CONTENTS

(continued)

I. Analysis of age reading from the cod otolith exchange program

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As a result of the recommendation of the Research and Statistics Committee, 16 samples of cod otoliths were exchanged and aged by scientists of five fisheries research institutions of four member countries of ICNAF.

The observed ages reported by the various institutions were tabulated by B. F. Calvin DeBaie and circulated as ICNAF Serial No. 1429, 14 August 1964.

This document presents the results of an analysis to determine the degree of agreement among the various readers.

Two of the 16 samples (Nos. 11 and 14) were not aged by Canada (M), and were excluded from the present analysis. There were 20 fish which were not aged by Spain, and these also were excluded from the analysis. The ages recorded for the remaining otoliths by the various institutions are summarized in Table 1. All fish under 4 years of age, and over 15 years of age, were grouped in the commercial-sized samples in order to bring the expected value up near 5. Small-sized fish of 0 + 1 and 4 + 5 years of age were grouped for the same reason.

The expected values were estimated from the marginal totals of observed values. The hypothesis of independence of observed age and country was tested by calculating chi-square (χ^2) values using deviations between observed and calculated values.

The total χ^2 values of 89.54 (52 d.f.) for the commercial-sized fish, and 79.40 (12 d.f.) for small-sized fish are both significant at the .01 probability level (Table 1), and indicate that the observed age distributions are dependent upon the country (i.e., individuals) which aged them. Note that the largest χ^2 value is associated with the smallest age grouping.

A rather large share of the χ^2 value is caused by the divergence of observed ages reported by Spain. The analysis was re-run without Spain's readings (Table 2). Chi-square values for both size groups were reduced to about half the former values. The χ^2 for the commercial-sized fish, 40.09 (39 d.f.) was not significant; but that for the small fish, 32.74 (9 d.f.) was significant, primarily because of the discrepancy in observed frequencies of the one-year-old fish reported by Norway.

Thus, the analyses indicate some rather serious discrepancies in age reading among the countries involved, most particularly in the youngest age grouping for both commercial and small fish.

Table 1. Chi-square (X^2) analysis of dispersion of observed ages of cod in otolith exchange program.

Country		≤3	4	5	6	7	8	9	Age 10	11	12	13	14	15	≥16	Total
Commercial Size Fish																
Canada (M)	Observed	5	19	35	31	33	22	19	16	22	11	9	7	3	4	236
	X^2	3.27	.03	.36	.03	.49	.00	.23	.06	.05	.35	.07	.10	.34	.01	5.39
Canada (N)	Observed	5	17	35	30	29	22	24	11	27	6	10	9	7	4	236
	X^2	3.27	.69	.36	.00	.00	.00	.37	2.12	1.71	1.11	.39	1.26	1.87	.01	13.16
Germany	Observed	15	19	29	32	24	30	21	21	16	6	9	7	2	4	235
	X^2	1.45	.03	.21	.13	.93	2.9	.00	.94	1.19	1.11	.07	.10	1.15	.01	10.22
Norway	Observed	5	20	25	21	39	21	21	18	22	11	11	7	9	6	236
	X^2	3.27	.03	1.38	2.7	3.29	.04	.00	.06	.05	.35	.96	.10	5.48	.77	18.48
Spain	Observed	25	29	34	36	21	15	21	19	18	12	2	1	-	3	236
	X^2	17.82	3.23	.18	1.2	2.30	2.23	.00	.23	.43	.85	4.69	4.36	4.2	.57	42.29
Total	Observed	55	104	158	150	146	110	106	85	105	46	41	31	21	21	1,179
	X^2	29.08	4.01	2.49	4.06	7.01	5.17	.60	3.41	3.43	3.77	6.18	5.92	13.04	1.37	89.54
Expected per Country		11.0	20.8	31.6	30.0	29.2	22.0	21.2	17.0	21.0	9.2	8.2	6.2	4.2	4.2	

Small Size Fish		Age ≤1	2	3	≥4	Total
Canada (M)	Observed	2	14	37	13	66
	X^2	6.98	.00	3.88	.10	10.96
Canada (N)	Observed	3	18	27	18	66
	X^2	5.45	1.02	.00	1.02	7.49
Germany	Observed	4	11	30	21	66
	X^2	4.11	.72	.38	3.28	8.47
Norway	Observed	17	7	25	17	66
	X^2	3.86	3.65	.12	.55	8.18
Spain	Observed	27	21	15	2	65
	X^2	25.37	3.26	5.19	10.48	44.30
Total	Observed	53	71	134	71	329
	X^2	45.77	8.65	9.57	15.41	79.40
Expected per Country		10.60	14.20	26.80	14.20	

Table 2. Chi-square (X^2) analysis of dispersion of observed ages of cod in otolith exchange program, Spain excluded.

Country		≤3	4	5	6	7	8	9	10	11	12	13	14	15	≥16	Total
Commercial Size Fish																
Canada (M)	Observed)	5	19	37	35	34	22	22	16	24	14	12	9	3	4	256
	X^2	.83	.00	.55	.66	.00	.30	.02	.28	.02	1.37	.00	.07	1.69	.41	6.20
Canada (N)	Observed)	5	17	38	31	32	22	25	14	28	9	12	9	9	5	256
	X^2	.83	.21	.84	.01	.09	.30	.22	.99	.58	.15	.00	.07	1.21	.04	5.54
Germany	Observed)	15	20	30	34	27	33	21	23	20	7	10	7	3	5	255
	X^2	7.5	.05	.23	.40	1.35	2.75	.13	.99	.74	1.03	.33	.19	1.69	.04	17.42
Norway	Observed	5	20	26	22	42	22	23	20	25	11	14	8	10	8	256
	X^2	.83	.05	1.39	2.37	2.01	.30	.00	.19	.02	.05	.33	.00	2.25	1.14	10.93
Total	Observed	30	76	131	122	135	99	91	73	97	41	48	33	25	22	1,023
	X^2	9.99	.31	3.01	3.44	3.45	3.65	.37	2.45	1.36	2.60	.66	.33	6.84	1.63	40.09
Expected per country		7.5	19.0	32.75	30.5	33.75	24.75	22.75	18.25	24.25	10.25	12.0	8.25	6.25	5.5	

Small Size Fish		≤1	2	3	≥4	Total
Canada (M)	Observed	2	14	37	13	66
	X^2	3.11	.18	1.77	1.05	6.11
Canada (N)	Observed	3	18	27	18	66
	X^2	1.88	2.42	.25	.03	4.58
Germany	Observed	4	11	30	21	66
	X^2	.96	.18	.00	.81	1.95
Norway	Observed	17	7	25	17	66
	X^2	16.96	2.42	.76	.00	20.14
Total	Observed	26	50	119	69	264
	X^2	22.91	5.20	2.78	1.89	32.78
Expected per country		6.5	12.50	29.75	17.25	

II. Results of cod tagging by the Federal Republic of Germany in the Greenland area from 1959 to 1964

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From 1959 to 1964, 2,936 cod were tagged. The main aim of these tagging experiments was to study the migration of the East Greenland stock of cod. Therefore tagging was carried out mainly off Southwest, South and Southeast Greenland (Table 1). Up to 31 July 1965, 218 tags were returned. The recovery rate to date is 7.6%.

Table 1. Numbers of cod tagged off Greenland, by regions and years, from 1959 to 1964.

Year / Region	1959	1960	1961	1962	1963	1964	Total
E Greenland	-	-	121	4	-	-	125
SE Greenland	-	201	-	-	-	-	201
1F	215	432	-	120	38	327	1,132
1E	274	215	-	-	40	33	562
1D	62	329	-	105	15	221	732
1C	-	-	-	-	-	155	155
1B	-	-	-	-	-	29	29
Total	551	1,177	121	229	93	765	2,936

The recaptures came from the following regions:

	Recaptures No.	Recaptures %
Subarea 1	159	73
Southeast Greenland (south of 63°N)	5	27
East Greenland (north of 63°N)	9	
Iceland	40	
East Greenland or Iceland	5	
	218	100

Table 2 shows the areas of taggings and recaptures of 59 cod caught off the eastern coast of Greenland and off Iceland and the time in days between tagging and recapture.

Table 2. Number and location of tagged and recaptured cod in Greenland and Iceland waters showing the range and average number of days (in brackets) from tagging to recapture.

Recaptured off / Tagged off	SE Greenland (5 cod)	E Greenland (9 cod)	Iceland (40 cod)	E Greenland or Iceland (5 cod)
E Greenland (125 cod)	- - -	1 390 days -	3 182-750 days (Avg.461)	- - -
SE Greenland (201 cod)	1 182 days -	- - -	2 258-840 days (Avg.549)	1 720 days -
Div.1F (1,132 cod)	2 108-343 days (Avg.225)	3 94-335 days (Avg.181)	9 184-1,230 days (Avg.502)	2 240-690 days (Avg.465)
Div.1E (562 cod)	- - -	2 450-1,650 days (Avg.1,050)	14 164-1,620 days (Avg.952)	1 840 days -
Div.1D (732 cod)	2 570 days -	2 255-315 days (Avg.285)	11 139-1,590 days (Avg.613)	1 1,200 days -
Div.1C (155 cod)	- - -	1 130 days -	1 147 days -	- - -
Div.1B (29 cod)	- - -	- - -	- - -	- - -

Table 3 gives for the different areas the distribution of recaptures over the years 1960 to 1965. It also shows the range in length and the average length and, for 26 returns with otoliths, the range in age, the mean age, and the year-classes of the recaptured fish.

Table 3. Length, age and year-class of cod recaptured east of Greenland and off Iceland between 1960 and 1965.

	SE Greenland	E Greenland	Iceland	E Greenland or Iceland
1960	1	1	4	-
1961	2	1	6	-
1962	-	1	8	1
1963	-	-	6	2
1964	2	1	9	1
1965	-	5	7	1
Length (cm)	73-91 (Avg.82.3)	75-93 (Avg.80.0)	71-97 (Avg.83.8)	58-92 (Avg.79.0)
Age	7-14 years (Avg. 10.2)	7-11 years (Avg.8.7)	7-11 years (Avg.8.2)	7-11 years (Avg.8.2)
Year-classes	1947, 1949, 1950 1956, 1957	1950(2), 1956(2), 1957, 1958(2)	1950(2), 1951, 1952(2) 1953(3), 1954(2), 1955 1956(4), 1958(3)	1951, 1956(3) 1957

Tables 2 and 3 show a considerable migration of cod from Div. 1C, D, E and F to the eastern side of Greenland and to Iceland. From the length and age composition as well as from the state of the gonads and the time of recapture of the fish, we can deduce that their eastward migration is a spawning migration. Only maturing and mature cod move from West Greenland to the presently known East Greenland spawning grounds on Bille Bank (62°N), Fylkir Bank (62°30'N) and Dohrn Bank (30°W) and to the spawning areas off West and Southwest Iceland. Seventy-five percent of the 40 recaptures off Iceland were made within the short time (spawning time) between 14 March and 20 May (Fig. 1). Thirteen of the 14 recaptures off Southeast and East Greenland

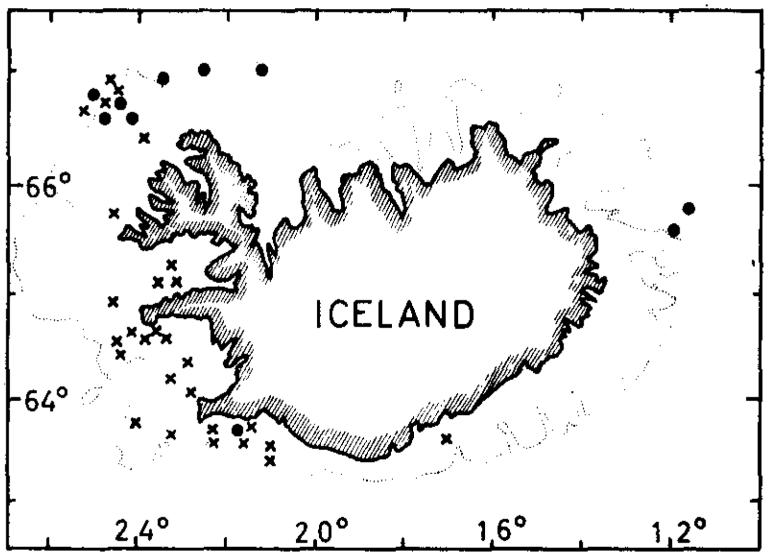

Fig. 1. Location of recaptures off Iceland. Recaptures from 14 March to 20 May (x), recaptures at other times of the year (•).

were made from 1 December to 5 May. From the fact that, to date (the only exception seems to be a tagging experiment in 1931 off Southwest Iceland), no cod tagged off Iceland has been recaptured in Greenland waters, we may presume that Greenland cod spawning off Iceland remain after spawning in Iceland waters. This is confirmed by the fact that most recaptures after the spawning time come from Northeast, North and even from East Iceland, where the cod were caught on their feeding migration. The only cod caught in the spawning area outside the spawning time was found on 16 February 1965. This cod of the 1956 year-class was ready to spawn for the second time.

The speed during the spawning migration must be considerable. Within less than 205 days, a cod tagged on Fyllas Bank covered at least 1,270 nautical miles to Ingolshöfdi on the south coast of Iceland. This is an average speed of at least 6.2 miles per day. Another cod tagged on Danas Bank was recaptured 133 days later off Northwest Iceland (Gammelloch). The speed must have been more than 7.5 miles per day. But the highest speed of more than 8 miles per day showed a female cod, 7 years old and 86 cm long, tagged on 16 November 1964 on Lille Hellefiske Bank (1C), and recaptured on 12 April 1965 off Snäfells

Jökull (West Iceland).

