

The pattern for 1954–64 is quite different (Fig. 5B), producing a significant negative correlation ($r = -0.90$, $P < .01$). In view of the foregoing it is most unlikely this is a real effect of increased inshore effort. In fact three of the cluster of four high values are for the years 1955–57; the four lowest values are for 1961–64. It is most likely that the increase in offshore fishing since 1959 has resulted in decreased stock abundance, reflected as a much lower catch per man inshore. A similar pattern of decline in catch per man inshore on the east and northeast coasts of Newfoundland, coincident with increased participation in the fisheries by trawlers, has been reported by Hodder (1965).

Beverton (1965) observes that fairly intense fishing would be necessary to attain maximum sustained yield in the Labrador Area. This conclusion is based on values of parameters for Divisions 2H and 2J combined as follows:

L_c (mean selection length) = 50 cm

L_∞ (average "final" length in population) = 65–70 cm

k (rate of change in length increment) = 0.3,

giving a range of 0.71–0.77 for L_c/L_∞, and assuming a range of 0.5–1.0 for M/k. Growth has recently increased in Division 2J (but not in Division 2H) for those ages taken in quantity by the fishery. Values of L_∞ and k for Division 2J in 1963 were 74 cm and 0.2 respectively (May, MS, 1966*a*). The value of M (natural mortality) appears to be about 0.2 (May, MS, 1966*b*). Assuming mesh sizes of 110–120 mm, L_c lies between 38–42 cm (Hodder and May, 1965). This gives a range of 0.51–0.57 for the ratio L_c/L_∞, and 1.0 for M/k. The effect of these changes is to modify Beverton's (1965) conclusion, to an extent depending on the as yet uncertain value of the ratio F/M. If this ratio were as low as 3, and inserting the recent values for other parameters in Beverton's (1965) figure 1, it would be concluded that such a level of fishing is at or beyond that giving maximum sustained yield.

Catch per unit effort more than doubled in the offshore fishery from 1958 to 1963 (Hodder, 1965) as the fleets became increasingly familiar with seasonal cod distribution and devoted increasing effort to the spring spawning concentrations. There was a slight decline in catch per unit effort for the autumn period. The inshore fishery continues to expand in spite of reduction in catch per man.

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Hydrological Conditions and Distribution of Silver Hake, *Merluccius bilinearis* Mitchill, on Georges Bank and off Nova Scotia in 1962 – 64

BY A. A. SARNITS[1] AND V. I. SAUSKAN[1]

Abstract

Research carried out from 1962 to 1964 on Georges Bank and the Scotian Shelf showed that silver hake, *Merluccius bilinearis* Mitchill, were distributed at different stages in their life history in relation to annual and seasonal variations in the hydrological conditions. Distribution in the warm year 1963 is shown to be quite different from the cold year 1964.

Introduction

Compared to previous years, 1964 was noted for a number of peculiarities in the distribution of silver hake, *Merluccius bilinearis* Mitchill, off Nova Scotia and on Georges Bank. Data collected from 1962 to 1964 by AtlantNIRO research vessels and statistics from the commercial fishery provided a basis for the present study into the nature and causes of these peculiarities.

Knowledge of the hydrographic conditions, particularly water temperatures, was obtained from data collected during hydrographic surveys, from standard sections and from research stations. Ichthyological studies, as part of all hydrographic work, were also conducted on experimental catches from silver hake shoals. Hydrographic conditions and the distribution and biological state of hake in different parts of its habitat were compared for different seasons.

Results of a comparison of 1963 and 1964 data show that hydrographic conditions were different during these 2 years.

Georges Bank

Tables 1 and 2 show that the affect of warm Atlantic water on Georges Bank was less pronounced during the 1964 seasons than during the 1963 seasons. This is confirmed in Fig. 1, which shows the distribution of water temperatures on the section across the Fundy Channel in May of 1963 and 1964, in Fig. 2, which shows off-bottom temperatures on the southeastern slope of Georges Bank in June of 1963 and 1964, and in Fig. 3, which shows monthly temperature fluctuations on the southern and northern slopes of Georges Bank in 1963 and 1964.

Based on observations made in 1962 and 1963, Sauskan (1964) developed a general seasonal pattern of silver hake distribution. He found that during April and June of 1962 and 1963, spawning and maturing silver hake were concentrated on the southeast part of Georges Bank at depths of 85 – 200 m along the slope of the Bank within the frontal zone separating waters of Atlantic and Labrador origin. These silver hake concentrations were composed of first-time spawners, 3 – 4 years of age and 29 – 30 cm in length. In June of 1962 and 1963 schools of maximum densities were reported in the area. Most females were shedding the first portion of their eggs. In July and August the fish moved to feeding grounds on the northern slope of Georges Bank and on the shallows of Georges and Browns Banks. During the summer months, schools of silver hake were observed at depths of 40 – 110 m with off-bottom temperatures from 6° to 10°C over the northern part of Georges Bank, in an area exposed to the action of Labrador and coastal waters and with a high content of food organisms. The density of these schools was somewhat lower than those on the southeastern slope of the Bank. By the end of 1963 and early in 1964, schools of immature fish and recruits were observed in Georges Basin in the southern part of the Gulf of Maine at depths of 200 m or more (Fig. 4).

Figure 5 shows the distribution of silver hake schools and Fig. 6 gives the length composition and state of maturity of silver hake on Georges

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[1] West Atlantic Research Laboratory of the Atlantic Scientific Research Institute of Marine Fisheries and Oceanography, (AtlantNIRO), Kaliningrad, USSR.

Bank and off the coast of Nova Scotia for each month of 1964.

One of the most characteristic features of silver hake distribution on Georges Bank in 1964 was an almost simultaneous movement of the fish into two areas of the southern slopes of the Bank in March and April. The one area was near the Welker, Hydrographer, and Veatch Canyons in the south and the other area was in the eastern part of Lydonia Canyon.

In March and April samples from research and commercial catches showed a predominance of maturing fish. In May there was further gonad development, and by the end of May and in June and July, catches contained males and females with flowing gonad products.

The rate of gonad development was found to be basically the same as in 1962 and 1963. Contrary to previous years, no mass spawning was noted. This was apparently due to the water temperatures which ranged from 4.5° to 9.5°C lower in 1964 creating unfavourable conditions at the usual spawning grounds during May and June 1964 (Table 1). Repeated attempts, based on an analogy with previous years, to take commercial quantities of silver hake from these spawning grounds at the end of May and during June were invariable unsuccessful. However, it is remarkable that dense concentrations of silver hake were reported in this area as early as March. These concentrations, as mentioned, were located simultaneously in two areas – an eastern and a western area.

TABLE 1. Comparison of the water temperatures over the southeastern slopes of Georges Bank in May and June of 1963 and 1964.

1963				1964				
Date	Position	Depth (m)	t°C	Date	Position	Depth (m)	t°C	△ t
23 May	40°56′ N 66°38′8 W	100 200	14.0 11.0	29 May	40°55′ N 66°38′8 W	100 200	6.5 6.5	7.5 4.5
23 May	40°50′1 N 66°49′2 W	100	11.8	29 May	40°49′5 N 66°52′5 W	100	3.6	8.2
24 May	40°33′3 N 67°21′ W	100	11.4	22 May	40°33′ N 67°28′ W	100	4.2	7.2
23 May	41°05′5 N 66°24′5 W	100 200	13.6 11.7	29 May	41°10′ N 66°17′ W	100 200	4.1 4.5	9.5 7.2
9 June	40°39′ N 67°02′2 W	100 200	11.1 9.7	6 June	40°30′ N 67°12′5 W	100 200	2.6 2.9	8.5 6.8
9 June	40°32′ N 67°43′5 W	100	9.0	9 June	40°28′5 N 67°50′ W	100	3.7	5.3

TABLE 2. Comparison of water temperatures west of Georges Bank in April of 1963 and 1964.

1963				1964				
Date	Position	Depth (m)	t°C	Date	Position	Depth (m)	t°C	△ t
18 April	40°03′5 N 70°13′1 W	100 150 200	9.3 9.8 9.2	14 April	40°02′ N 70°22′5 W	100 150 200	4.9 7.1 7.0	4.4 2.7 2.2
18 April	40°07′8 N 70°37′8 W	100	10.1	13 April	40°10′ N 70°37′9 W	100	4.3	5.8
17 April	40°04′5 N 71°06′ W	100 200	11.8 8.1	15 April	40°03′7 N 71°09′9 W	100 200	4.7 6.2	7.1 1.9

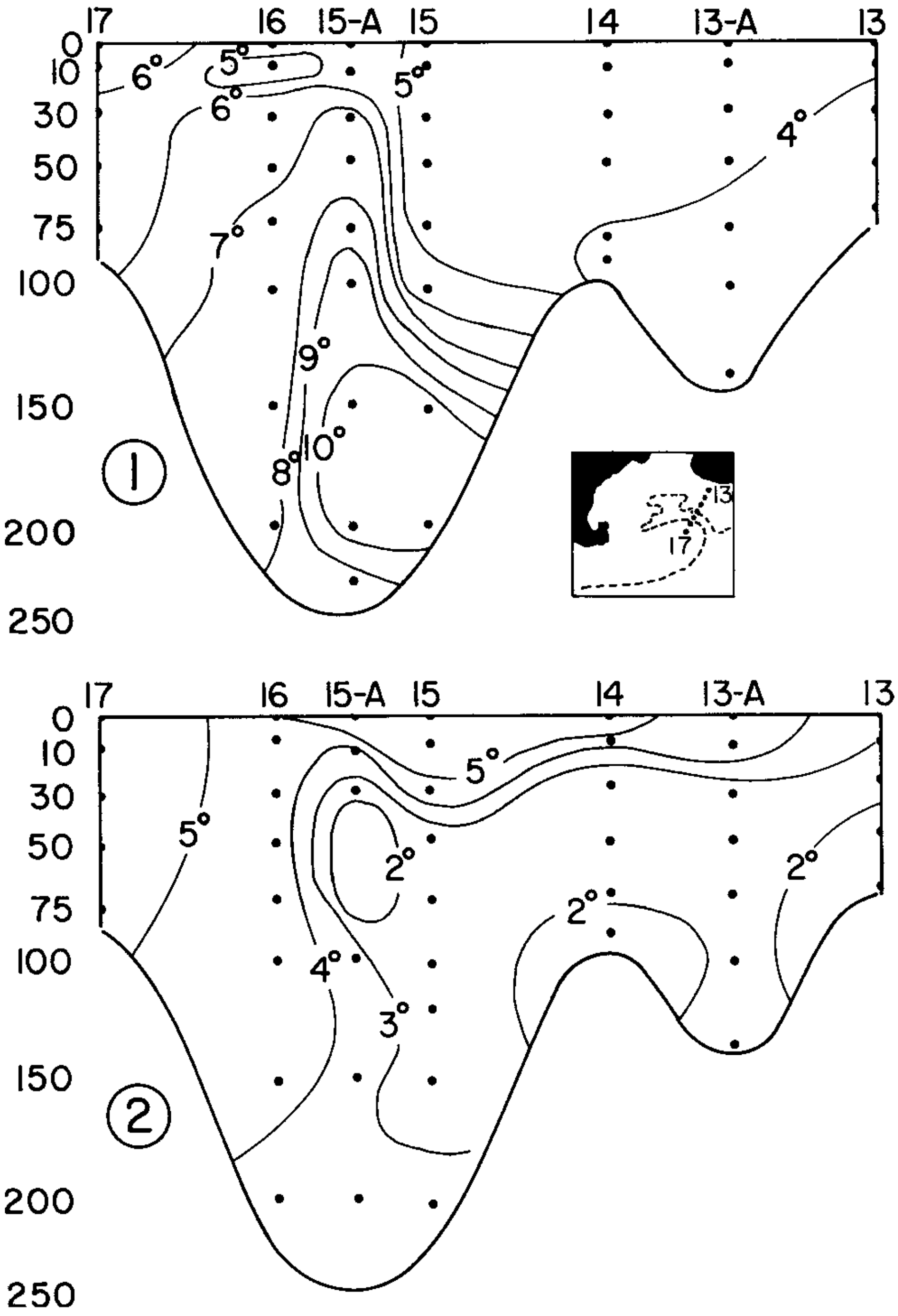

Fig. 1. Distribution of water temperatures (°C) in the passage between Browns and Georges Banks. ① 20 May 1963. ② 20 May 1964.

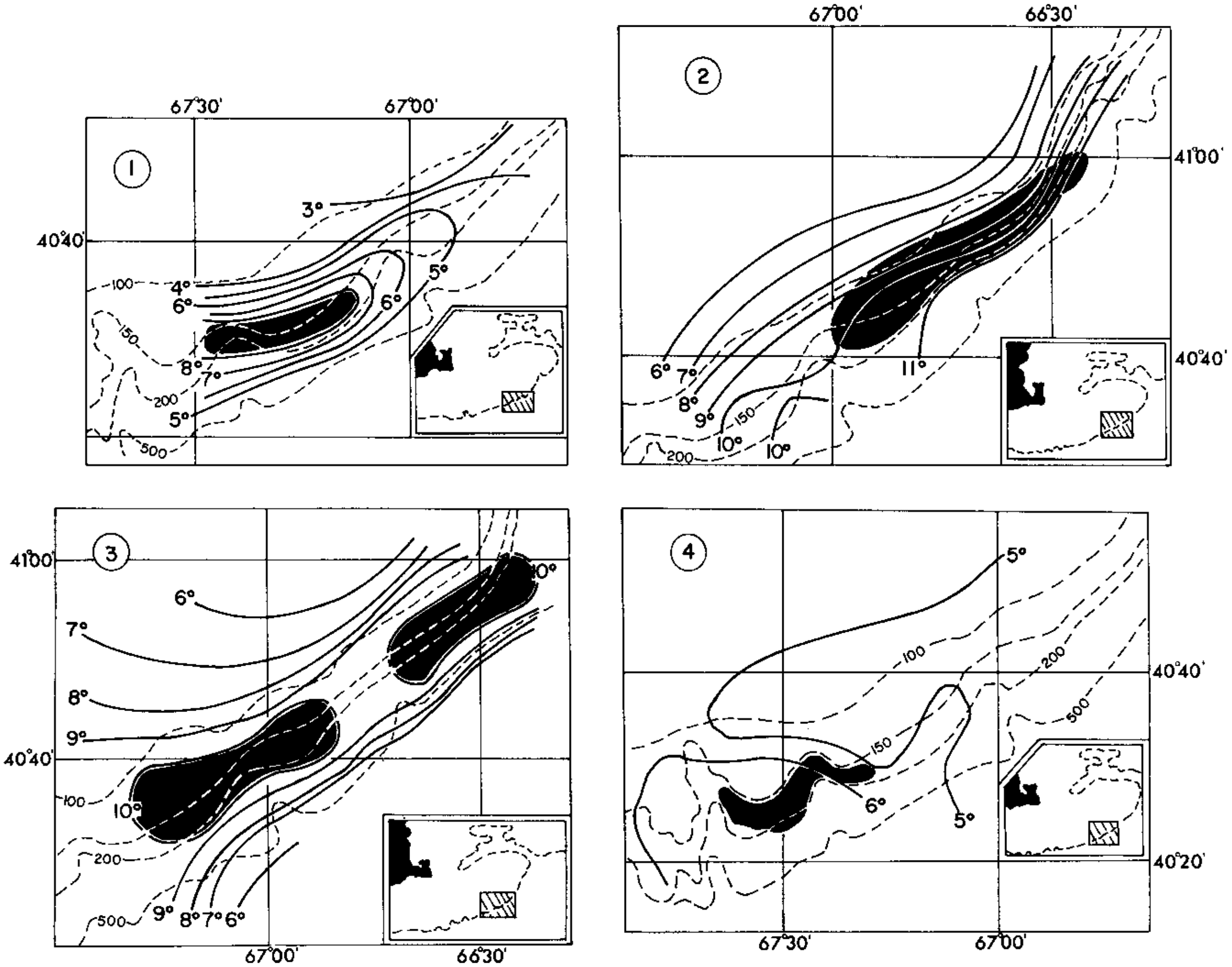

Fig. 2. Distribution of water temperatures (°C) off the bottom and silver hake concentrations on the southeastern edge of Georges Bank. ① The end of March-beginning of April 1964. ② The end of May 1963. ③ June 1963. ④ June 1964.

In the eastern area (east of Lydonia Canyon), silver hake were in a small area at depths of 140 – 230 m with bottom water temperature 7° to 8°C (Fig. 2, 7). To the eastward of 67°W, conditions for silver hake were totally unsuitable. Warm water, as seen from the results of the hydrographic section (Fig. 7 ②), did not reach the slope. Hydrographic conditions west of this concentration and along both sides of Lydonia Canyon were somewhat unstable owing to the pulsating inflow of warm Atlantic water which caused frequent shifts of the silver hake in this area.

In the western area (Welker, Hydrographer, Veatch Canyons) similar hydrographic conditions were found to be related to the accumulation of silver hake. It is characteristic that owing to unfavourable conditions no silver hake were found between the eastern and western concentrations on the continental slope bordered by Oceanographer and Welker Canyons (Fig. 7 ③). During March and April 1963 no silver hake schools were observed along the southern and southeastern slopes. A careful hydrographic survey of this area in April showed relatively high water temperatures in all parts of the slope which were, most probably, unfavourable at this time for schooling silver hake were observed in these regions only in May, with male and female gonads near the

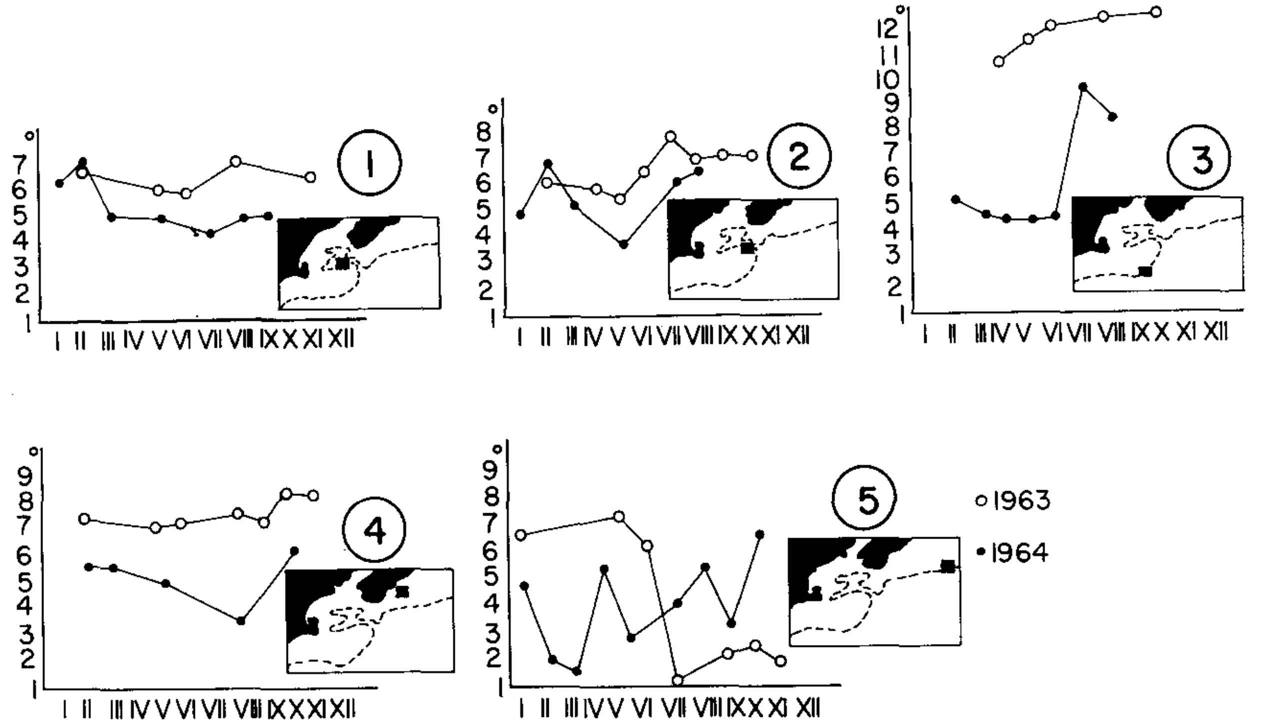

Fig. 3. Monthly water temperatures (°C) at 200 m in 1963-64. ① and ② The northern slope of Georges Bank ③ The southern slope of Georges Bank. ④ Scotian Bay. ⑤ To the south of Sable Island.

spawning stage III. In March and April 1964, concentrations of silver hake were observed over many parts of the southern slope, undoubtedly associated with lower bottom temperatures than those in 1963 which created favourable conditions for hake with maturing gonads.

A comparison of silver hake distribution with the hydrographic conditions for the end of May 1962, 1963, and 1964 shows that the most dense concentrations of spawning silver hake on the southeastern slope occurred in 1962 and 1963 in areas with bottom temperature 10° to 12°C. In cooler water (even at 9°C off bottom) silver hake were found in small quantities (Fig. 2). Early in May and late in June 1964, concentrations of silver hake were not great in this area. It appeared that off-bottom temperatures did not rise above 8° and 9°C and were as low as 4°C at lesser and greater depths than those occupied by these concentrations (Fig. 8). Silver hake that had reached the spawning stage by the end of May were scattered over an extensive area and did not form any bottom concentrations as in 1962 and 1963. Evidently conditions were such that the silver hake did not form dense spawning concentrations during the late spring and early summer of 1964. It is interesting to note in this connection that, according to the catch data from certain areas, such as the northern slope of Georges Bank, spawning hake were observed in greater numbers in the summer of 1964 than in 1962 and 1963.

