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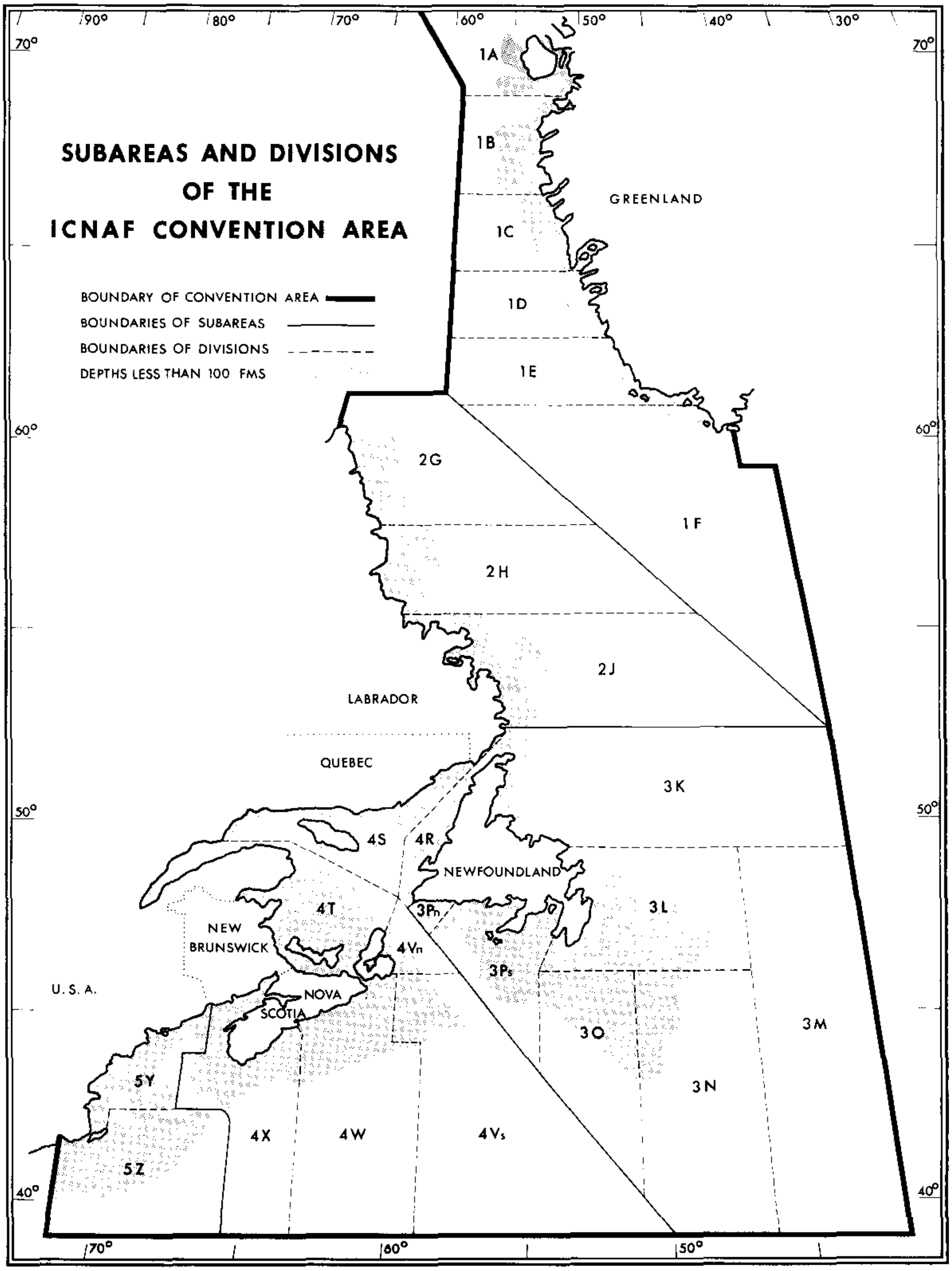

SUBAREAS AND DIVISIONS
OF THE
ICNAF CONVENTION AREA
BOUNDARY OF CONVENTION AREA
BOUNDARIES OF SUBAREAS
BOUNDARIES OF DIVISIONS
DEPTHS LESS THAN 100 FMS
GREENLAND
LABRADOR
QUEBEC
NEWFOUNDLAND
NEW BRUNSWICK
NOVA SCOTIA
U. S. A.
1A
1B
1C
1D
1E
1F
2G
2H
2J
3K
3L
3M
3N
3O
3Pn
3Ps
4R
4S
4T
4Vn
4Vs
4W
4X
5Y
5Z
90°
80°
70°
60°
50°
40°
30°

Contents

Notes

A Standard Terminology and Notation for Otolith Readers

BY ALBERT C. JENSEN[1]

Abstract

One- and two-word terms are used to describe features and markings seen in otoliths. The terms are accompanied by synonyms and full definitions. Abbreviations and number notations describe certain characteristics (including clarity of markings) of otoliths.

Introduction

Results of the cod otolith exchange program (Anon., 1959), and the analysis of a questionnaire (Keir, 1960) distributed to biologists engaged in age determination of fishes, indicated some important disagreements between different workers, particularly in the terminology used to report their findings. Because of the fundamental importance of age data to the work of the International Commission for the Northwest Atlantic Fisheries (ICNAF), the Standing Committee on Research and Statistics recommended at the 1960 Annual Meeting (Anon., 1960) that a working party on ageing techniques be set up to resolve these disagreements and to draw up a uniform set of terms and symbols.

Dr Gunnar Rollefsen was appointed Convener of the working party that met in Bergen, 19-24 November 1962. During the meeting the working party discussed a preliminary listing of terms, definitions, and abbreviations prepared by the author. The present paper represents the consensus of the members of the working party and was adopted by the Standing Committee on Research and Statistics of ICNAF for gadoids, redfish, and halibut at its Annual Meeting for 1964. The paper is prepared for use in the laboratories of ICNAF members, in otolith exchange reports, and in the preparation of papers dealing with otolith studies.

Terminology

The terms have been kept as simple as possible (Table 1). Preference has been given to terms that have precedence in the literature or have a valid historical basis. Quite often the oldest term is the best term.

Terms that deal with validity of methods (e.g., year-marks), and terms for which the dictionary definition has been replaced by a common usage definition (e.g., annulus) are not considered here. The proposed terms are intended to be descriptive and of a restricted nature. Also, they are terms that will have a similar meaning when translated from English, the official language of ICNAF, into the various languages of the ICNAF members.

Notation

Character of otolith zones

A system of number notations is proposed to grade the character (readability) of the otolith zones (Table 2). Such notations can also serve as a guide to the reliability of the ages determined for each otolith. The numbers will permit use of these notations in IBM and similar machine systems.

Abbreviations and symbols

It is desirable to keep abbreviations and symbols to a minimum and as simple as possible. Any lengthy comments on the appearance of the otolith and its markings, or on the degree of confidence of the determined age, are best made in an appropriate remarks column on the form used to record the results of the otolith readings.

Asterisks, plus and minus signs, or other addenda to the age notation, serve only to clutter the data. When comparing the results of duplicate otolith readings, the reader's first concern is, "Do the ages agree?" After this, the question may be asked, "Why did the duplicate readings agree (or disagree)?" Symbols and remarks will serve to answer the second question, but they should not clutter the sheet such that, after the otolith has been studied and an age assigned, the data sheet must be studied to find the notation of age.

Type of edge growth

Determining the type of growth (hyaline or opaque) seen at the edge of the otolith can, at

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TABLE 1. Terminology to describe otolith marks.

Term	Synonyms	Definition
Zones	Annuli, rings, year marks, bands, winter rings, summer rings, growth zones	Bands of concentric hyaline or opaque material seen in otolith and counted for age determination.
Check	Check mark, check ring, false ring, secondary ring, secondary zone, split	Hyaline matter not counted in age determination. Checks are sometimes indistinct, discontinuous, or, in the judgment of the reader, do not meet the criteria established for identification as a year mark.
Nucleus	Focus, center, origin, kernel	The central area of the otolith bounded by the first check or zone. (In most laboratories the center of the otolith is not fully understood, thus many biologists have not yet developed a firm definition for this term.)
Opaque edge	Summer edge, fast-growth edge, dense edge	The otolith periphery composed primarily of white, material that blocks light.
Hyaline edge	Winter edge, slow-growth edge, transluscent edge	The otolith periphery composed primarily of translucent material that passes light.
Spawning zones	Spawning marks, spawning rings	Hyaline and opaque zones formed in the otolith from the onset of sexual maturity. (For gadoids, both hyaline and opaque zones of spawners are, in general, uniform in size and form, and the opaque zones are distinctively narrower than those formed during the immature period of the fish's life. The hyaline spawning zones are clear and usually free of opaque material; in many species (e.g., cod) they are frequently broader than the subsequent opaque zones.)

TABLE 2. Notation to describe the character of otolith zones.

Notation and term	Definition
0 — Good	The zones are plainly visible with generally good definition between hyaline and opaque zones. Any check readily identifiable as such. The reader has a good degree of confidence in resulting age determination.
1 — Fair	The zones are visible but not well defined. There are many checks present. The reader has fair degree of confidence in resulting age determination. In many otoliths the zones may form distinct patterns that make reliable age determinations feasible.
2 — Poor	The zones are vaguely marked. Otoliths with zones so poorly defined as to be undecipherable, or where the age is merely estimated, are placed in this category.

times, be difficult and sometimes depends upon the subjective judgment of the reader. Final determination of the type of edge growth is influenced by the manner in which the otolith is read (whole, cut, or broken) and often the beginnings of new growth are best seen at the narrow tip of the long axis of the otolith. These factors must be taken into consideration by the reader when he records his observation of the type of edge growth. Since the type of edge growth is used to translate age determinations from zone counts, recognition of the edge type is essential to the otolith reading process. To help him in this recording, the following abbreviations are suggested:

Hn	— narrow hyaline zone at edge	(1)
Hw	— wide hyaline zone at edge	(2)
On	— narrow opaque zone at edge	(3)
Ow	— wide opaque zone at edge	(4)

For card punch systems (IBM, Keysort, etc.), the numerical notation may be substituted for the abbreviation, but care should be exercised to avoid confusing the edge code number with the age or zone-count number.

Checks

$C_{3,4}$ — check in third and fourth opaque zone

Spawning zones

12 (4s) — total of 12 zones of type counted (hyaline or opaque), 4 of which are spawning zones

Age determination

9 — clearly, nine completed zones of the type counted

9(10) — probably nine, possibly ten completed zones

(8)9(10) — probably nine but possibly eight or ten completed zones

12(?) — best estimate of count from ambiguously marked otolith

Summary

In 1960, the ICNAF Standing Committee on Research and Statistics recommended that a working party on ageing techniques be convened. A function of the working party was to discuss a uniform set of terms and symbols to be used in reporting the results of otolith studies.

The working party met in Bergen, Norway in the autumn of 1962. A proposed set of terms and notations, presented to the working party, was discussed, revised and accepted.

The terminology includes one- and two-word terms, their synonyms, and full definitions, to describe features and markings seen in otoliths.

Notations to describe characteristics of the otoliths are presented with abbreviations. Numerals are suggested, where feasible, for use in electronic data processing systems.

Acknowledgements

I wish to thank Dr Birger Rasmussen and the members of the working party for their suggestions and comments, many of which are included here.

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Otter-Trawl Selectivity and Girth-Length Relationships for Cod in ICNAF Subarea 2

BY V. M. HODDER[1] AND A. W. MAY[1]

Abstract

In 1962 and 1963 selection experiments on cod were carried out on Hamilton Inlet Bank, using both the covered-codend and alternate haul methods and codend mesh sizes between 95 and 130 mm. With covered codends selection factors ranged from 3.41 to 3.57 and with alternate hauls from 3.45 to 3.58. The 25–75% selection spans averaged 10.3 cm for the covered-codend series and 10.2 cm for the alternate hauls. The similarity of the selectivity results from both methods indicates that the greater effort required to obtain adequate results by the alternate haul method is probably not worthwhile. Further results indicated that most codend escapement probably occurs in the larger meshes in the after part of the codend.