The German tagging experiments further confirmed the validity of the age determinations. The greatest increase in length (47 cm) between tagging and recapture was made by a cod of 44 cm tagged on Danas Bank and recaptured off Northwest Iceland 4 years and 5 months later with a length of 91 cm. A much faster growth was demonstrated by a cod tagged at 40 cm off Noname Bank and recaptured 2 years and 11 months later off West Iceland with a length of 84 cm. Figure 2 shows the relation between time and increase of length of

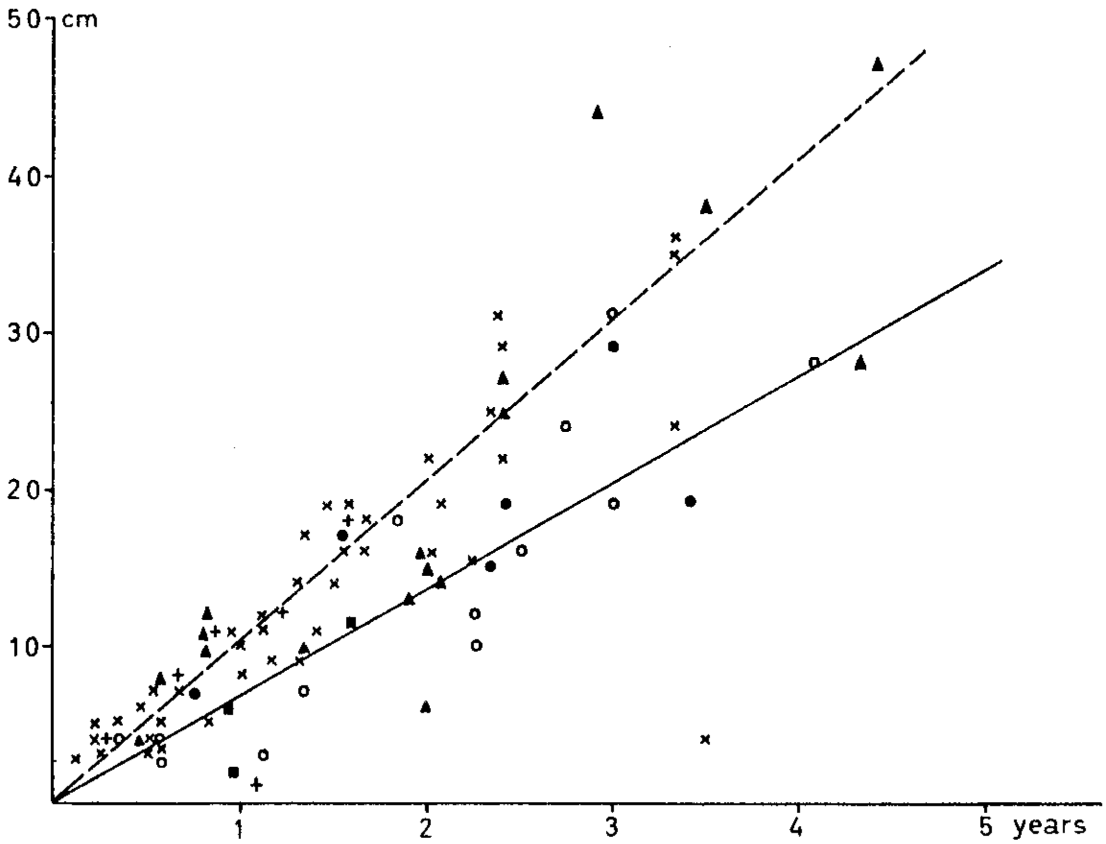

Fig. 2. Relation between time and increase in length. Average increase in length of immature cod (-----) and mature cod (______). Immature cod recaptured off West Greenland (x), East Greenland (+) and Iceland (▲). Mature cod recaptured off West Greenland (o), East Greenland (■) and Iceland (●).

tagged cod recaptured off West and East Greenland and Iceland. The broken line gives the average increase in length for all cod caught as immature fish or when spawning for the first time. The average increase in length of these cod is about 10 cm per year. The solid line shows the somewhat smaller growth

(7 cm per year) of those cod which were recaptured after having spawned one or more times.

We have very little information on the location of the spawning grounds of the West Greenland stock of cod. As far as we know they spawn on the western slopes of the banks in Div. 1D and E. But there are signs that the West Greenland cod, especially when they become older, tend to extend their spawning migrations more to the south and even to the eastern side of Greenland, as was shown by the strong 1947 year-class in West Greenland waters. Also the German Research Report for 1964 (1965 Research Document No. 11) shows that a substantial part of the 1957 year-class in West Greenland waters spawned in 1964 off Southeast Greenland, while the 1956 year-class in East Greenland waters migrated for spawning further to the north to Dohrn Bank and possibly to Iceland. Perhaps this surprisingly strong appearance of the 7-year-old cod off Southeast Greenland in 1964 should be examined in connection with the somewhat anomalous hydrographic conditions off West Greenland in 1963 and 1964.

III. Some of the unknowns in research information necessary for calculations of maximum sustained yields of commercial fishes in the ICNAF area.

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Introduction

It was originally intended that this paper should form part of the review by Templeman and Gulland of possible conservation actions for the ICNAF area (1965 Commissioners' Document No. 12). It was, however, considered wiser to submit the research section as a separate document.

Over the past decade fishing effort in the ICNAF area has increased greatly. The effects of this increased effort have been evident in declining standing stocks, especially of larger fish, and in decreases in catch per unit effort. The maximum effects of these increases in effort on the established fisheries for the major groundfish species have been reduced by the application of much of the increased effort to underfished stocks of redfish, cod, herring and silver hake.

Considerable additional increases in fishing effort in the ICNAF area are envisaged by many ICNAF and other countries and no unfished or very much underfished stocks of the major groundfish species are available. It thus appears likely, unless some additional regulatory action is taken and fishing effort controlled, that fishing may in due course, from the application of much too great an effort to limited and declining stocks of fish of commercial size, become unprofitable for many, if not all, the ICNAF countries.

Up to the present time, ICNAF has used only a few simple mesh specifications for fisheries regulation. At such a time as this, when the imposition of new regulations is likely to be considered and studied, it is as well for biologists to consider seriously how far the knowledge, theory, research vessels, equipment and staff at their command will enable them to give the necessary advice to their national fisheries administrators and to ICNAF and with what reservations this advice must be given. It is also as well for the Commission and fisheries administrators generally to realize the limitations under which the biologists operate and the amount of what President Franklin D. Roosevelt used to call "weasel words" (if, but, may possibly, etc.) which must be used in hedging when they give advice.

It seems certain that few fisheries biologists writing about these matters would speak with the same voice. They would have different opinions and different degrees of frankness and emphasis, and would give different advice depending on whether they were optimists or pessimists and on their backgrounds and interests in fisheries research.

A paper could be written with many literature references on each of the many subjects mentioned in the course of this presentation, but, in the interests of clarity and brevity of expression and to provoke discussion and controversy which often produce new ideas and new patterns of research, positive statements have been made, reflecting some of the experiences, thoughts, beliefs and prejudices of the author and without literature references.

In recent years an excellent body of mathematical theory has been developed for dealing with fish populations. In meetings devoted to consideration of other animal populations, the statement is often made by the biologists concerned with these populations that fisheries biologists are leaders in the field of population dynamics.

Fisheries biologists, associated with these studies in population dynamics of fish stocks, have developed a group of symbols constituting a special language, and it is only necessary to mention F, M, Z, E, S and Q, etc. of a fish population to begin a discussion or an argument. This special language, which, like all the many special languages in the fields of science, is absolutely necessary for the mental progress of its devotees and for the many and often complex mathematical equations, has tended to isolate many of the less mathematically-inclined fisheries biologists from the active thinking of the group working in population dynamics.

The pure fish biologists (i.e. those not knowing enough population dynamics language or theory or not having enough interest to follow the discussions and read the papers of their more mathematical colleagues) have usually followed at a distance in the disturbed wake of the fish-population theorists, assuming that such obviously intelligent and apparently confident people were likely to be right.

For most of the many fish stocks of the ICNAF area there are, however, far too few fisheries biologists and fisheries research vessels, and in some cases far too poor statistics of catch and effort. Also, the period of study has been far too short to provide adequate information on the effects of the environment on the fish stocks or on the resilience of the fish stocks when the rapidly increasing predations of man are added to those of the natural predators and the vagaries of nature. Under these circumstances, the best available fish-population theory must be used and presumably has been used by filling in the available data and by making the best assumptions possible regarding missing data. There is some latitude here in the choice of models and the choice will often be a personal one. However, it should be explicitly understood that any action by fisheries administrators taken under these theories is an experiment, and that the experiment requires an adequate background of data, time and study. It should also be understood that not all the results of the experiment (and very often only a few of them) can be predicted with confidence. For example, an increase in mesh sizes will certainly reduce the relative numbers of small fish caught by trawls. In some cases where much of the smaller fish is discarded, it can be predicted with some degree of confidence that the larger fish retained after the regulation will eventually be worth more than the fish retained before the regulation. It may also be predicted by the best available theory that the maximum sustainable poundage of fish caught will also increase, but as a rule there can only be very limited confidence in this third presumption. The result in any particular case remains to be proven.

Fish population workers, therefore, must at the present time usually work to a great degree in the dark. It is the purpose of this paper to point out briefly, but not necessarily to illuminate, some of these dark and dimly-lighted areas, in the hope that in the course of time more research effort can be devoted to them.

Present Research

Fisheries research in laboratories of ICNAF member countries chiefly produces the kind of useful information on catch, effort, size, age and growth, recruitment, mortality, selectivity by gear, fish distribution and relation of fish concentration to depth, temperature and food, migration and stock divisions, most of which can be used for the current ICNAF assessments of yield per recruit. These researches are reaching respectable proportions but in many cases the catch is sampled from only a very small part of the vessel units and in some cases the commercial catch is not sampled at all. In all cases the separation of mortality into natural and fishing mortality components could stand much closer definition. Reliable estimates even of total mortality are not available for many stocks. The natural mortality of the earlier years of the pre-recruit phases needs much more study even to arrive at approximations.

Stock and Recruitment

Equally important is the need for other research information necessary for estimating the real sustained yield of a population but of which little is known or in progress for ICNAF fish stocks. What egg production is necessary to keep the production of young recruits to the fishery at the maximum sustained level and to what degree are populations dependent on egg and larval recruits from other populations? At present biologists usually assume that for major populations of marine fishes the egg production is so great under the usual ranges of stock numbers that differences in the numbers of eggs produced will not greatly affect the number of recruits, i.e. at reduced stock levels there may be sufficient improvement in the survival from eggs to recruits to balance the reduced initial number of eggs. This improved survival to the recruit stage may be caused by reduction in direct competition for food between the young or by reduced adult predation. On the other hand, heavy fishing, especially on the spawning schools, must reduce very greatly the numbers and sizes of mature fish and the numbers of eggs produced. A situation such as the lack of sufficient production of recruits to the haddock fishery of the southern Grand Bank since 1955-56 makes one wonder whether, especially at the northern and southern outposts of a species, it is not dangerous to reproduction to reduce the mature population beyond a certain size or to reduce the production of eggs below a certain level. It is possible that larvae produced from some sizes and ages of parent females may have enough physical and physiological differences to provide higher survival than those produced by other sizes and ages. A wide range of sizes of females will produce different sizes of larvae, offering a better range of possibilities for survival when food size immediately after hatching is a factor. A wide range of sizes of fish sometimes extends the spawning time by as much as 2 months, as in the Labrador area where the small mature cod spawn in March and early April and the large cod in May and June, and also greatly extends the horizontal and vertical area over which spawning or larval extrusion occurs. These factors provide for the stock a great margin of safety which is decreased when the spawning stock is reduced to a few younger year-classes. Because of the great natural fluctuations in survival of young even when the spawning populations are large, this field is a very difficult one for research and precise answers cannot be expected very quickly. In any case the answers would very likely be different for each stock and situation and would vary with changing water climates.

Interspecific and Intraspecific Competition, Utilization of Food and Predator Control

A population change from a majority of one fish species to a majority of another in the same area can presumably occur in the sea as it does in lakes. A fishery specializing in the catching of large predator fishes but with no fishery or a small fishery for food fishes provides the possibility of a reversal in species abundance. On the southern Grand Bank, for example, the numbers of capelin are controlled by predation by larger fishes, especially cod, and by haddock feeding on their eggs during the capelin spawning season. The numbers of launce are also kept in control by groundfish feeding on them. The predation pressure on these food species has been greatly lifted in recent years both in the offshore and near shore areas by the great decrease in the standing stock of large groundfish, especially cod. Because there is no offshore and only a small inshore commercial fishery for capelin and none at all for launce, increases in the numbers of these species are difficult to measure, but capelin were reported to be unusually abundant on the Grand Bank in 1963 and in the inshore area of southern Labrador in 1964. A great abundance of capelin and launce is likely to produce increased food competition for and predation on very young groundfish.

Other possible effects may favour the cod but be unfavourable to the fishermen. In the inshore region an overabundance of capelin compared with cod will greatly reduce the effectiveness of all line fishing in June, July and early August. These well-fed cod may grow faster and, if not caught in the usual amounts by the inshore fishery, will be relatively more numerous offshore in winter and spring. Thus the trawl fisheries will profit.

Interspecific and intraspecific competition and interaction provide a field for research almost untouched in the ICNAF area at present and some of these studies of interspecific competition are very difficult to develop in the absence of a large fishery for the food fishes.

In fish population work it is usually assumed that, when the stock of old mature fish is reduced by the increasing fishing effort, the younger fish increase in number and by turning more of the food into muscle rather than into eggs and milt and body maintenance provide a greater surplus for the fishery. In other words, what is assumed (but not known) to be a surplus of eggs and milt becomes a surplus of flesh. It is a common observation, however, that the size of food eaten by fishes increases with increase in fish size and to make good use of all the food of various sizes present requires a balanced population of fish and not one reduced to a small fraction of its size range and consequently feeding on a small size range of food. If, by the removal of the larger fish of a species, the standing stock of small fish of the species increases considerably, there will be greater competition than before for the sizes and kinds of food on which these fish depend. This may result in lower growth rates, as occurred with the large year-classes of Grand Bank haddock between 1949 and 1956. It is also probable that for cod, the dominant species over most of the ICNAF area, only a balanced population including a fair proportion of large and very large fish is likely to control the numbers of adult predators of other species and competitors for food. This field is wide open for study. However, as more and more of both predators and food fishes are used commercially, the predator population will not be so much affected by the interspecific competition between predator and food fishes and the populations of these two groups should again reach a balance.

With reductions or increases in the size of fish, the different size requirements of food can presumably have considerable effect on the size constitution of the invertebrate fauna. When most of the larger invertebrates are not used for food because of the reduction in the numbers of large predators, a predominance of large invertebrates may occur, resulting in less room on the bottom for the quantities of smaller invertebrates which may serve as food for the smaller fish now on the fishing ground. The American plaice of the Grand Bank slopes, for example, at their larger sizes eat great quantities of adult sand dollars, Echinarachnius parma, which grow to a size of about 7 to 8 cm and carpet the sea bottom in sandy areas. As the numbers and sizes of large plaice are reduced by heavy fishing, it cannot be expected that the larger sand dollars can be eaten in quantity, so that in time they may cover much of the area to the probable detriment of the smaller sand dollars, which can be utilized by the smaller plaice, or to the detriment of other bottom organisms which may be utilized by cod and plaice. A similar case could be argued, based on the utilization of large crabs, such as the very numerous Chionoecetes opilio, by large cod but smaller sizes by smaller cod. Presumably, if very great numbers of the larger crabs were present, the smaller crabs might become less numerous. The diet of the wolffish will provide many such examples but these fish are not usually very numerous even in the virgin condition.

Eumetric Fishing

The eumetric yield curve shows the relation between catch and effort (fishing mortality) when the size (age) at first capture at any given level of effort is adjusted to give the maximum catch (only yield per recruit at present) for that effort.

With increasingly high fishing intensities, population dynamics theory usually finds it possible to reason, using such data as growth, fishing and natural mortality and catch per recruit, that the size at first capture (i. e. the mesh size in trawl fisheries) should be gradually increased to obtain the best weight of fish from the fishery. The result under any intensity of fishing is to increase the stock of larger fish beyond that which would have occurred if the sizes at first capture had been smaller.

Apart from the gain from the growth and survival of the recruits already present, there may be several consequences which cannot be assessed before the size at first capture is actually considerably increased or decreased.