As stated above, schools of young hake were observed in the winter of 1963–64 in the southern part of the Gulf of Maine at depths of 200 m or more (Fig. 4). Schools of young silver hake from 21 to 27 cm in length, the so-call "recruits", were also observed in this area at the beginning of the winter of 1964–65, though nw distributed in midwater. Studies conducted over 5 days showed that silver hake remained in midwater without sinking to off-bottom depths. This is obviously due to a general temperature drop in 1964 which also affected this area. As early as August 1964, as a result of this process, the temperature in the lower strata of the deep parts of the southern part of the Gulf of Maine was 2°C lower than in August 1963 (Fig. 3). This might also be the

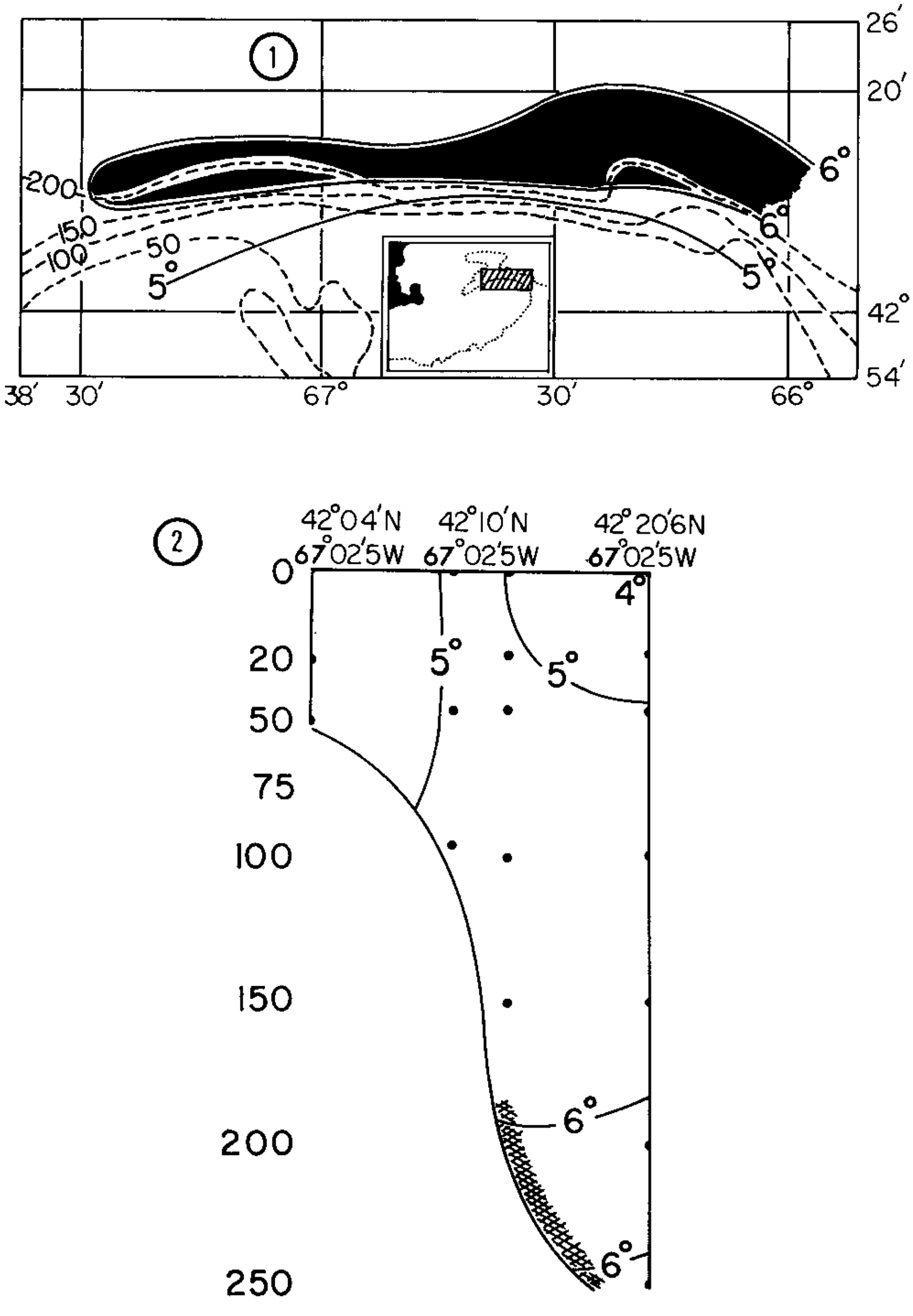

Fig. 4. Distribution of water temperatures (°C) and silver hake concentrations off the northern slopes of Georges Bank in the winter of 1963-64. ① Temperature and hake at 200 m and off the bottom in depths greater than 200 m. ② Vertical distribution of temperature and silver hake.

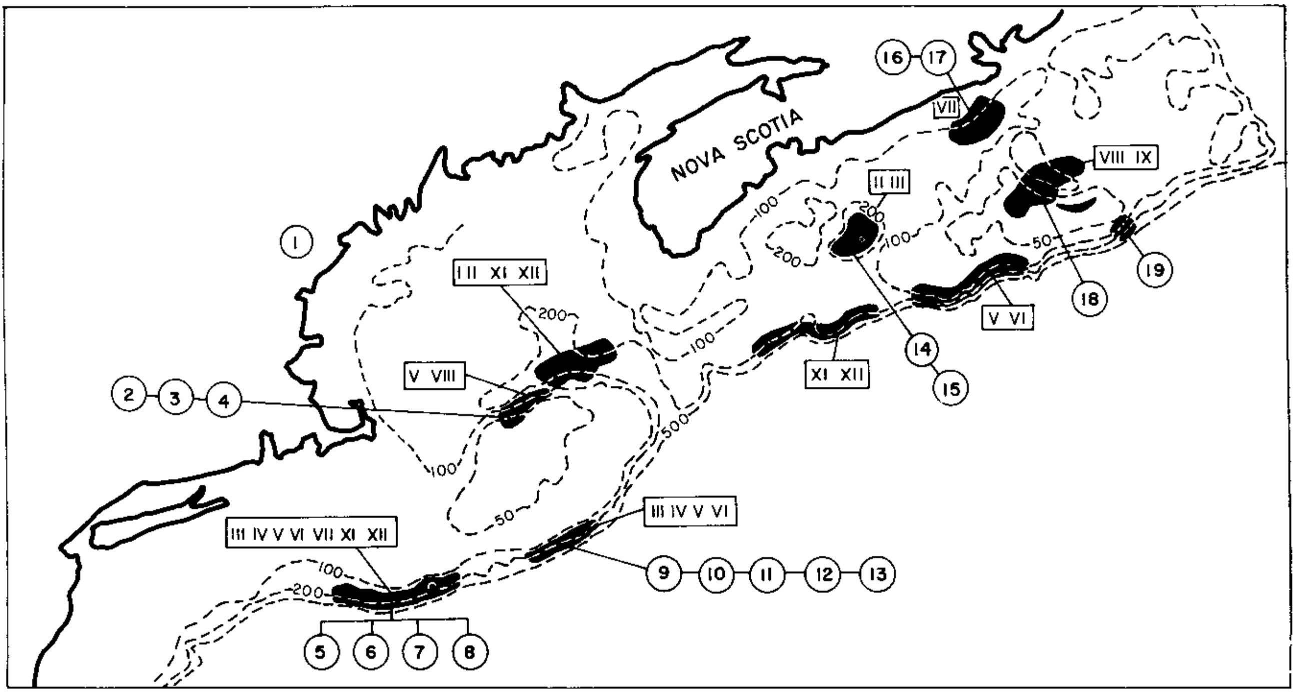

Fig. 5. General scheme of the distribution of silver hake concentrations on Georges Bank and the Scotian Shelf in the different months of 1964. (Circled numbers identify sampling locations; Roman numerals identify the months. See also Fig. 6.)

reason for a complete absence of off-bottom concentrations of silver hake fry north of Georges Bank in the summer of 1964–65.

Scotian Shelf

Analysis collected from 1962 to 1964 show that hydrographic conditions on the Scotian Shelf have been widely different in the 3 years. Figures 3 and 9 present these differences for the deep waters of Scotian Bay and the outer slopes of the Shelf. As an example of the difference, off-bottom water temperatures on the inner slope of Sable Island were 1° to 3°C lower in 1964 than during the corresponding period of 1963.

Silver hake concentrations were observed in three areas on the Scotian Shelf. During the winter months immature and young mature fish usually inhabit regions of Scotian Bay which are affected by an inflow of warm slope water with bottom temperatures about 4° to 6.5°C. In the spring, silver hake move through the deeps onto the continental slope and concentrate between LaHave Bank and the Deep of Hali where they remain at the bottom in temperatures of 6° to 8°C. Towards the end of the summer, with water temperatures over Sable Island Bank warming gradually to 12°C, silver hake appear there in increasing quantities. Most of the spawning takes place here. Later, with a drop in temperature during the winter months, silver hake leave the Bank.

The general pattern of silver hake distribution on the Scotian Shelf in 1964 is shown in Fig. 5. The distinctive feature in 1964 as compared with 1962 and 1963, is that silver hake concentrations were not found on the continental slope just south of Sable Island but were found farther west beyond LaHave Bank along the continental slope. Also, concentrations of silver hake fry were not observed in the northeastern part of Scotian Bay in the winter of 1963–64, nor were they found anywhere in Scotian Bay in the winter of 1964–65. Figure 3 suggests that this was apparently due to a reduction, which had started at the end of 1963, of the inflow of warm slope water to the Bank. In the spring of 1964, however, with the abrupt rise of bottom temperature

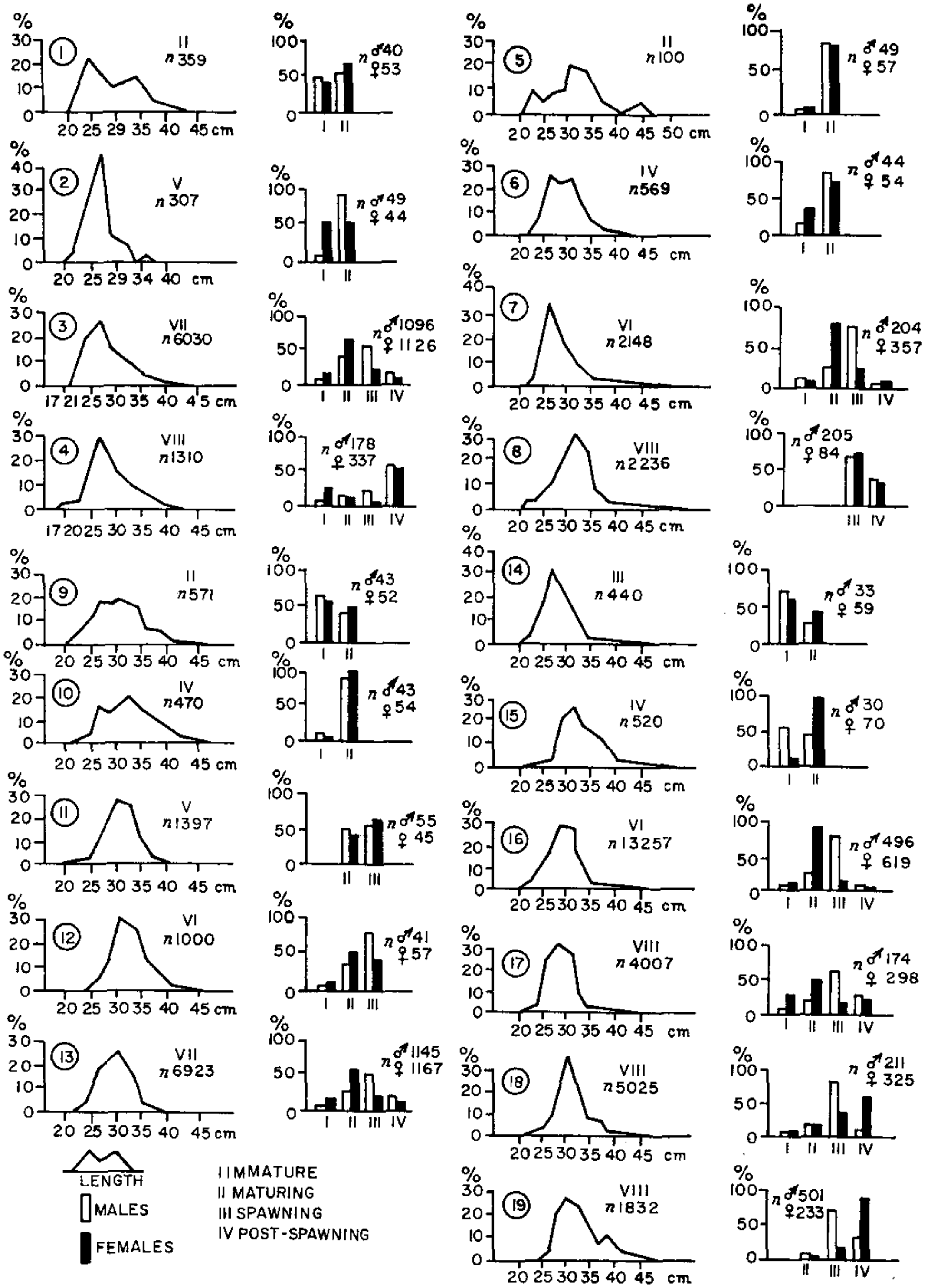

Fig. 6. Length frequencies and state of maturity of male and female silver hake on Georges Bank and the Scotian Shelf in the different months of 1964. (Sampling locations are indicated from the circled numbers in Fig. 5.)

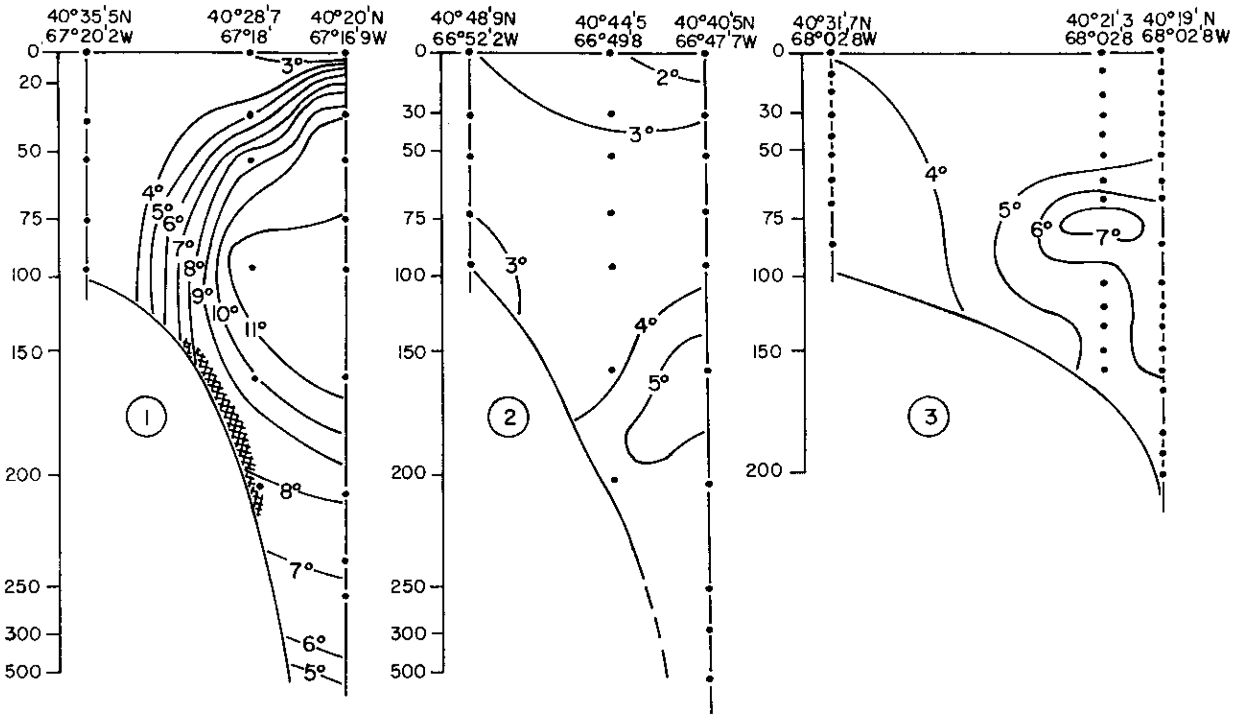

Fig. 7. Distribution of water temperatures (°C) on the southeastern slope of Georges Bank in April of 1964. ① The area of silver hake concentration to the east of Lydonia Canyon. ② To the east of silver hake concentration. ③ To the west of silver hake concentration (between the Walker and Oceanographer Canyons.)

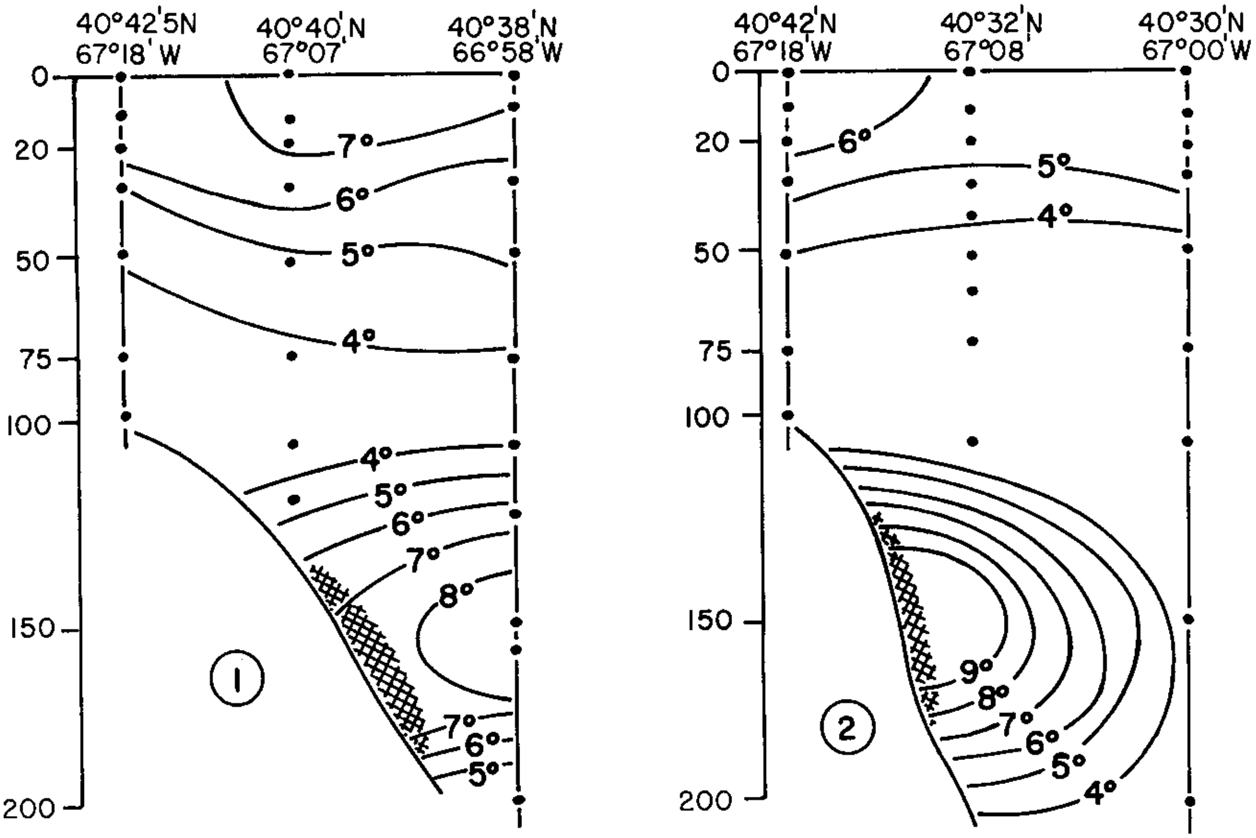

Fig. 8. Distribution of water temperatures (°C) in silver hake concentration area to the east of Lydonia Canyon in May 1964.

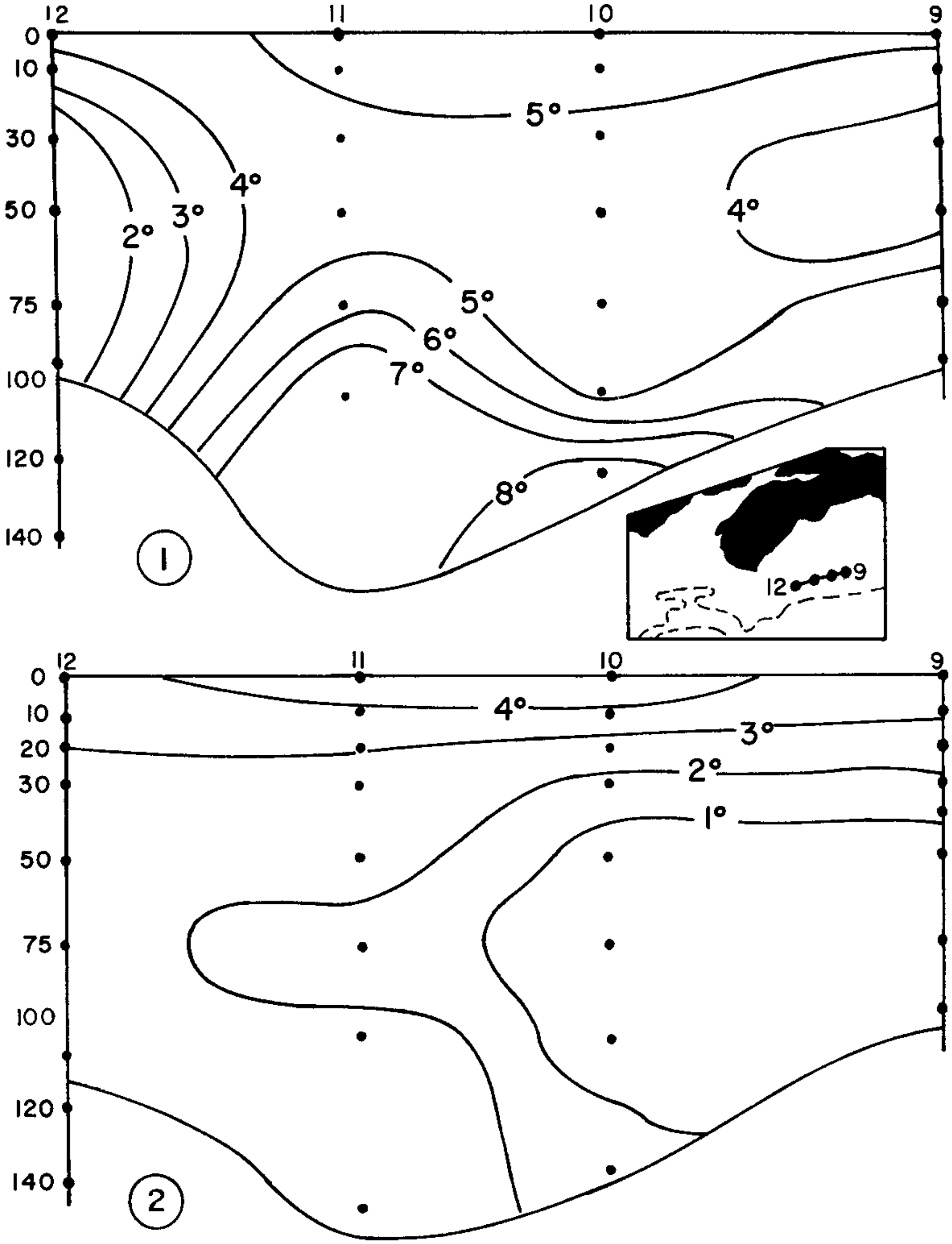

Fig. 9. Distribution of water temperatures (°C) in the channel between the LaHave and Emerald Banks. ① 18 May 1963. ② 3 May 1964.

silver hake "recruits" were found on the slope of the shallow west of Sable Island.

Length and state of maturity of silver hake in the spring of 1964 were similar to those of previous years.

Hake spawning took place during June and August 1964 on Sable Island shallows and in Scotian Bay. Initial spawning occurred in the Bay in June and July. Further spawning occurred in August on Sable Island Bank. From the 1963 observations, the second wave of mass spawning was expected to take place in September. Unfortunately it was not possible, owing to circumstances beyond the control of the research party, to verify this.

Conclusions

Substantial changes in silver hake distribution over the Scotian Shelf and Georges Bank are governed, to a large extent, by annual changes in hydrographic conditions in the areas.

Throughout 1964 the influence of warm Atlantic water on Georges Bank and over the Scotian Shelf was much less than during corresponding periods in 1963. This resulted in water temperatures, particularly of the off-bottom layers, being from 1° to 5°C lower on Georges Bank and from 1° to 3°C over the Scotian Shelf.