The relationships between fish length and maximum and pectoral girths are described by linear equations. Seasonal differences in maximum girth were greater than in pectoral girth, but the differences are not reflected in the selectivity results. Thus selectivity may be more dependent on pectoral girth than on maximum girth, since the maximum girth is probably affected by such factors as expansion of the air bladder and heavy feeding.

Introduction

Since the establishment of the International Commission for the Northwest Atlantic Fisheries much concern has been expressed for the conservation of fish stocks and much study devoted to methods of reducing the destruction of small fish, particularly by trawlers. An accepted method of controlling to some degree the fishing mortality of small fish is by adjusting the size of mesh in the trawls so that fish below a certain size may be permitted to escape.

Much experimental work has been carried out in the Northeast and Northwest Atlantic on the selection of various species of fish by trawls in order to provide adequate bases for the regulation of mesh sizes. An extensive series of experiments (Clark, 1963), on several species of fish with trawls of various materials and mesh sizes, was carried out in ICNAF Subarea 5 by the Woods Hole Laboratory, U.S. Fish and Wildlife Service. Similar but less extensive experiments have been reported by McCracken (1963) for Subarea 4 and by Templeman (1963) for Subarea 3. Hodder and May (1964) reported on the effect of catch size on the selectivity of trawls for haddock of Subarea 3 with some limited data for cod of Subarea 2. It is the purpose of this paper to present the results of selection experiments, as well as girth-length relationships, obtained on 2 recent cruises to the Hamilton Inlet Bank area of Subarea 2. The experiments were carried out by the research trawler *A. T. Cameron* in August 1962 and in October 1963.

Materials and Methods

Gear

The gear consisted basically of the No. 41–5 Yankee trawl shown schematically in Fig. 1. On both cruises a number of covered-codend hauls were made using codends of three different mesh sizes in each case, and on the first cruise three large-mesh trawls were tested against a standard small-mesh trawl by the method of alternate hauls. All hauls were of 1-hr duration dragging on bottom.

For the covered-codend hauls the trawl consisted of manila twine ranging from single 100/3 (3 ply running at 100 yards per lb.[2]) in the wings, square and forward belly section to single 75/4 in the after belly and single 50/4 in the lengthening piece (8.5 m in length). The mesh size ranged

[1]Fisheries Research Board of Canada, Biological Station, St. John's, Newfoundland.
[2]1 yard = 0.914 m; 1 lb. = 0.454 kg.

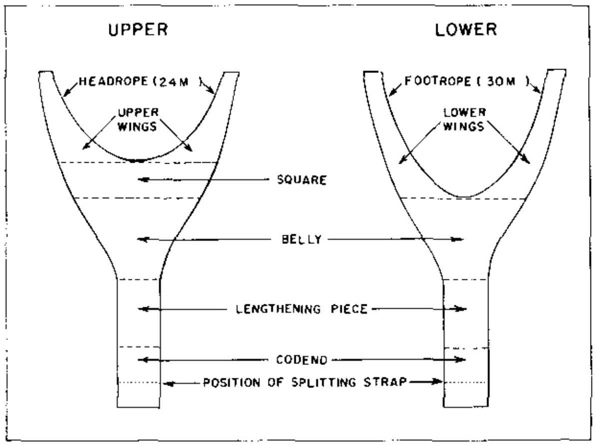

Fig. 1. Schematic diagram of the 41–5 trawl.

from about 110 mm in the forward parts to about 65–70 mm in the lengthening piece. The codends used consisted of double 50/4 manila twine. The bottom section of each codend was lined with small-mesh (30-mm) nylon netting and the top section covered with 50-mm courlene netting, the width of which was more than twice the width of the codend. The cover was constructed in such a way that the posterior portion formed a bag or cover "codend" which extended about 2.3 m posteriorly beyond the end of the main codend. The method of attachment provided the greatest ease of handling in that the cover could be emptied independently of the codend.

For the alternate hauls the procedure was to alternate most of the trawl (codend, lengthening piece and about two-thirds of the belly) rather than just the codend as is usual in covered-codend hauls. Except for differences in mesh size the four trawls used were of the same general dimensions and for convenience were labelled A, B, C and D. The average mesh sizes (millimetres, internal wet measurement) of the various sections of each trawl were as follows:

Section	A	B	C	D
Codend, 50/4 double manila	54	96	106	113
Length. piece, 50/4 single manila	66	101	111	114
Belly[a], 75/4 single manila	70	105	112	116
Wings and square 100/3 single manila		110 to 120		

[a]After section of the two belly sections.

Fish measurement and sampling

Fish lengths were measured from the snout to the mid-fork of the caudal fin (fork length). The measurements were recorded to the nearest centimetre on a measuring board, the first space of which was 1.5 cm and subsequent spaces of 1-cm intervals. In nearly all cases length measurements were taken from the entire catches of both codend and cover. Only on two occasions was it necessary to sample the catches and in both cases one-half or more of the catch was measured.

During the process of measuring each catch 20–30 cod were usually taken (at random over the selection range) for girth measurements and their lengths recorded in millimetres. Both pectoral and maximum girths were measured to the nearest millimetre using a plastic-coated cloth tape (20 mm wide) put completely around the fish, firmly, but without constricting the body. For the pectoral girth measurement the tape was placed around the fish such that it covered the bases of the pectoral fins and the anterior edge of the tape touched the extreme posterior edge of the operculum. The maximum girths were taken somewhat more posteriorly, the tape usually covering the posterior tips of the pectoral fins. However, for some emaciated fish the maximum girth coincided with the pectoral girth measurement.

Mesh measurements

All mesh measurements obtained on the first selection cruise to the area in 1962 were made with a 1959 model Westhoff longitudinal pressure gauge (Westhoff and Parrish, MS, 1959), while those in 1963 were made with the new ICES gauge (Westhoff, MS, 1961; Westhoff *et al.*, 1962). The gauges were used at a spring pressure of about 4 kg, but on the first cruise the row of meshes was also measured with a pressure of 5.5 kg (12 lb.) for comparison. All mesh measurements are internal wet measurements.

For the alternate-haul data mesh measurements were taken in a longitudinal row along the upper surface of the trawl (at least seven meshes from the side lacings) from codend to belly (every consecutive mesh in the codend, every third mesh in the lengthening piece and every second mesh in the belly). Periodically a few meshes in the wings and square were also measured. For the covered-codend hauls mesh measurements were taken in a longitudinal row of consecutive meshes along the top side of the codend only. All mesh measurements were recorded in millimetres and each set of codend measurements was taken along a different row of meshes, except for those involved in the 4 kg and 5.5 kg comparisons.

Analysis of the data

The covered-codend catch frequencies were combined and analyzed in the usual way by taking, for each centimetre length group, the ratio of the number in the codend to total number caught. To facilitate the drawing of the selection curves the ratios were smoothed by moving averages of three. The 25, 50 and 75% retention lengths were then estimated from the curves.

For the alternate-haul data the catch length frequencies were combined, and for each codend tested the ratio of the number in the large-mesh to the number in the standard small-mesh trawl was computed for each fish-length interval. These ratios were also smoothed by threes and the upper asymptote of each curve was obtained by taking the average of the ratios over about 10–12 fish-length intervals beyond what was considered to be the length where 100% retention was attained (as judged from the covered-codend curves of similar mesh sizes). The curves were then adjusted so that the upper asymptote corresponded to unity.

The selection factors were obtained by taking the ratio of the 50% retention length to the size of mesh involved, both values expressed in millimetres. Except where noted otherwise, all selection factors were computed from the codend mesh measurements made at a pressure of 4 kg.

The girth measurements were averaged after grouping into 1-cm fish length intervals and straight lines were fitted by the method of least squares.

Results

Size selection from covered-codend hauls

Codends of three different mesh sizes were used on each of the 1962 and 1963 cruises. Data pertaining to the mesh sizes, catches and selectivity are given in Table 1 and the curves are shown in Fig. 2. All curves approximate symmetrical sigmoids, except for some slight skewness in the part of each curve below the 25% retention length. This has been found by most workers in selectivity studies and is probably due to differential behaviour in the net or to the decreased ability of small fish to escape through the meshes (Clark, 1963). For 5 of the 6 series of covered-codend experiments with codends ranging in mesh

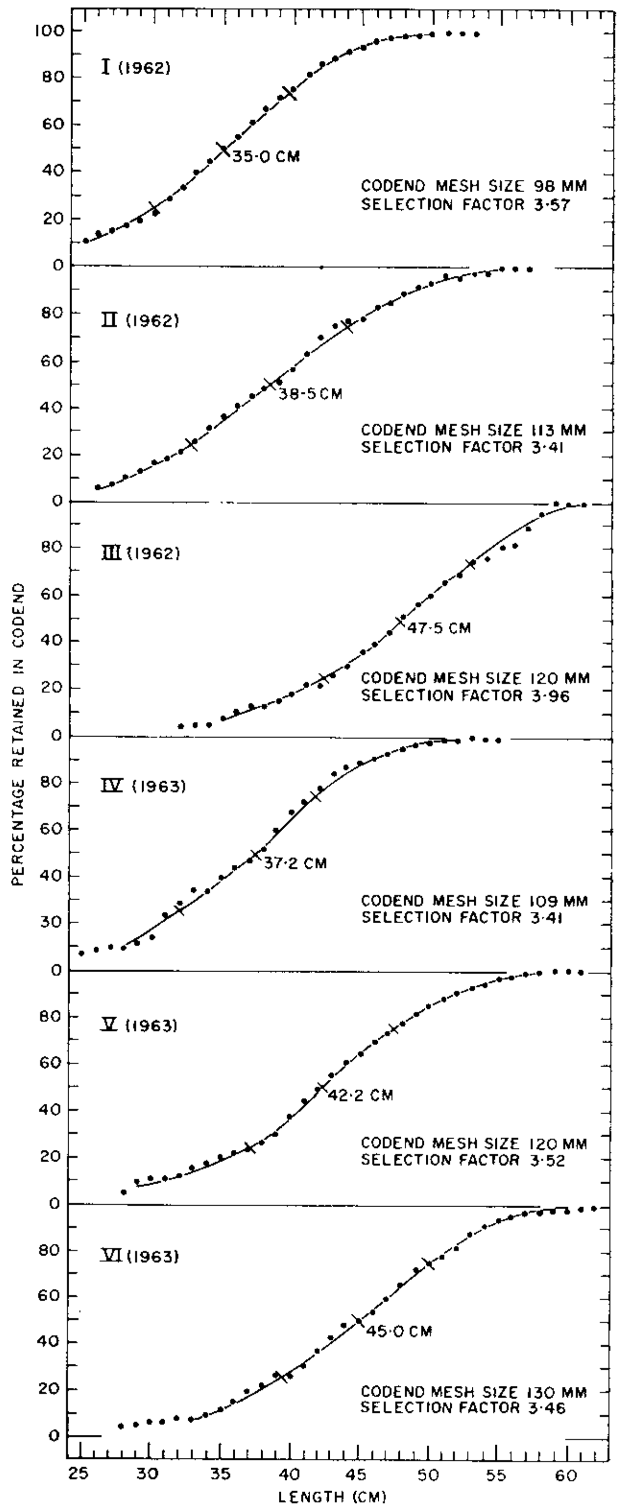

Fig. 2. Selection curves for cod of Subarea 2 from covered-haul experiments in 1962 and 1963.

TABLE 1. Results of covered-codend selection experiments, with codends of various mesh sizes, carried out in the Hamilton Inlet Bank region of Subarea 2.