In the actual cases studied in the ICNAF area, of which the Georges Bank haddock has received the greatest attention, it is usually the case that the period of intensive background study before the change has been far too short for any close comparison of the new with the old situation. It is probable that this will be the case in most other experiments in introduction of new laws, because there is usually scientific and administrative and sometimes industry pressure for the change. None of these groups is noted for patience. They all want to see some improvement within their lifetimes. At the present time, even under favourable conditions for study, because of the many unknown or poorly known factors and the estimated small differences in long-term landings under the old and the new regulations, there is small likelihood of scientific proof of the benefits to quantities landed of small changes in mesh and other fisheries regulations.

Under any given intensity of fishing, raising the size at first capture should increase the number of fertilized eggs produced, which under conditions of heavy fishing may be favourable or at least provide a safety factor. There is the possibility that these extra eggs are not needed, or even that, at certain very high levels of egg production, they may be detrimental. The results will vary greatly with the stock, the place of spawning, and the related current systems which in some cases may disperse and lose the eggs from the fishing ground and in others conserve and retain them on the ground.

For some stocks an increased abundance of larger fish will probably reduce the numbers of adult food fishes and of other competitors and predators of the smaller sizes of fish in the stock which it is desired to increase. This may result in more young surviving the larval stages and some increased survival later. Increasing the catching size may provide advantages to the stock by using a wider variety and size of food. As a probable disadvantage greater numbers of protected larger fish remain on the ground, and, if the protected sizes are large enough, the condition found in virgin fisheries may be approximated. In this situation the recruitment of large numbers of younger fish to the fishable sizes may be suppressed by competition and sometimes predation by the older fish of the same species, so that the expected number of recruits may not appear. Since, when size limits are raised, the quantities of fish in the sizes immediately below and adjacent to the recruit sizes may be considerably increased, additional competition for food may reduce the growth of these fish.

An opportunity for the study of some of the factors involved arises when any increase in mesh size occurs which produces a considerable change in the size of fish caught, when any considerable increase in fishing intensity occurs with consequent reduction in standing stock, when an unusually strong year-class appears, progressing in size from year to year, or when an area is closed to fishing for some time.

Maintenance of Customary Migration Patterns

As standing stocks and sizes of fish are reduced by increasing fishing effort and a greater proportion of the population is caught at the smaller mature and the immature sizes, the average patterns or extent of migration may change. Off Labrador, for example, the larger cod spawn a month or two later than the smaller cod and the elimination of the larger cod is almost certain to produce differences in the average pattern of after-spawning feeding migration.

The spreading of feeding fish after spawning provides the great inshore Newfoundland cod fishery in which the hungry pelagic cod follow the spawning capelin to the shore. Previous to this the cod live during winter and spring in deep water. As cod become scarcer, a greater proportion of them may be able to find food in the offshore wintering or deep water areas and may not need to move to the inshore areas for feeding. The immature part of the population may not move as far offshore in winter as the spawning fish nor migrate as freely in summer as the hungry spent fish. On the other hand the offshore deepwater spawning and the pelagic inshore capelin-feeding movements may be such inherent and instinctive parts of the cod behaviour that great differences from the present migration patterns will not be noted. It is fairly certain, however, that there will be some differences in migration patterns as the size constitution and numbers change.

Grand Bank haddock, when stocks were great, migrated in May-June across the bank from their winter-spring abode on the southwestern slopes and occupied in summer the shallow water of the Southeast Shoal. There in July and August they fed on capelin eggs and on the spawning capelin. During the past several years with stocks greatly reduced, no concentrations have been found in the former shallow-water areas of abundance and they have been relatively more plentiful in summer on the slopes of the bank.

These changes, if they occur, may not affect maximum yield of the whole stock but may affect the quantities caught by different countries or different sections of the industry.

Hydrography

Far too little is known about current direction and strength over a great part of the continental shelf, especially in the bank areas. This and the related sea temperature information for the spawning months and for several months afterward are necessary if drift and survival of fish larvae and fry are to be understood.

Changing Water Climates

The whole recorded knowledge by biologists and hydrographers of the periodicities in changes in water climates and their effect on the abundance of fish stocks is of too brief duration for adequate forecasting or prediction either of the temperature cycles to be expected or of their effects on the size and constitution of fish populations.

Productivity

The productivity of the area needs much more and continuing study and the linkages between chemical productivity, plankton and bottom fauna productivity and fish productivity revealed. Otherwise natural changes in fish productivity, whether produced by changes in water climate, current directions or volume transport or by chemical changes in the sea, will not be understood and reasoning about them will be incorrect.

Total Maximum Yield

It is apparent to all that a greater weight of rabbits or field mice or lemmings could be obtained than of the foxes which feed on them and that if the maximum amount of meat is necessary it is better to eat the rabbits and the other rodents than to eat the foxes. Similarly with fishes, it is apparent from available food conversion rates that for fish it is at least several times more productive of food poundage to eat the grazers on the plankton such as herring and capelin than to eat the final predators of these fishes such as the cod. It may be possible that the argument is similar for using small cod at the plankton eating or mainly pre-fish-eating stages. At the present time, however, it is usually the fish predator and bottom feeder and large fish which are desired by most nations fishing the ICNAF area and which bring the highest market prices. Consequently such arguments regarding grazers and fish predators must remain academic until more fish protein could be profitably utilized and these plankton feeders or smaller fish are desired in quantity by more nations. It will be necessary, however, to study and provide information for many fishes on food preferences, species competition for food and on utilization of various foods and their conversion into usable fish flesh.

Conclusions

We may conclude, therefore, that at present scientists can arrive at some approximations for ICNAF fish stocks with regard to the yield per recruit and some approximations of what kind of mesh, fish size and yearly catch would produce the maximum sustained yield per recruit under various fishing intensities. However, with the brief period of very heavy fishing pressure on most of the species and the short period and lack of variety and coverage of essential factors by research operations, it is not usually possible to know the magnitude and size composition of a population which will give the maximum sustained yield, and consequently it is not possible to set a figure, based on adequate scientific evidence, for the maximum sustained yield.

Major errors of judgement are possible if a calculation of yield per recruit is accepted as a basis for maximum sustained yield. In the Assessment Subcommittee report for June 1964, it is concluded, on the basis of yield per recruit, that in 1962-63 the yield of haddock from Div. 3NO was probably a little below maximum. At the same time, from lack of successful year-classes since 1955-56, this fishery has declined rapidly since 1962 and will remain at a low level until good year-class survival occurs. The main unknown questions here are what conditions lead to successful survival and how large a spawning population is necessary and of what size constitution to ensure a very successful year-class when hydrographic and food conditions are favourable.

Catch per unit effort, however, is the factor which directly affects the fishing enterprise and with improved statistics this information can be made readily available. If a great or increasingly great amount of fishing effort is applied to the fish population without corresponding increases in size at first capture the total catch will eventually fall below its maximum level and, by the reduction of the number of year-classes available, become gradually more fluctuating as it comes to depend more and more on the new recruits to the fishery.

Even if the appropriate researches are greatly intensified a very long period of biological and statistical information on a fishery will usually be necessary to arrive at close approximations of maximum sustained yields. For the highly fluctuating haddock population of the southern Grand Bank, it may be possible to have some reasonable opinions in another 50 years. For Georges Bank haddock, which have had a longer period of study and whose year-class fluctuations are not so great, some tentative conclusions on maximum sustained yield may be made in a shorter time.

For redfish, many ages and slow growth and heavy concentrations on a restricted slope area are involved, and the fishery developed rapidly to a high level, but usually in each newly exploited area catch per unit effort and total catch and total effort fell quickly. Over most of the area much more time and research effort and the application of fairly intensive fishing must elapse before approximations can be made of sustained yield of most redfish stocks.

Cod have usually a smaller number of year-classes in the fishery than redfish, but the number is great enough that one year-class does not usually control the major part of the fishery as it often does for haddock.

The total catch of cod in most subareas has been levelling off in recent years in spite of increasing effort. For Subarea 2, it is much too early for consideration because the great offshore fishery in this subarea developed very recently. For Subareas 1, 3 and 4, if, in spite of increasing effort, the catch continues to level off for another 10 years or more, it may then be reasonable to suppose that, unless water climate changes significantly, it should be possible to maintain a sustained catch of the sizes being taken, approximately equal to that of the level period.

Some action beyond mesh regulations will obviously be necessary to obtain the combination of approximate maximum sustained yields and adequate economic returns from the ICNAF fisheries. From a biological point of view, the picture is so complex as to be in the field of experiment. It is thus desirable before great changes in regulation are made to make special and, where possible, cooperative efforts to fill in as much of the missing data necessary to estimate the probable effects of these changes as can be obtained in a reasonable time. Even with these additional efforts, for most ICNAF fish stocks in the near future biologists will generally be able to supply at the most only more or less reasonable opinions on real sustained yield. Consequently, it will be necessary to proceed on a somewhat pragmatic basis, using biological-mathematical-statistical calculations that appear reasonable and where necessary arguing to some degree from analogy with better known fish stocks. For each major stock, it will be necessary to study the responses of the stock to the fishery, and to estimate as precisely as possible the most desirable quantities and sizes of fish in the standing stock. It will then be necessary to produce, on the basis of available knowledge, a figure for sustained yield to be aimed at, regulating on this basis, and allow time and the accumulation of new information and theory to indicate advance or retreat from the previous position. The tempo of fisheries research and of statistical recording should be increased and, where necessary, changed in direction to follow more closely the effects of the fishery and of nature on the fish population.

IV. The use of redfish statistical data by depth zones

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It is a commonplace in fishery research that the size of fish often increases with depth, and that this tendency is particularly marked among redfish. This effect has been clearly shown in several contributions to previous ICNAF meetings. For example Hennemuth and Brown (1964) gave a detailed statistical treatment of US data, and showed that, using four depth zones at intervals of about 50 fathoms, the differences were statistically significant; between the deepest and shallowest zones the difference in median was over 7 cm, which is biologically a very important difference for a fish which (in the areas considered) only grows to around 35 cm. As these and other authors have pointed out, these differences may be very important in the study of the dynamics of redfish populations.

So long as the depth distribution of fishing (either by research vessels or by the commercial fleet) does not change there is no special problem, though the size composition of the catch may not be the same as that of the population. Changes in the size composition of the population will be reflected proportionally in changes in the size composition of the catch. Any changes in the depth being fished will, however, produce changes in the size composition of the catches which may be quite different from the changes in the population. For instance, if the fleet fishes deeper the average size of the catch will tend to increase, perhaps enough to hide completely any possible decrease in average size of the population due to heavy fishing.

Correct estimates of any change in the size composition of the population will be obtained by using only data from the same depth zones, e.g. from routine research vessel surveys, or from commercial trawlers when depth of fishing is known. However, this information by itself is not sufficient to determine the size composition of the catches. It follows from the differences in size with depth that, except for a uniform distribution of fishing with depth, the fishing mortality is not the same for all sizes or ages of fish, and a detailed study of the population dynamics is only possible by taking into account this variation of fishing with size, for which the actual size composition of the commercial catches is a vital piece of information. Recent experience of the cod stocks in the northeast Atlantic has shown that fishing mortality varies with size, and that the pattern has probably not remained constant; it appears that in recent years there has been a shift toward concentrating more on the smaller fish. It has been possible to study successfully some of the effects because full data of the size and age composition of the catches were available, but the results are not entirely satisfactory because without data on the detailed fishing positions, e.g. by depth zones, the shift to smaller fish is a presumption rather than a demonstrable fact.

To estimate the possible size of effect on redfish I have looked at one area (3M) where there are both length data of catches of <u>Sebastes mentella</u> by depth zones (from USSR, Chekhova 1964) and catch data for 2 years which show changes in the depth distribution (from Poland, Chrzan 1963, 1964). Assuming that the length distribution in each depth zone was the same in both years, the percentage length composition of Polish catches in 1962 and 1963 was estimated as follows:

LENGTH (CM)	26	28	30	32	34	36	38	40	42	44	46	48	POLISH CATCHES (TONS)	
	RUSSIAN CATCHES (%)												1962	1963
150-200 FM	1.6	4.4	16.4	12.8	20.4	13.6	18.8	10.4	1.6				60.2	210.6
200-250 FM		0.6	2.9	18.0	35.2	20.6	16.6	4.5	1.0	0.6			182.2	175.8
250-300 FM			2.9	18.9	27.2	27.5	12.2	6.4	3.5	0.8	0.6		19.3	100.4
	POLISH CATCHES (%)													
1962	0.4	1.4	6.0	16.9	31.2	19.5	16.8	6.0	1.3	0.5	0.1			
1963	0.7	2.1	8.7	15.9	27.1	19.0	16.6	7.4	1.8	0.4	0.1			

The first three rows give the composition of Russian catches from each depth zone (taking the 300-400 m zone as equivalent to 150-200 fathoms etc.), and the last two rows the weighted mean percentages, using as weighting factors the Polish catches given in the right-hand columns. There is no very obvious difference in the distributions for the two years, particularly for the central length groups, for which in fact the percentages do not vary much between the depth zones. However, there are substantial differences at the tails of the distribution; as proportionally more fishing was done in both the shallowest and deepest zones in 1963, there are more of both very small and very big fish in the 1963 catches. Thus the percentage of fish over 40 cm increases from about 7.8% in 1962 to 9.7% in 1963, i.e. by about a quarter.

The implications of this depend on whether the Polish data are used to give estimates of the size composition of the actual population (in which case there would be an apparent increase of 25% in the abundance of large redfish), or whether the Polish data are used to estimate the effort on redfish (in which case there would, for a given catch, be a real but undetected increase of fishing on large redfish of 25%). Either of these changes could be important, and the changes in the pattern of fishing over a longer period than just two years would probably cause even more significant changes.

To avoid these errors both catch and length-composition data should be presented by depth zones. Then the best estimate of the composition of the catch would be obtained by weighting the composition in each depth zone by the catch in that zone, and the composition of the stock by weighting according to the estimated abundance in each zone. This requires more detailed sampling data than are at present given in the Sampling Yearbook, where the depth-zones samples are usually stated, but there is no separation of data when more than one zone has been sampled. There is also some lack of uniformity in depth zones used, though zones at 50-fathom intervals seem the most frequent.

No detailed examination of seasonal variation of either depth of fishery, or of size composition by depth has been made. If there is no seasonal variation in either of these then it would be possible to use annual figures of catch and length data by depth zones without introducing a risk of bias, but until such constancy has been established it seems advisable to use monthly or quarterly data.

Detailed statistics of catch and effort by depth zones have also been provided; if the catches vary greatly with depth then a change in the average depth fished could alter the catch per unit effort even though the abundance does not change. However, in a commercial fishery it seems unlikely that there will be any substantial amount of fishing in a depth zone in which the catch per unit effort is much less than at another depth in the same area. Thus Brown and Dreyer (1964) found no consistent differences in catch per unit effort between depth zones in the same area, and where the differences were large (e. g. in 3P in 1963) the data were based on only a small amount of fishing. Probably therefore depth-zone data may not be particularly helpful in interpreting catch and effort data, but if catch statistics are produced to be used with length composition data, then the small extra trouble involved in including effort statistics as well may be worthwhile.