Depending upon their biological state, silver hake requires definite hydrographic conditions which are largely affected, directly or indirectly, by water temperatures. Obviously owing to lower temperatures in 1964, the hydrographic conditions prevailing on the southern slopes of Georges Bank in early spring 1964 were more favourable for maturing silver hake and less favourable for spawning than in 1963.

During 1963 silver hake spawning occurred within a limited area on the southern slope of Georges Bank between Corsair and Lydonia Canyons, but in 1964 spawning occurred over almost the entire southern slopes as far as Veatch Canyon. Specimens with flowing gonads were also observed over the northern slopes.

During the winter of 1964–65, owing to a general lowering of water temperatures, no silver hake concentrations were observed on the bottom in the southern part of the Gulf of Maine and in the Scotian Bay, the usual silver hake grounds.

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Changes in the Fishery for Atlantic Halibut, *Hippoglossus hippoglossus* L., in ICNAF Subareas 3 and 4, 1954 – 64

BY A. C. KOHLER[1]

Abstract

An examination of fishery statistics showed that landings of halibut by Canadian longliners declined recently. Part of the reason for this was a shift in their effort to swordfish longlining. Also, there appeared to be increasing pressure by otter-trawl units on immature fish in the stocks. The effect of these changes on the future of the stocks cannot be assessed until spawning and recruitment mechanisms are known.

Introduction

The fishery for halibut in the Northwest Atlantic has changed in a number of ways since 1954. Statistics show changes in amounts landed, area fished, and relative importance of types of fishing gear. To examine these changes, statistical data on halibut from the ICNAF Statistical Bulletins for the years 1954-64 have been summarized. Data on swordfish landings were taken from unpublished records at the St. Andrews Biological Station.

Statistics of the Fishery

The fishery for halibut is concentrated in Subareas 3 and 4 of the ICNAF Convention Area. Total landings for all countries for these two subareas are shown in Fig. 1A. From 1954 to 1960 there were increasing landings from the area, with a high of 5,480 metric tons in 1960. In 1960 these landings were divided almost equally between Subareas 3 and 4. From 1960 until 1963 landings decreased, the decrease being mainly in Subarea 3. A slight increase from Subarea 3 is shown again in 1964.

Figure 1B shows that Canadian halibut landings have also fluctuated during 1954–64. The Maritimes and Quebec landing statistics were used here since the fishery specifically for halibut is pursued principally by mainland fishermen. Newfoundland landings made up only about 10% of the total Canadian catch until 1962, and the majority of these landings were incidental catches

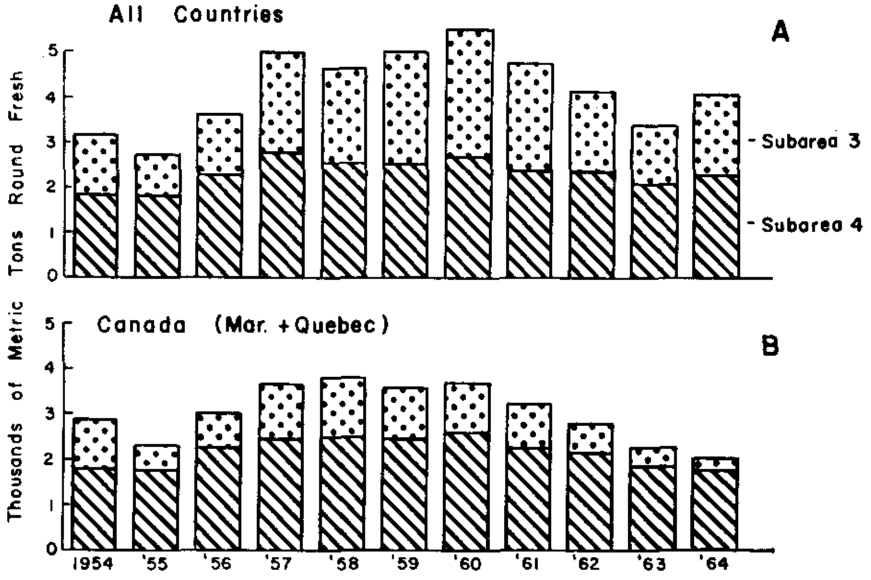

Fig. 1. Landings of halibut from ICNAF Subareas 3 and 4.

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[1] Fisheries Research Board of Canada, Biological Station, St. Andrews, New Brunswick.

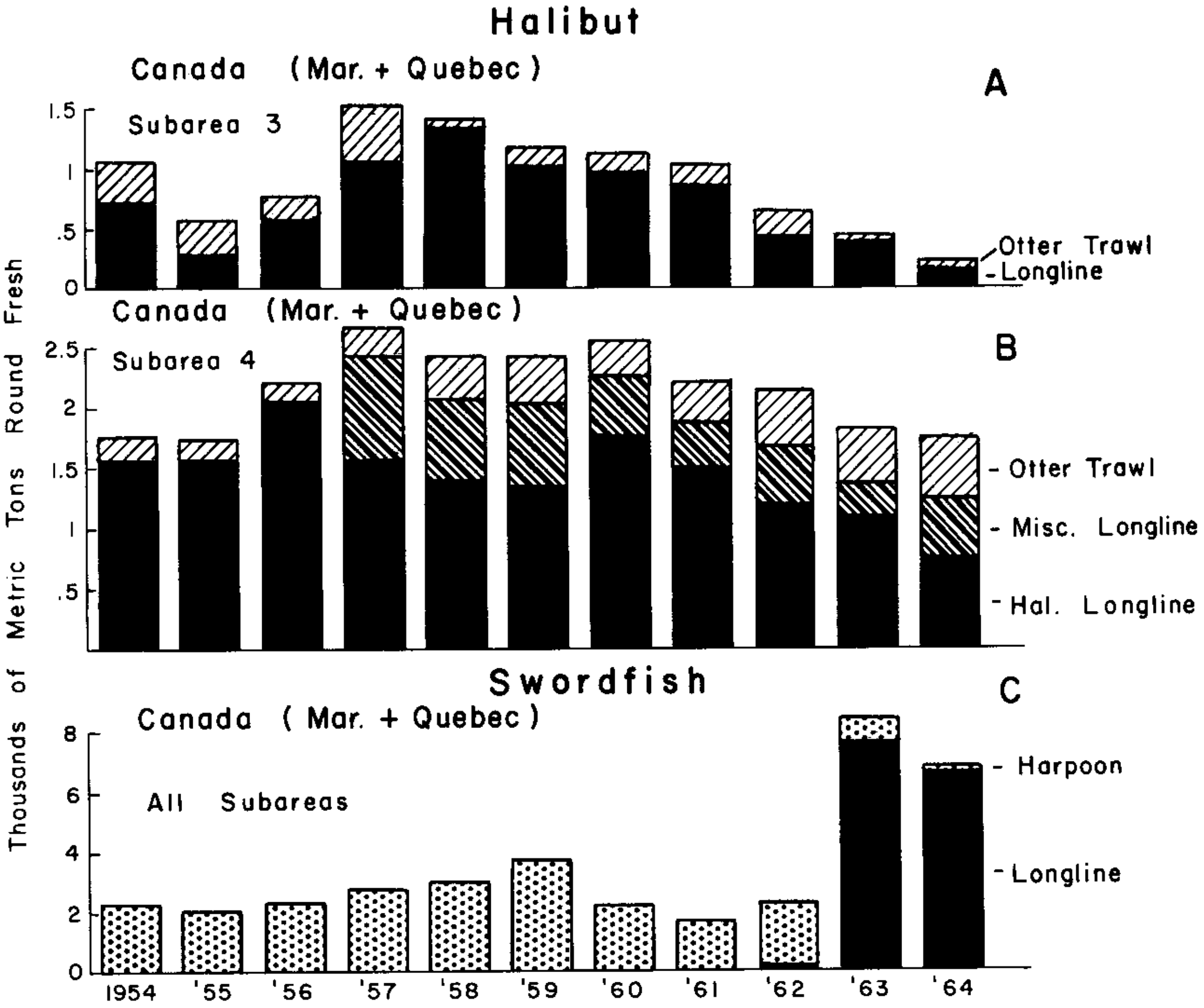

Fig. 2. Canadian (Maritimes and Quebec) landings of halibut and swordfish by type of gear.

from boats fishing for other species. Maritimes and Quebec landings reached a high plateau between 1957–60 of around 3,700 metric tons, with about 30% coming from Subarea 3. Since 1960 these landings have gradually decreased until in 1964 a total of 1,978 metric tons was recorded as landed on the Canadian mainland, of which 11% came from Subarea 3.

Since the fishery specifically for halibut is carried out by bottom longline, the Maritimes and Quebec landings, broken down by type of gear, were examined (Fig. 2A, 2B). For Subarea 3 (Fig. 2A) longline landings reached a peak in 1957 and dropped off gradually to 1961. In 1962 the longline landings decreased further to about half the 1961 values, and continued to fall until only 184 metric tons were landed from Subarea 3 by this gear in 1964.

Maritimes and Quebec landings from Subarea 4 show the same trends but have not fallen to such low levels (Fig. 2B). Longline fishing for halibut has been separated from longline fishing for other species in this figure. Although the peak halibut landings in total occurred in 1957, the peak landings by boats fishing specifically for halibut did not occur until 1960. At this time, 1,772 metric tons were attributed to boats fishing for halibut. This diminished to 738 metric tons in 1964.

One reason for the drop in halibut landings in the Maritimes has been the newly developed pelagic longline fishery for swordfish. This fishery which began late in the summer of 1962 has attracted many of the vessels that formerly fished halibut by bottom longline throughout the summer. Swordfish landings from the ICNAF area fluctuated around 2,000 metric tons from 1954 to 1962 (Fig. 2C), and almost all these fish were taken by harpoon. In 1963 and 1964 the new longline fishery for swordfish expanded greatly. Landings from longlining were 7,840 metric tons in 1963 and 6,856 metric tons in 1964. By 1964 harpoon landings had dwindled to 128 metric tons. The diversion of effort from halibut longlining to swordfish longlining was undoubtedly the main reason for lowered halibut landings.

Fishing pressure is exerted on the halibut stocks in Subareas 3 and 4 by Newfoundland and by countries other than Canada, but their total take is not nearly as great as that by mainland Canada. Landings for these groups from Subarea 3 increased from 1954 to 1960 (Fig. 3A) when about 1,500 metric tons were landed and over half of this by longline fishing. The growth of the line component in these landings was due to an increase in activity of Norwegian longline vessels. In the period 1960–63, total landings dropped, due mainly to a decrease in the Norwegian fishery, although the otter-trawl component became more important. A relatively large total landing is shown for 1964, due mainly to a doubling of the otter-trawl catch by the UK and USSR.

Halibut landings from the same countries operating in Subarea 4 have increased over the whole period (Fig. 3B) but are still relatively small. The line component of these landings is mainly fishing by Newfoundland in the northeastern Gulf of St. Lawrence. In recent years the otter-trawl part represents both European and Newfoundland incidental landings.

This summary of statistics shows the changing effort and types of effort affecting the halibut fishery. To generalize on what effects these changes might have on the halibut stocks, the sizes of fish involved in these landings must also be known.

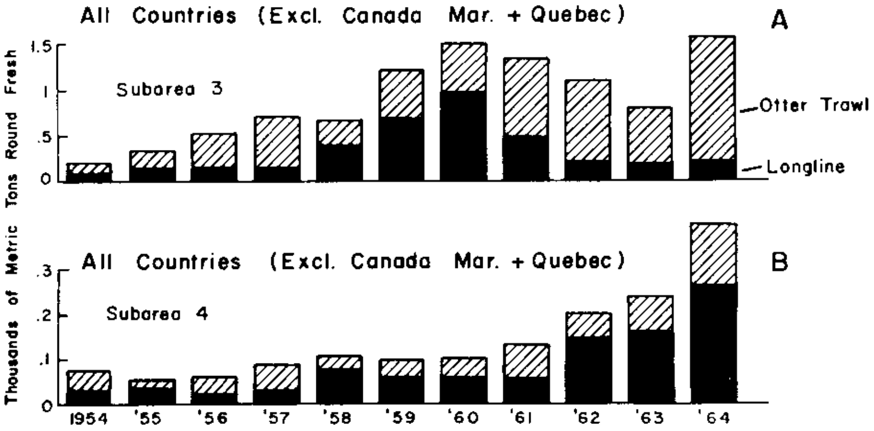

Fig. 3. Landings of halibut from ICNAF Subareas 3 and 4 other than on the Canadian mainland (Maritimes and Quebec).

Sizes of fish landed by otter-trawl and longline units

Differences in sizes of fish caught by longline and otter trawl have been shown elsewhere (Kohler, 1967). An example of length compositions of fish landed from the two gears (Fig. 4) illustrates the well known fact that longline catches contain much bigger fish than otter-trawl catches. One reason is that the No. 6283 Mustad hooks used by Canadians for longlining halibut are too big to fit easily into the mouth of small fish. A second reason may be the selective feeding by small halibut which have been shown to prefer invertebrates (Kohler, 1967). Longline vessels use fish (mainly herring and "trash" fish in their catch) almost exclusively as bait for halibut. A third reason may be differential distribution of sizes of halibut on the banks, with the smaller fish tending to remain on the shoaler grounds that are fished regularly by otter trawl while the larger fish tend to be on the deeper and

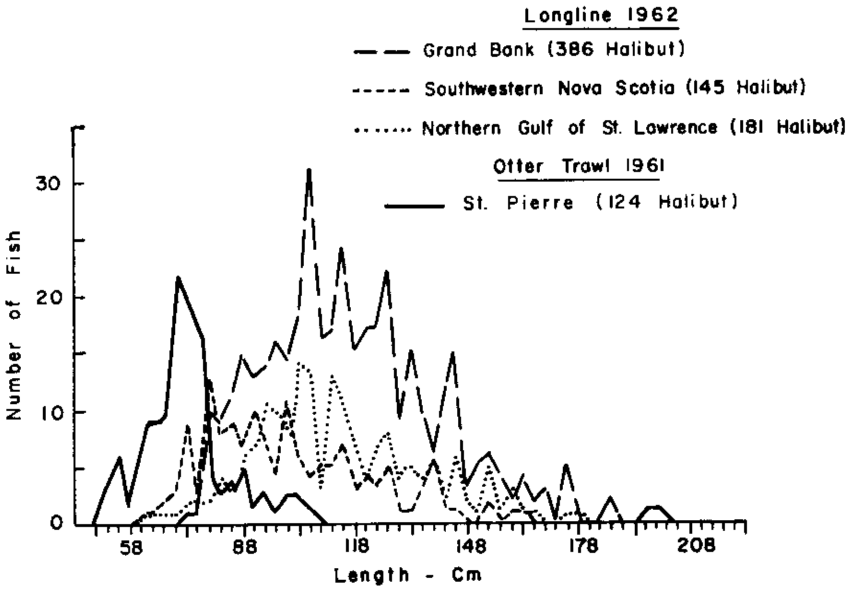

Fig. 4. Length composition of halibut landings.

rougher edges of the banks where the longline fishing for halibut generally takes place.

It has been shown that most halibut are not mature until they reach 100 cm in length (Kohler, 1967). Therefore the majority of halibut landed by otter trawl (Fig. 4) will be immature fish. A large portion of the longline fish are over 100 cm in length and are probably mature at this size.

Effects of changes in the fishery on halibut stocks

With the available data, one may speculate only very generally on the effects of the fishery on halibut stocks since 1954. McCracken (1958) indicated that the approximate long-term annual average of landings of halibut from ICNAF Subareas 3 and 4 was of the order of 5 million pounds and that fluctuations in this were related mainly to changes in the magnitude of the Canadian fishery. From 1954 to 1964 landings have been above this long-term average. Canadian mainland landings have gone down but there were increased landings by other fleets. However, the type of pressure exerted on the stock by these other units is different from that exerted by the Canadian longliners which now leave the halibut fishery seasonally in favour of the swordfish fishery. At present there seems to be an increasing pressure on the stocks by otter-trawl units (Fig. 2B, 3).

If this trend continues, assuming that all otter trawlers tend to select like sizes of halibut, there may be some detrimental effects on survival of spawning stock since the otter trawlers take a much greater percentage of immature fish than the longliners. To say how great these effects may be would be speculative at present since we know practically nothing about spawning and recruitment of halibut stocks in the Northwest Atlantic. If the halibut fishery is to continue to be an important source of economic return to fishermen, this aspect of the biology of halibut and the effect of the fishery on it should be thoroughly investigated soon.

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Age Determination of Nova Scotian Greysole, *Glyptocephalus cynoglossus* L., from Otoliths

BY P. M. POWLES[1] AND V. S. KENNEDY[1,2]

Abstract

The otolith method of ageing was applied to *Glyptocephalus cynoglossus* L. from Middle Ground (ICNAF Division 4W). Seasonal changes in edge deposition, a modified Petersen method, and back-calculations of mean lengths were used to validate the ageing methods. In a study sample of small and large fish from the same grounds, clear (as opposed to "diffuse") otoliths appeared to be associated with slower growing fish. Von Bertalanffy growth equations computed from the study sample (306 fish) and for ICNAF Division 4W as a whole (784 fish) did not differ significantly.

Introduction

Huntsman (1918) used scales to determine the age and growth rate of greysole or witch flounder. In old individuals of such a long-lived species as greysole the present authors found outer checks on scales difficult to interpret consistently. Bowers (1960) determined ages of Irish Sea witch by otoliths and found the method reliable. This study scrutinizes the validity of applying the otolith method of ageing to greysole from the Middle Ground region off Nova Scotia.

Validity of the otolith ageing method was assessed in three ways: by studies of the edge of the otolith at different seasons; by back-calculations of lengths at certain ages; and by checking otoliths against ages determined by a modified Peterson method (assignation of ages to length modes). Tag recoveries were too few to permit checking the growth rate of recovered tagged fish against growth rates determined from otolith examination.

Sampling greysole for validation studies is complicated by their natural heterogeneous size distribution. Unreported studies indicate little mixing of adult populations between the Gulf of St. Lawrence, Sydney Bight, Scatari, and Middle Ground regions. Within these separate regions young fish (less than 30 cm in length) are quite segregated from older fish and often occur over deep, rough bottom. Further complications are introduced by migrations into shallow water in summer, with the result that it is difficult to follow one segment of the stock with certainty.

Methods and Materials

In one restricted area, just west of Middle Ground, a sample of 955 large and small fish was taken. This was used as a study sample, thus avoiding possible complications arising from combining several units of populations whose biology and growth might differ. Furthermore, the otoliths from this group appeared clearer than those from other areas sampled, including the Gulf of St. Lawrence, Sydney Bight, and Scatari regions. For general growth rates in the Middle Ground area, other samples were combined with the study sample. In comparing seasonal changes in otolith edge appearance, otoliths collected from a number of separate areas off Nova Scotia were used, since only in this way were samples available throughout the whole year.

Otolith collections

Some 1,474 otoliths were collected from the Sable Island-Banquereau area off Nova Scotia in 1964 and 1965 during cruises of the two research trawlers, *M. V. Harengus* and C.G.S. *A. T. Cameron* (see Powles, 1965, for details of the gear) while the remaining (567) samples were taken by deep-sea Norwegian shrimp trawl (Squires, 1958), or from commercial trawlers and seiners. Only those from the Middle Ground area (784) were used in the final growth equation. Otoliths from the study sample (306) were used for otolith typing, back-calculation studies, and tests of validity of the ageing method.

Otoliths were kept in vials containing a 50% aqueous solution of glycerin with a few crystals of

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[1] Fisheries Research Board of Canada Biological Station, St. Andrews, New Brunswick.

[2] *Present address*: Department of Zoology, University of Rhode Island, Kingston, Rhode Island, USA.

thymol added. Initially, trials of dry collections and alcohol-preserved collections were also made. Tests showed little difference between these methods with regard to clarity of zones when otoliths were read whole. However, for otoliths which were split longitudinally for reading (old fish and otoliths in which the central nucleus was not clear), the dry method of preservation was best. The otolith reading terminology followed Jensen (1965).

Measurements

All fish were measured from the snout to the distal end of the longest caudal fin-ray, i.e., mid-line length to the nearest centimetre. For example, 30.6–31.5 cm was assigned a length of 31 cm. The sex and gonad condition were determined by internal examination.

Otolith measurements were made on the flat surface of the right saccular otolith using a Nikon Model SMZ stereoscopic microscope with 6× oculars and 1× objectives. One ocular was fitted with a screw micrometer eyepiece. The drum on the screw micrometer was divided into 100 divisions for one complete rotation. One division measured 0.011 mm of the field of view with the above lens combination. Measurements were recorded in terms of units of the rotating drum and converted to millimetres.

To establish the relationship between total (mid-line) length and otolith half-length, measurements were made from the centre of the nucleus to the outermost edge of the otolith at the longest axis (Fig. 1). Individual variates were then plotted on a linear scale. For back-calculating lengths-at-age, measurements were made from the centre of the nucleus to the distal or outermost margin of each hyaline zone (the so-called half-length) along the line shown in Fig. 1.

Results

Seasonal edge deposition

In a series of otoliths collected over an 18-month period, the majority (75–95%) of otolith edges were hyaline from October to May and opaque from June to September (Fig. 2). Hyaline zones were therefore presumed to be associated with winter, opaque zones with summer, and the bands were not randomly formed, but represented true annuli.

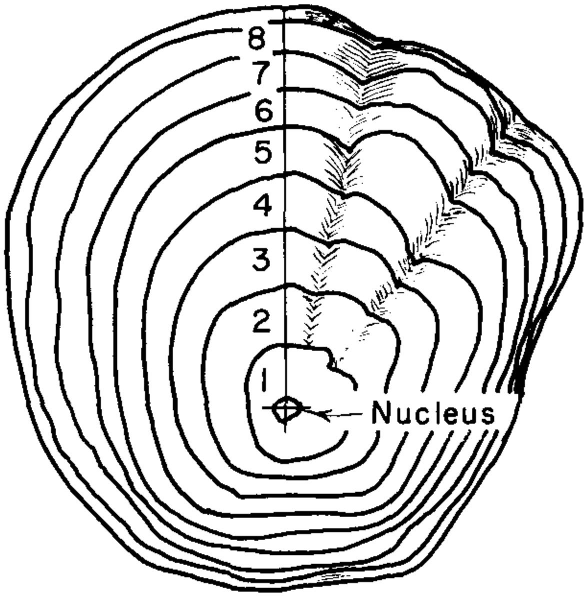

Fig. 1. Diagram of greysole otolith showing position of hypothetical line used for ring measurements.

Length modes of small fish and appearance of otoliths

In April 1965 a number of small greysole (Fig. 3) were captured by shrimp trawl. Length data from these show four discrete length modes. The smallest length mode occurred at 6–8 cm and was assigned to age I. (Had these fish been captured prior to 1 February, the arbitrary birthday used, they would have been assigned age 0.) Following in order, the next distinguishable length modes occurred at 10–15, 16–19, and 20–24 cm, and were assigned ages II, III, and IV, respectively. When clear otoliths from each length mode were examined, those from the 6 to 8 cm length group of fish had a small central nucleus in an opaque zone which was surrounded by a hyaline band on the outside. Otoliths from the 10 to 15 cm group contained a nucleus followed by two sets of alternating opaque and hyaline bands. Clear otoliths of the 16–19 cm and 20–24 cm groups were characterized by three and four sets of alternating opaque and hyaline zones respectively. The regularity in spacing of length modes and corresponding consistency in number of hyaline zones associated with each length mode suggest that assigned ages were valid.