Cruise:	August 1962			October 1963			
Codend series:	I	II	III	IV	V	VI	Average
No. of 1-hr hauls	8	4	8	9	12	8	
Avg number caught — codend	456	480	211	685	447	283	
— codend + cover	742	1067	857	815	667	507	
Avg weight caught (kg) — codend	375	430	240	1075	810	475	
— codend + cover	465	620	560	1140	930	615	
Avg mesh size of codend (mm)	98	113	120	109	120	130	
50% retention length (cm)	35.0	38.5	47.5	37.2	42.2	45.0	
Selection factor	3.57	3.41	3.96[a]	3.41	3.52	3.46	3.48
25% retention length (cm)	30.0	32.7	42.3	31.9	37.0	39.4	
75% ,, ,, ,,	39.7	43.6	52.8	41.9	47.4	50.0	
Unadjusted selection span (cm)	9.7	10.9	10.5	10.0	10.4	10.6	10.3

[a]Not included in average.

size from 98 to 130 mm selection factors of 3.41 to 3.57 were obtained, the average being 3.48. For Series III, however, a somewhat higher selection factor of 3.96 was obtained with the 120 mm codend.

The size compositions of the cod catches for the 6 series of tests are shown in Fig. 3. During the 1962 cruise most of the cod caught were between 22 and 55 cm, and the upper part of the selection curves extended well beyond the second mode of the catch frequencies. During the 1963 cruise the catches consisted of considerably larger cod, and the upper asymptote of the selection curves coincided approximately with the second mode of the size distributions. Despite the great difference in size composition between the 1962 and 1963 series of experiments, the selection factors for the 1962 series (except the one value of 3.96) are essentially the same as those for the 1963 series. Although the lowest selection factor for the 1962 series (3.41) was obtained from the data of Series II, which had relatively more small fish in the first modal group, this argument cannot be used to explain the high selection factor of 3.96 for Series III.

The 25–75% selection spans (unadjusted) are indicated in Fig. 2 and given in the last row of Table 1. The similarity of these values for all six series of experiments is remarkable. The average selection span is 10.3 cm. Clark *et al.* (1958) in their summary of gear selection information for the ICNAF Area observe that the selection span for data available to them was quite variable (6 – 12 cm from 18 experiments with manila codends), and they considered a value of 10 cm as most representative.

All of the results given above are based on the average mesh size of the whole codend, that is, the average mesh size of a single longitudinal row of meshes taken periodically throughout each series of hauls. However, during the 1963 cruise (Series IV–VI) it was noted from the first drag or two with each codend that the meshes in

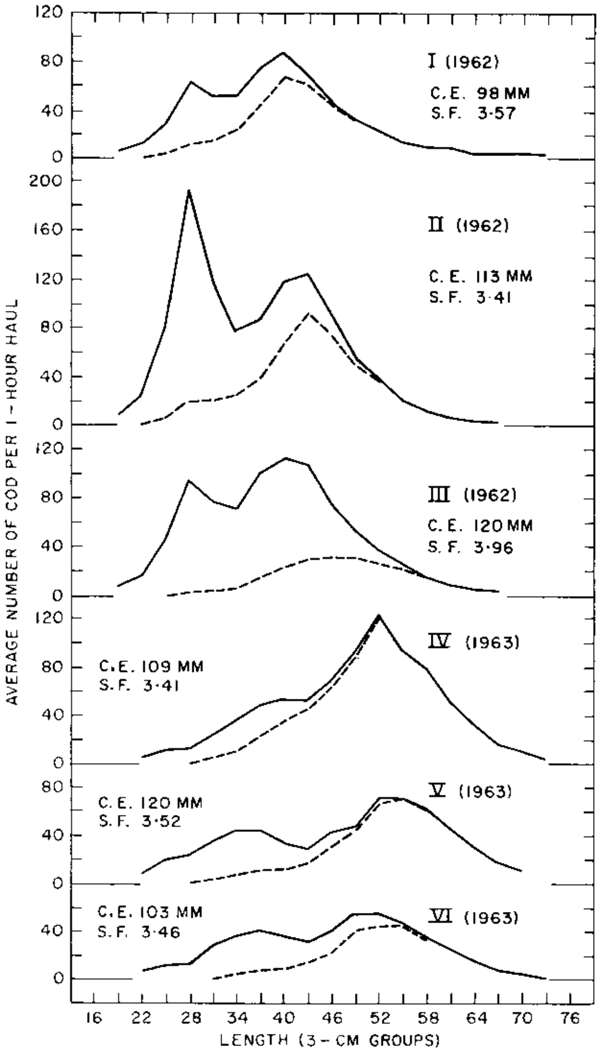

Fig. 3. Size composition of cod catches for the 6 series of selection experiments with covered-codends in Subarea 2 (the broken lines represent codend frequencies).

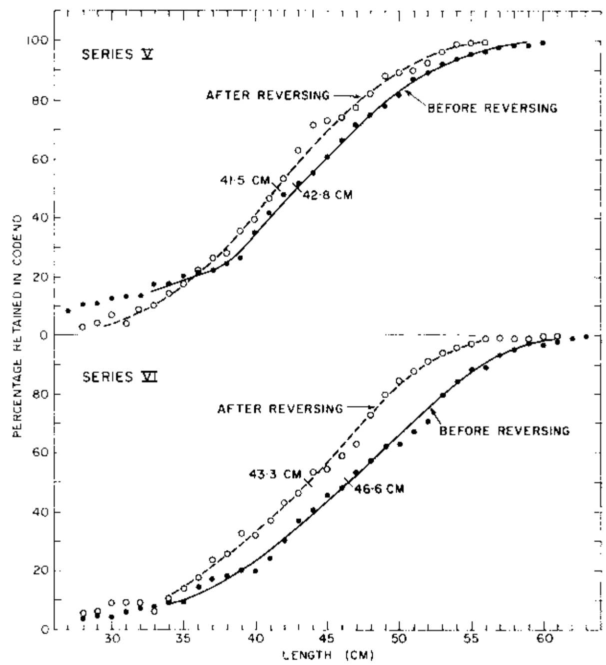

Fig. 4. Selection curves for cod before and after reversing the 120 mm (above) and 130 mm (below) from covered-codend experiments in 1963.

the after part, especially behind the splitting strap, were somewhat larger than those farther forward. About half-way through each of Series V and VI the codends were reversed so that the end which was previously forward now formed the bag posteriorly. The results of these experiments are given in Table 2 and the curves plotted in Fig. 4.

Although in each case the average mesh size of the whole codend was essentially the same before and after reversal of the codend, the 50% retention lengths decreased in each case corresponding to the decrease in size of the meshes in the after part of the codend. The selection factor decreased from 3.60 to 3.43 for the Series V codend and from 3.58 to 3.33 for the codend of Series VI. If the selection factors are based on the average size of the meshes in the after one-quarter of the codend only (about that part of the codend behind the splitting strap), the selection factors before and after reversal of both codends are very similar, but the range is reduced from 3.33–3.60 to 3.38–3.49.

Table 3 compares the selection factors of all six codends based on the average mesh size of the whole codend and the last one-quarter of the codend only. No significant trend in selection factor is indicated with variation in mesh size. There is, however, more than a threefold reduction in the variance when the selection factors are computed on the basis of the average size of the meshes in the last one-quarter of the codend. This is probably much more significant for the relatively small catches involved here than it would be for larger catches of commercial importance.

Size selection from alternate hauls

During the 1962 cruise some results were obtained by alternating a small-mesh trawl with three other trawls of larger mesh sizes. Details of the mesh sizes, average catches and selectivity

TABLE 2. Results of covered-codend selection experiments in Subarea 2 with 120 mm and 130 mm codends before and after reversal.

	Codend V (120 mm)		Codend VI (130 mm)	
	Before reversal	After reversal	Before reversal	After reversal
Number of 1-hr hauls	7	5	4	4
Avg codend + cover catch — No.	839	428	493	520
— kg	2,625	1,230	1,250	1,450
Avg mesh size for whole codend (mm)	119	121	130	130
Mesh size of last one-quarter of codend only (mm)	124	119	138	125
50% retention length (cm)	42.8	41.5	46.6	43.3
Selection factor based on mesh size of whole codend	3.60	3.43	3.58	3.33
Selection factor based on last one-quarter of codend meshes	3.45	3.49	3.38	3.46

TABLE 3. Comparative results of covered-codend selectivity data based on the average mesh size of the whole codend and on the average size of the meshes in the last one-quarter of the codend.

Codend series	50% retention length	Avg mesh size		Selection factor for	
		Whole codend	Last quarter	Whole codend	Last quarter
	cm	*mm*	*mm*		
I	35.0	98	103	3.57	3.40
II	38.5	113	116	3.41	3.32
III	47.5	120	128	3.96[c]	3.71[c]
IV	37.2	109	110	3.41	3.38
V[a]	42.8	119	124	3.60	3.45
V[b]	41.5	121	119	3.43	3.49
VI[a]	46.6	130	138	3.58	3.38
VI[b]	43.3	130	125	3.33	3.46
	Average selection factor			3.48	3.41
	Variance			0.067	0.020

[a]Before reversal of codend.
[b]After reversal.
[c]Not included in average.

TABLE 4. Results of selection experiments in Subarea 2 from alternate hauls with trawls of three different mesh sizes.

Cruise:	August 1962				
Trawl:	A	B	C	D	Average
No. of 1-hr hauls	16	8	16	8	
Avg number caught	761	614	367	363	
Avg weight caught (kg)	520	465	345	330	
Codend mesh size (mm)	54	96	106	113	
Estimated 50% retention length (cm)	—	34.0	38.0	39.0	
Selection factor	—	3.54	3.58	3.45	3.52
Selection span (cm)	—	12.4	8.7	9.4	10.2

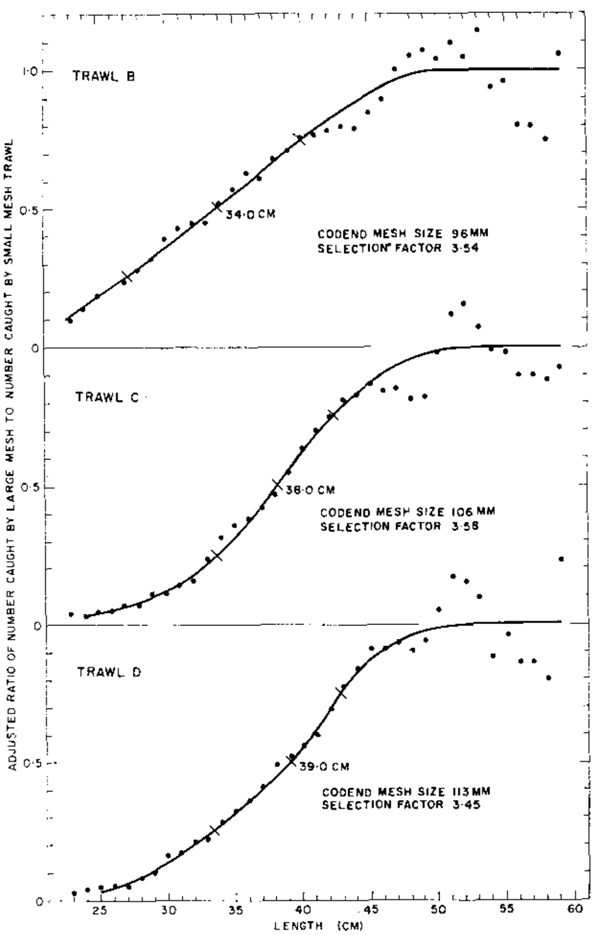

Fig. 5. Selection curves for cod of Subarea 2 from alternate-haul experiments in 1962.

information are given in Table 4, and the curves are shown in Fig. 5. Altogether 48 hauls were made, with trawls A, B and C alternated during the first 24, and trawls A, C and D during the remaining 24. Thus the catch length frequencies of Trawl B are compared with the first 8 catches of the small-mesh trawl (A) and those of Trawl D with the last 8 catches of Trawl A. Since Trawl C was alternated during the entire series of drags, it is compared with all the drags of Trawl A.

While equal amounts of fishing effort are involved in the large mesh/small mesh comparisons, the upper asymptotes of the curves as initially estimated by inspection for Trawls B and C did not coincide with a large-to-small-mesh ratio of 1.0 for the larger sizes of cod. This was largely due to catch variability and the small numbers of hauls involved. Consequently the upper asymptotes of these curves were adjusted to unity by the factors 1.30 and 0.77, which were obtained by averaging the ratios over 10–12 fish-length intervals beyond the length where 100% retention was judged to be attained. An interesting feature of the curves is the downward trend in the ratios beyond the fish length where 100% retention is attained. This phenomenon has been reported by other authors and is considered further in the discussion. The selection factors based on the 50% retention lengths and the average mesh sizes of the corresponding codends agree remarkably well with those obtained from the series of covered hauls. Also the average selection span of 10.2 cm is essentially the same as the average for the covered hauls.