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V. Another cold year: 1964

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Monitoring of temperature conditions in Subarea 4 was continued in 1964 from surface and bottom temperature observations. Halifax Section over the central Scotian Shelf was occupied 7 times during the year by CSS Baffin, CSS Hudson, CNAV Sackville and CGS A. T. Cameron. If the seasonal coverage had apparently been neglected, repeated coverage within a relatively short time has been emphasized. Surface observations at six coastal stations were continued in Subarea 4 as well as bottom observations at two stations in the Gulf of Maine-Bay of Fundy area. Some of the features observed in 1964 are described here.

Halifax Section

Figure 1 shows only four of the seven sections occupied during the year.

Early spring (26 March): A cold mixed layer, with a maximum thickness of 100 m, extended across the Scotian Shelf and to at least 40 miles south of the Shelf. The surface temperature varied between -1.2° and 1.9°C. Similar conditions have been observed during winter in 1959 and 1961. The mixed layer extended down to only 60 m over Emerald Bank where bottom temperatures varied between 3.0° and 4.0°C. South of the bank they varied between 2.0° and 3.0°C. These bottom temperatures were all below average. The observed maximum temperature in the deep waters of the Scotian Gulf, 6.1°C, was below average by approximately 2.0°C.

Summer (15 and 24 July): The general features of temperature and salinity distributions have changed slightly in the 8-day interval. In both cases the surface layer of temperature below 15.0°C extended across the Shelf down to a maximum of 20 m. However, on the shore end of the section, the surface temperatures had decreased by almost 2.0°C, from 15 to 24 July. The intermediate temperature layer, observed in both series, occupied the whole width of the Shelf. The maximum temperature observed in the deep waters of the Scotian Gulf, 5.1°C, and the bottom temperature on Emerald Bank, 2.2°C, were much below average, the former being a record low temperature, associated with a relatively low salinity (<34.5‰). Also during both series, an area of steep gradient of bottom temperature, from 3.0° to 7.0°C, was predominant south of Emerald Bank. Changes in both temperature and salinity distributions were observed south of the Scotian Shelf from 15 to 24 July.

Late summer (9 September): The temperature of the surface layer had

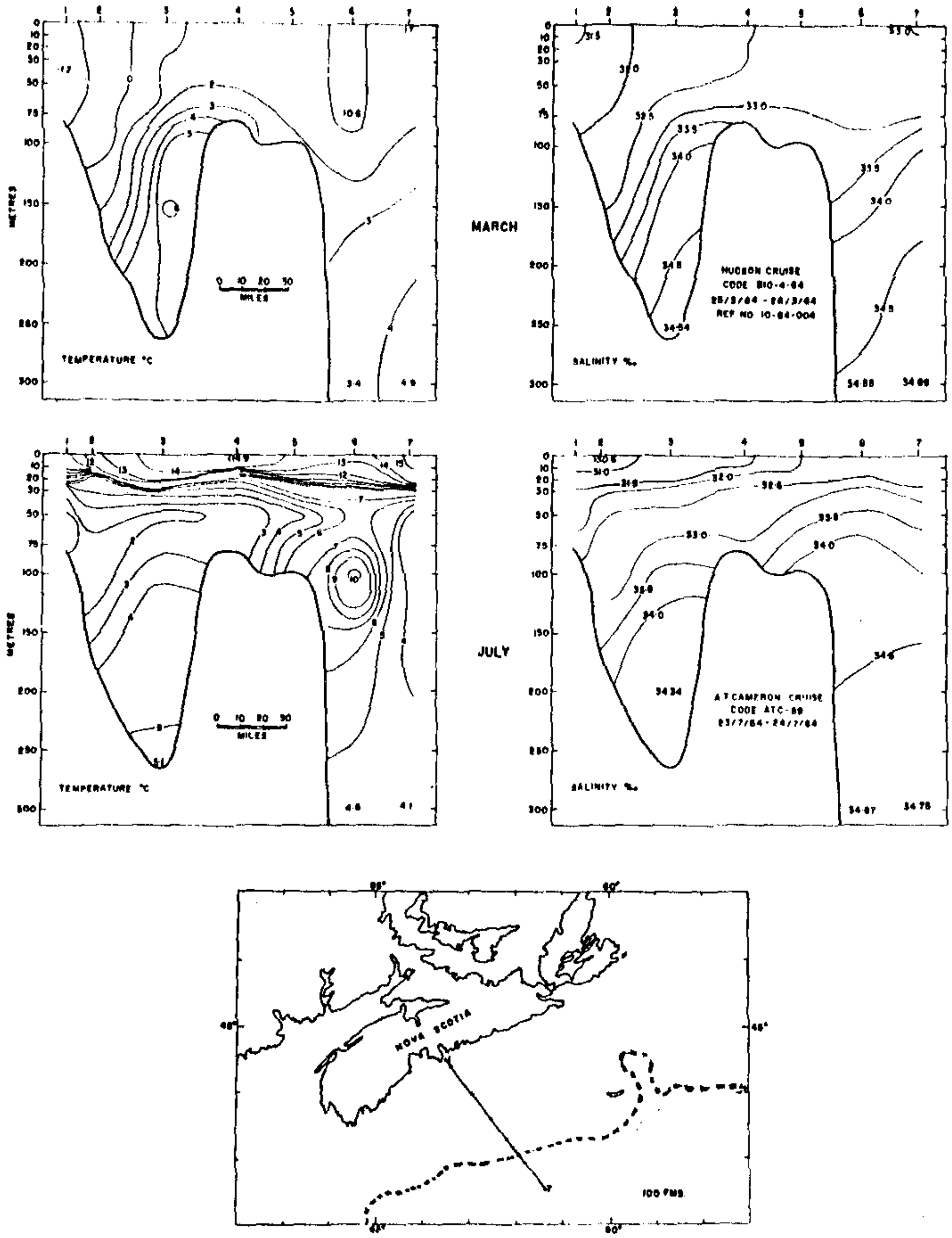

Fig. 1. Temperature and salinity distributions off Halifax, N. S., 1964.

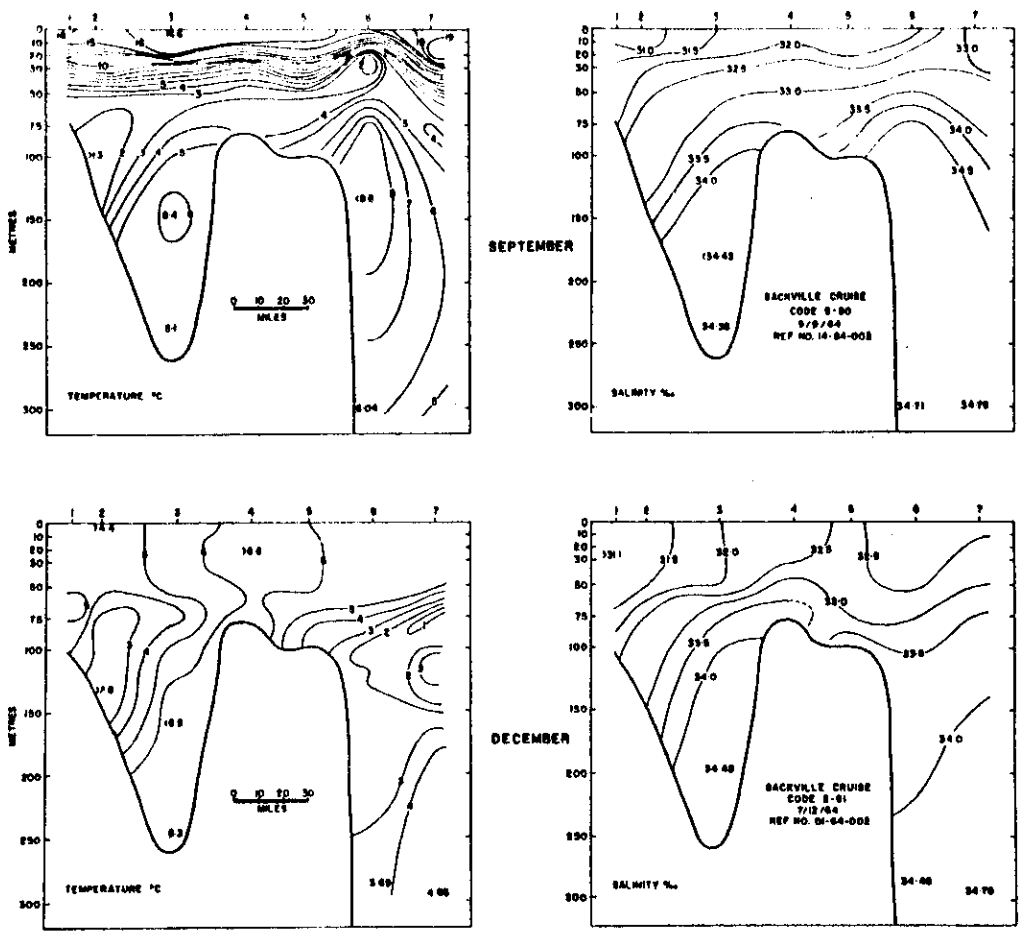

Fig. 1 (cont'd). Temperature and salinity distributions off Halifax, N.S., 1964.

increased from 13.0°-15.0°C to 16.0°-19.0°C from July to September. A well defined intermediate temperature layer with temperature below 3.0°C was observed across the Shelf at an average depth of 55 m. Observed maximum temperature in the Scotian Gulf, 6.4°C, and bottom temperature on Emerald Bank, 3.7°C, were still below average. The steep temperature gradient on the bottom, south of Emerald Bank, was observed again in September, leading to a core of warm water between the Shelf and cool waters offshore.

Late autumn (25 November, 3 and 7 December): The three series have similar features, a mixed layer from surface down to 50 m or deeper, a segmentation of the intermediate temperature layer resulting from a wedge-like intrusion of warm waters over the Scotian Shelf. Such an intrusion is indicated by surface temperature distribution from charts produced by Oceanographic Services for Defence, by the vertical uniformity of temperature distribution as compared to the stratification of adjacent stations and by the relatively high salinity in Emerald Bank area. A similar intrusion had been observed previously, in November 1962. The effect of this intrusion seemed to last for at least 2 weeks. The observed maximum temperature, 6.5°C, in the Scotian Gulf was a slight increase over the September temperature. However, the volume of this body of relatively warm water had increased considerably, presumably as a result of the wedge-like intrusion. By 7 December, the bottom temperature on Emerald Bank was 6.9°C. South of the bank towards the edge of the Continental Shelf, the bottom temperatures decreased to less than 3.0°C.

Coastal stations (Table 1)

The main features of the 1964 surface temperatures are: a general decrease from the 1963 level, more pronounced during the second half of the year with the exception of the Gulf of St. Lawrence (4T) and a negative deviation from long term averages. The bottom temperatures in 4X also indicate a decrease from 1963 to 1964 and a negative deviation from long-term averages generally more pronounced during the second half of the year.

The St. Andrews surface temperatures are taken as an index of temperature variations on the Continental Shelf (4X, V, W). For the year, these surface temperatures were the lowest since 1948. During the third quarter, they were the lowest since 1943. Bottom temperatures on the northern side of the Bay of Fundy during the fourth quarter (October-December) were the lowest since 1935.

Discussion

The years 1959 and 1961 have also been labelled "cold years" but the year 1964 was colder than these previous ones. The main difference between them consists in the time of year of greatest negative anomaly. In 1959 and 1961, the greatest negative anomalies generally occurred during the first half of the year, and in 1964 they occurred during the second half. In this sense, the year 1964 is unusual. Within the deep layers of the Scotian Gulf, during mid-summer 1964, the waters were the coldest ever observed.

The cooling trend experienced since the mid-1950's is still continuing but is somewhat more pronounced since 1960 than in the previous five years.

Table 1. Average temperature variations and anomalies.

		Bay of Fundy-Gulf of Maine 4X		Central Scotian Shelf 4V	Gulf of St. Lawrence 4T
		surface	bottom	surface	surface
		°C	°C	°C	°C
Average monthly variation from 1963 to 1964	January-June	-0.8	-0.9	-0.7	-0.5
	July-December	-1.3	-1.4	-0.9	-0.3
Average anomaly from long-term average	January-June	-0.6	-0.9	-1.5	-0.1
	July-December	-1.3	-1.9	-1.4	-1.0

VI. Defects in the recovering and reporting of cod tagged by Denmark in Subarea 1

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In most fish tagging experiments there is a greater or minor difference between the number of fish actually recaptured and the number of recaptures reported back to the respective authorities. This difference is due partly to non-recovery of recaptured tags and partly to a non-delivery or non-reporting of recovered tags.

As for non-recovery of tags, by far the best remedy is to make the tags more visible, while non-reporting may be relieved by rewards and propaganda making the fishermen more interested in the delivering and reporting of tags.

It is often difficult to distinguish the two sources of error mentioned but, in practice, the most essential thing to know is the total error, hereinafter called the non-return rate.

This non-return rate has been calculated in various tagging experiments. Aasen (1958) and Margetts (1963) used seeding experiments which, under certain circumstances, make it possible to calculate each of the sources of error. Paulik (1961) used a direct method of estimating the non-return rate by having trained observers examine a portion of the catch for tags. Stroud and Bitzer (1953) compared the returning from ponds where a partial creel census was made and a high reward combined with a lottery was offered with the returning from ponds where no creel census was made and no reward offered. Hylen (1963) tried to estimate the non-return rate from the number of tags from previous years suddenly turning up when Norway introduced a lottery system. This last method, of course, gives only the non-reporting rate.

In this paper, an attempt is made to estimate the non-return rate in Danish tagging experiments on cod in Greenland waters. This has been done in earlier years (Poulsen, 1957; Horsted, 1963). As in these earlier attempts the calculations in the present paper are based on some considerations and assumptions:

1. The Greenlanders are so interested in the fishery and the fishery problems and the contact between the fishermen, fishery officers and biologists is so good, that the Greenlanders' reporting rate is supposed to be very close to 100%. Furthermore, cod caught by Greenlanders will pass through the hands of a person several times. The recovery rate is therefore also supposed to be close to 100% and the non-return rate hence negligible.

2. Since 1953 Portugal has developed an excellent organization for collecting recaptures. The Portuguese reporting rate may very well be close to 100%. The recovering rate will differ between gears. Dory vessels are supposed to be able to obtain a recovery rate of 90 to 100%. The recovery rate for Portuguese trawlers is supposed to be less than the rate for the dory vessels and may be estimated as stated in 3 below.

3. Within each ICNAF division tagged cod are supposed to be evenly mixed with the whole stock some time after tagging (here taken as from the calendar year after tagging). Hence, within a division, the chance of catching a cod tagged in previous years is supposed to be proportional to the catch (Greenlanders' fishing inshore not included here, as tagging inshore is more intensive than offshore). Hylen (loc. cit.) has pointed out that the differences in size composition of catch between gears and fleets is a source of error here. It has, however, not been possible to find a practical way of correcting this error.

4. The error arising because of tagged cod having a higher catchability than non-tagged cod in some gears (e.g. tag tangled in net) is regarded as negligible.

In Table 1 the return rate for Portuguese dory vessels is compared with the return rate for Portuguese trawlers. In the years 1952 and 1953, the number of tags returned is too small for any comparison, but in 1954 as many as 182 tags were returned. From this year, the well-organized Portuguese reporting system seems to work.