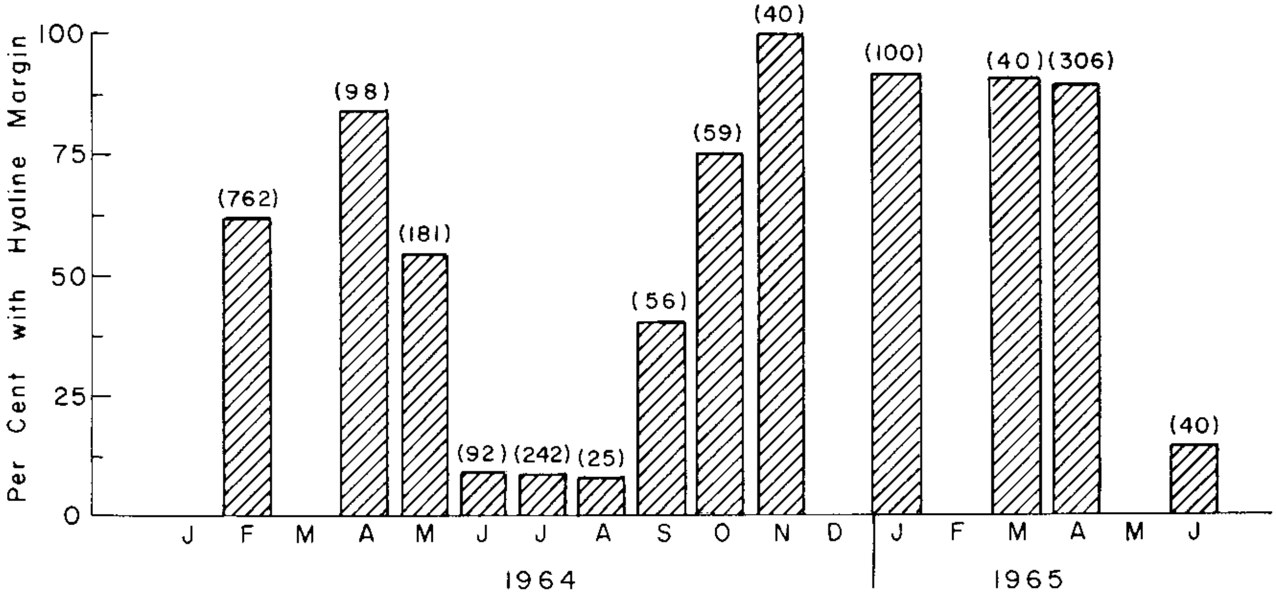

Fig. 2. Proportion of hyaline and opaque edges found in the otholiths of greysole from Middle Ground to Banquereau. Numbers in parentheses represent sample size.

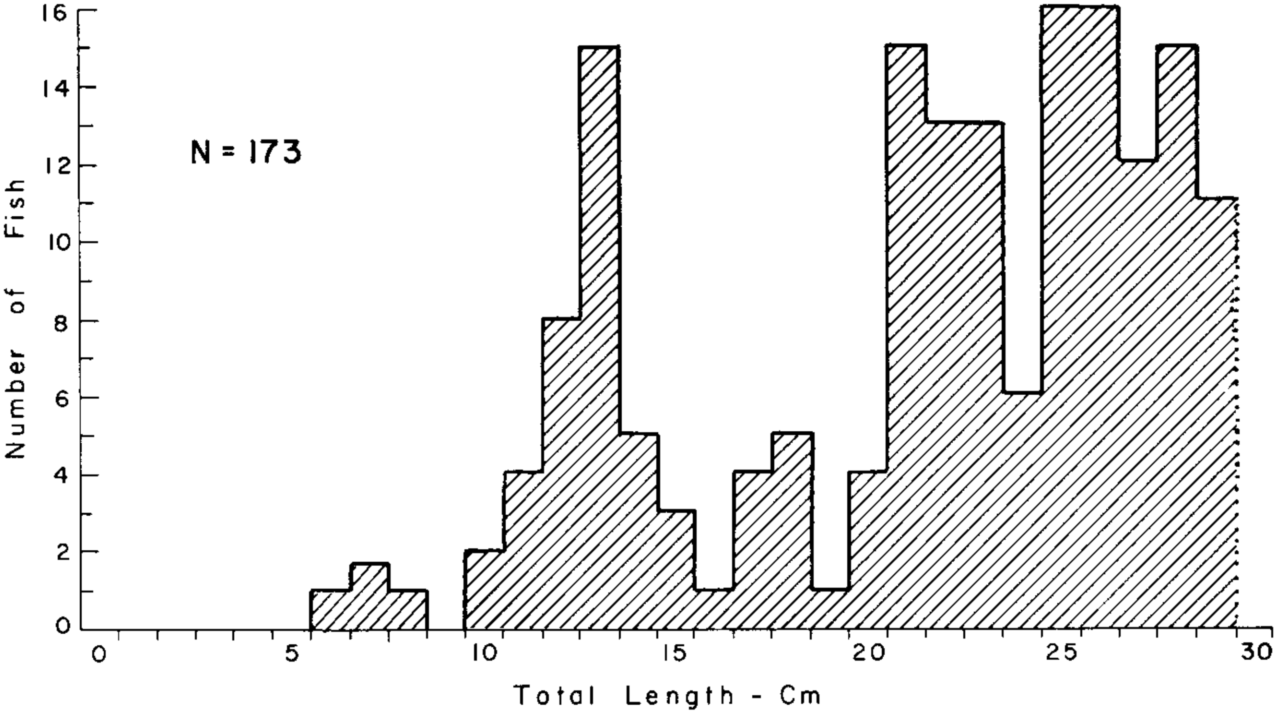

Fig. 3. Length distribution of greysole taken by deep-sea Norwegian shrimp trawl on Middle Ground in April 1965.

Back-calculation of total lengths from otoliths

For accurate back-calculations of lengths at successive ages, it is necessary to find the true proportional relationship between growth of the otolith and the fish throughout its life. "Half-lengths" of otoliths were therefore plotted against corresponding individual total lengths of fish. A plot of the data (Fig. 4) showed that the points lay along a straight line, indicating that growth of the long axis of the otolith and growth of the body are isometric. A least squares fit applied to the data gives the following equation:

$$L = 0.1195\ (\sigma - 40.0)$$

where L = fish length and σ is otolith "half-length" in eyepiece units. A method similar to that devised by Frost and Kipling (1959, p. 327) was then used to back-calculate the lengths at successive ages for greysole.

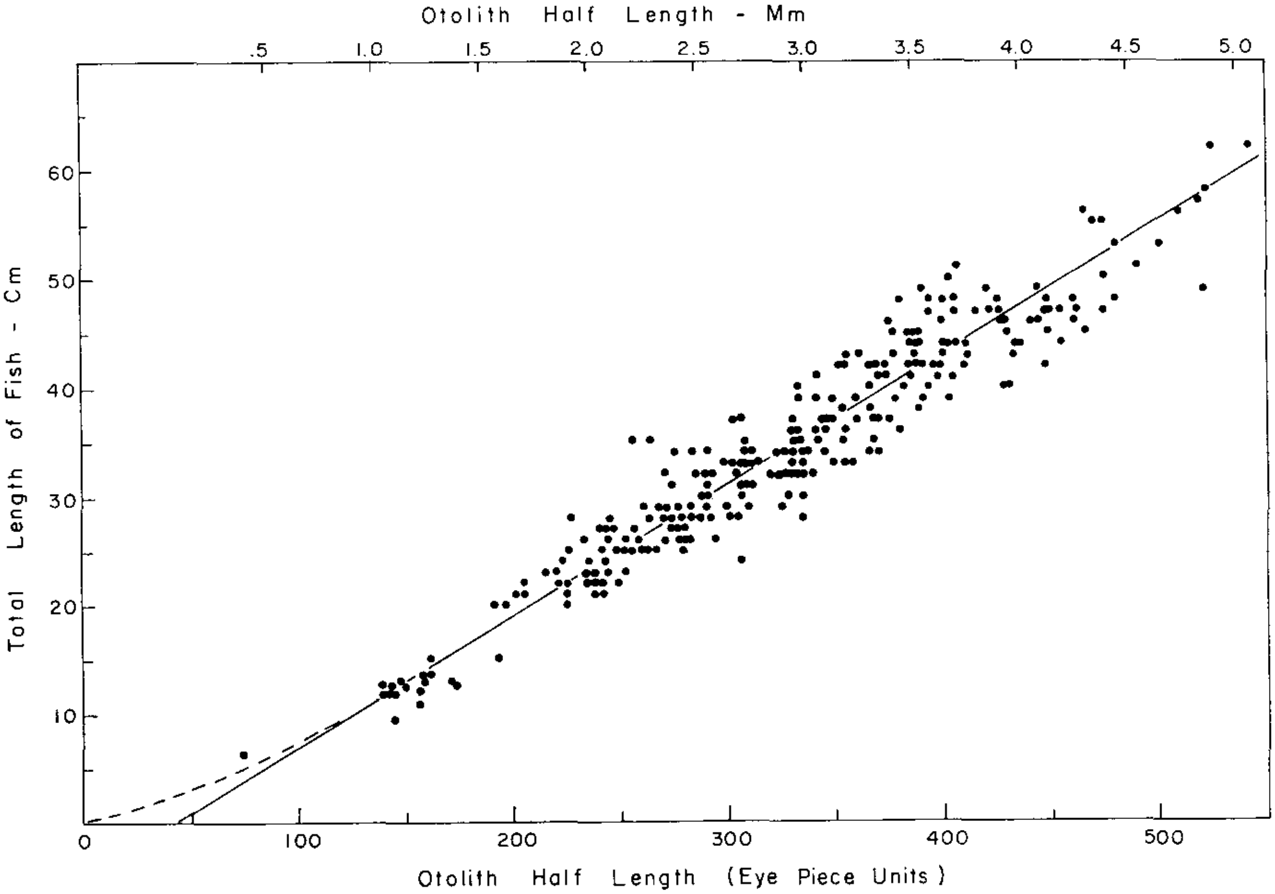

Fig. 4. The relationship between otolith length and total length for Middle Ground greysole.

Back-calculations were made from 42 clear otoliths taken by otter trawl from an area close to where the study sample was obtained. The otolith back-calculations were arranged by age groups because of the possible occurrence of Lee's phenomenon. The overall mean lengths corresponded very closely to the length-frequency modes of small greysole taken by shrimp trawl from the study area (Table 1). This is good evidence that the ageing techniques applied to younger fish on the basis of length modes and number of hyaline zones are applicable to older fish as well.

Rate of growth

Nova Scotian greysole have a rather low proportion of clear as opposed to diffuse otoliths ("checky" and/or "cloudy"). Because some otoliths were more difficult to read than others, otoliths were classified into four categories. Otoliths with clear, wide hyaline zones were placed in class 1. Checky and/or cloudy otoliths were placed in class 4. Intermediate types between these two classes were placed in classes 2 and 3. A small proportion were unreadable because of crystallization, and these were discarded. From a random sample of 100 otoliths agreement on ages between the two authors was: class 1, 92%; class 2, 80%; class 3, 65%; and class 4, 46%.

Since preliminary ageing methods were based on clear otoliths, it was necessary to compare mean lengths at age obtained from clear and diffuse or checky otoliths. The degree of confidence placed in the latter type of otoliths and the proportion of these otoliths in the population will naturally influence numbers required for adequate sampling. Therefore, mean lengths-at-age from clear and unclear otoliths were compared within the Middle Ground study sample. Classes 1 and 2 (excellent and clear) were grouped together and the mean lengths for each age computed. Similar computations were carried out for classes 3 and 4 (fair and poor). In the Middle Ground region it can be seen that the proportion of clear otoliths is relatively low (Table 2). (Attempts to improve readability by the "burning" technique of Christensen (1964) have so far not met with success. Burning did not eliminate questionable checks, and rendered the otoliths almost useless for back-calculation of lengths because of the unpredictable way in which the otoliths split.) Among young fish (ages 3–7) there were fewer clear otoliths proportionately than among older fish. This is probably because annuli on otoliths of older fish (within limits) are easier to discern, since the greater number of rings present a criterion for judging spacing.

From Fig. 5 it appears as though the clear otoliths belonged to slower growers. The sign test (Siegel, 1956) for small samples was applied to test the significance of this result. The null hypothesis used was: Mean length is independent of clarity in the otolith. On this assumption, a mean length from diffuse otoliths is as likely to lie below as above a mean length derived from clear otoliths. First, all ages were dropped for which there were fewer than 10 age readings. This left eight ages (4–11) for females and six ages (4–9) for males. All tied points (equal mean lengths) were then also dropped, reducing N from 14 to 12. Each pair of points for corresponding ages was then counted as plus if the mean length for diffuse otoliths fell above that for clear otoliths, and as minus if otherwise. The null hypothesis would lead to about as many pluses as minuses; however, a tabulation shows:

	+	−	tied
males	5	1	–
females	5	1	2
Total	10	2	2

Table D of Siegel (1956) shows that, for $N = 12$, an $\chi \leq 2$ has a two-tailed associated probability of occurrence of $p = 0.038$. This value falls under 0.05, and therefore we conclude that clear otoliths are, in fact, associated with a smaller mean length-at-age. In both males and females there is little difference up to and including age 5. But there is an increasing difference beyond this age. This suggests that the difference is due to increasing failure to read the full number of rings in diffuse otoliths. If this is the case, clear otoliths present the more reliable growth picture. Because of the lack of clear experimental evidence on annuli formation, however, we have chosen to present general growth rates based on readings from all otoliths combined.

Computed growth rate of Middle Ground greysole

The mean length-at-age data compiled from all Middle Ground otoliths were plotted. Clear and unclear otoliths were combined in the computations, but back-calculated lengths-at-age were omitted. Von Bertalanffy growth equations were fitted to the males and females following the method of Allen (1966) which involves a weighted least squares fit.

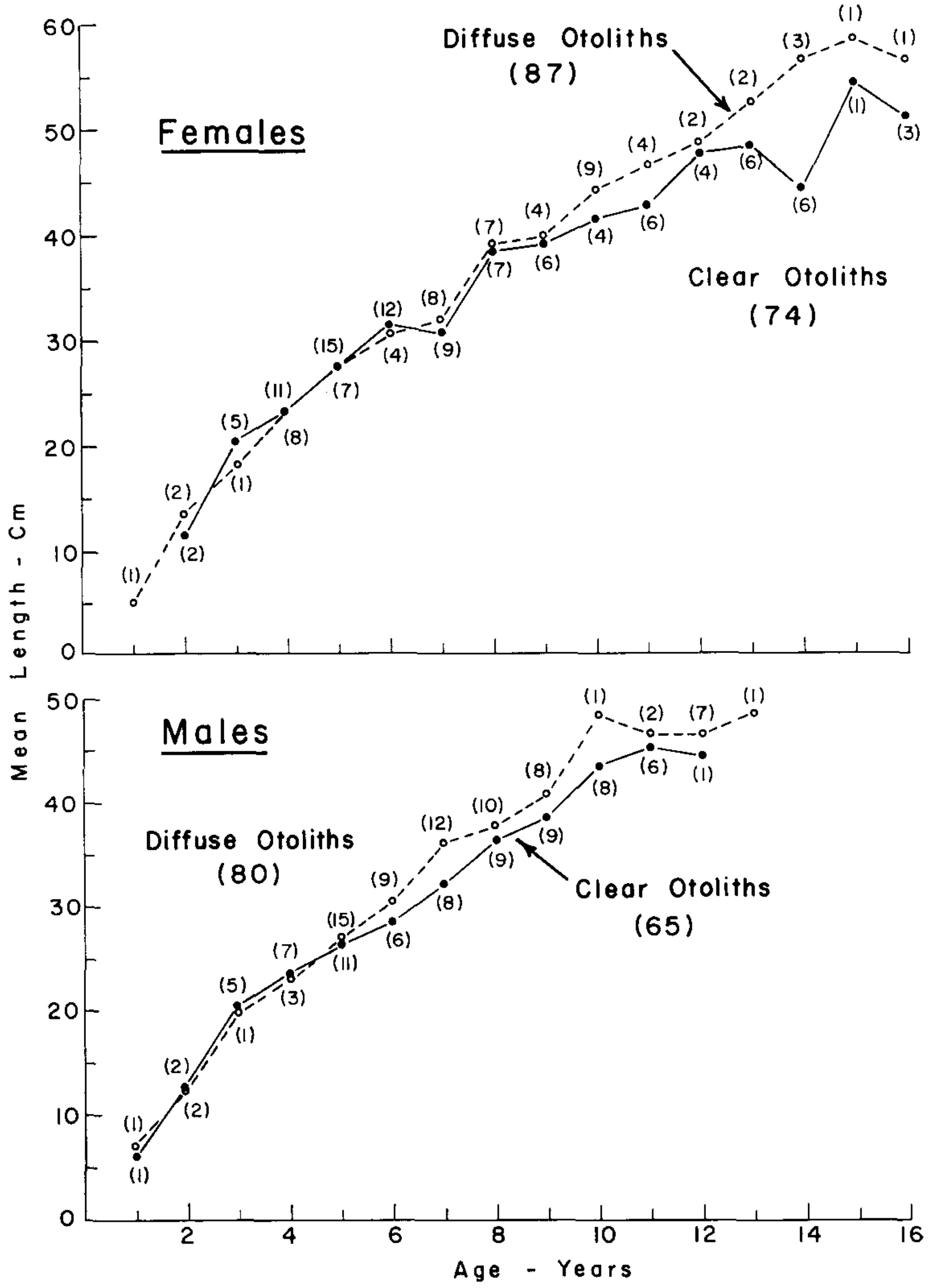

Fig. 5. A comparison of the mean lengths-at-age obtained from clear and diffuse otoliths of Middle Ground greysole.

The computed equations for all Middle Ground in Quarter I (Feb.–Mar.–Apr.) for males were,

$$l_t = 60.93 \left[1-e^{-0.12(t-(-0.04))} \right] \quad (1)$$

and for females,

$$l_t = 83.77 \left[1-e^{-0.07(t-(-0.42))} \right] \quad (2)$$

where l_t is the length in centimetres at any age, t; 60.94 and 83.77 were the asymptotic lengths in centimetres; –0.04 and –0.42 were the estimates of t_o, the time at which the fish would have been zero length if they had always grown in the manner described by the equations; and 0.12 and 0.07 were the growth or curvature coefficients, K, for males and females, respectively, in the von Bertalanffy equation.

Both males and females followed the von Bertalanffy type growth curve, as a good fit was obtained (Fig. 6). The curves obtained coincided fairly closely to age 7, but diverged beyond this point. Past age 7, females grew more rapidly than males and also attained a greater age and size.

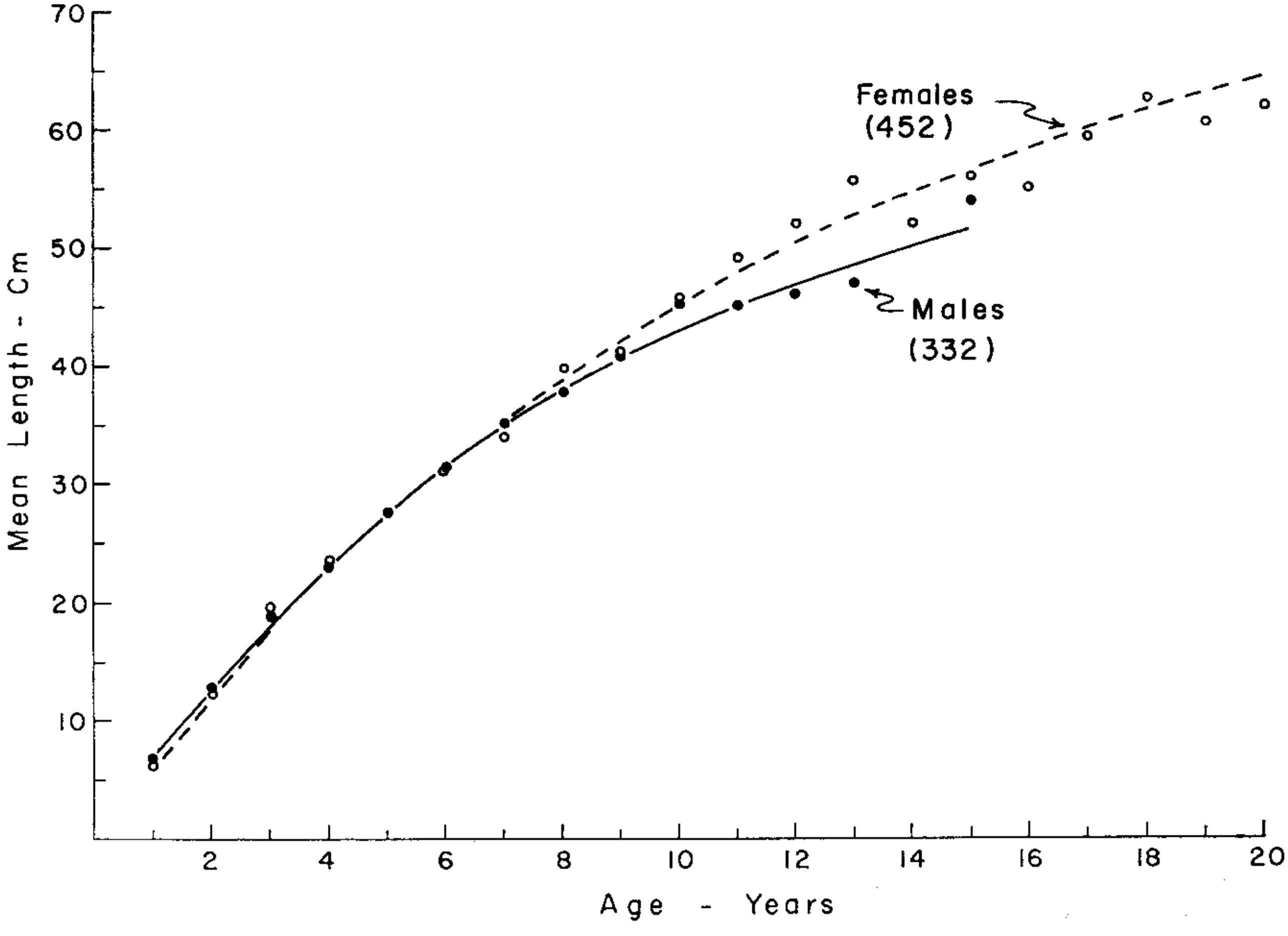

Fig. 6. Increase in length with age of greysole from Middle Ground. The von Bertalanffy growth curves were superimposed on observed mean lengths, and fitted by the method of Allen (1966).

Subsequently, the growth data compiled from study sample otolith readings within the Middle Ground region were again fitted to a von Bertalanffy growth curve (Fig. 7).