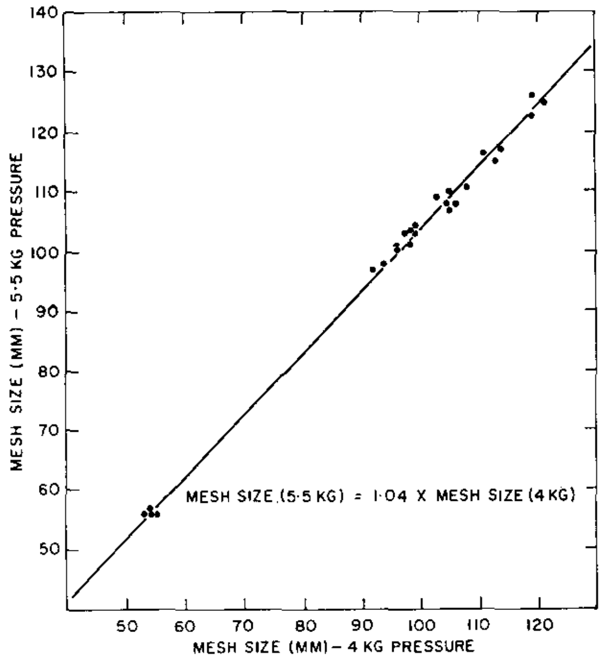

Fig. 6. Comparison of average internal mesh sizes of codends using gauges adjusted to exert pressures of 4 kg and 12 lb. (5.5 kg).

Mesh size comparison with 4 - and 5.5 - kg pressures

During the August 1962 cruise the codend meshes were measured with a gauge adjusted to exert a pressure of 4 kg on the mesh. Another set of mesh measurements was taken along the same row of meshes using a gauge adjusted to exert a pressure of 5.5 kg (12 lb.), so that a conversion factor would be available to apply to the results of previous selection studies in which the mesh measurements were made with gauges exerting a pressure of about 5.5 kg.

As shown in Fig. 6 the results indicate that the mesh size obtained with a 5.5-kg gauge is equal to 1.04 times the mesh size obtained with a 4-kg gauge. Thus the average selection factor of 3.48 for the covered-codend experiments based on the 4 kg gauge (Table 3) becomes 3.35 in terms of the 5.5-kg gauge.

Girth-length relationships for cod and their application to mesh selection

During the course of sampling the catches, both pectoral and maximum girth measurements were made on 1,503 cod during the first selection cruise in August 1962 and on 589 cod during the cruise in October 1963. In view of the differences involved the results are plotted separately for the two cruises in Fig. 7. The linear relationships were obtained by the method of least squares. The greater differences between the maximum and pectoral girths for the October 1963 cruise are attributed to heavy feeding on capelin, whereas in August 1962 most of the cod were feeding on ctenophores and amphipods.

Taking the mesh perimeter size as being twice the stretched mesh-size measurement, the relationships between the girth of the fish at the 50% retention length and the internal lumen perimeter of the mesh are given in Table 5, both for the whole codend and for the meshes in the last one-quarter of the codend. The values for girth at 50% retention length were computed from the

ABLE 5. Relationship between girth and trawl selectivity for cod in Subarea 2.

		August 1962								October 1963					
		Alternate hauls				Covered-codend hauls				Covered-codend hauls					
Experiment		B	C	D	Avg	I	II	III	Avg	IV	V[a]	V[b]	VI[a]	VI[b]	Avg
% retention length (cm)		34.0	38.0	39.0		35.0	38.5	47.5		37.2	42.8	41.5	46.6	43.3	
irth at 50% retention (mm)	Pect.	160	179	184		165	182	224		177	206	199	225	209	
	Max.	167	187	192		172	189	234		192	224	216	245	227	
esh size of codend (mm)		96	106	113		98	113	120		109	119	121	130	130	
ercentage of mesh lumen occupied by 50% retention length fish	Pect.	83.3	84.4	81.4	(83.0)	84.2	80.5	93.3[c]	(82.4)	81.2	86.6	82.2	86.5	80.4	(83.4)
	Max.	87.0	88.2	85.0	(86.7)	87.8	83.6	97.5[c]	(85.7)	88.1	94.1	89.3	94.2	87.3	(90.6)
esh size of last one-quarter of codend (mm)		101	110	115		103	116	128		110	124	119	138	125	
ercentage of mesh lumen occupied by 50% retention length fish	Pect.	79.2	81.4	80.0	(80.2)	80.1	78.4	87.5[c]	(79.3)	80.5	83.1	83.6	81.5	83.6	(82.5)
	Max.	82.7	85.0	83.5	(83.7)	83.5	81.5	91.4[c]	(82.5)	87.3	90.3	90.8	88.8	90.8	(89.6)

[a]Before reversal of codend.
[b]After reversal.
[c]Not included in averages.

appropriate equations given in Fig. 7. The unusually high values for Series III have not been included in the averages (see discussion). The pectoral girths, expressed as percentages of the various mesh perimeters, were essentially the same for both cruises. However, the maximum girths were consistently greater in October 1963 than in August 1962, but this factor is not reflected in the selectivity results of Table 3.

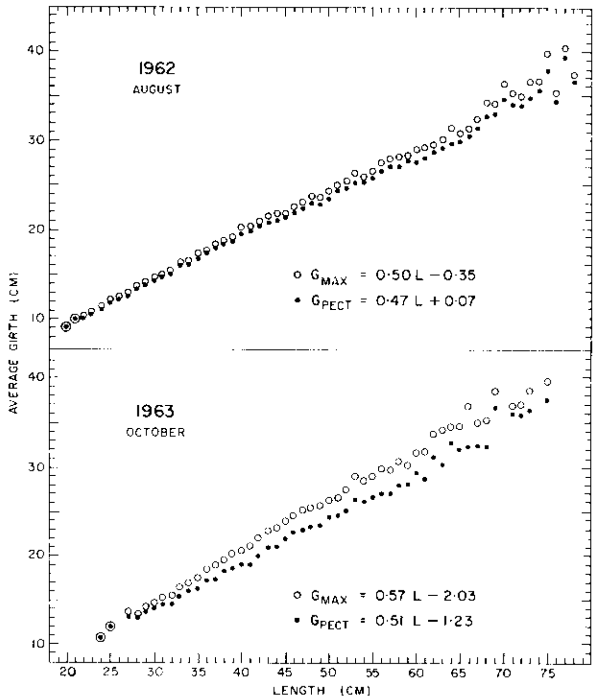

Fig. 7. Relationships between pectoral and maximum girths and length of cod taken during the 1962 (above) and 1963 selection experiments in Subarea 2.

Discussion and Conclusions

The covered-codend experiments on Subarea 2 cod gave selection factors between 3.41 and 3.57 (excluding an unusually high value of 3.96 for one of the six series of experiments), the average being 3.48. These were based on codend mesh sizes obtained with gauges exerting a pressure of 4 kg. With a pressure of 5.5 kg the average selection factor was 3.35. This value is the same as obtained by McCracken (1963) for Subarea 4 cod. From eight experiments with manila codends of similar twine sizes and with mesh sizes between 109 and 129 mm his selection factors varied between 3.10 and 3.50, the average being 3.34. The average selection span (distance between the 25 and 75% retention lengths) for McCracken's data was 10.5 cm, a value similar to ours. For Grand Bank cod, using manila codends of 102 and 112 mm, Templeman (1963) obtained only slightly lower selection factors of 3.27 and 3.17 respectively. Both McCracken's and Templeman's results were based on the use of the wedge-type gauge with pressures of 12–15 lb. (5.5–6.8 kg).

An unusually high selection factor of 3.96 was obtained for Series III in August 1962. This factor might not be considered abnormal if it were based on a single haul, but eight hauls were involved in the series and the catches were generally the same as those for Series I and II. Careful examination of the codend after each haul revealed no damage. In search of an explanation the catch frequencies of the individual hauls were examined. Selection factors were found to vary between 3.81 and 4.20, all considerably higher than those for Series I and II, whose ranges were 3.52–3.74 and 3.30–3.67 respectively. It would appear, therefore, that the average mesh size obtained for the Series III codend is not fully representative of the codend meshes as a whole, although mesh measurements were taken along the top surface of the codend in a different longitudinal row on three occasions. Even when the selection factor for Series III is based on the average mesh size of the last one-quarter of the codend meshes it is still high at 3.71. Unlike the codends of Series I and II, which were used only on this cruise, the Series III codend was used extensively on a previous cruise in which catches up to 7,000 kg were taken. This may have caused distortion in the after meshes of the codend to such an extent that the three sets of measurements taken may not be representative of the actual effective mesh size. Beverton and Holt (1957) mention two criteria which should be reasonably satisfied in dealing with alternate-haul data: (a) It is desirable that the fish in question should not segregate into shoals within each of which the size range is small, and (b) the selection range should not be too large a part of the total range of length covered by the data. If these criteria are also applicable to covered-codend experiments, it is apparent that the second is not adequately satisfied for the Series III codend (Fig. 3), since the selection range covers all sizes up to 58 cm leaving only about 3% of the fish by number above the selection range. Consequently the selection factor for this series was not considered representative of the mesh size involved.

Some data were presented above which illustrate, at least indirectly, that the after part of the top surface was the area of greatest escapement from the codend. These results agree with the observations of several authors from selection studies on various fish species. Cieglewicz and Strzyzewski (1958) from experiments on cod in the Baltic and North Seas, using compartmented covers, conclude that the escape of small cod takes place mainly through the upper and back part of the codend, but the percentage of fish escaping through the front part of the codend may be increased when this part is made of fine material with larger meshes. Beverton (1963) carried out experiments using a compartmented cover over the codend and found that for five species of fish, including both demersal and pelagic species (whiting, haddock, dab, horse-mackerel, mackerel), about 90% of each species escaped through the after one-third of the codend. Essentially the same observations were reported by Clark (1963) for Subarea 5 haddock, but he also observes that escapement may be diminished when catches are heavy, due in part to blocking of the normally larger meshes in the after part of the codend and forcing the fish to escape through smaller meshes. In view of this evidence, and the more consistent results reported above, when escapement is related to the mesh size in the after part of the codend only, selection factors, at least for small catches, might be more meaningful if they were expressed in terms of the average mesh size of the after part of the codend behind the splitting strap, where after several hauls the meshes normally become larger than those farther forward. This, however, may not be true when catches are large.

The selection ogives obtained from the alternate-haul data show a phenomenon found by other authors in that the curves rise to a maximum and then the ratios decrease approximately linearly, despite the great variation in these ratios due to the small numbers of fish caught at the greater lengths. Beverton and Holt (1957) discuss this problem in the light of selection experiments on North Sea plaice and adjusted some of their curves by extrapolating linear regressions. Their method was initially applied to our data but gave much less consistent results than those obtained by simply averaging ratios beyond the empirical 100% lengths to determine the upper asymptotes of the curves. As a possible reason for the descending regressions Beverton and Holt (1957) postulate that, if the ability of fish to swim against the water flow becomes progressively greater with increase in the size of fish, the efficiency of the larger-meshed trawl would become progressively less pronounced for larger fish. This, of course, must be based on another assumption that many fish, once they find themselves in the trawl, will head into the simulated current and swim toward the mouth of the trawl to eventually attempt an escape through the mouth opening or through the larger meshes of the forward parts. Templeman (1963), in discussing the same phenomenon for alternate-haul selection studies on redfish, speculates that in the small-mesh trawl the resistance to towing may result in a water build up near the mouth of the trawl and relatively greater flow through the wings, square and anterior part of the belly, whereas in the large-mesh trawl resistance to towing is reduced and relatively more water is strained through the after parts. Thus the fish may spend more time in the anterior parts of the small-mesh trawl and are selected by the large meshes of the light single twine of the forward parts, whereas in the large-mesh trawl the fish entering it are carried back more quickly by the water current to be selected by the double twine of the codend, Whatever factors are involved in producing the downward trend in the ratios for the larger sizes of fish, doubtless these would vary with the species studied. Templeman's hypothesis might seem more reasonable for such species as redfish, while Beverton's hypothesis might seem more reasonable for a more streamlined and soft-rayed species such as cod.