Excluding the years 1952, 1953, 1954 and 1957 when many tags are not gearwise specified and the year 1962 (special problems, see below), a mean return rate of 48% is calculated for Portuguese trawlers. This mean has been weighted according to the catch of trawlers. The non-return rate is thus 52%, which is very close to the earlier figures estimated by Poulsen (50%) and Horsted (60%). To simplify the calculations, a conversion factor of 2 is therefore used for tags returned by Portuguese trawlers.

Poulsen (loc. cit.) estimated separate conversion factors for each nation. Horsted (loc. cit.) found this impractical and estimated a combined conversion factor for other nations. There are still so few tags returned from other nations, except Germany, that it is not practical to estimate conversion factors for each nation. As the German fishery in Subarea 1 has increased considerably it is, however, of great interest to get a conversion factor for Germany, but other nations are still treated as a whole.

Table 1. Comparison between returns from Portuguese trawlers (OT) and dory vessels (DV). Fish recaptured in the year of tagging not included. NK = gear not known; Rt = number of returns; Rt/Y = number of returns per 1,000 tons cod caught. Mean Rt/Y unweighted is calculated from total figures, while weighted mean is weighted with catch of OT in each division as weighting factor.

Year of Recapture		1952		1953		1954		1955		1956		1957	
Division	Gear	Rt	Rt/Y	Rt	Rt/Y	Rt	Rt/Y	Rt	Rt/Y	Rt	Rt/Y	Rt	Rt/Y
1B	DV	0	-	0	-	29	-	68	2.02	91	2.86	125	3.21
	OT	1	-	0	-	9	-	5	2.05	5	1.00	1	0.60
	NK	2	-	13	-	63	-	2	-	0	-	8	-
	Total	3	0.09	13	0.41	101	1.84	75	2.07	96	2.61	134	3.30
1C	DV	0	-	0	-	2	-	52	5.56	31	4.23	74	7.07
	OT	1	-	0	-	2	-	24	2.28	15	1.38	8	1.46
	NK	3	-	0	-	5	-	0	-	1	-	6	-
	Total	4	1.75	0	0.00	9	3.53	76	3.82	47	2.59	88	5.51
1D	DV	0	-	0	-	19	-	41	2.31	104	3.52	136	5.48
	OT	0	-	0	-	12	-	37	1.24	56	1.49	13	1.32
	NK	1	-	12	-	41	-	0	-	1	-	4	-
	Total	1	0.06	12	0.67	72	1.32	78	1.64	161	2.40	153	4.41
Total	DV	0	-	0	-	50	-	161	2.65	226	3.29	335	4.51
	OT	2	-	0	-	23	-	66	1.54	76	1.42	22	1.29
	NK	[illegible]	-	25	-	109	-	2	-	2	-	18	-
	Total	6	0.12	25	0.48	182	1.61	229	2.21	304	..49	375	4.11
Mean Rt/Y OT	unweighted	-		-		-		58		43		29	
[illegible] of Rt/Y DV	weighted	-		-		-		43		40		(23)	
Tons caught by OT		11,101		6,119		42,503		42,876		53,513		17,051	

Year of Recapture		1958		1959		1960		1961		1962		1963		1964	
Division	Gear	Rt	Rt/Y	Rt	Rt/Y	Rt	Rt/Y	Rt	Rt/Y	Rt	Rt/Y	Rt	Rt/Y	Rt	Rt/Y
1B	DV	54	1.71	82	2.56	51	1.42	15	0.51	18	0.35	42	1.15	33	-
	OT	7	1.55	6	1.30	8	25.32	0	0.00	2	0.37	1	24.39	11	-
	NK	0	-	0	-	0	-	0	-	0	-	0	-	0	-
	Total	61	1.69	88	2.40	59	1.63	15	0.48	20	0.35	43	1.13	44	-
1C	DV	79	9.17	28	3.54	30	3.09	46	5.01	6	0.85	13	1.55	43	-
	OT	16	1.45	0	0.00	4	36.00	0	0.00	3	2.21	0	0.00	0	-
	NK	0	-	0	-	1	-	0	-	0	-	2	-	0	-
	Total	95	4.83	28	3.46	35	3.57	46	5.00	9	1.07	15	1.79	49	-
1D	DV	135	4.66	38	4.27	75	5.59	104	3.91	21	0.94	55	3.27	97	-
	OT	24	2.54	5	1.20	3	5.49	2	38.46	1	0.94	2	30.77	27	-
	NK	0	-	0	-	0	-	1	-	0	-	1	-	0	-
	Total	159	4.14	43	3.29	33	5.58	107	4.01	22	0.94	58	3.44	124	-
Total	DV	268	3.88	148	3.03	156	2.65	165	2.53	45	0.56	110	1.79	173	-
	OT	47	1.88	11	1.23	20	10.62	2	0.97	6	0.77	3	24.79	44	-
	NK	0	-	0	-	1	-	1	-	0	-	3	-	0	-
	Total	315	3.35	159	2.61	177	2.91	168	2.49	51	0.58	116	1.88	217	-
Mean Rt/Y OT	unweighted	48		41		401		35		138		1,585			-
[illegible] of Rt/Y DV	weighted	44		39		444		25		132		1,224			-
Tons caught by OT		25,033		3,971		1,883		2,063		7,328		121			-

Table 2. Returning of German fleet and other nations' fleets compared with returning of Portuguese fleet (1952-54) or Portuguese dory vessels (1955-63). Rt = number of returns; %P and %DV = number of returns per 1,000 tons cod in % of corresponding Portuguese figure; (P = Portugal all gears, DV = Portuguese dory vessels). Mean is weighted with catch as weighting factor and is only based on figures from Div. 1B, C and D. Mean is raised by the proportion of tags from Div. 1NK. x = no catch reported.

Year of Recapture		1952		1953		1954		1955		1956		1957	
Division	Nation	Rt	%P	Rt	%P	Rt	%P	Rt	%DV	Rt	%DV	Rt	%DV
1B	Germany	0	-	0	-	0	-	0	-	1	x	0	0
	Other	6	111	8	44	9	9	7	13	4	4	3	4
1C	Germany	0	-	0	-	0	-	0	-	2	x	2	37
	Other	1	3	4	-	3	3	4	3	9	7	5	4
1D	Germany	1	-	0	-	0	-	2	13	15	15	0	0
	Other	7	133	14	46	14	14	13	8	21	9	9	4
1E	Germany	0	-	0	-	0	-	0	-	0	-	0	-
	Other	0	-	0	-	0	-	6	-	7	-	11	12
1F	Germany	2	-	0	-	1	-	0	-	0	-	5	-
	Other	5	-	13	-	3	-	2	-	3	-	7	-
1NK	Germany	1	-	0	-	0	-	0	-	3	-	1	-
	Other	0	-	0	-	1	-	1	-	7	-	4	-
Total and Weighted Mean	Germany	4	-	0	-	1	0	2	13	21	21	8	3
	Other	19	111	39	45	30	10	33	8	51	8	39	4
Tons cod in 1B+1C +1D	Germany		x		x		1,080		6,904		28,403		9,310
	Other		161,905		109,929		147,817		117,603		129,446		87,065

Year of Recapture		1958		1959		1960		1961		1962		1963	
Division	Nation	Rt	%DV	Rt	%DV	Rt	%DV	Rt	%DV	Rt	%DV	Rt	%DV
1B	Germany	2	67	4	868	0	0	0	0	0	0	5	35
	Other	12	22	21	16	13	27	14	45	16	63	12	27
1C	Germany	1	14	1	-	5	150	22	19	18	42	17	24
	Other	18	5	6	23	8	15	18	14	22	74	14	27
1D	Germany	8	10	6	10	20	25	64	47	32	130	32	29
	Other	19	8	31	24	18	9	36	24	50	104	29	14
1E	Germany	3	-	1	-	3	-	8	-	12	-	46	-
	Other	13	-	7	-	14	-	14	-	1	-	35	-
1F	Germany	14	-	8	-	6	-	16	-	15	-	22	-
	Other	11	-	15	-	18	-	16	-	16	-	19	-
1NK	Germany	7	-	1	-	3	-	27	-	15	-	28	-
	Other	7	-	3	-	5	-	7	-	12	-	9	-
Total and Weighted Mean	Germany	35	19	21	22	37	35	137	41	92	70	150	33
	Other	80	12	83	20	76	18	105	34	117	88	118	23
Tons cod in 1B+1C +1D	Germany		19,826		14,464		16,123		62,686		93,352		91.940
	Other		119,264		89,584		87,022		123,704		158,764		136,246

Table 3. Comparison between returning of Portuguese dory vessels and number of fish tagged. The figures refer to Div. 1B, C and D. Returns include all returns except those recaptured in year of tagging. Number tagged refers only to offshore tagging.

Year of Recapture	1955	1956	1957	1958	1959	1960	1961	1962	1963
(1) Returns per 1,000 tons	2.65	3.29	4.51	3.88	3.03	2.65	2.53	0.56	1.79
(2) Number tagged one year before	1,628	896	2,023	1,644	1,300	1,379	2,923	1,973	909
(1) in ‰ of (2)	1.63	3.67	2.29	2.36	2.33	1.92	0.87	0.28	1.97

In Table 2, the number of tags returned by Germany and by other countries (except Portugal and Greenland) per 1,000 tons of cod caught is compared with the corresponding figure for Portuguese dory vessels (1955-63) or Portugal all gears (1952-54). If the years 1952-53 (few data) and 1962 (see below) are excluded, a weighted mean from Table 2 gives a return rate of 30% for Germany and 15% for other nations combined. This corresponds to conversion factors 3.3 and 6.7 respectively.

In the fisheries of other nations, a part of the catch is taken by longline. Various research reports show that longline catches normally consist of larger cod than trawl catches. Therefore, the relative chance of longliners catching tagged cod may well be less than that of the trawlers (Hylen, loc. cit.). It is therefore reasonable to reduce the conversion factor for other nations. Here it is roughly estimated to be 5.

As mentioned earlier in this paper, special problems arise in relation to the recaptures made in 1962. Table 2 shows that Germany, as well as other nations, apparently had a much better return rate in 1962 than in preceding years. In 1963 these rates are back at a more normal level. However, it is not a much better return from Germany and other nations that is the reason for these outstanding 1962 figures but a lower return rate for Portugal. The relatively small number of tags from Portugal in 1962 indicates this. There is not only a small number of Portuguese returns in 1962, but the Portuguese figures for returns per 1,000 tons is also remarkably low. To judge whether something extraordinary has happened to Portuguese returns in 1962, it is necessary to compare between years the number of returns per 1,000 tons with the number of tagged cod present. This is rather impossible, but as the calendar year after tagging nearly always is the year giving most recaptures from the respective experiments, then it may be sufficient to use figures as simple as those in Table 3, which gives a review of the number of offshore releases in Div. 1B, C and D where the Portuguese fleet is concentrated. These figures are compared with the number of returns per 1,000 tons in the following year. It is quite obvious then that the Portuguese return rate is extraordinarily low in 1962, hardly reliable to be 100% for dories or 50% for trawlers.

Provided that the 1962 return rates for Germany and for other nations are 30% and 15% respectively, as in other years, then Table 2 indicates that the return rate for Portugal (all gears) in 1962 was between 43% (based on the German figure) and 17% (based on the other nations' figure). Roughly estimated it looks as if 2/3 of the Portuguese tags caught in 1962 disappeared in one or the other link of the reporting system.

In practice the following conversion factors are used, but the factors for Portugal in 1962 must be taken with even greater reservation than the other factors:

Greenland	All gears	1	
Portugal	Dory vessels	1	(in 1962 perhaps 3)
"	Otter trawlers	2	(in 1962 perhaps 3)
Germany	Otter trawlers	3	
Other nations	All gears	5	

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VII. Assessment of the crop of separate year-classes of the beaked redfish (*Sebastes mentella* Travin)

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The purposes of studying the biology of the young of the "beaked" redfish of the Northwest Atlantic is to obtain the data on the strength of their year-classes and on feasible prospects for their fishery.

The small amount of material available is really inadequate to draw conclusions on this matter, but some regularities of the distribution and size composition of the immature fish made it possible to estimate the relative size of separate year-classes of this species.

The size composition of the young and small redfish of the local stocks in the northern, southern and Flemish Cap areas were considered according to depth. From the fact that, in the northern areas (ICNAF Div. 3K and 3L), the greatest number of the immature redfish of the northern local stock is distributed in depths of 200-300 m and the majority of the immature redfish belonging to the southern stock (3O and 3P) is distributed at 50-250 m depths, their size composition is fully justified by the samples collected just in these depths.

The curves plotted in Fig. 1 indicate the composition of the future recruitment. The similarity of these curves in Div. 3K, 3L and 3O, 3P where, as mentioned, two separate local stocks of the redfish are distributed, makes it possible to judge on the reliability of those curves. The peaks of the curves correspond to the abundant year-classes of 1958, 1960, 1961 and 1962. An analysis of the hydrographical conditions during this period showed that these years were relatively warm with the high river discharge (Elizarov, 1963) and, consequently, were characterized by the most favourable conditions for fattening of larvae and pelagic young fish.

The variation in intensity of inflow of the Arctic waters of the Labrador current results in an increase or decrease in the size of the area of distribution of relatively warm waters of Atlantic origin (Elizarov, 1962 and 1963). As a result, in warm years when the warm highly productive Atlantic waters are more widely spread, surface layers of the frontal zone are mostly enriched with biogenic elements, and the conditions of fattening of larvae and pelagic young fish become more favourable (Izhevsky, 1961; Elizarov, 1963).

The same relationship between the hydrographical regime and the crop of redfish was observed in other areas of the Atlantic. For instance, the strength of year-classes of the redfish also increased near the Icelandic coast during warm years.

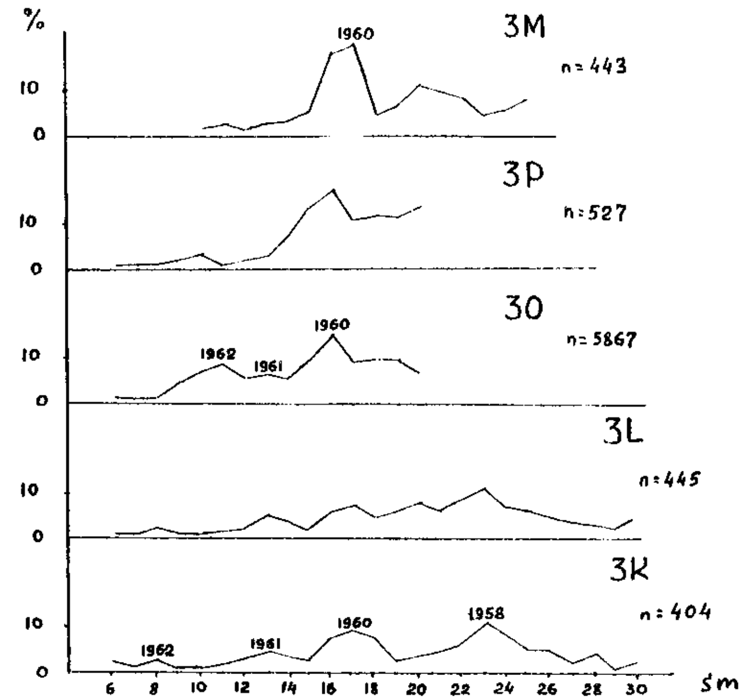

Fig. 1. Percentage size composition of the young of the beaked redfish (Sebastes mentella Travin), January-April 1964.