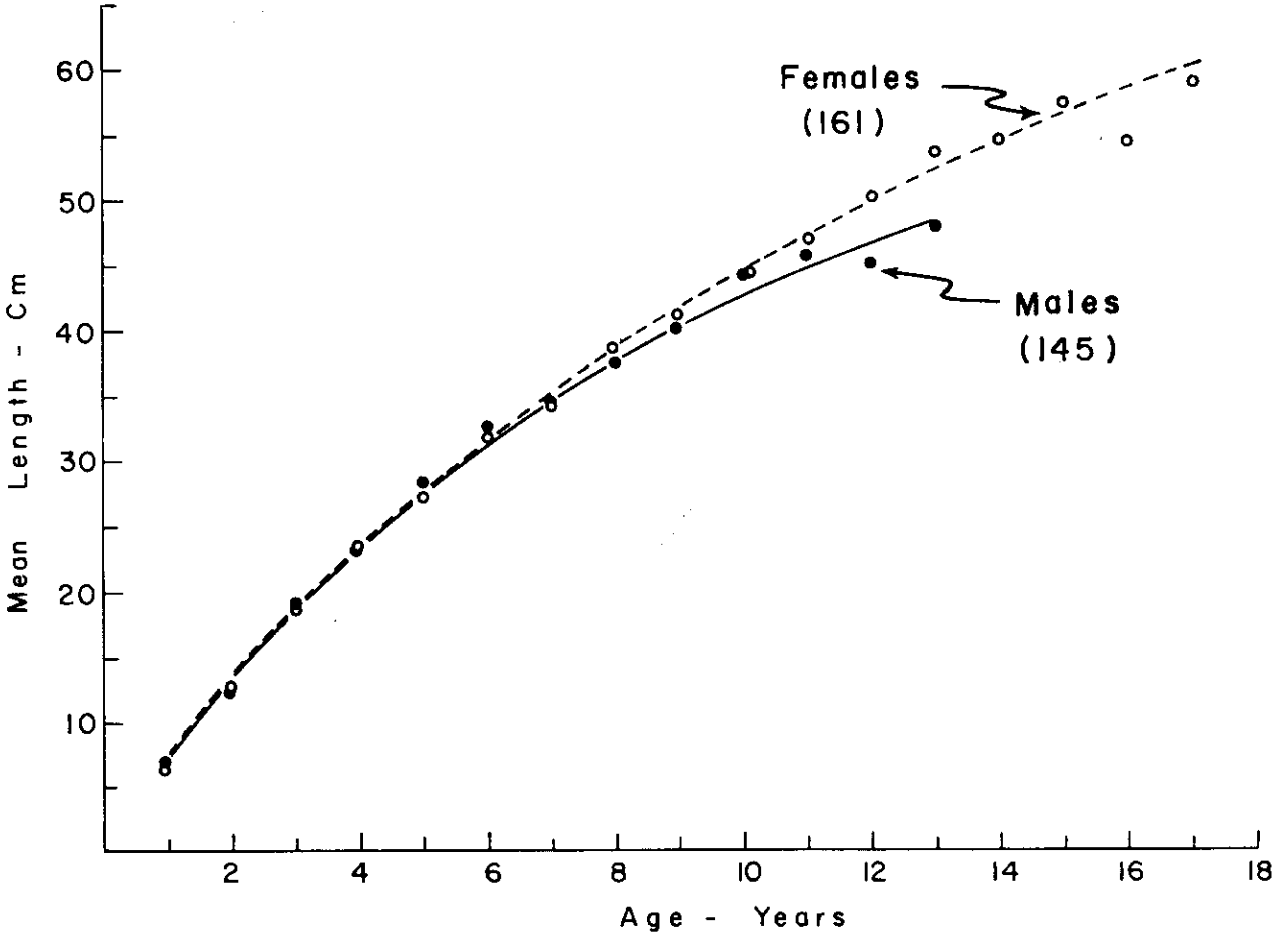

Fig. 7. Bertalanffy growth curves for the greysole study sample from Middle Ground.

This time the computed equations were for males,

$$l_t = 61.1 \left[1-e^{-0.13(t-0.25)} \right] \quad (3)$$

and for females,

$$l_t = 79.1 \left[1-e^{-0.08(t-(-0.09))} \right] \quad (4)$$

The parameters obtained for the study sample growth curve did not differ significantly from parameters obtained from study sample data except for t. The asymptote for males became slightly larger, from 60.93 to 61.07, and K increased from 0.12 to 0.13. For females, the asymptote was reduced from 83.77 to 79.13, and K increased from 0.07 to 0.08. Thus, a growth curve derived from a sample of 306 otoliths did not differ significantly from the growth curve based on 784 otoliths. (For practical purposes, the two growth curves superimpose one another.) This is further evidence that ageing techniques based on the study sample apply equally well to the area as a whole.

Discussion

Bowers (1960) carried out quantitative growth studies of *Glyptocephalus cynoglossus* L. in the Irish Sea, and reviewed other European studies. He found real differences in growth rate between sexes, though each sex lived about 10 years. The asymptotic length for females was 36 cm, and for males 31 cm. In the Irish Sea, the hyaline zone was a feature associated with winter growth (November–April), which is a shorter winter growth period than we observed for Nova Scotian waters. These two parallel features, growth differences between sexes, and seasonal pattern of deposition on the otolith, support our findings.

With regard to clarity of otoliths, Gulland (1956) has already pointed out the dangers in selecting only clear otoliths for use in growth studies. Recently (1965) Berry *et al.* found that n the case of *Pseudopleuronectes americanus*, a slower growth rate was associated with clarity in otoliths within particular regions. We have demonstrated a similar relationship for greysole. An obvious implication of such a result is that one might miss an annulus in diffuse otoliths by mistaking it for a false check. This would result in an apparently greater mean length-at-age for that fish. Without experimental evidence on annuli formation, there is no way of resolving this problem. However, we have shown that even a small sample of clear otoliths does yield a reliable estimate of growth.

The largest size and greatest age recorded for *Glyptocephalus cynoglossus* in European waters were 48 cm and 14 years for Icelandic waters (Bowers, 1960). The present study indicates that Middle Ground greysole may reach 65 cm and 20 years of age, surpassing its European counterpart for areas so far studied.

Acknowledgements

We are grateful to Dr William Knight for statistical advice and to Mr K. R. Allen for counsel and recommendations in programming the growth data. Mrs I. Thompson carried out the back-calculations.

TABLE 1. Mean lengths (cm) at age computed by otolith back-calculation of Middle Ground greysole taken by otter trawl compared to observed length-frequency modes of a sample taken by shrimp trawl.

	Mean lengths (cm)by age group						Overall mean length, sexes combined (otter trawl)	No. measurements	Range of length modes, sexes combined (shrimp trawl)
	1 to 4 year olds		5 to 8 year olds		9 and over				
Age	M	F	M	F	M	F			
I	11.9	8.4	6.7	9.0	7.4	7.4	7.6	36	6– 8.0
II	20.0	14.6	13.3	15.3	13.4	14.8	14.0	36	10–15.0
III	24.8	18.7	18.2	20.8	19.4	18.1	19.0	39	16–19.0
IV	27.5	22.3	22.2	25.4	24.4	22.9	22.8	42	20–24.0

TABLE 2. The numbers and percentages of greysole otoliths in the study sample (Middle Ground) by clarity, sex, and age groups (class 1 — excellent; class 2 — clear; class 3 — fair; class 4 — poor).

Age (years):	M (1–7)		F (1–7)		M (> 7)		F (> 7)	
Readability class	No.	%	No.	%	No.	%	No.	%
1	15	18.2	12	14.1	21	33.8	18	23.7
2	17	20.2	19	22.4	12	19.4	25	32.8
3	26	31.4	30	35.3	14	22.6	17	22.4
4	25	30.2	24	28.2	15	24.2	16	21.1
Total	83	100.0	85	100.0	62	100.0	76	100.0

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Observations on the Distribution of Herring, *Clupea harengus* L., on Georges Bank and in Adjacent Waters in 1962 – 65

BY V. N. ZINKEVICH[1]

Abstract

Seasonal distribution of commercial concentrations of herring, *Clupea harengus* L., on Georges Bank and adjacent waters was determined from observations conducted by the Western Atlantic Laboratory of the AtlantNIRO in 1962-65. Attempts were made to relate the migration of herring to water temperatures and quantities of plankton at different seasons of the year. Data on the herring fishery and the length composition of the catches from different areas and seasons are given.

Introduction

Herring from Georges Bank was one of the main species taken by the Soviet fishery in the ICNAF Area from 1961 to 1964. Some herring were also caught in 1965, mainly as a by-catch in fisheries for other species.

The Soviet herring fishery in the area of Georges Bank in previous years has been described by Chukshin and Vyalov (1963), Bryantsev (1964), Benko (1964), Pahorukov, Wilson, and Benko (1962), Yudanov (1963), and others. At that time herring was fished almost solely in the area of Georges Bank.

Present data make it possible to increase our knowledge of the Georges Bank herring.

This paper summarizes the results of observations made on herring distribution in the years 1963–65 using material collected by Soviet fishing and scouting vessels. Materials collected in 1961–62 and some data on the distribution of plankton and temperatures in the waters within the investigated area have also been used.

Seasonal Distribution of Herring

Herring concentrations were plotted from the distribution of the fishing fleet and from observations made by scouting vessels. Figures 1–3 show the distribution of herring for the period from April to October when fishing was intense and in other months when fishing was less intense.

Herring were distributed over the greatest area in the winter months. From November to March, herring were fished from 36°N along the Continental Shelf to the northern extremity of Georges Bank. During that period the herring were active and did not form stable commercial concentrations. In February and March, the bulk of the fish was observed in the areas of Long Island, Hudson Canyon, and farther south. For instance, in March 1964, the bulk was found in the area from 36° to 38°N.

In the spring months, the herring moved from the area of Wilmington and Hudson Canyons to the southern parts of Georges Bank, where they gradually increased in numbers, whereas they decreased in number to the south of 40°N.

From May to October, the bulk of the fish was feeding or spawning on Georges Bank.

Water Temperature, Plankton Development, and Herring Distribution

The distribution of herring each year is, probably, related to seasonal changes in water temperature and in the amounts of zooplankton. The distribution and characteristics of the water masses have been studied by Bryantsev (1964). His results are given in Fig. 4 and Table 1. Comparing his scheme of distribution of water masses (Fig. 4) with herring distribution in 1963–65 (Fig. 1, 2, 3) one can see that herring from Georges Bank are distributed in the "coastal" water.

Figure 5 shows the typical seasonal distribution of herring concentrations in relation to the distribution of temperature in the near-bottom layers.

Seasonal development of zooplankton in the frontal zone, apparently determines herring migrations from Wilmington and Hudson Canyons to Georges Bank and back, as well as the summer distribution of herring on the Bank.

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[1] Western Atlantic Laboratory of the Atlantic Scientific Research Institute of Marine Fisheries and Oceanography (AtlantNIRO), Kaliningrad, USSR.

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Herring concentrations were plotted from the distribution of the fishing fleet and from observations made by scouting vessels. Figures 1–3 show the distribution of herring for the period from April to October when fishing was intense and in other months when fishing was less intense.

Herring were distributed over the greatest area in the winter months. From November to March, herring were fished from 36°N along the Continental Shelf to the northern extremity of Georges Bank. During that period the herring were active and did not form stable commercial concentrations. In February and March, the bulk of the fish was observed in the areas of Long Island, Hudson Canyon, and farther south. For instance, in March 1964, the bulk was found in the area from 36° to 38°N.

In the spring months, the herring moved from the area of Wilmington and Hudson Canyons to the southern parts of Georges Bank, where they gradually increased in numbers, whereas they decreased in number to the south of 40°N.

From May to October, the bulk of the fish was feeding or spawning on Georges Bank.

Water Temperature, Plankton Development, and Herring Distribution

The distribution of herring each year is, probably, related to seasonal changes in water temperature and in the amounts of zooplankton. The distribution and characteristics of the water masses have been studied by Bryantsev (1964). His results are given in Fig. 4 and Table 1. Comparing his scheme of distribution of water masses (Fig. 4) with herring distribution in 1963–65 (Fig. 1, 2, 3) one can see that herring from Georges Bank are distributed in the "coastal" water.

Figure 5 shows the typical seasonal distribution of herring concentrations in relation to the distribution of temperature in the near-bottom layers.

Seasonal development of zooplankton in the frontal zone, apparently determines herring migrations from Wilmington and Hudson Canyons to Georges Bank and back, as well as the summer distribution of herring on the Bank.

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[1] Western Atlantic Laboratory of the Atlantic Scientific Research Institute of Marine Fisheries and Oceanography (AtlantNIRO), Kaliningrad, USSR.

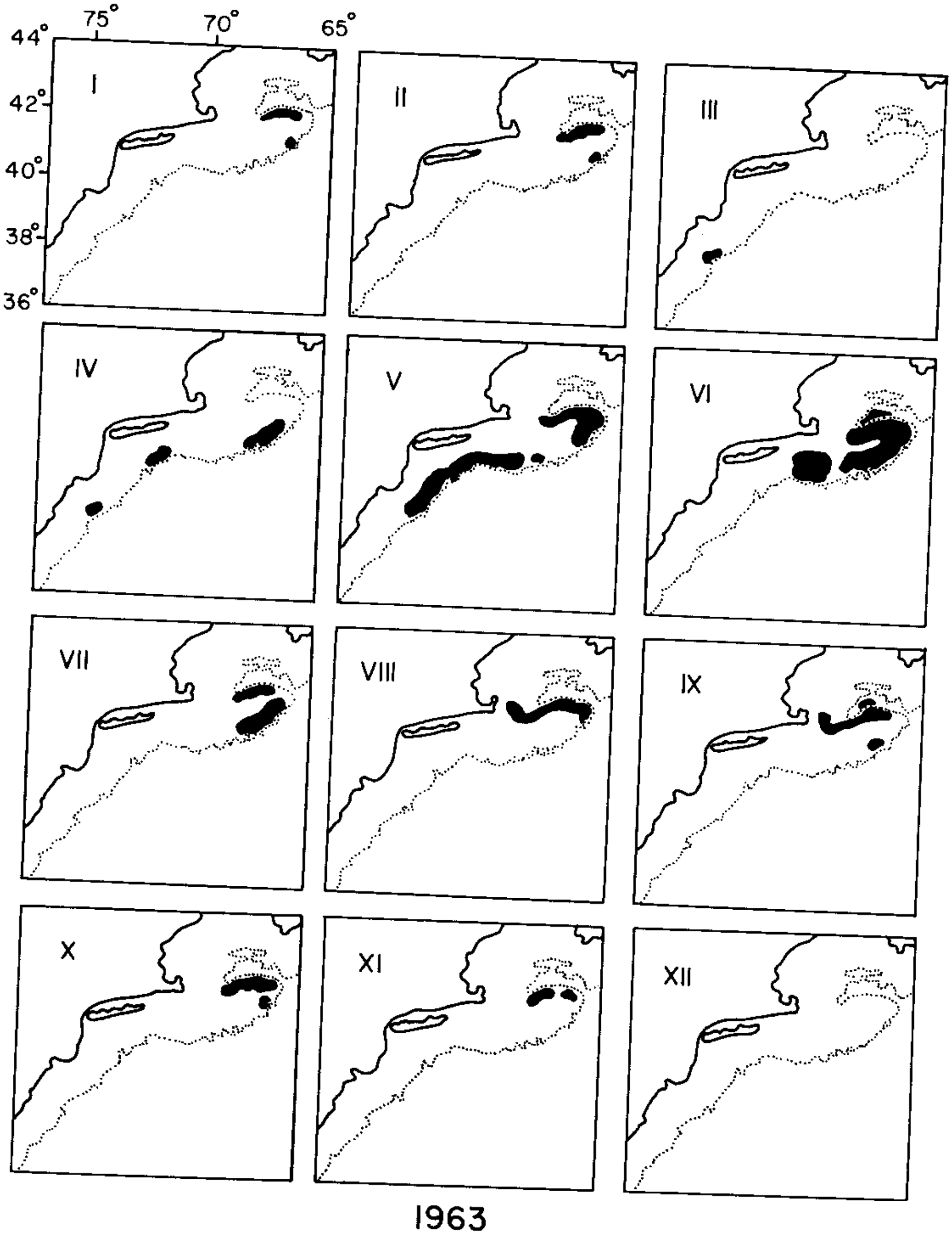

Fig. 1. Monthly distribution of herring, *Clupea harengus* L., in 1963.

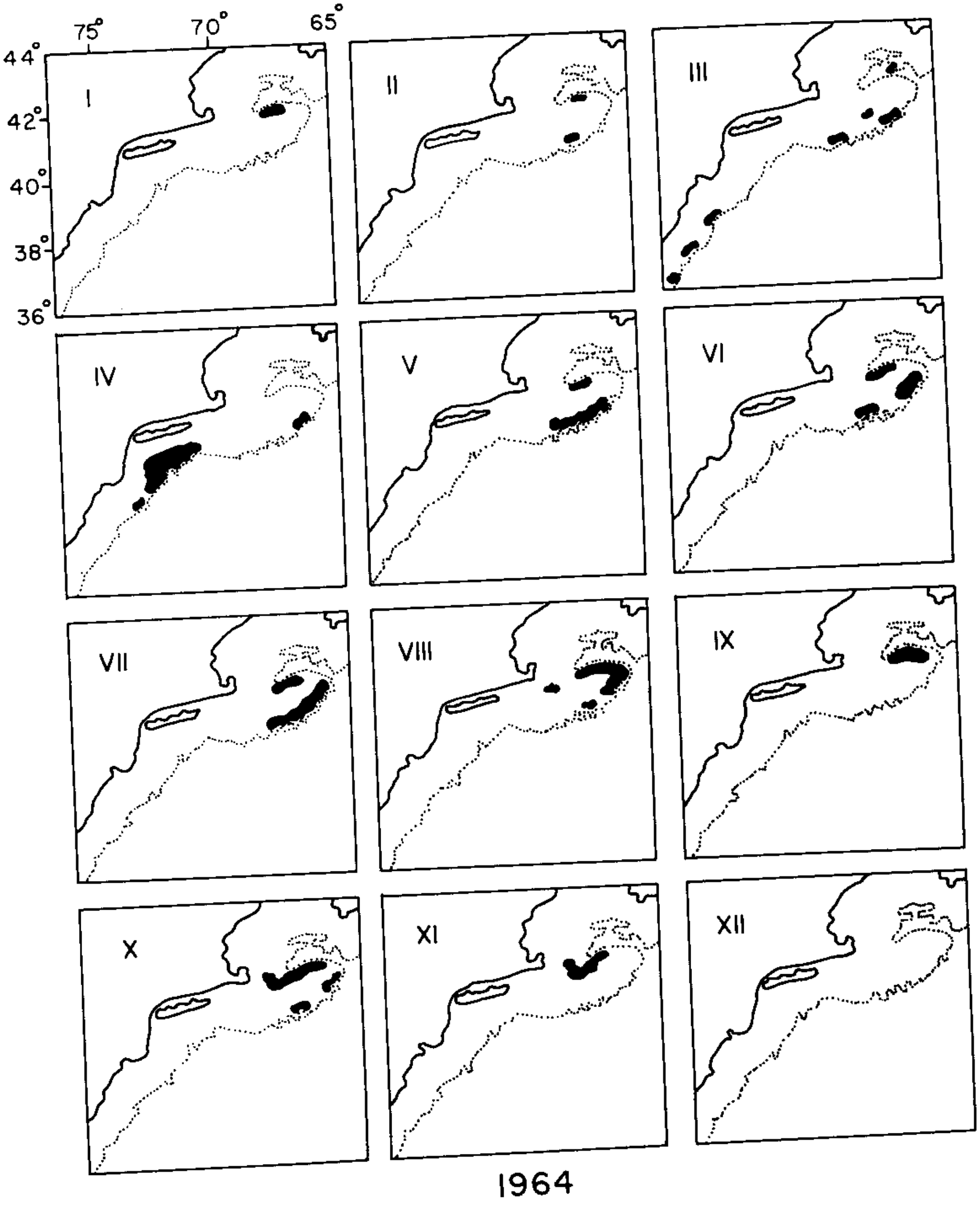

Fig. 2. Monthly distribution of herring, *Clupea harengus* L., in 1964.

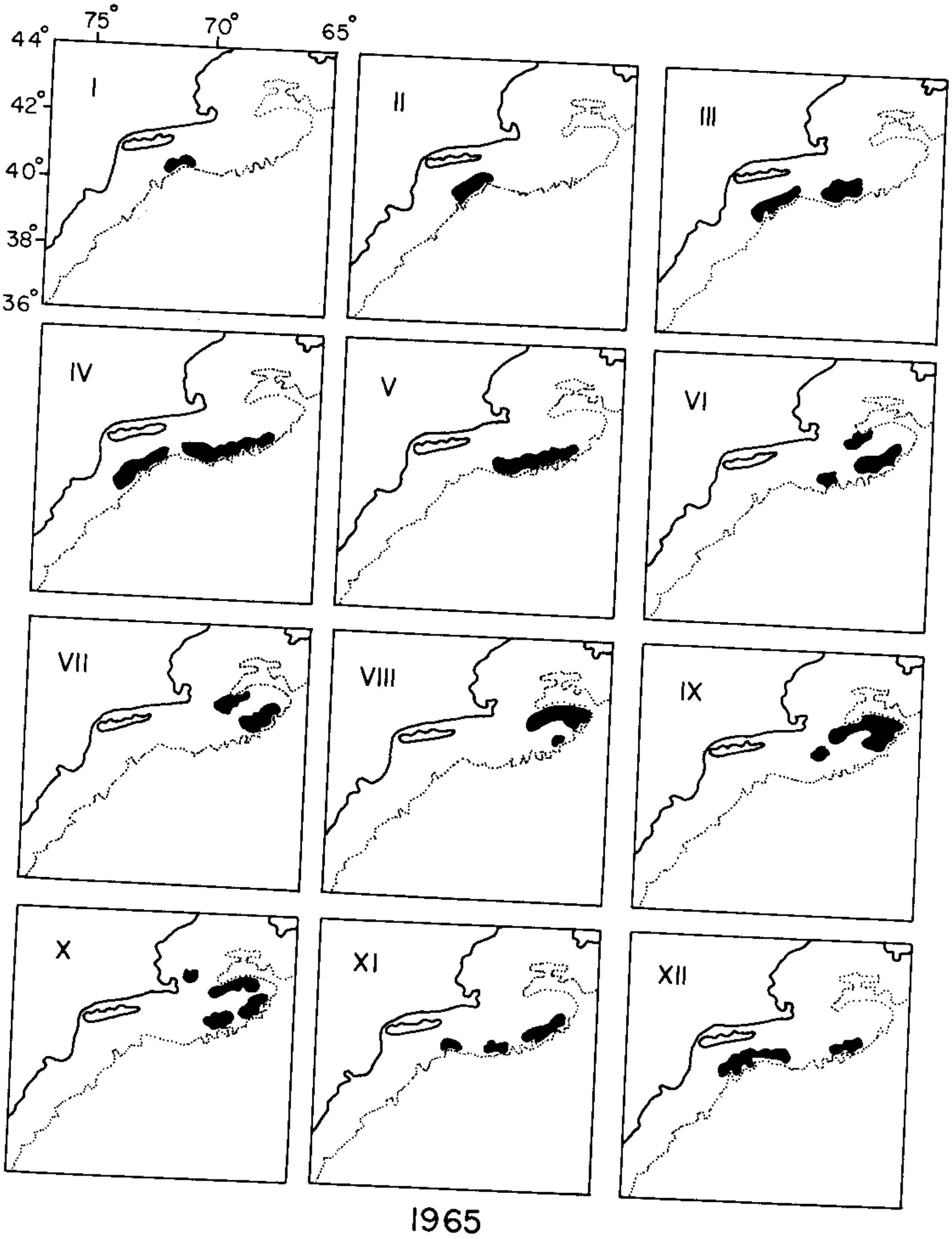

Fig. 3. Monthly distribution of herring, *Clupea harengus* L., in 1965.