In view of the similarity of the selection factors from the covered-codend and alternate hauls, although the latter (or paired hauls) are useful in validating the results of covered-codend hauls, it is doubtful whether they are worth the much greater effort necessary to obtain adequate results in addition to the oft-encountered difficulties of interpreting the results. Hodder and May (1964) from a number of alternate-haul experiments on Grand Bank haddock found that the selection factors obtained, even when catches were very large, were similar to those reported by Clark (1963) and McCracken (1963) for haddock in Subareas 4 and 5 respectively, both using the covered-codend method.

In the present data the maximum girths are shown to differ more widely than the pectoral girths between the two periods, but these differences are not reflected as differences in selectivity. Consequently selectivity may be more dependent on pectoral girth than on maximum girth. Margetts (1957) carried out an analogous procedure in measuring maximum and constricted girths of cod and whiting, and considered the restricted girth measurement to be of greater practical value because it is less likely to be affected by expansion of the air bladder and because fish will normally exert some force in swimming through the meshes. Heavy feeding may also affect the maximum girth much more than the pectoral girth measurement.

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The Validity of Otolith Ages of Southern Grand Bank Cod

BY A. W. MAY[1]

Abstract

Length frequency distributions of research vessel catches of cod from the southern Grand Bank (ICNAF Divisions 3N and 3O) are typically polymodal. Petersen's method, and progression of dominant year-classes, are used as evidence of the validity of otolith ages. Rather large fluctuations in year-class survival apparently occur, and during the 1946–1960 period, best survival of new year-classes occurred in 1946, 1949, 1953, 1955, 1958 and 1959.

Introduction

Age determination of fish from skeletal structures was brought to fruition during the early years of the present century. Validity studies, confirming the accuracy of the method for a number of species, are reviewed by Graham (1929). In recent years the tendency has been to accept the validity of a particular structure for a particular species, and to use it to determine age of fish from widely separated areas without further tests of validity. The importance of a critical approach to the ageing problem, in order that results of different workers and from different areas be comparable, has been pointed out by Dannevig (1933) and Saetersdal (1953). More recently, variable results from otolith exchange programmes have led to the recommendation by the Research and Statistics Committee of ICNAF (1963 Redbook, Part 1, p. 48) "that studies of validation of cod otolith age reading methods be vigorously pursued by member countries."

Evidence on the validity of otolith ages for various localities in the Newfoundland area, through examination of seasonal changes in the otolith edge, is presented by Fleming (1960). The present study gives further evidence of the reliability of otoliths to determine age of cod from the southern Grand Bank (ICNAF Divisions 3N and 3O), through agreement with Petersen's method, and observations on dominant year-classes.

Material and Methods

The length and age data were obtained from annual survey cruises on the southern Grand Bank from 1950 to 1962, by research vessels of the St. John's Biological Station. These were carried out during the months of April–June of each year, with additional cruises in March, 1961 and February, 1962. Depths fished ranged from about 25 fathoms (45 m) on the Southeast Shoal to 150 fathoms (275 m) on the southwest slope of the Grand Bank (Fig. 1). The fishing was carried out along a regular pattern of stations, mainly along lines B, D, F and H of Fig. 1. The otter-trawl codends were either lined or covered with $1\frac{3}{4}$-inch manila netting from 1950 to 1957, and lined with $1\frac{1}{8}$-inch nylon netting from 1958 to 1962.

The primary purpose of these cruises was to study the distribution and abundance, and to collect samples of the haddock population of this area. Thus cod were not always measured, or otolith samples taken from each set in which they occurred. Where length measurements were obtained, they were either of the entire catch of cod or of random samples of the catch. In the latter case the length frequencies were adjusted to catch on a set by set basis. Otolith collections were generally made from random subsamples of the fish selected for measurements. These were used to construct yearly age-length keys, by means of which the adjusted length frequencies were broken down by age. Otolith collections in 1950, 1954, 1955 and 1957 were insufficient for this purpose, and the length frequencies for the former 2 years were broken down by means of an age-length key based on

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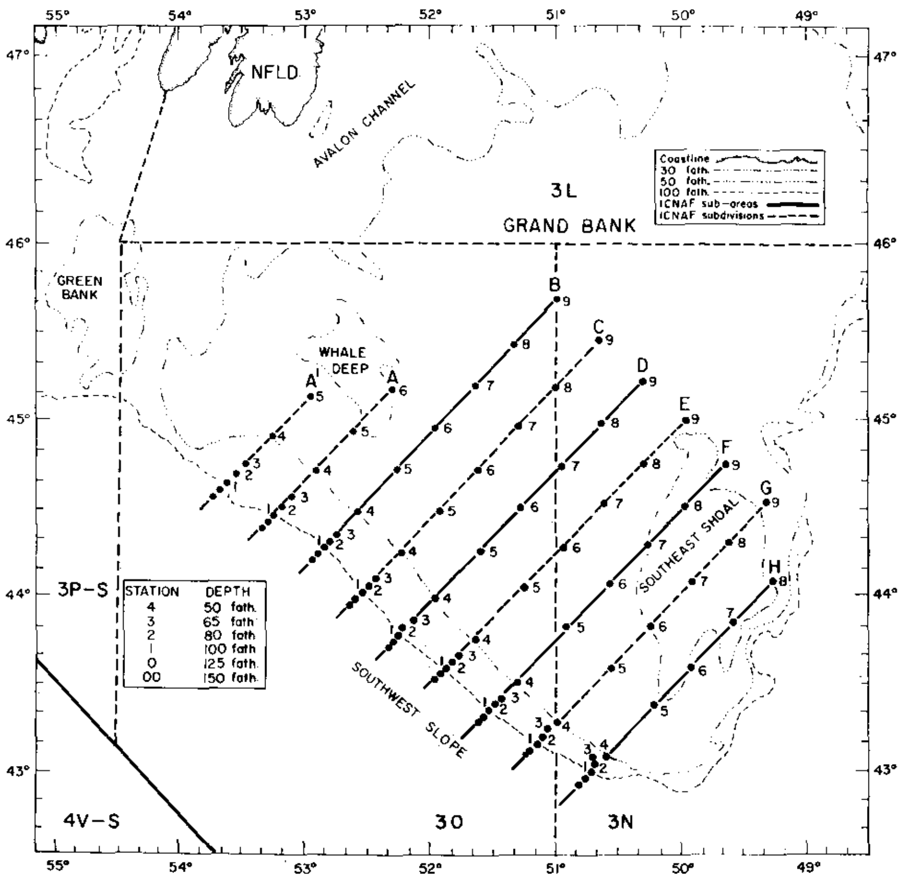

Fig. 1. Map of the southern Grand Bank showing lines of stations fished in surveys by research vessels of the St. John's Biological Station.

combined collections during 1950–54, while those for the latter 2 years were broken down by means of a key based on 1955–59 data.

The ages were read from otoliths by Mr G. R. Williamson, a former member of the staff of the St. John's Biological Station, in consultation with the author. The age reading technique is described in the summary by Keir (MS, 1960). The fish length measurements were invariably from tip of the snout to mid-fork of the caudal fin (fork length).

Validity of Otolith Ages

Parrish (1956) summarizes the principles underlying Petersen's method as follows:

(1) If a fish population has a single restricted spawning season, the lengths of the individuals of an age-group are normally distributed.

(2) Growth of each age-group is such that the modes of the length distributions of successive age-groups are sufficiently separated along the length axis as to make them readily distinguishable.

(3) The separate modes of the polymodal length distribution represent the approximate mean sizes of the age-groups present.

Since the method cannot be used to determine age of individuals, it is generally employed only as a last resort, but remains very useful as a check on the reliability of other methods (Kohler, 1958, 1964; Sandeman, 1961). It is particularly applicable to the southern Grand Bank where a restricted annual spawning season occurs (Thompson, 1943) and where annual growth at most ages is greater than in any other part of the Newfoundland area (Thompson, 1943; Fleming, 1960; May *et al.*, MS, 1964).

The adjusted length and age distributions for each year are shown in Fig. 2. Fish greater than 101 cm in length and 12 years of age were generally not very abundant and are included together for present purposes. The length distributions (per cent in each 3-cm length group) are seen to be typically polymodal up to about 70 cm. The smallest size at which a peak in

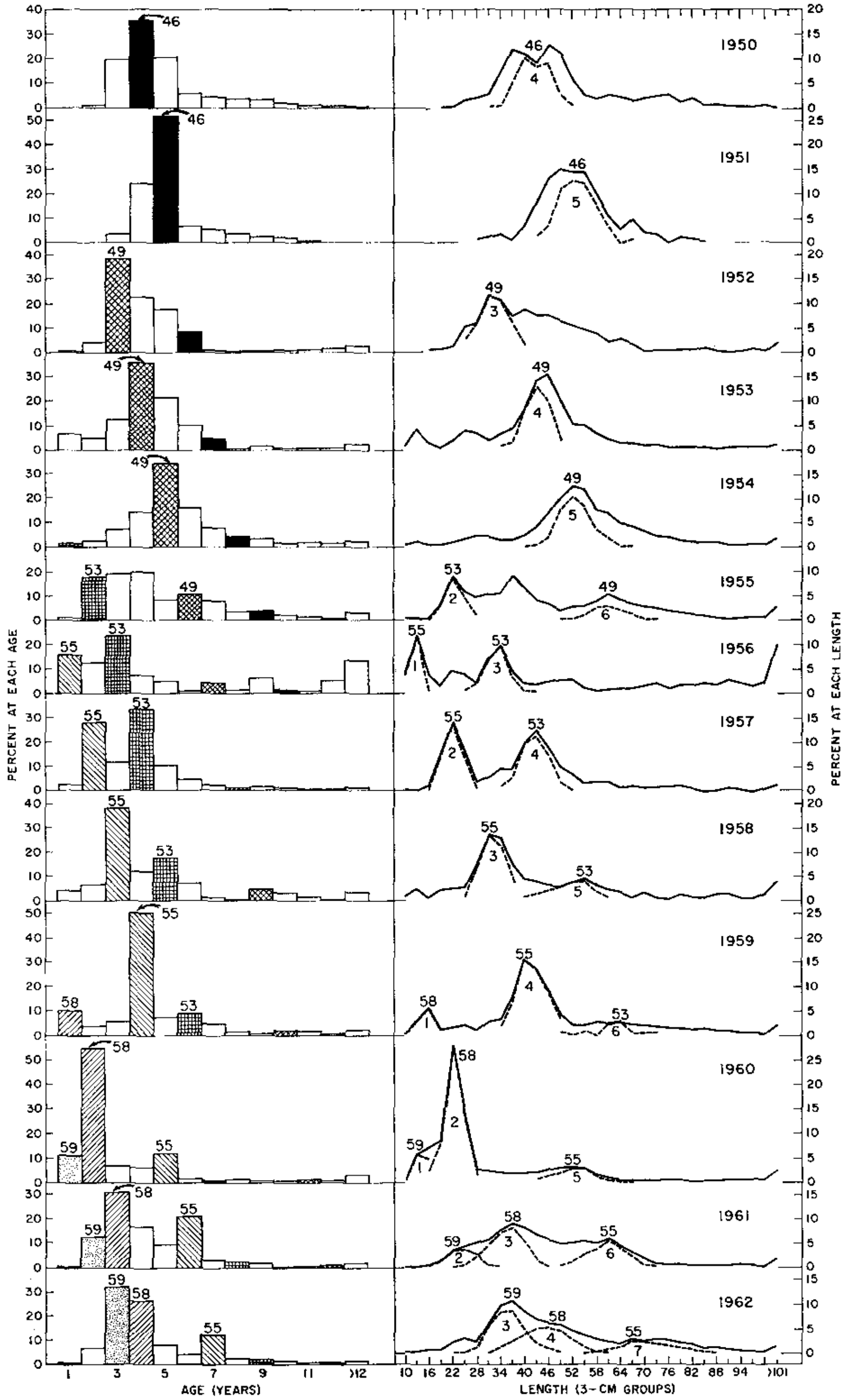

Fig. 2. Adjusted age and length distributions of research vessel catches of cod from spring surveys on the southern Grand Bank, 1950–1962.

the length distributions occurs is 13–16 cm. Otoliths of these fish typically show an opaque central area, surrounded by a well-defined translucent zone, with sometimes a small amount of opaque material on the otolith edge (Fig. 3A). These are regarded as having completed one year of growth, with any opaque edge material representing the beginning of the next growing year. Some otoliths also exhibit a very narrow translucent zone close to the centre (Fig. 3C and 3D), and this is regarded as a "settling check", its formation probably related to the attainment of a bottom or near-bottom dwelling existence.