However, Elizarov (1961 and 1963) showed that the rise of temperature in the Labrador and Newfoundland areas is usually associated with a fall of temperature in the Icelandic area. Such a difference in regime can be explained by peculiarities in the atmospheric circulation and the intensity of permanent currents in these areas. As a result, the appearance of abundant year-classes of redfish in the Icelandic area is accompanied by a reduction in the strength of their year-classes in the Labrador and Newfoundland areas. Henderson (1964) counted the average number of larvae of redfish in the Icelandic area during April-May:

Year-class	1955	1956	1957	1958	1959	1960	1961	1962	1963
No. larvae	2.7	1.3	3.1	0.4	4.9	1.1	5.4	5.8	0.45

The results show the 1959, 1961, 1962 year-classes are rich compared with the poor year-classes of 1956, 1958, 1960, 1963. The data obtained by Henderson (1964) in the Icelandic area and Soviet data on the size composition of the immature portion of the stock of beaked redfish in various areas of the Northwest Atlantic have been included in Table 1 characterizing the strength of separate year-classes in these areas.

Table 1 shows that the abundant year-classes appear in these areas during warm years.

Table 1. Assessment of the strength of separate year-classes of the beaked redfish in areas of Iceland, Labrador and Newfoundland.

Year-classes	Icelandic area		Labrador and Newfoundland area	
	Type of regime	Characteristic of year-classes	Type of regime	Characteristic of year-classes
1955	warm	average	moderate	no data
1956	cold	poor	cold	no data
1957	moderate	average	warm	rich [1)]
1958	cold	poor	warm	rich
1959	warm	rich	cold	poor
1960	cold	poor	moderate	average
1961	moderate	rich	moderate	average
1962	moderate	rich	moderate	average
1963	cold	poor	warm	rich

[1)] The 1957 year-class is estimated by Hansen and Templeman as a rich one

Since rich year-classes of cod and redfish are produced in the Labrador-Newfoundland area during warm years (Elizarov, 1963), the temperature conditions in this area seem to be a sufficiently suitable regime index, the definite type of which corresponds to the definite degree of abundance of commercial fish year-classes.

The quantitative estimation of their young indicates, to some extent, the abundance of these fish.

Studies of the maturation of redfish show that rich year-classes are recruited to the spawning stock in the northern areas of the Labrador-Newfoundland area in 10 years, on Flemish Cap Bank in 7 years and in the southwest area of Grand Newfoundland Bank and Saint Pierre Bank in 6 years.

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VIII. Changes in length and weight of Maine sardines due to freezing, brining and salting

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Samples of herring, Clupea harengus harengus, collected for morphometric studies from the Maine sardine fishery have usually been salted, brined and frozen before being weighed and measured. To compare data on length and weight of fish in these samples with data for samples of fresh fish from other areas, the effects of salting, brining and freezing must be determined. In the summer of 1964, several samples of fresh herring were measured and weighed before being frozen and again after being thawed in air or water. Other samples were brined and salted before being frozen to determine the combined effects of salting and freezing.

Effects of Freezing on Length and Weight

Seven samples were tested for the effects of freezing only (Table 1).

Table 1. Sample description and length and weight of fresh herring in samples used to determine the effects of freezing, brining and salting.

		Treatment of Sample				Length (mm)			Weight (grams)		
Sample Number	Number of Fish	Time in Brine (hours)	Time in Salt (hours)	Frozen Storage Time (months)	Method of Thawing	True Mean*	Variance	Range	True Mean	Variance	Range
1	50	--	--	3	Water	150.16	149.7347	127-179	20.53	51.5420	11.9-35.7
2	100	--	--	3	Water	143.61	127.7374	123-184	17.11	21.8025	9.8-37.9
3	100	--	--	3	Water	150.88	121.3838	130-187	20.11	25.3147	12.3-39.0
4	100	--	--	3	Water	148.28	153.8889	121-186	19.60	26.1728	11.1-38.6
5	100	--	--	3	Water	144.88	168.2525	119-178	17.70	38.5657	9.9-36.2
6	50	--	--	3	Air	144.00	142.2245	121-172	20.44	22.6528	12.0-35.3
7	100	--	--	1	Air	140.03	59.2829	115-167	20.61	10.7873	10.9-32.3
8	100	21	--	1	Air	139.61	97.2121	110-165	19.66	16.3806	9.4-29.8
9	100	21	--	1	Air	225.50	80.1717	209-241	80.71	92.8286	63.0-102.1
10	100	22	--	1	Water	138.74	88.5354	107-157	19.43	14.2964	10.9-29.0
11	100	19	--	1	Water	227.28	56.3232	211-239	82.40	69.6167	65.0-99.5
12	50	23	--	3	Water	152.52	69.3878	130-172	21.04	15.8445	15.0-31.6
13	50	68	--	--	-----	149.16	82.4893	135-165	20.22	10.0586	14.9-27.0
14	100	--	21	1	Air	139.42	68.7172	111-166	20.56	14.1036	10.9-34.0
15	100	--	20	1	Water	140.31	70.0404	117-164	19.84	12.8976	11.1-32.9

*The total length used was natural total length, with the lobes of the tail in the normal position.

Samples 1 through 5 were measured and weighed fresh and again after being frozen 3 months at -16°C and thawed in warm, fresh water. The average length and weight decreased in all five samples (Table 2).

Table 2. Changes in length and weight of herring due to freezing.

Sample number	Percent length change	Percent weight change
1	-4.10	-0.45
2	-3.78	-0.13
3	-3.41	-5.97
4	-2.40	-4.66
5	-3.35	-1.81
6	-4.46	-6.36
7	-1.25	-11.16

Regression lines were constructed with the Y variable as the original measurement, on the measurement after freezing.

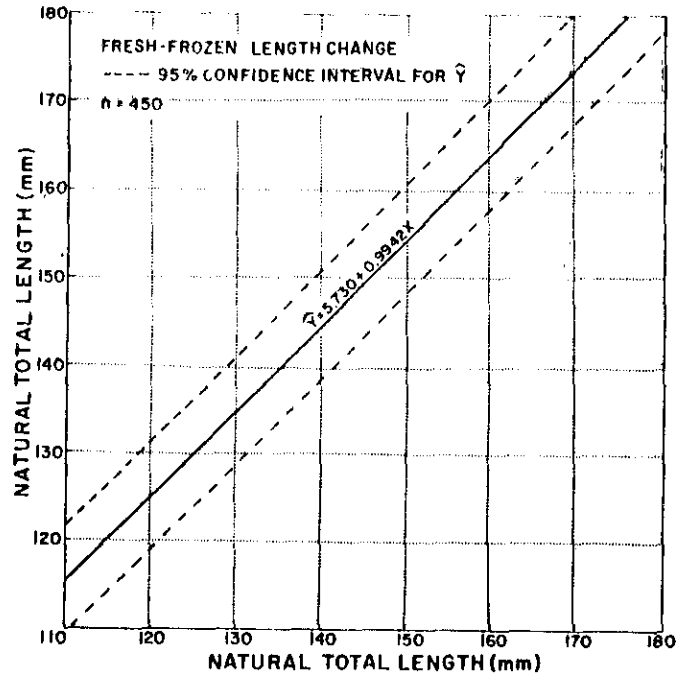
Although covariance tests indicated that the first five samples were different for both length and weight changes, the samples were combined with the usability of the data depending upon the confidence limits. Such irregular pooling caused the confidence limits to be very wide (Fig. 1). The 95% confidence limits of the regression slopes for the grouped data were 0.9698 and 1.0186 for length and 0.9618 and 1.0320 for weight.

Paired t tests were run on individual samples to test for significant changes in length and weight due to freezing. Values for all changes were highly significant ($P<.01$), except for the weight changes of sample 2 ($P<.20$).

Samples 6 and 7 were frozen for 3 months and 1 month, respectively, and then thawed at room temperature. The results from the two samples were very different. The length decrease in sample 6 was 4.46% as compared with only 1.25% in sample 7; in contrast, the weight decrease was greater in sample 7 - 11.16%, as compared with 6.36% for sample 6. Significant F values ($P<.01$) were obtained for the tests of common and parallel regression lines for both length and weight.

Effects of Brine and Brine plus Freezing on Length and Weight

Six samples of fish (8 through 13) were placed in brine solutions and then frozen (Table 1). These fish were measured and weighed fresh, after brining and after freezing. Samples 8 through 11 were held in a 16% brine (50° salometer - 1.116 specific gravity measured at 20°C assuming the density of water at 4°C as unity) for 19 to 22 hours, measured and weighed and immediately frozen. The brine caused the length and weight to decrease in all 4



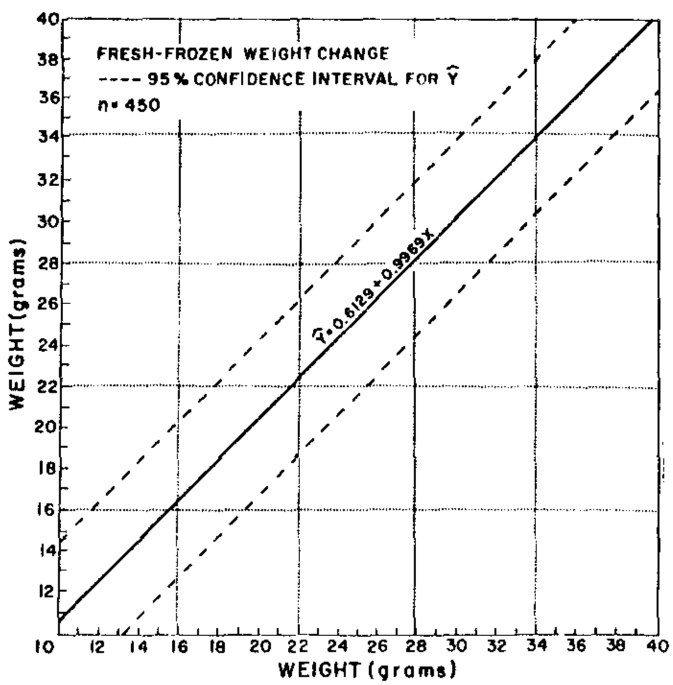


Fig. 1. Regression lines and individual $\hat{Y}$ confidence intervals for length and weight changes due to freezing.

samples. The decrease varied from 3.15% to 4.20% with an average of 3.56% for length and 3.54% to 5.15% with an average of 4.76% for weight (Table 3).

Table 3. Changes in length and weight of herring due to brining and brining plus freezing.

Sample number	Percentage length change			Percentage weight change		
	Brining	Freezing	Brining plus Freezing	Brining	Freezing	Brining plus Freezing
8	-4.20	+0.43	-3.79	-4.94	-20.81	-24.72
9	-3.49	-1.23	-4.67	-5.15	-4.34	-9.28
10	-3.15	+0.19	-3.22	-3.54	-8.70	-11.93
11	-3.34	-0.45	-3.77	-4.63	-0.80	-5.40
12	-1.89	-3.14	-4.97	+8.84	-10.20	-2.26
13	-2.45	-	-	+12.09	-	-

Weber (1921) held herring in a 23.5% brine (specific gravity of 1.1729) for 8 hours and found that the weight of the fish decreased 8.2%. This greater percentage decrease was apparently due to the stronger brine solution indicating that time in brine is of minor significance when compared with brine strength.

After 1 month samples 8 and 9 were thawed in air and samples 10 and 11 were thawed in water. The disparity within samples thawed in air and water was greater than between samples - apparently due to differences in fish size (Table 3). Samples 9 and 11 contained fish with a natural total length range of 209 to 241 mm, as compared with a range of 107 to 165 mm in samples 8 and 10. As the smaller fish thawed they lost a greater percentage of their body weight than the larger fish, but at the same time increased slightly in length.

The length and weight changes due to brining and freezing for all 4 samples were significant ($P<.01$) except the 0.19% length increase for sample 10 after freezing. Neither the length nor weight regressions due to brining for samples 8 through 11 were the same ($P<.01$) or parallel ($P<.05$). The regression lines for the additional changes in weight due to freezing also were not the same ($P<.01$) but were parallel ($P<.25$).

The length and weight regressions and the 95% confidence limits for individual $\hat{Y}$ values for the combined samples 8 through 11 are given in Fig. 2. The 95% confidence limits of the regression slopes for the grouped data were 1.0226 and 1.0322 for length and 1.0494 and 1.0554 for weight.

Samples 12 and 13 were held in a 5.5% salt brine (1.038 specific gravity at 20°/4°C) for 23 and 68 hours, respectively. In both samples the fish gained weight and lost length. Covariance tests for common and parallel lines showed significant differences ($P<.01$) in all comparisons, except in the parallel-line

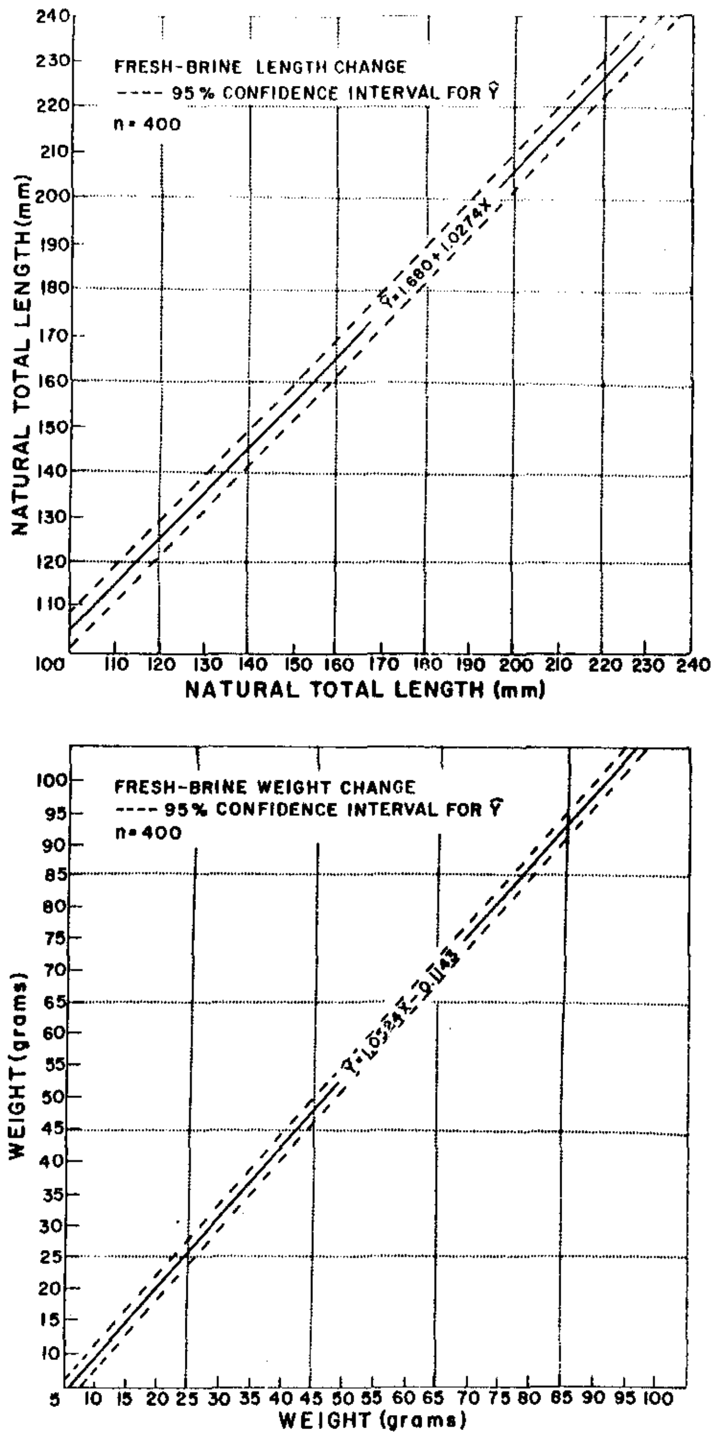


Fig. 2. Regression lines and individual $\hat{Y}$ confidence intervals for length and weight changes due to brining.

test for the weight data. Apparently the salt in the brine was insufficient to replace the water in the tissues of the fish and the fish gained weight by the addition of water. Reay (1936) showed that in concentrations of brine up to 8% (1.056 specific gravity at 20°/4°C) a definite increase in weight took place (up to 30% in 10 days).