The waters of Georges Bank are known to be poor in plankton in the winter months. Riley (1947) has reported a mass bloom of phytoplankton in April and of zooplankton by mid-May. At the same time, investigators have reported a great biomass of plankton in areas of Nantucket Island and of Hudson Canyon. For example, Grise and Hart (1962) have stated that the greatest amount of zooplankton consisting of 60% copepods, which are the main food item for herring, are found on the Continental Shelf between New York and Bermuda.

Unpublished material collected in October-November 1965 by AtlantNIRO, show that the primary development of *Calanus finmarchicus* is in the northwestern part of Georges Bank and the southern part of the Gulf of Maine, also *Centropagus typicus* on the Shelf south of Nantucket Island (Fig. 6).

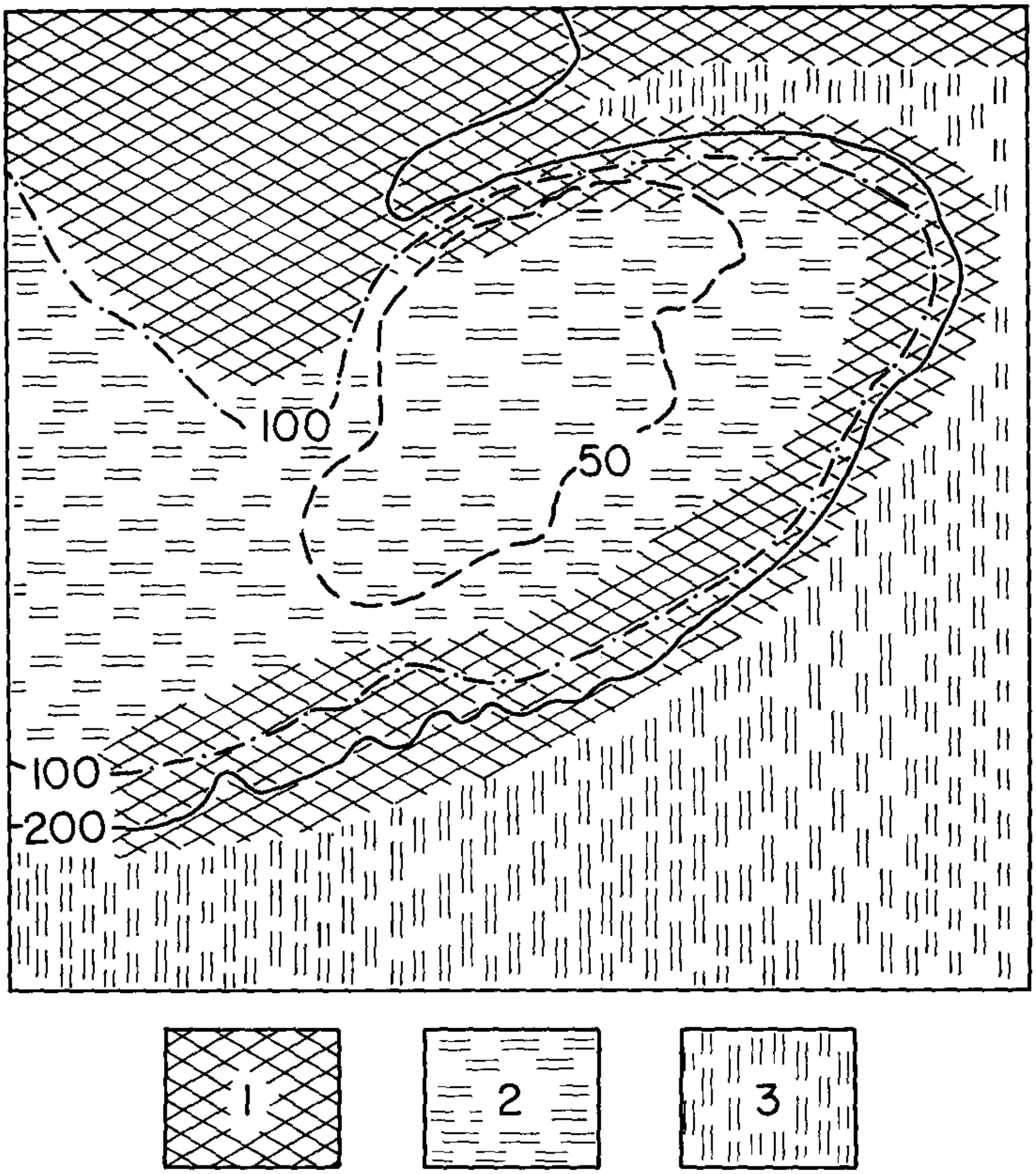

Fig. 4. Scheme of distribution of water masses on Georges Bank. (1) Water of Labrador origin. (2) Coastal water. (3) Gulf Stream water.

Spring herring migrations are connected with the development of zooplankton in the southern part of the Georges Bank. The relationship between herring and zooplankton concentrations on the southern slopes of the Bank in April–May is confirmed by research conducted by Shkinder (1963), and Pavshtics and Gogoleva (1964), who report a high biomass of zooplankton (more than 1,000 mg/m³) in this area. The greatest biomass of *Calanus finmarchicus* was 657 mg/m³ and *Pseudocalanus elongatus* was 327 mg/m³. The authors also showed that in

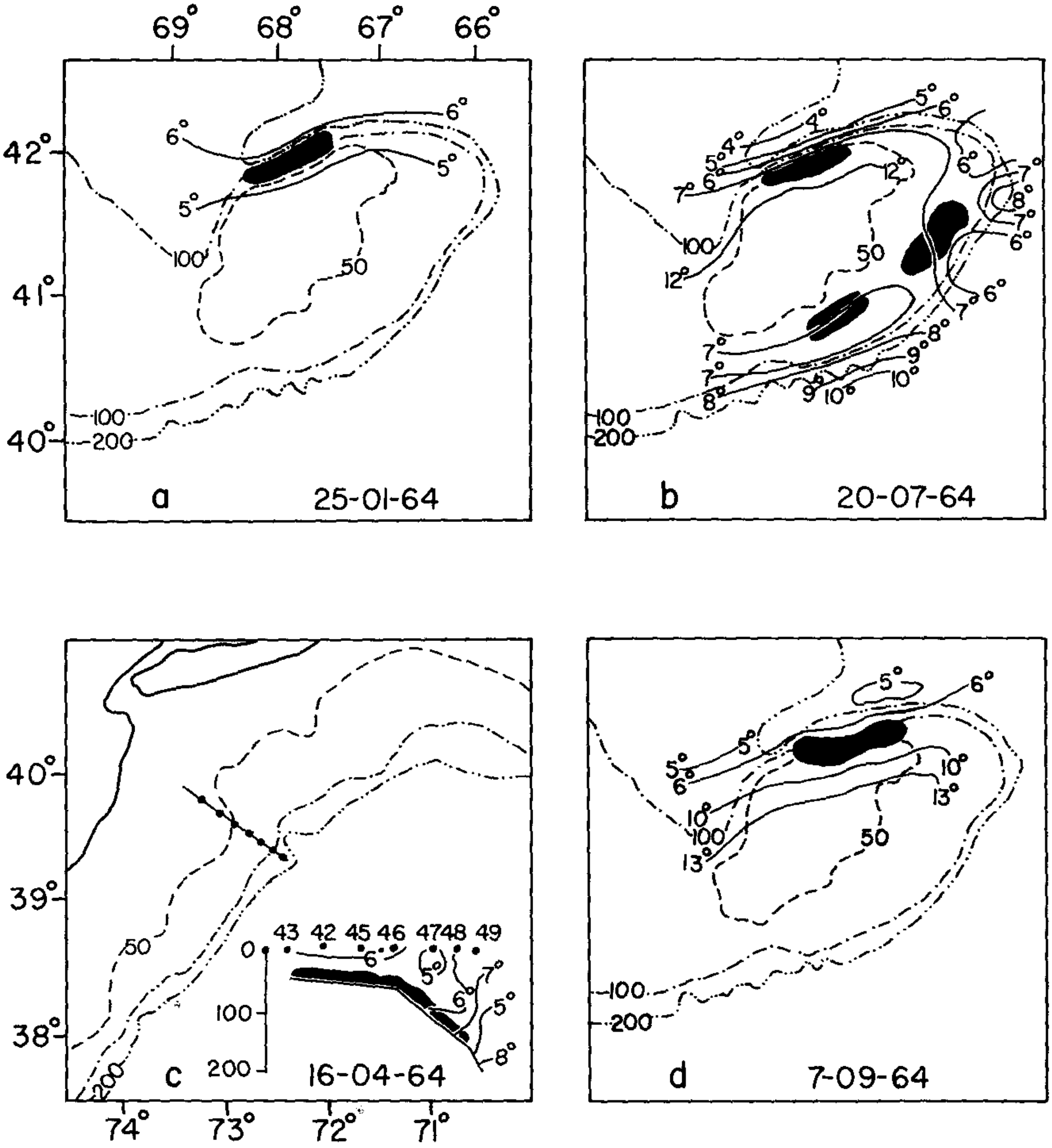

Fig. 5. Typical distribution of near-bottom temperatures and of herring concentrations, Georges Bank (a, b, and d) and Hudson Canyon area (c), 1964.

June and July the greatest biomass of zooplankton was found on the northern and northwestern slopes of the Bank.

Plankton investigations conducted by AtlantNIRO showed that there was the same general trend in the development of plankton on Georges Bank in both 1963 and 1964. In April–May 1963, dense concentrations of zooplankton and feeding herring were observed on the southern part of the Bank. In June there was a reduction of biomass to the south and an increase to the north and northwest. In March 1964, there was an appreciable development of phytoplankton on the shallows of the Bank and a high biomass of zooplankton (400–600 mg/m^3) on the northern slopes.

Figure 7 presents a general scheme for the summer distribution of plankton over Georges Bank.

As the waters become warmer, the zone of high biomass of zooplankton shifts to the north and there is a primary development of zooplankton in the zones of the hydrological fronts and of phytoplankton in the shoal waters of the Bank.

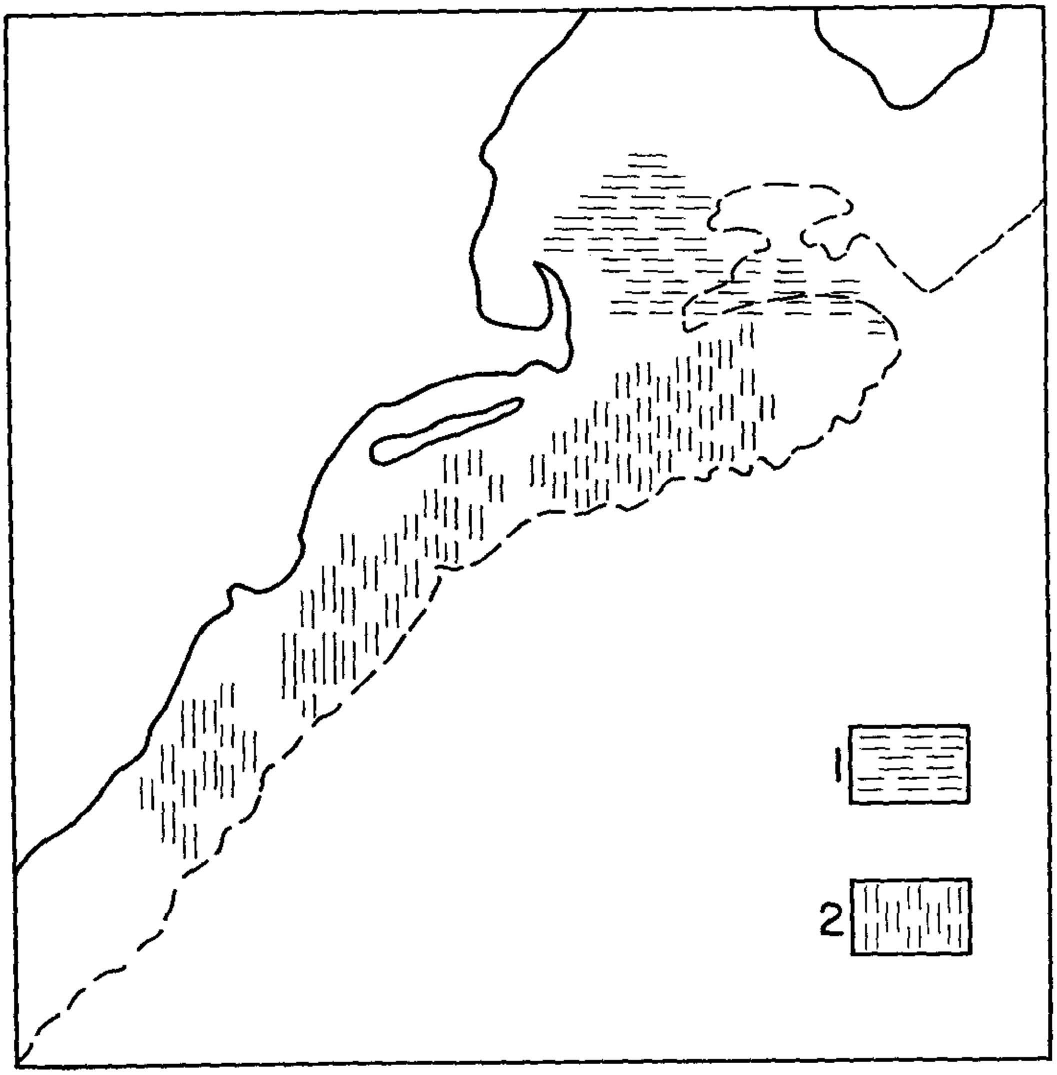

Fig. 6. Areas of high biomass of zooplankton, October–November 1965. (1) *Calanus finmarchicus*. (2) *Centropagus typicus*.

Herring Distribution on Georges Bank in Summer 1962

Observations conducted from May to August 1962 show the pattern of herring distribution on Georges Bank.

Data on the distribution of plankton and on the distribution of the fishing fleet for each 5-day period from May to August, showed that herring concentrated in zones along the hydrological front where a high biomass of zooplankton was found.

An analysis of the distribution of the herring fishing vessels suggests that the herring move against the permanent current, along the hydrological front from the southern to the southeastern slopes of the Bank, then to the northern slopes and along the northern and northwestern slopes of the Bank. In the latter area, a decrease in commercial concentrations of herring was often observed. This is apparently due to lack of well-defined frontal zone in that area. At the same time, the formation of stable concentrations of herring was observed in the frontal zone to the south and southeast. This suggests that the herring moved into that area from the northwest. Figure 8 presents a scheme of the feeding migrations of herring in the summer of 1962.

Similar migrations were observed on Georges Bank during May, June, and July. The centre

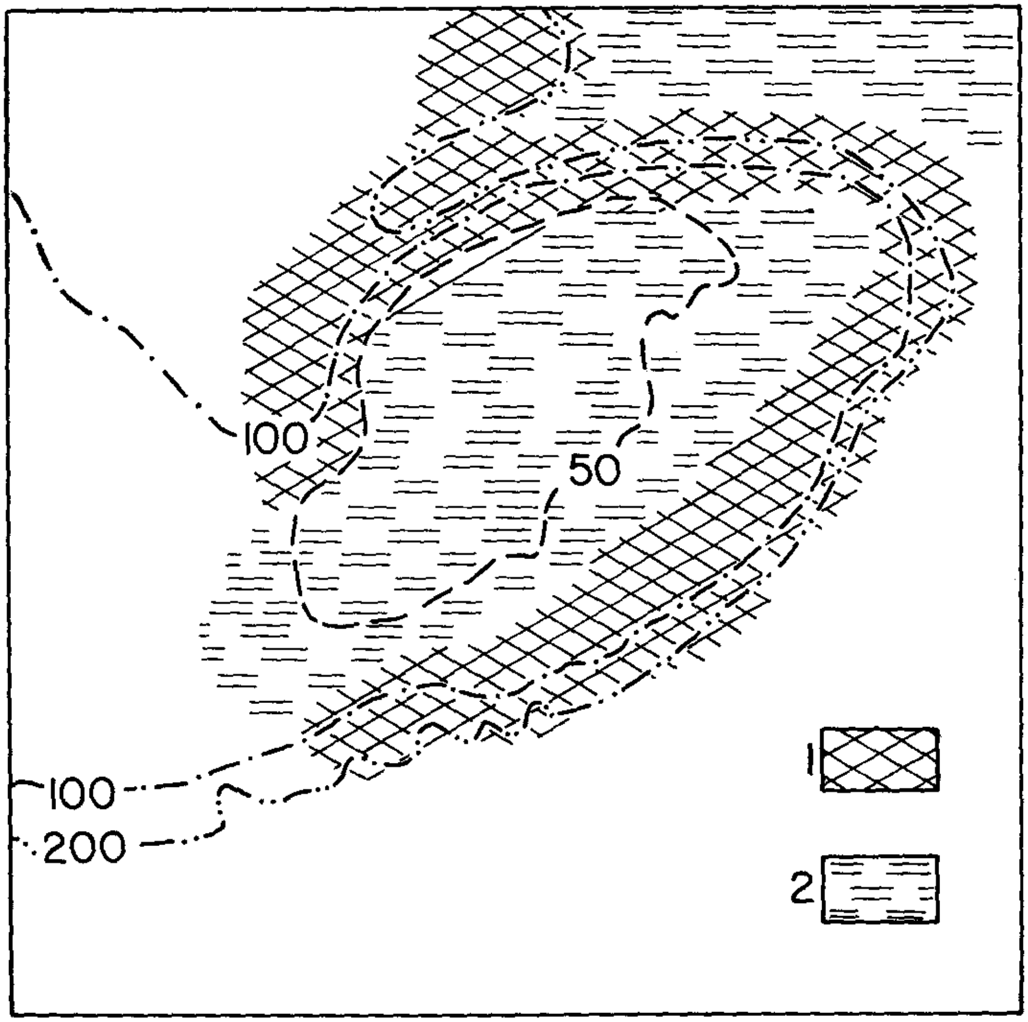

Fig. 7. Distribution of plankton on Georges Bank in summer. (1) Primary development of zooplankton. (2) Primary development of phytoplankton.

of fishing shifted successively from the northwestern to the southern area in May, then extended to the northeast, the north, and to the southeast in June, and to the eastern area in July.

Some peculiarities of the distribution of herring for that period are:

1) Herring on their feeding migrations were found at lower water temperatures (6°C) than silver hake, *Merluccius bilinearis*, (9°C) which were spawning in the same area of the southern slopes of Georges Bank in June 1963 (Fig. 9). However, these temperature limits can change due to the inflow of warm water from The Atlantic and as a result, the density of the herring concentrations would change and the herring shift to the north.

2) Labrador waters extend to the northeastern extremity of the Bank (Fig. 5b, isotherm 6°C), where the frontal zone is apparently the most dynamic. During certain periods water temperatures could be lower than 6°C and there would be changes in the distribution of herring concentrations.

3) As mentioned above, the hydrological front in the extreme northwestern part of Georges

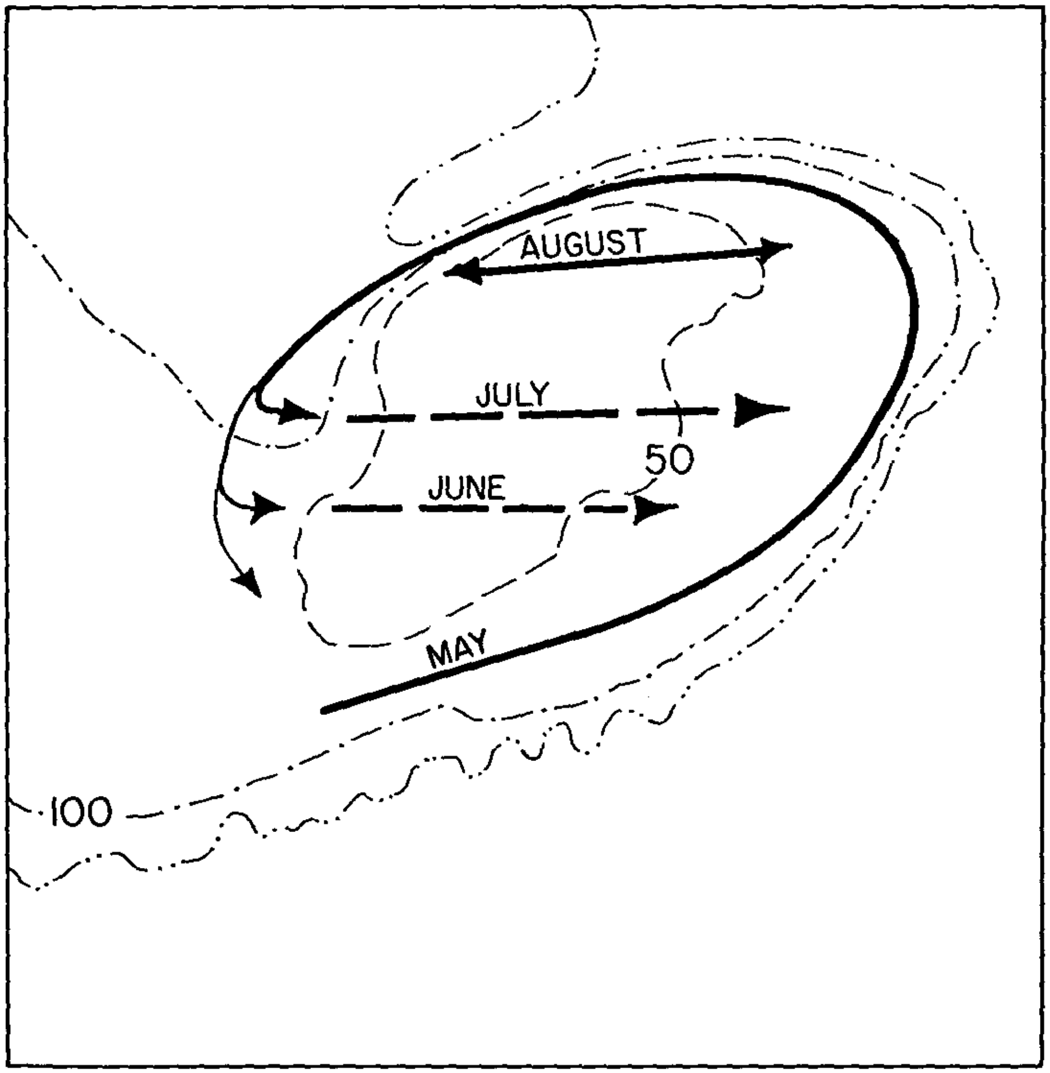

Fig. 8. Scheme of herring migrations on Georges Bank, 1962.

Bank is not well defined. This caused decreases in the density of commercial herring concentrations and changes in their distribution during such periods as late May, late June, and late July of 1962.