The next largest size at which a well-defined mode occurs is 22–25 cm, and after that at 31–37 cm, 40–46 cm and 52–55 cm. Thus it would be expected that these represent ages 2–5 respectively. This assumption is quite justified by the progression of modes through each of these length ranges from year to year. This is particularly evident for fish of the 1955 year-class in the length distributions of 1956 to 1960, and the presence of this year-class can even be discerned in the length distributions of 1961 and 1962. On this basis, ages can be assigned to the most prominent modes in the length distributions

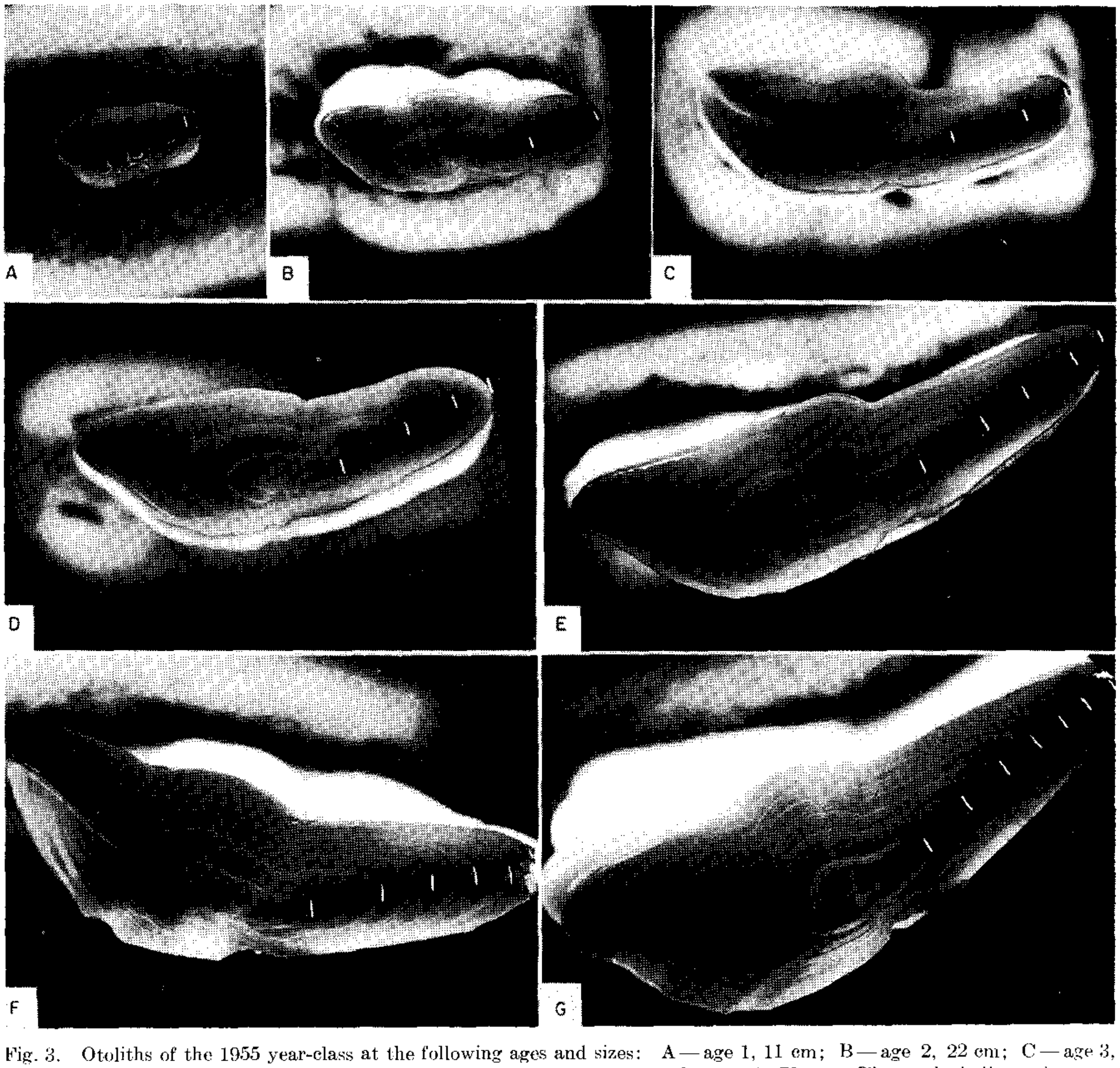

Fig. 3. Otoliths of the 1955 year-class at the following ages and sizes: A — age 1, 11 cm; B — age 2, 22 cm; C — age 3, 36 cm; D — age 4, 41 cm; E — age 5, 52 cm; F — age 6, 65 cm; G — age 7, 70 cm. The marks indicate the outer edge of each complete annulus.

(Fig. 2), and show that the most abundant year-classes in this period were those of 1946, 1949, 1953, 1955, 1958 and 1959. The modes tend to become indistinct beyond age 5.

Figure 2 also shows the adjusted age distributions for each year and the calculated length distributions of the dominant age-groups. These have been determined from yearly age-length keys (except as noted earlier) constructed on the basis of otolith ages. The very close correspondence of the calculated length distributions for dominant ages to the modes of the overall length distribution, and the progression of dominant year-classes through the yearly age distributions, provide very convincing evidence of the validity of otolith ages in the area under consideration.

Representative otoliths of the 1955 year-class at ages 1–7 are illustrated in Fig. 3. It is obvious that assignation of annuli sometimes involves grouping of zones (Fig. 3F and 3G).

Discussion and Conclusions

The importance of validity studies to determine the reliability of a particular method of age determination should not be underestimated. Aside from the need to establish the reliability of an ageing method for a particular species or area, determination of age from skeletal structures usually involves interpretation of zone patterns rather than straightforward counting. Validity studies provide criteria for such interpretation. Thus Sandeman (1961) uses Petersen's method to support evidence from scales and otoliths of slow growth rate for Hermitage Bay (Newfoundland South Coast) redfish, and Kohler (1964) uses it to establish a basis for identification of the first annulus on otoliths of cod from the Western Gulf of St. Lawrence (Division 4T).

In the present study the following of dominant year-classes, and the comparing of their length distributions with the various sections of the overall length distributions, are facilitated by the obvious variability in year-class survival. While there are no complete failures of year-classes, such as occur in the haddock population of this area (Templeman, MS, 1964), some year-classes are consistently poorly represented (1950 and 1956), while others (1949 and 1955) dominate the age distributions for several years and continue to stand out even at ages up to 7–9. It is of interest to note that the two apparently largest year-classes (1949 and 1955) are followed by two of the smallest.

Also worthy of note is the correspondence between the relative survival of cod year-classes and those of haddock in the same area. Templeman (MS, 1964) describes haddock survival as very successful in 1949 and 1955, years of very successful cod survival as well. Haddock survival is described as moderate in 1946 and 1952, and modest in 1947, 1953, and 1956. Of these years, particularly significant survival of cod year-classes occurred in 1946 and 1953. Thus with the exception of 1958 and 1959, best survival of cod occurred in years in which haddock were particularly abundant. This would appear to point to some physical factor or factors, operating simultaneously on both species as having the controlling influence on survival. The adverse effect on cod should not be as great as on haddock, since fluctuations in survival of cod year-classes might be evened out by replenishment at the larval and later stages from areas to the north, while no northerly haddock populations are present in the area.

Acknowledgements

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A Comparison of Random and Stratified Sampling Methods for Age and Growth Studies in the Newfoundland Inshore Cod Fishery

BY A. T. PINHORN[1] AND A. M. FLEMING[1]

Abstract

Comparisons were made between age distributions and average length-at-age values calculated from random samples and "stratified" samples derived from these random samples of cod caught in the Newfoundland inshore fishery. Results indicated that the age distributions and average length-at-age values were similar for both types of samples. The greatest differences between individual age-groups occurred with the trap samples whereas the greatest difference between age distributions as a whole occurred with the gillnet samples. Average length-at-age values showed some differences between random and "stratified" samples for fish 10 years and older but this would be somewhat corrected in actual stratified samples. The conclusion was that stratified samples using lesser numbers of otoliths can be used to study age distributions and growth rates in the Newfoundland inshore fishery. The limitations of the method of stratified sampling are discussed.

Introduction

The use of age-length keys, together with random subsampling as a method for calculating age distributions from a relatively small number of otoliths and a large number of length measurements, was first proposed by Fridriksson (1934) in the study of the cod of the North Atlantic. It was later employed by Graham (1938) for cod and Hodgson (1939) for herring and has since become very widely used in fisheries research. However, this method of sampling has certain disadvantages. First, it usually involves the collection of large numbers of otoliths, because, to obtain sufficient numbers of otoliths of the larger and smaller fish in the population, 10–20% of the fish measured must be subsampled for otoliths. Second, even with this sampling proportion, the larger and smaller fish are still not adequately sampled and insufficient numbers are obtained for use with age-length keys and in growth-rate studies. This latter problem can be solved by obtaining, in addition to the regular random sample, a number of category otoliths in the larger and smaller length-groups but this only adds to the first problem of a large number of otoliths from which to determine ages.

Stratified subsampling and an age-length key has been used by Ketchen (1950) in determining the age distribution of samples of Pacific flounder (*Parophrys vetulus*). Essentially, it involves the collection of an equal number of otoliths in each length-group. This method ensures that the larger and smaller fish in the population will be adequately represented in the sample while at the same time the collection of unnecessarily large numbers of otoliths at the peak of the length frequency will be avoided. This will usually result in the collection of fewer otoliths in any one sample and a lesser number of time-consuming age determinations will be involved. Tanaka (1953), Gulland (1955, 1962) and Pope (1956) review the theoretical and statistical aspects of random and stratified sampling.

Prior to the 1963 sampling season the usual procedure of sampling in the inshore Newfoundland fishery was to measure large numbers of cod and collect a smaller random sample of otoliths for age and growth studies, supplemented in some cases by the collection of category otoliths at the larger sizes. However, when the ages of these otolith samples were determined and age distributions calculated in recent years, the difficulty of using age-length keys based on these random and category samples and the large numbers of unnecessary otoliths at the peaks of the length frequencies became apparent. Consequently, a system of stratified sampling was employed in the 1963 sampling season.

The purpose of this paper is to compare age distributions and average length-at-age values calculated from random samples of otoliths with

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TABLE 1. Details of samples used in the comparison of random and stratified sampling of cod in the Newfoundland inshore fishery.

ICNAF Division	Sampling center	Gear	Date of capture	Random otoliths	"Stratified" otoliths	Percentage S/R
				no.	*no.*	
3Ps	Burin	Trap	June–July 1962	412	195	47
3L	St. John's	Trap	June–Aug. 1962	810	230	28
3L	Bonavista	Trap	June–July 1962	315	171	54
3L	Bonavista	Handline	June–July 1962	236	175	79
3Ps	Burin	Linetrawl	May–July, Sept. 1962	610	276	45
3L	Bonavista	Longline	June, July, Sept. 1962	473	260	55
3L	Trepassey	Gillnet	July–Aug. 1961, June–July 1962	524	344	64
Total				3,380	1,651	49

those calculated from "stratified" samples derived from these random samples by a procedure of random selection. The "stratified" samples referred to here are actually modified stratified samples since a greater number of otoliths are selected in the larger length-groups than in the smaller length-groups. The random samples referred to will actually consist of random samples plus category samples at the larger and smaller sizes.