Freezing affected sample 12 as it did samples 1 through 7, which had not been held in brine solution. For example, the average length of sample 12 decreased an additional 3.14% after freezing as compared with an average shrinkage of 3.09% for samples 1 through 7 and 0.40% for brined samples 8 through 11. The weight, however, decreased an additional 10.20% for sample 12 as compared with 4.70% for samples 1 through 7 and 4.92% for samples 8 through 11. Although this weight loss was large, it probably was related to the large gain in weight that occurred while the fish were soaking in the light brine solution. Sample 13 was not frozen, but discarded after brining. All changes in length and weight due to brining, freezing or both were significant.

Effects of Salt and Salt plus Freezing on Length and Weight

To determine the maximum shrinkage in length and weight due to salting, samples 14 and 15 were held in dry salt[1] 21 and 20 hours, frozen and thawed in air and water, respectively (Table 4).

Table 4. Changes in length and weight of herring due to salting and salting plus freezing.

Sample number	Percentage length change			Percentage weight change		
	Salting	Freezing	Salting plus Freezing	Salting	Freezing	Salting plus Freezing
14	-3.69	+0.14	-3.56	-28.52	-11.14	-36.48
15	-4.68	+0.73	-3.99	-27.89	-2.42	-30.31

The length regression lines were parallel but a common line could not be fitted to the data. The regression lines for the weight data were identical, however. All changes in length and weight due to the salt were significant. Freezing restored some of the length - 0.14% in sample 14 and 0.73% in sample 15 - but caused the weight to decrease further. All changes in length and weight due to freezing were significant ($P<.01$) except the length increase for sample 14. All regression lines were parallel but differed in elevation ($P<.01$). Figure 3 gives the combined sample regression lines for changes in length and weight caused by salting. The 95% confidence limits of the slope for the grouped data are 0.9137 and 0.9835 for length and 1.2215 and 1.3015 for weight.

[1] The salt was "Watkins Granulated Salt" from the Watkins Salt Company, Watkins Glen, N.Y.

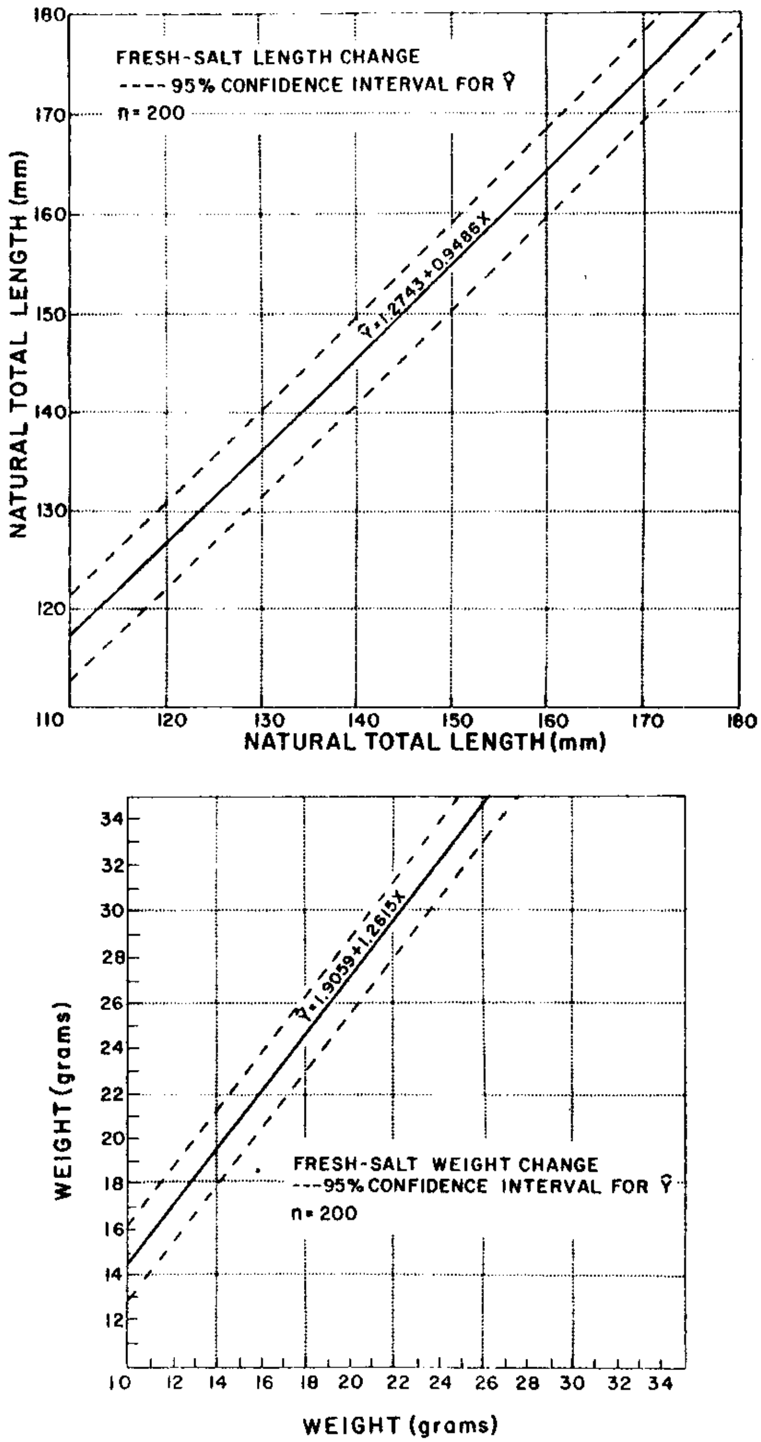


Fig. 3. Regression lines and individual $\hat{Y}$ confidence intervals for length and weight changes due to salting.

In 1951 similar experiments on length and weight changes were conducted at the Boothbay Harbor Biological Laboratory. Two samples of herring (total of 100 fish) were held in dry salt for 17.5 hours. The ranges in length and weight of the fresh fish were 91 to 178 mm and 6.7 to 65.5 grams. The average decreases for length and weight were 3.78% and 20.65%, respectively. Nikkilä (1951) salted herring (mean weight 34 grams and range in length 120 to 180 mm) with various quantities of salt and found that the minimum weight was reached in 2 to 3 days, after a shrinkage of about 20%.

Conclusions:

Length data for age-length keys, length-frequency modes, ... can be seriously biased by freezing, brining and salting. In this study freezing alone (-16°C for 3 months) decreased the average total length in a 100-fish sample by 3.1% and the weight by 4.7%. When herring were held in brine for 21 hours the length decreased by 3.6% and the weight by 4.8%. Freezing the fish after they had been brined resulted in a small length increase (0.3%) for small fish (107-165 mm) and a small decrease (0.8%) for large fish (209-241 mm). The additional loss in weight due to freezing was 14.7% for small fish and 2.6% for the larger fish. Holding the fish in dry salt (20-21 hours) caused the greatest average decrease in length (4.2%) and weight (28.2%). Freezing after salting increased the total length slightly (0.4%) but further decreased the weight by 7.3%.

Because of the numerous significances between samples throughout the experiments, it was difficult to compare the effect on changes in length and weight by thawing at room temperature against thawing in water. The percentage length decrease after thawing in air was smaller than the percentage decrease after thawing in water for the freezing experiment (samples 1 through 7), but greater than the percentage decrease after thawing in water for the brining and salting experiments. The percentage weight decrease was greater in all experiments when the samples were thawed in air. When all the experiments were combined the weight decrease was 7.4% for samples thawed in water and 15.1% for samples thawed in air. The length decreases were nearly the same.

This study has pointed out the need for further examination of length and weight changes due to freezing, brining, and salting by sizes of fish, intermediate brine strengths (10% to 14% salt) and thawing method. Length and weight changes due to the various brines of individual processing plants remain to be defined, so that appropriate corrections can be applied routinely to sample data.

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IX. The effect of storage on the length and weight of herring

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It often becomes necessary to store for considerable periods of time, fish obtained for scientific purposes. Changes occur in lengths and weights of fish held in storage and these changes must be taken into account when recording measurements of stored fish. Therefore, the present study was undertaken to determine the magnitudes and rates of length and weight changes due to storage.

Herring, divided into two groups of 100 fish each, were used. The fish were measured to the nearest millimetre from tip of the snout to the end of the longer lobe of the caudal fin and weighed on a Mettler electronic balance to the nearest tenth of a gram. Measurements were recorded at weekly intervals for the first four weeks of storage and then once a month for a total period of six months. One group was stored in a 5% solution of formalin in a sealed metal container. The other was stored on racks, uncovered, in a cold storage vault at approximately 0°F (-17.7°C).

Initially, the fish ranged in size from 94 to 260 mm for the formalinized group and from 94 to 287 mm for the refrigerated sample. The fish were arranged in 10-mm length categories and 10-g weight categories. Average lengths and weights were then calculated for each category on each date the fish were measured. The number of fish in each category was determined by the size composition of the sample and no attempt was made to pick out equal numbers of fish of each size.

After a period of storage of 183 days (6 months), loss in length ranged from 1.0% to 3.2% of the original for the refrigerated herring and from 0.5% to 2.2% for the formalinized lot (Tables 1 and 2).

Loss of weight in stored herring was much more pronounced than loss in length. Refrigerated herring lost from 11.7% to 59.3% of their original weights over the 183-day period, the smaller fish undergoing the largest percent loss (Table 3). The rates at which loss in weight was incurred are presented in Fig. 1 for the refrigerated sample.

For the first two weeks of storage, some of the formalinized fish gained rather than lost weight, due to the absorption of preservative (Table 4). Thereafter, a loss was generally recorded for all individuals, but it was difficult to control the amount of moisture adhering to the surface of the fish. Therefore, the weight change for individual fish between dates of weighing could not be determined with any degree of accuracy. At the end of 183 days, the average loss in weight ranged between 4.2% and 7.8% of the initial body weight.

Table 1. Cumulative percent loss in length of refrigerated herring.

Initial Length Interval (mm)	No. of Fish	Days of Storage 7	14	21	28	63	91	124	154	183
90- 99	1	0.0	0.0	1.1	1.1	1.1	2.1	2.1	2.1	2.1
100-109	8	0.9	0.9	0.9	0.9	1.9	1.9	2.8	2.8	2.8
110-119	8	0.9	0.9	1.8	1.8	1.8	1.8	1.8	2.7	2.7
150-159	2	0.6	0.6	1.3	1.9	1.9	1.9	2.6	3.2	3.2
160-169	7	0.0	0.0	0.6	0.6	0.6	1.2	1.2	1.8	1.8
170-179	17	0.0	0.0	0.6	0.6	1.1	1.1	1.1	1.7	1.7
180-189	31	0.5	0.5	1.1	1.1	1.6	1.6	1.6	2.2	2.2
190-199	10	0.0	0.5	0.5	1.0	1.0	1.6	1.6	2.1	2.1
200-209	6	0.5	0.5	0.5	1.0	1.0	1.5	1.5	2.0	2.0
210-219	1	0.0	0.5	0.5	0.5	0.5	0.9	1.9	1.9	1.9
250-259	1	0.4	0.8	0.8	0.8	0.8	1.9	1.9	1.9	2.1
260-269	3	0.0	0.4	0.4	0.4	0.4	0.8	1.1	1.1	1.1
270-279	4	0.0	0.0	0.4	0.4	0.7	0.7	0.7	1.1	1.1
280-289	1	0.0	0.0	0.3	0.7	0.7	0.7	1.0	1.0	1.0

Table 2. Cumulative percent loss in length of herring stored in formalin.

Initial Length Interval (mm)	No. of Fish	Days of Storage 7	14	21	28	63	91	124	154	183
90- 99	1	0.0	0.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1
100-109	9	0.5	0.1	1.0	.4	.9	1.6	1.2	1.0	0.5
110-119	8	1.4	.2	.2	1.0	.9	1.8	1.1	1.7	.5
120-129	1	2.4	.8	3.2	2.4	1.6	1.6	1.6	1.6	1.6
160-169	8	.8	.5	.6	1.3	1.5	1.2	1.7	1.7	1.2
170-179	18	.6	.2	1.0	1.1	1.4	1.2	1.5	1.9	1.8
180-189	33	.7	.3	1.1	1.1	1.3	1.6	1.7	1.7	1.6
190-199	15	.6	.8	.7	.9	1.3	1.3	2.2	1.5	1.1
200-209	5	1.0	.4	1.3	1.1	1.4	1.6	1.8	2.1	2.2
210-219	1	1.4	1.4	1.9	1.0	1.4	1.4	1.9	2.4	1.9
260-269	1	0.0	0.0	.8	.8	.8	1.5	1.5	1.2	1.9

Table 3. Cumulative percent loss in weight of refrigerated herring.

Initial Weight Interval (g)	No. of Fish	Days of Storage 7	14	21	28	63	91	124	154	183
		%	%	%	%	%	%	%	%	%
0.0- 9.9	3	12.1	20.9	24.2	27.5	39.6	47.3	51.6	56.0	59.3
10.0- 19.9	14	9.1	15.7	19.8	22.3	33.1	38.0	43.0	46.3	49.6
30.0- 39.9	12	6.3	9.5	11.1	12.2	16.8	19.6	22.0	23.9	25.3
40.0- 49.9	25	5.4	8.0	9.8	11.1	14.3	16.5	18.0	19.5	20.6
50.0- 59.9	27	5.4	8.2	9.5	10.3	13.2	14.9	16.4	17.5	18.5
60.0- 69.9	7	4.5	6.9	8.2	9.2	11.2	13.3	14.3	15.3	15.9
70.0- 79.9	2	4.7	6.5	8.4	9.2	11.1	12.6	13.4	14.2	14.6
80.0- 89.9	1	5.1	7.9	8.9	9.6	12.0	13.2	14.3	15.2	15.8
140.0-149.9	1	4.2	5.5	6.9	7.6	9.8	11.3	12.9	14.2	15.3
150.0-159.9	1	4.4	6.2	7.0	7.5	9.5	10.9	12.2	13.1	14.0
160.0-169.9	4	4.6	6.2	6.8	7.2	8.6	9.7	10.6	11.3	11.8
170.0-179.9	1	4.6	6.2	6.7	7.2	8.5	9.7	10.8	11.6	12.1
190.0-199.9	1	5.4	6.7	7.4	7.9	9.1	10.2	11.0	11.7	12.1
210.0-219.9	1	3.6	5.0	5.5	6.1	8.0	9.2	10.2	10.7	11.7

Table 4. Cumulative percent change in weight of herring stored in formalin.