4) On the southern and southeastern plateau, herring are widely dispersed. During the spring-summer period, the fish are found between zones of plankton bloom on the shallows of the Bank (below 50 m) and the hydrological front (6° to 7°C isotherm) in the area of the slopes. However, the greatest herring concentrations lie in the zone of the hydrological front. On the northern slopes, the area between the zone of the hydrological front and the plankton bloom is quite narrow, due to the distinctive configuration of the Bank. Feeding herring avoid zones of intense development of phytoplankton and are distributed over a small area along the northern slopes where they form dense concentrations.

Therefore, it follows that the area of the southeastern slopes of the Bank, mainly the zone of the hydrological front and the northern slopes of the Georges Bank are considered to be the most favourable places for the formation of feeding herring concentrations.

In August, the bulk of the herring is distributed along the hydrological front on the northern slopes of Georges Bank and move only short distances.

In September and early October, pre-spawning and spawning herring concentrations remain on the northern slopes until the termination of spawning. During the spawning period, dense concentrations of fish are found in a small area. Spent herring leave their spawning grounds and

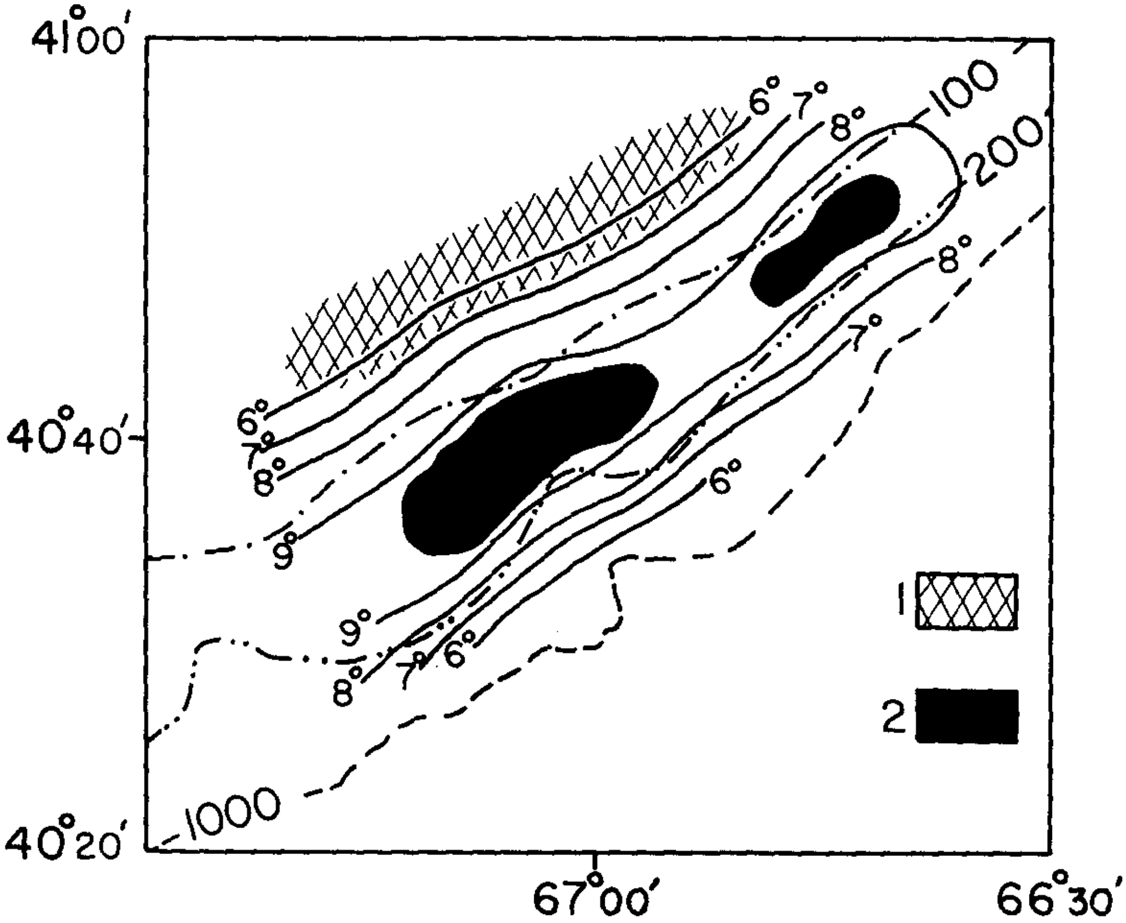

Fig. 9. Near-bottom temperature and distribution of feeding herring and spawning silver hake on the southeastern part of Georges Bank, June 1963. (1) Herring. (2) Silver hake.

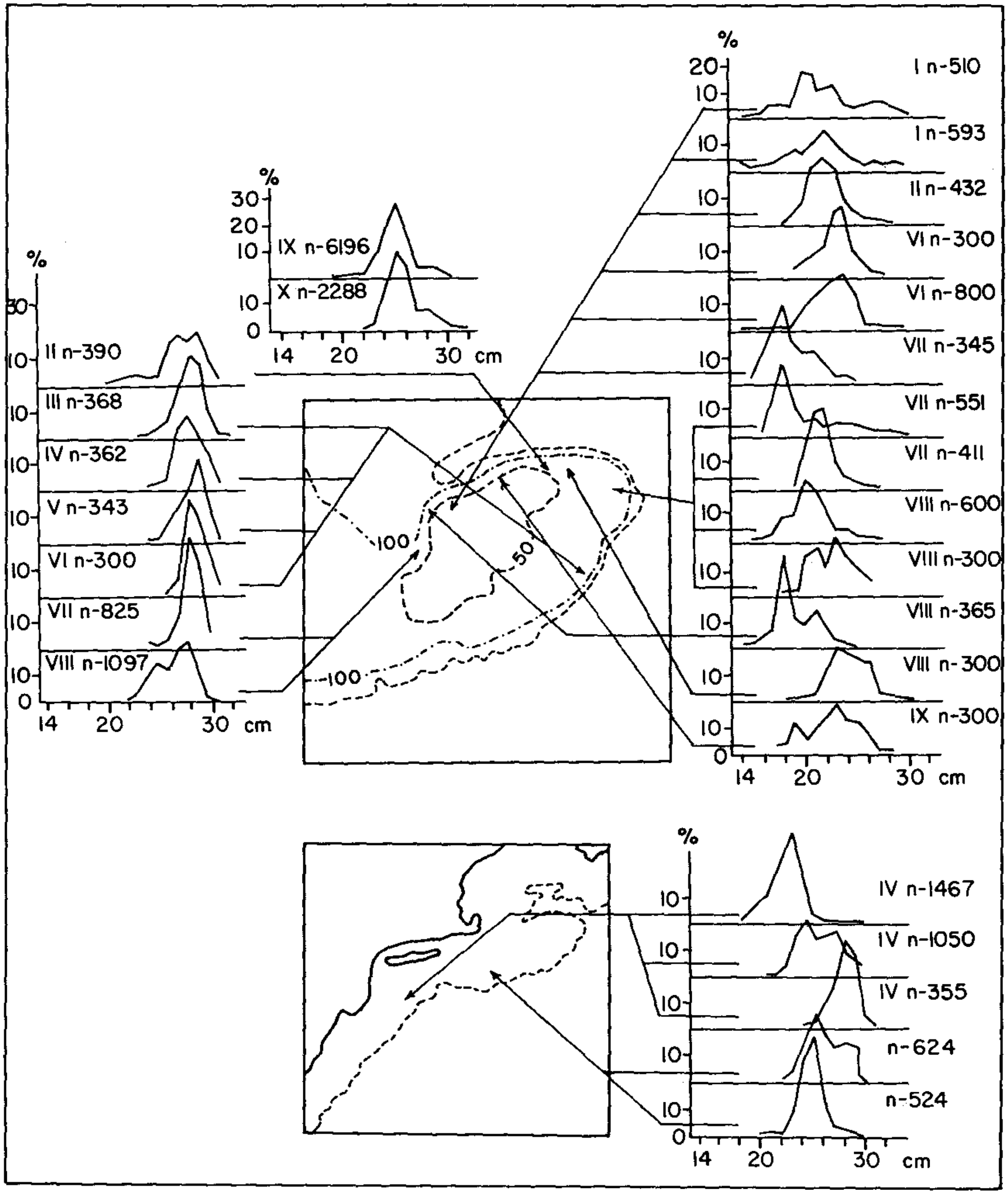

Fig. 10. Size composition of herring by areas and season, 1964.

are fished to some extent, mainly on the extreme western area of the Bank. Later the concentrations divide into small schools.

During October and November, some species of zooplankton are rather numerous and available as herring food (Fig. 6). Separate feeding schools were seen over most of the Bank. Short-term formation of commercial concentrations in frontal zones was also observed.

Later, as water temperatures fell and plankton disappeared, the bulk of herring shifted westward. In December, the herring were often fished in the Cape Cod Area and south of Nantucket Island where they were still feeding. In January and February, they were spread over a vast area and in the spring months they concentrated in the region of Hudson Canyon.

Vertical Migrations

Vertical migrations of the bulk of fish were pronounced throughout the season. During the daytime, herring schools settled to the near-bottom layers and at night they rose to or near the surface of the water. In foggy weather, herring were often observed off the bottom and near the surface, and on moonlit nights they were near the bottom.

Diurnal vertical migrations by young immature herring were seldom observed. They stayed at the surface of the water.

Herring schools were often seen at the surface on sunny days. The reason for this phenomenon is not known and no special research was conducted.

Herring Size-Composition and Distribution

Since 1961 the catch has consisted of herring from 14 to 35 cm in length and 3–6 years of age. The bulk (60–80%) of the catch has been made up of specimens 23–27 cm in length (mode 25–26 cm). However, herring length compositions differ slightly by season and by area. In winter and early spring, herring of all sizes were found south of 40°N and on Georges Bank. In the summer there were only two areas where larger or smaller herring were predominant. In the southeastern part of the Bank, larger herring (modal lengths 27–29 cm) were predominant, and the northwestern area, small herring (modal lengths 18–22 cm) were most common.

The seasonal and area distribution of the most typical size groups of herring during 1964 is given in Fig. 10.

The distribution of size groups of herring in the two areas was observed to be the same for the years 1961–65.

Herring of two or more size groups were almost never taken in the same trawl haul. This shows that herring schools, even in concentration, maintain their size structure.

Since herring migrate, the different size groups redistribute by areas. Thus, samples from catches indicated that a size composition was maintained in a particular area only for a certain period of time. During autumn, all size groups of mature herring were found on the spawning ground. Therefore, samples from fish caught on the spawning grounds were most indicative of the age/length composition of the mature part of the population.

The distribution of herring which have reached sex maturity for the first time is shown in Fig. 11. The 1963 material presented here shows that a strong year-class (1960) was recruited into the fishery and the abundance of the other year-classes decreased due to natural and fishing mortality.

Changes in the size composition of the spawning herring stocks from 1961 to 1965 are shown in Fig. 12. These changes are caused by the predominance of old or young fish.

Herring Fishing and Distribution

To describe the herring fishery during the different months, the data on fishery statistics for 1962 and 1964 were used as most characteristic (Table 2, 3).

In both years, the herring fishery was conducted over a considerable period of time. In 1962 drift net fishing was predominant and the strong 1956 year-class formed the bulk of the catch. In 1964 otter trawl fishing was introduced and the bulk of the catches was of the abundant 1960 year-class.

The increase in catch per haul from February to August 1962 indicates a decrease in the area of herring distribution and an increase in the density of fish concentrations for that period.

TABLE 1. Water masses and their characteristics in the Georges Bank area (Bryantsev, 1965).

			Extreme Value of Temperature (°C) and Salinity (‰)							
Water Mass	Water layer	Depth	Winter		Summer		Autumn		Summer 1962	
		m	°C	‰	°C	‰	°C	‰	°C	‰
Coastal	Upper	0–50 0–75	4	30	16	30	14–7	31–32.5	6–16	30–32.5
Labrador	Intermediate	50–150 75–150	–1	33	–1	33	3–7	32.5–33.5	1–16	32.5–33.5
Bottom modification of Gulf Stream	Near-bottom on the shelf	170–bottom 200–bottom	8	35	8	35	7–9	33.5–35.0	6–8	33.5–35.0

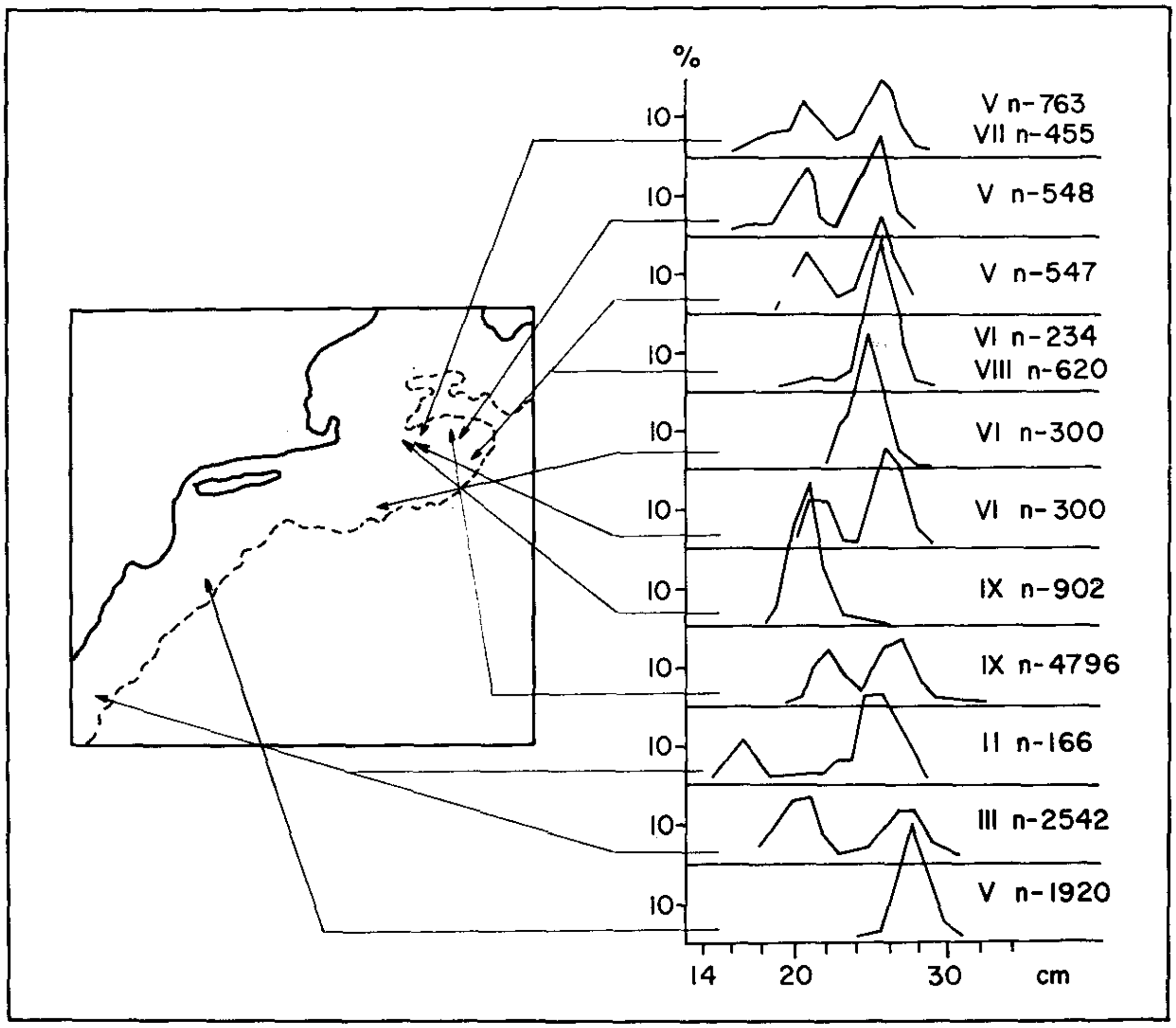

Fig. 11. Size composition of herring by areas and season, 1963.

TABLE 2. Monthly catch per effort by Soviet vessels of the SRT and SRT-R types for herring in the Georges Bank area in 1962 and 1964.

Month:	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
						1962					
No. of operating vessels:	1	4	48	93	101	108	89	48	38	23	5
Catch per haul (kg):	12	21	62	83	102	110	68	192	54	35	36
						1964					
No. of operating vessels:			5	48	89	94	85	31	5		
Catch per trawling hour (metric tons):			0.55	0.69	0.68	0.97	1.25	7.1	12.3		

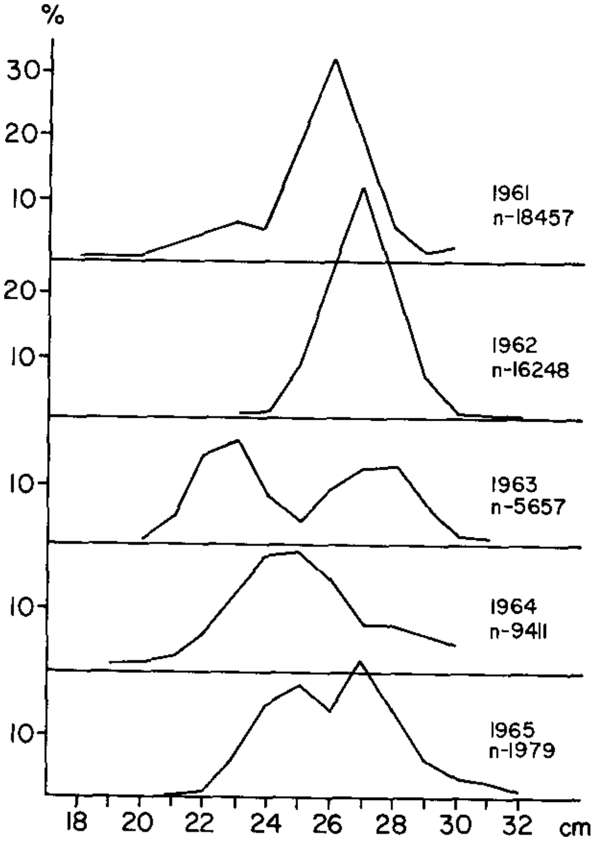

Fig. 12. Size composition of herring during 1961–65 on the spawning grounds in September.

The decrease in catch per haul to 68 kg observed in August 1962 (Table 2) was due to the introduction of trawl or combined fishing methods by the majority of the vessels and the decrease is not considered significant. Catch per trawling hour from April to August 1964 changed slightly. Therefore, these changes are less indicative of the magnitude and density of feeding concentrations and are, apparently, due to the specific character of the trawl fishery. However, both the drift net and trawl catches indicate that there were great concentrations of pre-spawning and spawning herring and maximum catches.

Summary

Since 1961 herring have been fished by the Soviet fleet from the northeastern slopes of Georges Bank to 36°N along the Continental Shelf. During the winter the bulk of the fish are distributed from 37° to 40°N, and during the summer and autumn on Georges Bank.

Herring migrations within the area are related to the development of zooplankton. The greatest biomass of zooplankton was observed in the zone of the hydrological front, formed by coastal waters and waters of Labrador origin from the size of coastal waters.

The formation and redistribution of commercial herring concentrations is related to

TABLE 3. Monthly Soviet catches (metric tons) of herring on Georges Bank in 1962 and 1964.

Year	Month: Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1962	41	5,699	1,894	13,151	22,736	24,669	26,142	22,636	28,079	11,112	3,219	922
1964	736	65	72	1,530	9,711	14,720	17,551	22,928	44,713	7,821	1,716	348

fluctuations in the borders of the hydrological fronts which, apparently, influence the distribution of zooplankton.

Herring from 14 to 35 cm in length were found in annual catches but the bulk of fish (60–80%) included individuals from 23 to 27 cm, mode 25–26 cm.

There were annual, seasonal, and area changes in the size composition of herring, depending on the predominance of old or young fish.

Two areas with distinct sizes of herring can be identified. The northwestern part of Georges Bank, has a large percentage of small herring; the southeastern plateau of the Bank, has predominantly larger herring.

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Otolith Age Validation in Labrador Cod

BY A. W. MAY

Abstract

Examination of seasonal changes in otolith edge deposits, and comparison of otolith ages with modes in the length distributions, show that otoliths are reliable for age determination of cod from Labrador. The opaque zone is formed mainly from September to November; the hyaline zone mainly from January to June. The opaque zone appears first in the youngest individuals.

Introduction

The importance of a critical approach to methods of age determination in fish has frequently been stressed (Dannevig, 1933; Saetersdal, 1953; Kohler, 1964; May, 1965). Determination of age from skeletal structures usually involves interpretation of zone patterns rather than straightforward counting. Validation of methods provides criteria for such interpretation. Procedures for testing the reliability of age determination are reviewed by Parrish (1956).

Previous validity studies of otolith ageing of Northwest Atlantic cod have been reported by Fleming (1960) for the Newfoundland area, Kohler (1964) for the southwestern Gulf of St. Lawrence, Williamson (MS, 1965) and May (1965) for the southern Grand Bank. The only previous data from Labrador were those of Fleming (1960) who reported on appearance of otolith edges in samples taken in July and August.

Material and Methods

Otolith samples were available from research vessel surveys offshore and from sampling of commercial catches inshore. The offshore material was almost entirely from the C.G.S. *A. T. Cameron*, using a No. 41-5 otter trawl having the codend either lined or covered with small-meshed netting to prevent the escape of small fish. Fishing was usually done in a series of depths on lines of stations across the offshore banks, from the shallowest depths available to that where the cod catch became very small. Inshore sampling was from the coastal commercial fishery. Small fish were not taken in the inshore commercial gears, but some were obtained by fishing with hook and line from the shore. All the material was from Division 2J.

Otolith ages were read by the author. The technique is described in the summary by Keir (MS, 1960). The type of edge deposit (opaque or hyaline) was recorded for all otoliths. Length measurements were of fork length. All samples were random samples of the catch.

The material offered two avenues of approach in testing the validity of otolith ages, i.e. through recognition of seasonal changes in appearance of the otolith edge, and by comparison of otolith ages in small fish with modes in the length distribution of the samples.

Seasonal Changes in Otolith Edge

Material covering eight consecutive months was obtained by combining collections from Division 2J (mainly Hamilton Inlet Bank) for the period 1958–64 (Table 1). This was entirely offshore material except for July, when no offshore data were available. Collections from codtraps inshore in Division 2J were made almost entirely during the latter half of July and these were included to complete the picture.

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

TABLE 1. Numbers of fish examined for otolith edge appearance, Division 2J, April–November, 1958–64. The July collections were from the inshore commercial fishery.