Materials and Methods

Table 1 gives details of the samples used in the comparison of random and stratified sampling. Otolith samples from each of the major gears in use in the Newfoundland inshore cod fishery are represented.

Essentially, the method used was to calculate age distributions and average length-at-age values by using age-length keys derived from random samples of otoliths and length measurements of larger numbers of fish. These random samples were then "stratified" such that equal numbers of otoliths were obtained for each 3-cm length-group at each level of stratification. The age-length keys derived from these "stratified"samples were used with the same length measurement frequencies to calculate age distributions and average length-at-age values. These values were then compared with those from the random samples.

The procedure of "stratifying" the random samples was as follows: Since the otoliths in the random samples were each assigned a specimen number at the time of sampling, the numbers ascending in order as the sampling season progressed, the first step was to arrange these specimen numbers by 3-cm length-groups but also in ascending order of magnitude. By a system of random selection with numbered cards, the specimen numbers in each 3-cm group were then arranged in a random order. Finally, the desired number of otoliths was randomly selected from the random otoliths in each 3-cm group to arrive at the "stratified" sample covering all length-groups. The ages of the otoliths selected were then used to derive an age-length key.

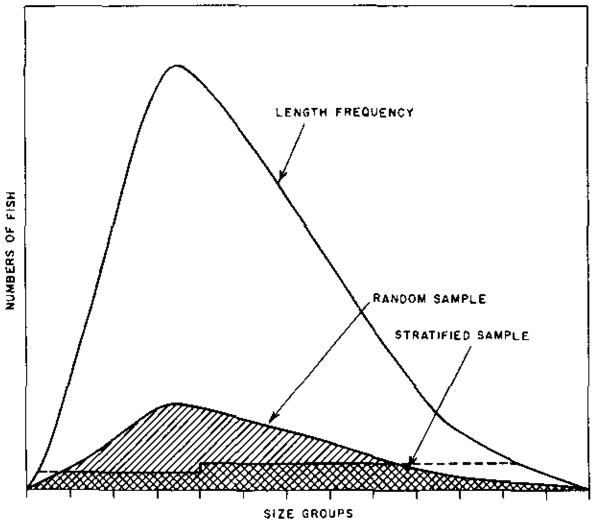

Fig. 1. Theoretical length frequency, random sample and "stratified" sample to illustrate the method of stratification used in this study.

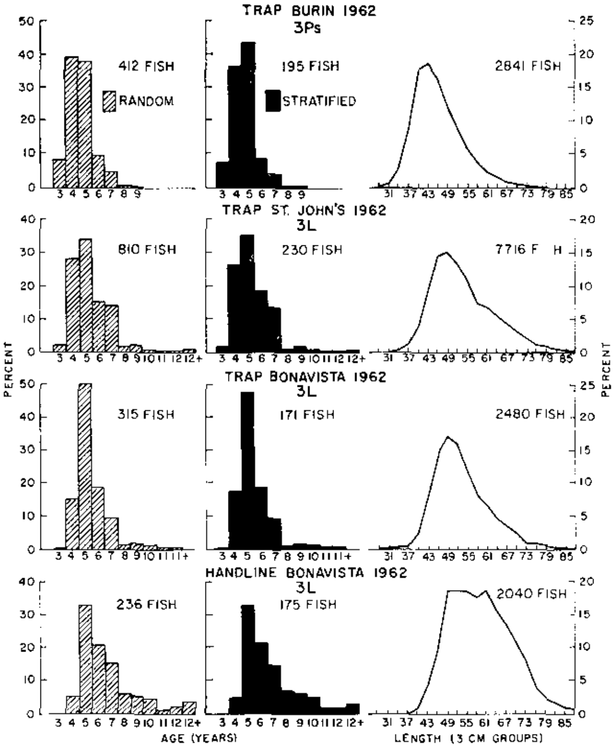

Fig. 2. Comparisons of age distributions of cod calculated from random and "stratified" otolith samples of fish caught by various gears in the inshore Newfoundland fishery. The actual length frequencies are shown for comparison.

Figure 1 shows the theoretical relationships between length frequencies, random samples and "stratified" samples as used in this study. The "stratified" sample obtained in this case does not represent a true stratified sample such as would be collected in actual practice since above and below certain length-groups the numbers of fish in the random sample were less than the level chosen for the stratification. In fact the dotted line represents the additional otoliths needed for a true stratified sample.

Except for gillnet fish in the Trepassey area (Table 1) the level of stratification was such that 10 fish in each 3-cm length-group were selected between 30 and 50 cm in length and 15 fish in each 3-cm group were selected above 50 cm. For gillnet fish from the Trepassey area the level of stratification necessary was found to be higher, 15 fish 71 cm and below and 20 fish above 71 cm. At the smaller sizes, when the number in any 3-cm group in the random sample was below the desired level of stratification, all the fish were selected for the "stratified" sample. At the larger sizes, when the number in any 3-cm group was only slightly below the desired number, all fish were selected but when the number was considerably below the desired number, the length-groups above this size were combined and considered as one large length-group. All the fish in this length-group were selected for the "stratified" sample even though this number at times exceeded the desired level of stratification. In calculating the average length for an age-group containing fish in these combined length-groups, the procedure was to calculate the average length of the fish in these combined length-groups from the random sample and use this value for both random and "stratified" samples. Although this procedure may not be strictly valid for purposes of computing actual growth rates of populations, it should yield comparable values in this study since any bias introduced should have the same effect on both random and "stratified" samples.

Results

The age distributions calculated from random and "stratified" samples are shown in Fig. 2 and 3 and Table 2. The close agreement between the percentages of fish at each age is apparent for each type of gear studied. The greatest differences between individual age-groups occurred with the trap samples where the age distributions are comprised of only a small number of early age-groups (4-, 5- and 6-year-old fish)

TABLE 2. Comparisons of percentages of cod at each age calculated from random (R) and "stratified" (S), otolith samples of fish caught by various gears in the Newfoundland inshore fishery.

Age years	Burin trap R	Burin trap S	St. John's trap R	St. John's trap S	Bonavista trap R	Bonavista trap S	Bonavista handline R	Bonavista handline S	Burin linetrawl R	Burin linetrawl S	Bonavista longline R	Bonavista longline S	Trepassey gillnet R	Trepassey gillnet S
3	8.5	7.5	2.3	1.8	0.3	0.3	—	—	0.7	0.5	0.4	0.5	0.1	0.1
4	39.5	36.5	28.8	26.5	15.2	17.8	5.9	5.0	10.2	9.5	6.6	7.8	0.3	0.3
5	37.8	43.1	34.1	35.5	50.6	47.9	33.3	33.4	30.2	33.8	20.8	19.0	0.7	0.7
6	9.1	8.4	15.6	18.5	18.8	18.9	21.0	21.2	15.7	14.4	16.5	17.1	3.8	3.5
7	4.5	3.9	14.3	13.4	9.3	9.4	15.9	15.1	26.5	24.5	15.1	16.5	15.1	15.8
8	0.4	0.4	1.6	1.2	1.8	1.7	6.0	7.0	3.8	4.3	4.6	4.0	10.4	9.3
9	0.3	0.1	2.1	1.9	1.7	1.7	5.3	6.4	4.7	4.8	7.8	8.0	11.4	10.2
10			0.8	0.8	1.4	1.4	4.6	5.1	3.4	3.7	6.5	4.8	9.5	12.0
11			0.1	0.1	0.5	0.5	1.7	1.7	1.3	1.4	2.4	3.0	10.4	11.6
					(11+)	(11+)								
12			0.2	0.1	0.4	0.4	2.3	1.8	0.8	0.5	2.0	2.0	12.2	11.0
			(12+)	(12+)			(12+)	(12+)						
13			0.2	0.2			3.9	3.3	0.7	0.6	3.8	3.3	11.6	12.2
14									1.4	1.5	3.4	2.2	5.6	5.4
									(14+)	(14+)				
15									0.6	0.6	5.6	6.4	5.3	4.3
16											1.5	2.3	0.9	0.9
											(16+	(16+)		
17											2.9	3.2	0.8	0.7
18													0.7	0.9
													(18+)	(18+)
18+													1.4	1.3

TABLE 3. Comparisons of average lengths in centimetres of cod at each age calculated from random (R) and "stratified" (S) otolith samples of fish caught by various gears in the Newfoundland inshore fishery.

Age years	Burin trap R	Burin trap S	St. John's trap R	St. John's trap S	Bonavista trap R	Bonavista trap S	Bonavista handline R	Bonavista handline S	Burin linetrawl R	Burin linetrawl S	Bonavista longline R	Bonavista longline S	Trepassey gillnet R	Trepassey gillnet S
3	36.7	35.7	39.9	37.9	36.0	35.8	—	—	38.2	38.7	39.7	40.3	37.0	37.0
4	42.0	42.2	45.6	45.4	44.0	44.1	44.7	43.9	45.8	45.5	47.5	48.3	46.3	46.3
5	47.7	47.2	50.8	50.4	50.1	50.5	51.2	51.2	52.0	51.9	52.4	52.5	55.5	55.5
6	56.0	56.9	57.7	57.4	57.5	57.3	58.8	58.4	59.3	60.9	59.2	59.6	62.1	61.6
7	62.2	62.6	65.4	66.3	64.7	64.6	65.4	65.5	66.1	66.4	64.8	64.9	70.0	70.6
8	70.9	70.0	70.5	71.4	71.2	71.2	67.2	66.4	71.2	71.4	67.5	68.3	75.2	74.9
9	80.3	80.3	74.1	75.4	66.7	66.5	70.0	69.3	77.6	76.7	68.9	70.2	79.5	78.7
10			75.8	75.9	68.9	68.9	78.4	78.1	81.1	80.7	73.2	73.6	82.0	82.9
11			90.0	90.0	74.1	74.1	70.6	71.2	83.3	82.8	76.5	74.7	84.2	83.5
12			69.3	73.0			68.1	68.5	84.4	88.9	73.6	75.1	87.8	88.3
13									91.9	95.0	78.4	80.1	89.7	89.9
14									92.2	91.5	76.2	78.3	92.8	93.3
15											76.9	76.0	94.5	94.4
16											77.0	75.3	104.6	104.5
17													101.1	100.6
18													105.0	103.1

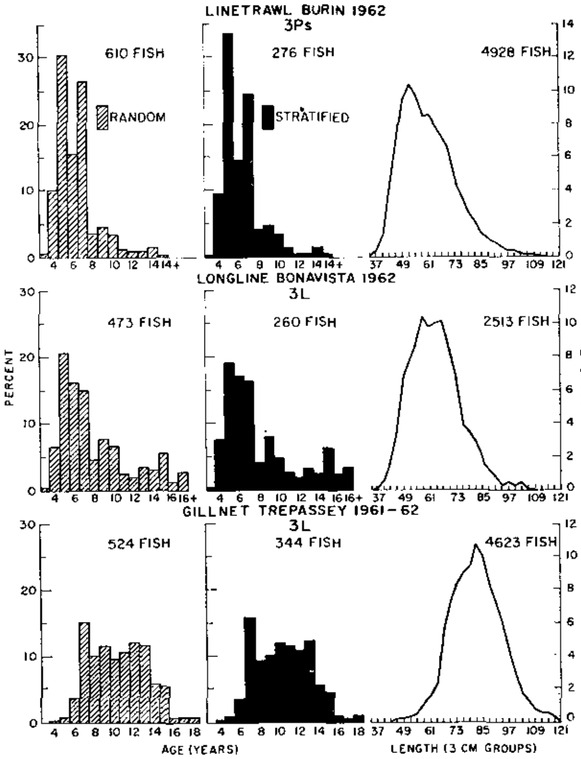

Fig. 3. Comparisons of age distributions of cod calculated from random and "stratified" otolith samples of fish caught by various gears in the inshore Newfoundland fishery. The actual length frequencies are shown for comparison.

and the length frequencies have peaks ranging between 40 and 60 cm. The greatest overall difference in the age distribution as a whole occurred with the gillnet samples where the distribution is based on a wide range of age-groups and the length frequency has a peak at 81–83 cm.