Initial Weight Interval (g)	No. of Fish	Days of Storage 7	14	21	28	63	91	124	154	183
		%	%	%	%	%	%	%	%	%
0.0- 9.9	6	+3.3	+2.2	0.0	0.0	-2.2	-6.6	-4.4	-3.3	-5.5
9.9- 19.9	13	+1.7	+1.7	0.0	-0.9	-3.5	-7.8	-6.1	-5.2	-7.8
30.9- 39.9	12	-1.1	-0.8	-1.9	-3.3	-4.1	-8.5	-5.8	-6.0	-7.1
40.9- 49.9	30	-1.1	-0.9	-1.8	-2.6	-3.3	-7.5	-5.1	-6.2	-7.3
50.9- 59.9	25	-1.7	-5.6	-2.8	-3.3	-7.6	-7.4	-5.6	-6.7	-6.9
60.9- 69.9	10	-0.3	-0.3	-1.1	-1.9	-2.5	-5.8	-4.1	-4.6	-5.2
70.9- 79.9	3	+0.1	-0.7	-0.8	-2.2	-2.6	-6.2	-3.5	-4.6	-4.8
130.9-139.9	1	+0.4	-0.4	-0.2	-1.7	-1.1	-4.4	-3.7	-3.4	-4.2

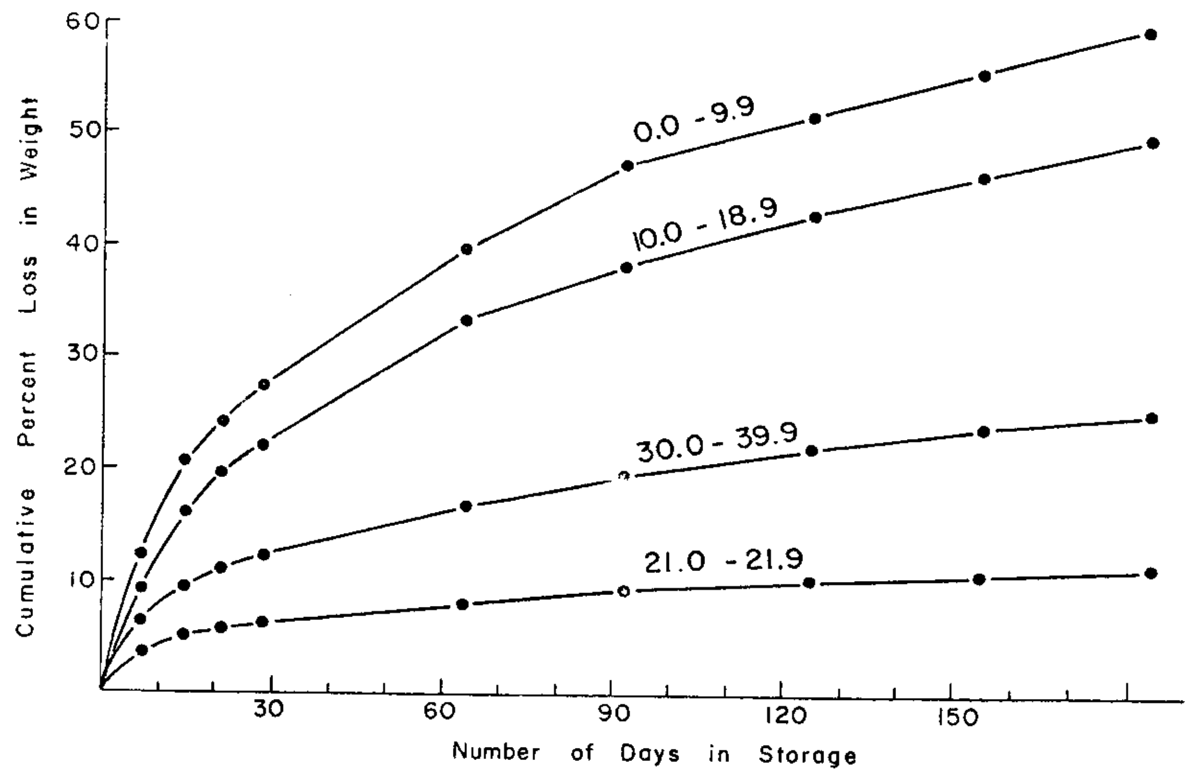

Fig. 1. Cumulative percent loss in weight of refrigerated herring. Initial weight intervals in grams. (Storage temperature approximately -17.7°C).

X. Report on recaptures in Greenland waters of salmon tagged in rivers in America and Europe

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1. The Greenland Salmon Fishery

Until a few years ago the salmon fishery has been of very little importance to the Greenland fisheries.

Kapisigdlit in the inner part of the Godthaab Fjord is the only river where salmon is known to spawn. The Greenlanders have in many years fished for salmon in stone traps built across the river. In the fjords Amerdloq and Ikertoq (Div. 1B), the Greenlanders carry out gillnet fisheries for salmon in the autumn months in the open fjord. These fisheries have been very modest, and the catch has mainly been used for local consumption. In the thirties, salmon occurred in the autumn along the coast and was caught occasionally in different places particularly near Napassoq in Sukkertoppen district (Div. 1C), but no commercial fishery was carried out. The Royal Greenland Trading Company which had monopoly of all trading in Greenland was not interested in buying salmon because the only possibility of curing the fish was salting, and salted salmon is a rather poor product. Furthermore, the occurrence of salmon along the coast fluctuated much from year to year.

According to reports from French, Spanish and Faroese trawlers, salmon were often caught in cod trawl in the autumn in the Davis Strait, especially on Store Hellefiske Bank.

More detailed information about the occurrence of salmon in Greenland waters has been given by Jørgen Nielsen (1961).

In recent years modern freezing plants have been built in the bigger Greenland towns which provide the possibility for production of frozen salmon which is a valuable product. Some few Greenlanders started a gillnet fishery for salmon in 1959 near Napassoq (Div. 1C). The output was modest, only 13 tons. In 1960 the production was 55 tons frozen salmon produced in the same freezing plant as in 1959. In 1961 the salmon fishery was also carried out in Holsteinsborg, Godthaab and Frederikshaab districts. The total catch was 115 tons. The following year the output doubled to 220 tons. The best catch was obtained in Div. 1C with 162 tons. In 1963 the output increased to 420 tons. The distribution on districts differed from 1962. Holsteinsborg (Div. 1B) had the best result, 134 tons.

The cod fishery which reached its peak in 1962 decreased abruptly in 1963 because the cod occurred in only very small amounts in the coastal region.

Also in 1964 the occurrence of cod was poor, and the total catch of cod showed a heavier decrease than in the year before. The scarcity of cod together with the high prices for salmon give rise to a more intensified salmon fishery. The total catch of salmon was 1,386.2 tons. Table 1 shows the catch per division and per month in 1964. The table shows that Div. 1A, B, C and F had their best catches in October and 1D and E in September. The biggest total catch was taken in 1C.

Table 1. Catch of salmon (gutted, head on) in tons per division, per month in 1964.

Div.	Aug.	Sept.	Oct.	Nov.	Dec.	NK	Total	%
1A	-	2.7	10.7	5.8	-	-	19.2	1.4
1B	0.4	13.4	152.5	105.5	3.3	19.0	294.1	21.2
1C	0.4	65.6	251.4	112.9	8.0	-	438.3	31.6
1D	8.1	63.0	40.4	19.7	2.5	30.7	164.4	11.9
1E	23.9	161.7	79.0	36.9	3.3	-	304.8	22.0
1F	0.5	31.6	34.1	25.4	3.8	-	95.4	6.9
1NK	-	-	-	-	-	70.0	70.0	5.0
Tons	33.3	338.0	568.1	306.2	20.9	119.7	1,386.2	
%	2.4	24.4	41.0	22.1	1.5	8.6		

Table 2 gives the catches per division in tons of salmon of different weights.

Table 2. Catch in tons of salmon of different weights per division.

Div.	Weights of salmon in kg 1.0-3.5	3.5-4.5	4.5-6.0	>6.0	Total tons	%
1A	3.7	6.2	2.6	6.7	19.2	1.6
1B	124.9	95.3	27.2	27.9	275.3	23.2
1C	231.7	165.4	30.3	10.9	438.3	37.0
1D	0.4	124.7	5.8	3.6	134.5	11.4
1E	156.2	50.5	11.8	4.2	222.7	18.8
1F	40.8	36.0	9.2	9.4	95.4	8.0
Tons	557.7	478.1	86.9	62.7	1,185.4	
%	47.1	40.3	7.3	5.3		

It is obvious that most salmon weigh between 1.0 and 4.5 kg, which means that medium-sized salmon predominate in the catches.

Figure 1 shows the size distribution of 343 salmon from Greenland catches off Fiskenaesset (1D) 3 October 1964, mainly between 60 and 77 cm and with maxima at 68 and 73 cm. Samples of scales have been taken from the salmon for age determination but the material has not yet been treated.

The minimum distance of migrations for the salmon caught off West Greenland has been about 2,500 nautical miles which must be considered as a record for the species.

Table 3 shows the distribution of recaptures of tagged salmon by divisions, years and countries where they were tagged and released.

Table 3. Recaptures in West Greenland, Subarea 1, of tagged salmon, distributed by countries where tagged and released, division of recapture and year of recapture.

Recapture Div.	Year	Canada	USA	Ireland	Scotland	England	Sweden	America	Europe	Total	%
1B	1961	1						1			
	1963	4	1					5			
	1964	2	1		2			3	2	11	16.7
1C	1956				1				1		
	1960	1						1			
	1961	3				2	1	3	3		
	1962				2	2	1		5		
	1963	2				2		2	2		
	1964	6		3	7	9		6	19	42	63.6
1D	1963				1	1			2	2	3.0
1E	1963				1				1		
	1964	3					1(or D)	3	1	5	7.6
1F	1962					1			1		
	1964	2		1	2			2	3	6	9.1
Total		24	2	4	16	17	3	26	40	66	100.0
%		36.4	3.0	6.1	24.2	25.8	4.5				

The largest number of recaptures were taken in 1964, which is not surprising, as the output of the salmon fishery in that year was much higher than in the other years.

The division where most recaptures were made was 1C which had the best catches of salmon (see Table 1).

The largest number of recaptures has been of salmon tagged in Canada, England, and Scotland with 24, 17 and 16 recaptures respectively. It must, however, be mentioned that the numbers of recaptures cannot give any idea about how many salmon migrated from each country to the West Greenland area because the number of salmon tagged by all the different nations is not known.

It is also possible that data on taggings and recaptures are not complete, because some tags are possibly sent directly from the fisheries officers in the places where the recapture was made to the institute which has carried out the tagging, without giving information about the recapture to the Greenland Fisheries Investigations.

3. Stages of Salmon when Tagged

Table 4 shows the distribution of the different stages (parr, smolt, kelt, grilse, and big salmon) according to countries where tagged. One single salmon was tagged as a 13.5 cm long parr in 1961 in an English river 35 months before it was recaptured off Christianshaab (1964) in West Greenland.

Table 4. Distribution of salmon by stages and when tagged

Nation	Parr	Smolt	Kelt	Grilse	?	Big fish
Canada	-	17	-	4		2
USA	-	-	-	-		2
Scotland	-	14	2	-		-
England	1	14	3	-		-
Ireland	-	-	-	-		4
Sweden	-	2	-	-	1	-
Total	1	47	5	4	1	8
%	1.5	71.2	7.6	6.1	1.5	12.1

The salmon tagged as smolts have been in majority among the recaptures. It seems probable to presume that this stage also predominates the whole commercial catch owing to the fact that the weight of the recaptured salmon tagged as smolts were between 2.4 and 4.1 kg (mean weight 3.2 kg), (gutted, head on), which is nearly the same weight limits found for 87.8% of all salmon in the Greenland catches in 1964 (see Table 2). Another evidence is that the lengths of salmon belonging to this group at recapture were between 60 and 77 cm with an average of 67-68 cm, which is in accordance with the lengths of 343 salmon caught by Greenland fishermen off Fiskenaesset in 1964 (see Fig. 1).

4. Time in Sea

Time from tagging until recapture off Greenland has been nearly the same for salmon tagged as smolts in Canada, Scotland, and England, namely from 16-17 months.

The four salmon tagged as grilse in Canada have been between 11 and 17 months in sea (average 14 months). The five salmon which were tagged as kelts in Scotland and England have been 6 to 11 months in sea. Four big salmon tagged in Irish rivers were recaptured in Greenland waters 6, 7, 11 and 13 months after tagging.

The longest time in sea, i.e. 35 months, had the salmon which was tagged as parr in an English river in 1961.

5. Minimum Distances of Migration

As we do not know by which route the salmon migrate from its home river to its feeding places in Greenland waters, we cannot give the exact distance migrated. The average minimum distances migrated (nautical miles) were the following: Canada 1,600, USA 1,900, Scotland 1,850, England 2,000, Ireland 1,950 and Sweden 2,500.

6. The Growth of Recaptured Tagged Salmon

The smolts tagged had total lengths from 10-20 cm. When recaptured 17-19 months after tagging their lengths ranged between 66 and 73 cm (2.50-3.75 kg).

Three salmon tagged as kelts were 64, 72, and 78 cm when tagged and 74, 82, and 95 cm when recaptured. This means that the two first had grown 10 cm each in 6 and 8 months respectively and the third 17 cm in 8 months.

Four big salmon tagged in Ireland had the following growth:-

Length tag. cm	Length rec. cm	Months in sea	Growth cm
58.5	70	7	11.5
62.5	78	6	15.5
74.0	89	11	15.0
79.5	90	13	10.5

7. Food of the Salmon

The stomach content of salmon consisted mainly of euphausians and capelin (Mallotus) and in some cases also of sandeel.

Summary

An important gillnet fishery for salmon has developed from September to December in the last three years in coastal waters off West Greenland (Subarea 1). Shoals of salmon much larger than known before appeared especially in 1964, when the total catch was about 1,400 tons. The majority of the salmon were of medium size with mean lengths from about 62-78 cm and weights between 1.0 and 4.5 kg. The largest total catch was obtained in Div. 1C.

Recaptures of 66 salmon tagged in Canada, USA, Ireland, Scotland, England and Sweden showed that the salmon had emigrated from rivers on both sides of the Atlantic. Most of the recaptured salmon were tagged as smolts the year before recapture. This fact together with the length and weight of all salmon caught makes it probable that the largest number of the salmon appearing

off Greenland in the autumn months are salmon which left their home rivers as smolts 13 to 19 months earlier.

The long migrations from about 930 to 2,500 nautical miles must be considered as a feeding migration.

The stomach content was found to be capelin, euphausians and sandeel.

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