Month	Year	Depth range (m)	No. fish	Total fish
April	1963	174–452	1,081	
	1964	238–362	302	1,383
May	1963	205–329	901	
	1964	201–220	292	1,193
June	1958	177	132	
	1962	277	44	176
July	1959	15–26	608	
	1960	11–24	1,061	
	1962	11–22	811	
	1963	17–26	803	
	1964	14–17	137	3,420
Aug.	1958	271	160	
	1960	163–558	567	
	1962	159–278	969	1,696
Sept.	1959	214–293	21	
	1962	176	120	
	1963	223–318	222	363
Oct.	1963	141–229	589	
	1964	148–183	139	728
Nov.	1964	161–320	417	417

The percentage of otoliths having opaque edge deposits is plotted for each month in Fig. 1A. A few fish show opaque edges as early as April, and they are present in more than 80% of the material from September to November. It is evident that only one opaque (and one hyaline) zone is formed each year. Age was estimated by counting hyaline zones. Beginning in September some fish show a narrow hyaline zone at the otolith edge. This is regarded as the beginning of the next annual hyaline zone, but would not be counted for ageing purposes until 1 January of the next year. A few otoliths, even in November, exhibit no opaque material at the otolith edge. These are invariably from very old fish, which typically have very much reduced opaque zones. These are so narrow in fact that they often appear as seemingly paper-thin separations between broad hyaline zones, and are almost impossible to recognize unless followed by a hyaline zone. This is typical in old mature fish and follows Rollefsen's (1933) description of "spawning zones".

The dorsal edge of cod otoliths is thinner than the ventral, and it is in this pointed edge (in cross-section) that opaque material first occurs. It is not until several months later that it appears all round the otolith. Opaque edge deposits occur much sooner in the year in young fish. This is illustrated by a more detailed analysis of the material for August (Fig. 1B), when about 50% of the offshore sample exhibited opaque edges. Scanty offshore material for ages 1 and 2 was supplemented by the addition of 177 fish of age 1 and 388 of age 2 from inshore collections. The opaque edge deposits by age (Fig. 1B) range from 100% of the fish at age 1 to zero at age 14. When these values are plotted the result is a double reverse sigmoid. The interruption between ages 5 and 6 is possibly due to the attainment of maturity by many fish ~~at~~ these ages (Fleming, 1960). As a result of the spawning process the onset of body growth and formation of the opaque zone are delayed, resulting in wider hyaline zones than in immature fish, again conforming to Rollefsen's (1933) description.

Length Distributions of Small Fish

Cod from Labrador grow very slowly (May *et al.* 1965). Thus Petersen's method, which requires recognition of separate modes in length frequency distributions, cannot be applied for much of the data since length distributions for each age overlap widely and catch length distributions tend to be unimodal. It can however be applied to the special collections of small fish inshore and to data from certain offshore collections where small fish were plentiful. Examination of length distributions of small cod taken inshore in Division 2J in August of 1959–63 (Fig. 2A) reveals two fairly consistent modes, one at 13–16 cm and the other varying between 19–22 cm. Otoliths of fish in the first mode typically show an opaque central area, one narrow hyaline zone and a substantial amount of opaque material at the otolith edge. These were regarded as having completed 1 year of growth plus a good deal of the second year's growth. The next mode should consist of fish which have completed 2 years of life, and otolith ages agree

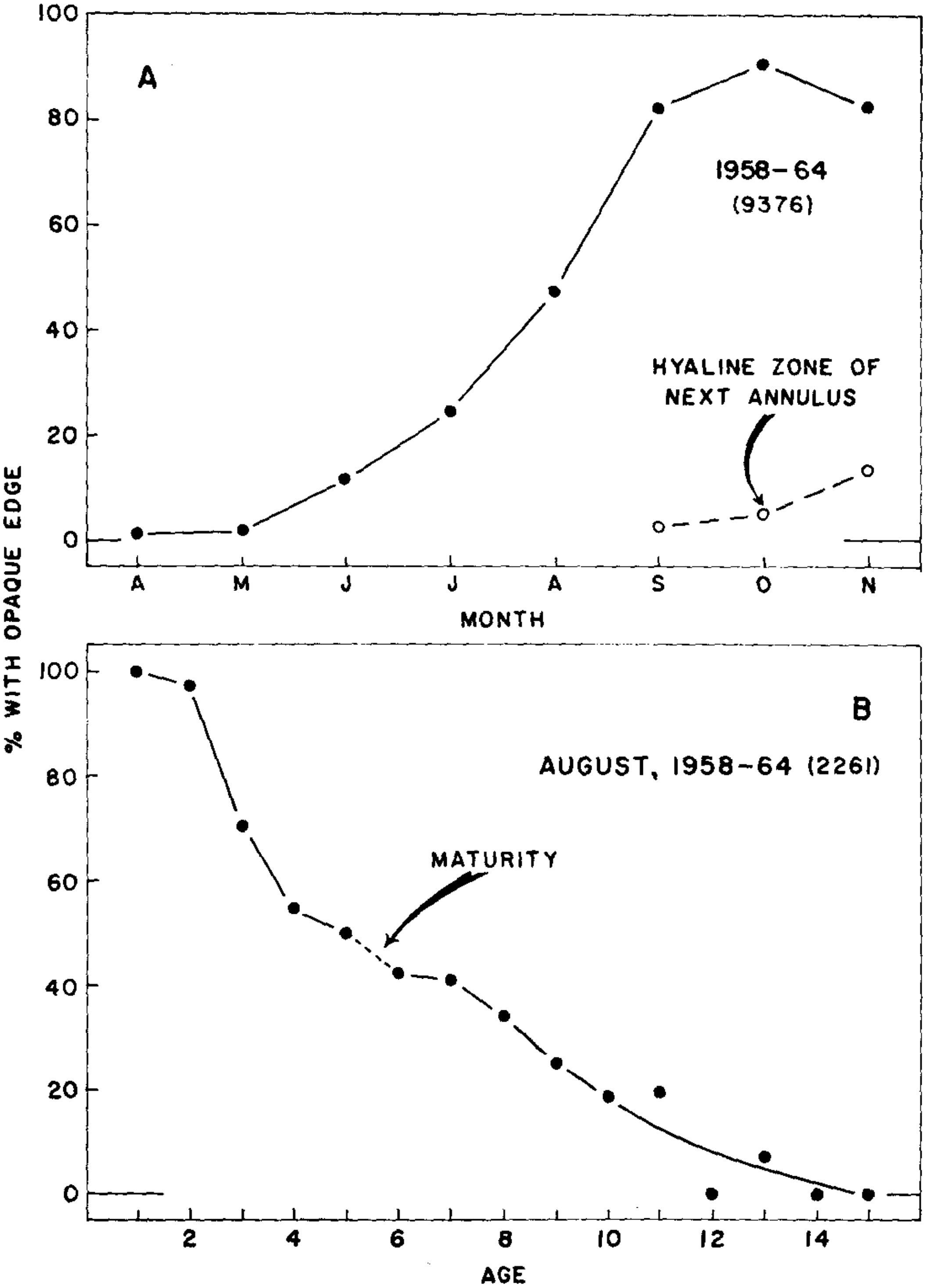

Fig. 1. (A) Monthly incidence of opaque edge deposits on otoliths from Division 2J. (B) Incidence of opaque edge deposits by age for August. Numbers of fish are in parentheses.

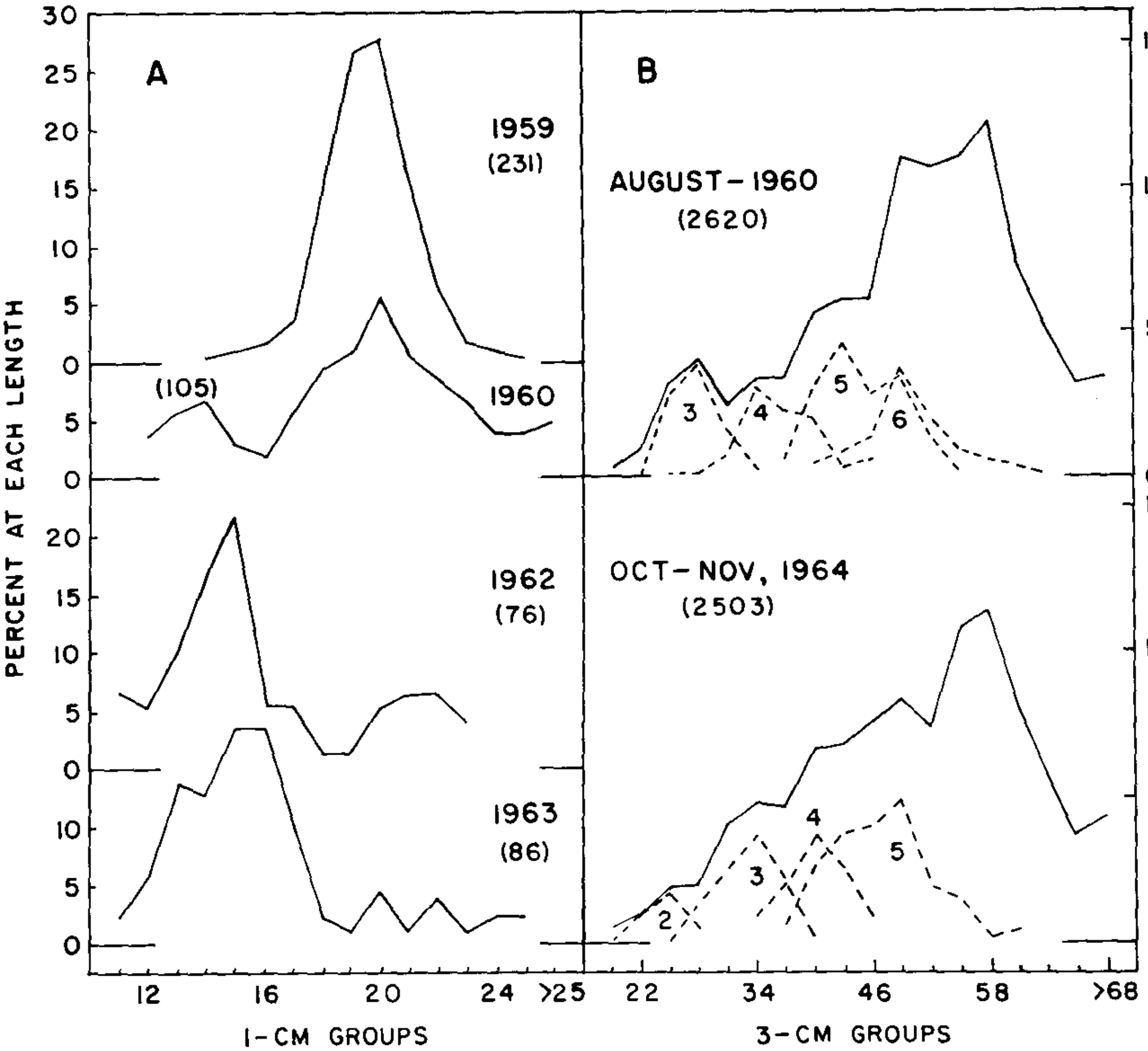

Fig. 2. (**A**) Length distributions of small cod taken inshore in Division 2J in August of each of the years indicated. (**B**) Selected length distributions from research vessel surveys offshore showing also length distributions of the youngest age groups based on age determination from otoliths. Numbers of fish are in parentheses.

with this interpretation. Modes in the offshore data of Fig. 2B are ill-defined, but extension of the method would result in age assignations to each mode as shown in the figure. These are in substantial agreement with age interpretation from otoliths, as indicated by the length distributions of each age group from otolith ages, though it will be noted that because of overlap of the length distributions the method would be of little use beyond age 5.

Discussion and Conclusions

From examination of seasonal changes in appearance of the otolith edge, it is clear that in general one opaque and one hyaline zone are formed each year. While complete monthly data were not available, it appears that there is considerable overlap in the population in time of formation of each type of zone. The period of opaque zone formation extends at least from April to November, and probably to December, but is mainly September–November. This is undoubtedly the period of fastest body growth. Some fish exhibit narrow hyaline zones at the otolith edge as early as September, but the period of main hyaline zone formation is probably January–June. It would appear that the growing season in this area is short. The decline in incidence of opaque edge deposits with age in August (Fig. 1B) suggests that the annual period of body growth is particularly short in old individuals.

Secondary or "check" zones often occur in otoliths from this area, especially during the second and third years of growth. These may cause difficulty in age interpretation, particularly if they are present at the otolith edge. However, they can usually be recognized as such on the basis of their appearance (less distinct than "annual" hyaline zones and often incompletely formed) and atypical spacing. A knowledge of the typical zone pattern, acquired through experience in age interpretation of otoliths from the area, is indispensable to accurate age assignation for those otoliths which exhibit check zones or otherwise anomalous appearance.

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NOTES

Length-Weight Relationships for American Plaice, Witch, and Yellowtail, in ICNAF Subarea 4

Introduction

The need for length-weight relationships data arises frequently in fisheries work but data for many species have not been published. With respect to Subarea 4, Brown (1963) demonstrated seasonal and areal differences in length-weight of redfish. Marcotte (1966) has reported on Division 4T cod, Kohler (1960) on 4X haddock, and Craigie (1927) on hake and pollock in 4X. With respect to flounders, McCracken (1958) presented length-weight data for Atlantic halibut in 4T and 4W, and Craigie (1927) documented the relationship for winter flounder in 4X. Royce's detailed report (1959) covers 5Z yellowtail by yearly quarters. This note presents length-weight data for American plaice, *Hippoglossoides platessoides*, witch, *Glyptocephalus cynoglossus*, and yellowtail flounder, *Limanda ferruginea*.

Methods

The data presented here were taken at sea during research cruises, except for the data on American plaice, which were recorded ashore. Because the numbers of witch and yellowtail were few, no sexual breakdowns were made for these species. To avoid length-weight bias resulting from mesh selection at the smaller sizes, a $1\frac{1}{8}$-inch (2.87-cm) mesh liner was used in the otter trawl.

Lengths for plaice, witch, and yellowtail, were recorded to the nearest centimetre, from the tip of the snout to the distal end of the longest caudal finray. Weights were recorded in pounds and ounces for individual fish, and later converted to decimal fractions of pounds and to grams. Weighing at sea was carried out only on calm days. All fish were weighed in the round fresh condition immediately after being caught. The sex and condition of gonads were determined by gross examination. Length-weight regressions were computed by the method of Swingle (1964). His program calculates parameters for the standard length-weight equations.

$$\log(\mathrm{W}) = \log(a) + b\log(\mathrm{L})$$

and

$$\mathrm{W} = a\mathrm{L}^{b}$$

Results

American plaice

A sample of 429 fish from 4T was obtained from catches by the M.V. *Harengus* (Fig. 1A). Females were heavier than males at all lengths. The standard length-weight formula for males was:

$$\mathrm{W} = 0.0000342\mathrm{L}^{2.81432}$$

and for females was:

$$\mathrm{W} = 0.0000086\mathrm{L}^{3.23414}$$

In October, female plaice are in early stages of ripening, as are most males (Powles, 1965), but the ovaries are not large. It therefore seems reasonable to assume that the greater weight-at-length of females was not completely due to differences in gonadal weight, but rather to sexual differences in growth and morphology. Royce *et al.* (1959) found similar weight differences existed between different sexes of the same length for 5Z yellowtail flounder. In addition to the fact that female plaice live longer and achieve a greater length than males, they progressively outweigh the more slender males as they grow older (Fig. 1A).

Witch

The body weight of witch from 4V and 4W was considerably less than of 4T plaice for any given length (Fig. 1A, 1B). Even though areas and seasons are not really comparable, the results accord with the body form of the two species, since witch are thinner and laterally more slender relative to their length than American plaice. Comparison of the two February samples taken by the C.G.S. *A. T. Cameron* (Fig. 1B) indicate that witch from 4W are slightly heavier at any corresponding length than 4V witch.

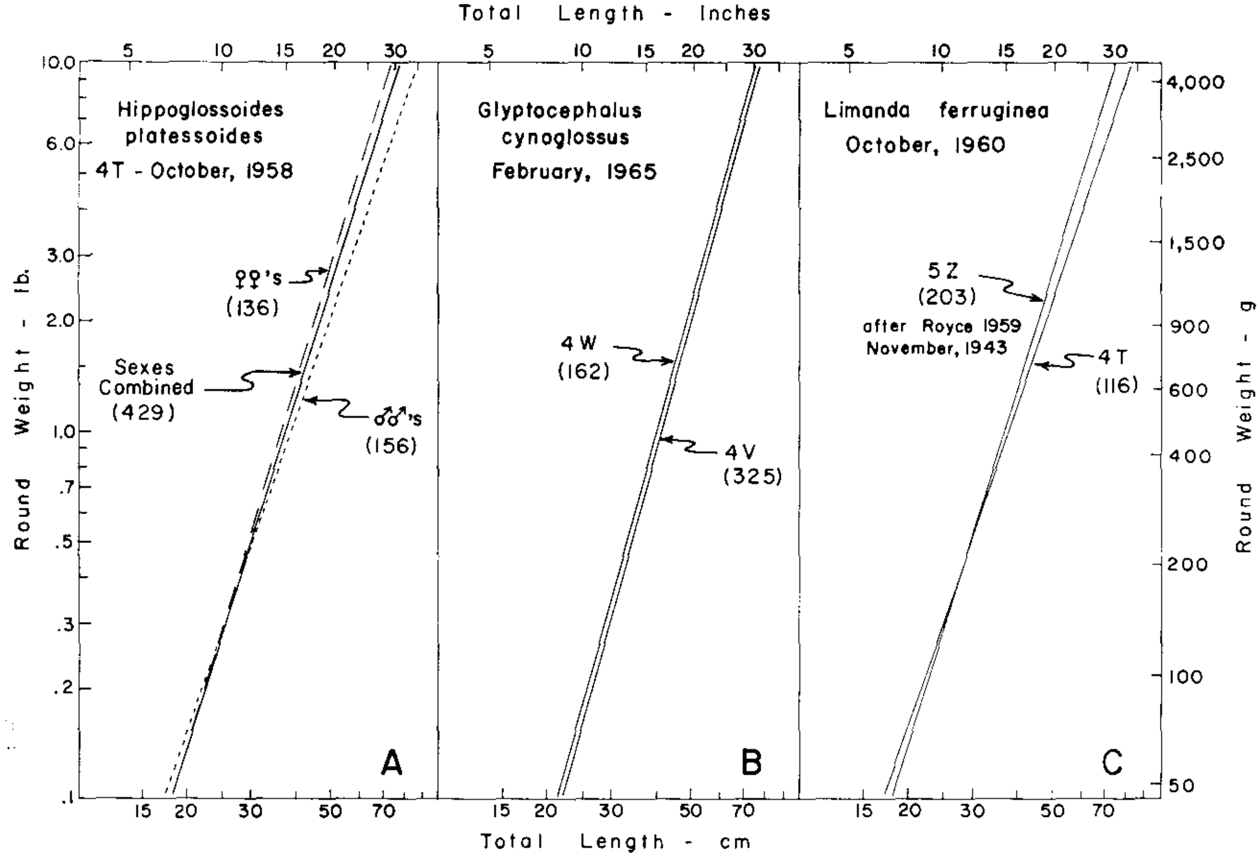

Fig. 1. (A) Length-weight relationship of 4T American plaice by sex and with sexes combined. (B) The length-weight relationship for 4W and 4Vs witch, sexes combined. (C) The length-weight relationships for 4T yellowtail and 5Z yellowtail (from Royce *et al.*, 1959). Numbers in parentheses indicate sample size. The scales are logarithmic.

Yellowtail

Only one sample of yellowtail (Fig. 1C) was obtained for length-weight relationships in October 1960. Comparison with Royce *et al.*'s data (1959) for 5Z yellowtail showed that the more southern and rapid growing fish from 5Z were heavier at corresponding lengths than 4T fish; 4T yellowtail (October) outweighed witch from 4W and 4V (February) at all corresponding lengths (Table 1). The length-weight relationship of 4T yellowtail and 4T plaice was quite similar in October samples (Fig. 1A, 1C). At lengths below 32 cm, yellowtail slightly outweighed plaice at comparable lengths (Table 1). As size increased (> 32 cm in length) plaice progressively outweighed yellowtail at corresponding lengths.

General considerations

Although the data presented here differ in time and area of sampling, there are two apparent trends which warrant comment. For both witch and yellowtail, the fish from the more southern areas were heavier at corresponding lengths (Fig. 1B, 1C). Because of such complexities as seasonal changes in flesh condition, morphology, and other interrelationships, which tend to alter slopes of the length-weight relationship, no hypothetical explanations or possible mechanisms can be offered without more detailed studies.

The data for American plaice, witch, and yellowtail shown in Table 1 will be useful in converting lengths to weights of fish discarded at sea when only lengths of discards and catch are available. The data for witch and yellowtail should be used with some caution because they are probably less precise than the length-weight data for plaice, which were recorded ashore rather than at sea.

TABLE 1. Computed weights-at-length for three flounder species from Subarea 4 together with parameters from the equation W = aL^b. Sexes are combined.

Length	*Hippoglossoides platessoides*		*Glyptocephalus cynoglossus*				*Limanda ferruginea*	
	4T		4W		4V		4T	
cm	*lb.*	*g*	*lb.*	*g*	*lb.*	*g*	*lb.*	*g*
16	.07	32.6	.04	16.8	.03	14.1	.09	40.4
18	.10	47.2	.06	25.4	.05	22.2	.12	56.2
20	.14	65.8	.08	37.2	.07	32.7	.17	76.2
22	.20	88.9	.12	52.2	.10	46.3	.22	99.8
24	.26	117.0	.16	71.7	.14	63.5	.28	127.5
26	.33	150.6	.21	95.3	.19	84.8	.35	160.1
28	.42	190.1	.27	124.3	.25	111.6	.44	197.3
30	.52	236.3	.35	159.2	.32	143.3	.53	239.9
32	.64	289.4	.44	200.5	.40	181.4	.64	288.0
34	.77	350.2	.55	249.0	.50	226.3	.75	342.0
36	.92	418.7	.67	305.7	.62	278.9	.89	401.9
38	1.09	496.2	.82	371.0	.75	339.7	1.03	468.6
40	1.29	583.3	.98	445.9	.90	410.1	1.19	541.6
42	1.50	679.9	1.17	530.7	1.08	489.9	1.37	621.9
44	1.73	786.5	1.38	626.9	1.28	580.6	1.56	709.4
46	1.99	904.5	1.62	734.8	1.51	682.7	1.77	804.7
48	2.28	1,033.7	1.89	855.5	1.76	797.4	2.00	907.7
50	2.59	1,175.3	2.18	990.2	2.04	925.3	2.25	1,018.8
52	2.93	1,329.5	2.51	1,138.9	2.35	1,067.8	2.51	1,138.1
54	3.30	1,496.4	2.87	1,303.6	2.70	1,225.6	2.79	1,266.5
56	3.70	1,677.4	3.27	1,484.6	3.09	1,399.4		
58	4.13	1,872.9	3.71	1,683.3	3.51	1,590.8		
60	4.59	2,083.4	4.19	1,900.1	3.97	1,800.3		
	a = 0.0000120		a = 0.0000013		a = 0.0000018		a = 0.0000350	
	b = 3.13944		b = 3.64864		b = 3.57559		b = 2.82938	

Fisheries Research Board of Canada,
Biological Station,
St. Andrews, New Brunswick.

P. M. Powles.

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International Commission for the Northwest Atlantic Fisheries

The Commission in Brief

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

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

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

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

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

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

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(a) Manuscript should be type-written, *double-spaced*, and on one side only of good quality white bond quarto paper, size 8½ × 11 inches (220 × 280 mm).

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

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

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

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

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All CORRESPONDENCE should be addressed to:

Executive Secretary,
International Commission for the Northwest Atlantic Fisheries,
Bedford Institute of Oceanography,
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Dartmouth, N. S. (Canada).