The average length-at-age values calculated from random and "stratified" samples are shown in Fig. 4 and 5 and Table 3. It can be seen that there is good agreement between the random and "stratified" curves with each gear used except the longline. In fact the two curves for trap gear at Bonavista are not shown in Fig. 4 and 5 because they are practically identical. The length-at-age values calculated from random and "stratified" samples are somewhat different for fish greater than 10 years of age and this is especially true of the longline sample for Bonavista (Fig. 5) where the differences are apparent at 8 and 9 years of age also.

Discussion and Conclusions

From the above results it is apparent that age distributions calculated from "stratified" samples of otoliths give results very similar to age

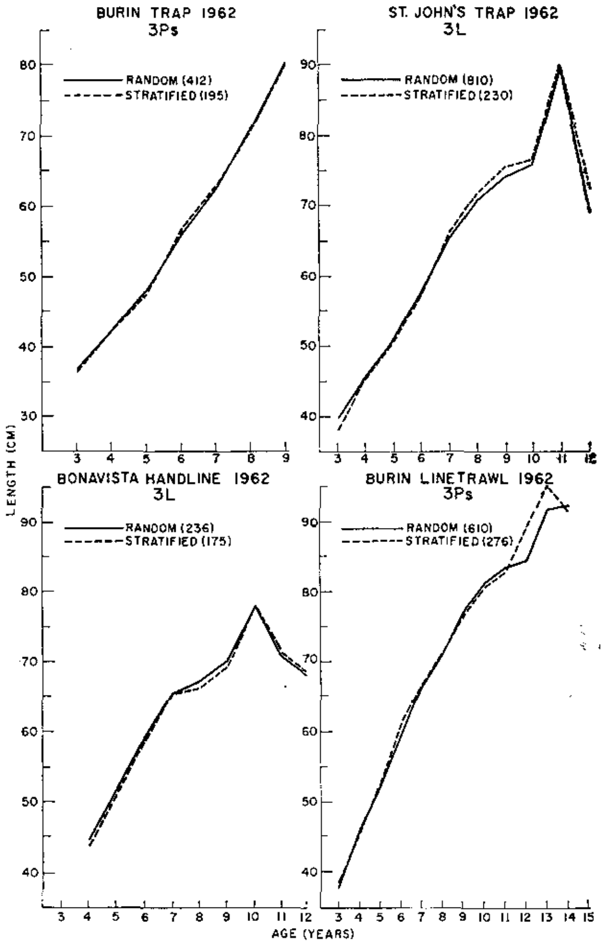

Fig. 4. Comparisons of average length at each age of cod calculated from random and "stratified" otolith samples of fish caught by various gears in the Newfoundland inshore fishery. Numbers in parentheses are numbers of otoliths in the samples.

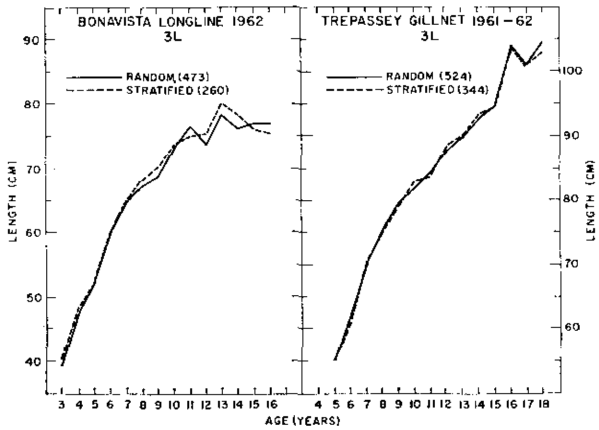

Fig. 5. Comparisons of average length at each age of cod calculated from random and "stratified" otolith samples of fish caught by various gears in the Newfoundland inshore fishery. Numbers in parentheses are numbers of otoliths in the samples.

distributions from random samples. In fact it means that by using approximately the same numbers of otoliths at the lower and higher lengths as in the random samples, but using considerably lesser numbers of otoliths at the peak of the length frequency, an age distribution can be calculated which represents the true age distribution of the fish caught by the inshore gear in question as well as that calculated from random samples with considerably more otoliths. The number in each length-group necessary for a "stratified" sample will, of course, depend on the peak of the length frequency as illustrated by the gillnet results in this study, where levels of 15 and 20 had to be used rather than 10 and 15 to obtain reasonable agreement between random and "stratified" samples. Some of the differences that did occur would in fact be decreased in magnitude in an actual "stratified" sample by the collection of proportionately more otoliths from fish of larger size than in the random sample.

Ketchen (1950) in comparing random and "stratified" samples for the Pacific flounder found significant differences using a χ^2 test when five fish were selected in each centimetre group but no significant differences with 10 and 15 fish in each centimetre group. These differences with five fish probably resulted because there was a considerable spread in the age distribution within any particular length-group.

The results of the present study also indicate that "stratified" samples can be used for growth studies, as good agreement was found between growth-rate curves calculated from random and "stratified" samples. The disagreement that did result at the higher ages would be somewhat corrected in an actual "stratified" sample since the number of otoliths collected at the larger sizes would be increased, and above a certain size for each gear the otoliths would be collected from all fish measured.

The differences found between the age distributions and growth rates from random and "stratified" samples are not very significant when one considers the errors that are possible and are probably made in the actual age determinations of the otoliths themselves. In fact the senior author has found differences as great as those demonstrated here by reading a sample of random otoliths on two different occasions.

A measure of the time and labor saved by taking "stratified" samples for age and growth studies is illustrated in Table 1. The % column represents the number of "stratified" otoliths expressed as the percentage of the number of random otoliths. It can be seen that, except for handline where only a small random sample was available initially, the values range from 28 to 64%, the average value being 49%. This means that age distributions based on only one-third to two-thirds as many otoliths would adequately represent the true age distribution of the fish caught by various gears in the Newfoundland inshore fishery.

The stratified sampling method is applicable to sampling for age distributions and growth rate studies in the commercial fishery, both inshore and offshore, where the fish landed and consequently sampled in a specified period are usually from the same area and the same population. However, the method may require some modification in research vessel surveys over a wide area in which there are wide ranges of depths and temperatures and wide ranges in numbers of fish caught at these different depths and temperatures. Also, the method is directly applicable to age and growth studies where it is customary to adjust to length distributions and can be used for sex and maturity studies after adjustment to the length frequency. It can also be used directly in length-weight studies where the weight values stratified by length groups can be used directly for calculation of length-weight curves. However, it may not be very applicable to such biological studies as vertebral and parasite studies for which random samples are usually preferable.

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Trends in the Cod Fishery Off the East Coast of Newfoundland and Labrador

BY V. M. HODDER[1]

Introduction

Prior to World War II the traditional fishery for cod off the east coasts of Newfoundland and Labrador has been largely an inshore fishery with extensive offshore line fisheries from dory vessels in the southern part of the region. Following the introduction of trawling in the late 1920's, the once important offshore line fisheries rapidly declined. Except for Portugal which still has a large dory-vessel fleet, most of the offshore cod fishery is carried on at present by large trawlers from a dozen or more countries, principal among them being France, Portugal, Spain and USSR. Even trawlers from as far away as Japan have recently started to fish the very productive fishing grounds of the Northwest Atlantic. With the rapid expansion of trawling fleets in the 1950's, there has been a steady movement of fishing operations from the Grand Bank northward into the waters of Division 3K and Subarea 2 as new cod concentrations were discovered.

The cod fishery considered in this paper is based on a stock complex which extends from the northern part of the Grand Bank northward along the continental shelf off the east coasts of Newfoundland and Labrador. Although there is a gradual decrease in growth from south to north (May *et al.*, 1964; Fleming, 1960), Templeman (1962) considers the stock as a complex of cod populations with no real temperature or depth barriers to north–south mixing other than distance. The stock complex follows a seasonal inshore–offshore migratory pattern, the degree of concentration both in the coastal waters and offshore depending largely on the temperature conditions of the Labrador Current. During autumn, winter and spring, when the shallow coastal water is too cold, the cod live in deep water on the slopes of the continental shelf, where they are available to the offshore trawl fishery. In late spring, when the coastal water becomes sufficiently warm, large numbers of cod move toward the coast in conjunction with the shoreward spawning migration of capelin, and for 3 or 4 months during the summer they are fished intensively by Canadian inshore fishermen.

The importance of this stock complex is reflected in the statistics of cod landings by the various countries with fleets of trawlers and other vessels fishing in the Northwest Atlantic as reported in Statistical Bulletins of ICNAF. For example, in 1961–63 the annual cod yield averaged 1,316 thousand metric tons for the ICNAF Convention Area, of which an annual average of 502 thousand tons (38%) was reported as landed from the waters off the east coasts of Newfoundland and Labrador (ICNAF Subarea 2 and Divisions 3K and 3L).

Trends in Landings, 1954–63

Examination of statistics of landings reveals that great changes have taken place in the fishery on the East Newfoundland-Labrador stock complex. In Table 1 the cod landings, expressed in thousands of metric tons, round fresh weight, for the years 1954–63 are given by countries and also by major gear components, insofar as they were available. Prior to 1954 statistics were not available by division or for all countries.

From 1954 to 1957 total cod landings for the stock complex were relatively stable at 265–305 thousand tons. A low value of 220 thousand tons occurred in 1958, due largely to poor fisheries by all gears in Division 3L. Starting in 1959 there was a rapid increase in total cod landings to just over 500 thousand tons in 1961 and 1962 with a slight decline in 1963. While the Canadian fishery, largely inshore, showed a decline over the period, the fishery by other major cod-fishing countries increased substantially. This increase is reflected by a four-fold increase in the cod landings by trawlers between the 1954–58 period and 1961–62.

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TABLE 1. Cod landings (thousands of metric tons) by countries and by major gear components for Subarea 2 and Divisions 3K and during 1954–63.

		Landings by country									Landings by gear		
		Canada	France	Germany	Portugal	Spain	USSR	UK	Others	Total landings	Trawl	Line	Insh
Subarea 2	1954	11.7	4.1	—	3.0	0.3	—	—	—	19.1	7.4	–	11
	1955	10.5	7.6	—	7.7	—	—	—	—	25.8	15.3	—	10
	1956	8.7	12.3	—	13.0	0.3	—	—	—	34.3	25.6	—	8
	1957	11.7	12.7	—	7.0	0.8	—	—	—	32.2	20.5	—	11
	1958	11.5	17.7	0.6	8.2	1.6	0.5	—	0.1	40.2	29.1	—	11
	1959	18.9	23.7	3.2	6.5	5.7	0.2	1.5	0.3	60.0	41.1	—	18
	1960	16.7	46.1	11.8	43.8	29.6	38.6	0.1	1.5	188.2	171.5	—	16
	1961	18.6	36.5	11.1	46.1	41.4	109.6	1.3	0.4	265.0	246.4	—	18
	1962	24.6	46.0	0.7	62.8	57.0	60.1	3.0	1.0	255.2	230.6	—	24
	1963	24.7	40.1	0.9	73.3	54.6	20.8	0.5	0.8	215.7	191.0	—	24
Division 3K	1954	82.6	18.5	—	5.4	0.7	—	—	—	107.2	24.6	—	8
	1955	59.2	15.9	—	5.9	—	—	—	—	81.0	21.8	—	5
	1956	70.3	6.6	—	2.2	0.3	—	—	—	79.4	9.1	—	7
	1957	67.5	13.6	—	2.1	0.1	—	—	0.1	83.4	15.4	0.5	6
	1958	33.7	22.2	—	7.2	9.3	0.7	—	0.4	73.5	39.8	—	3
	1959	56.3	21.5	—	28.2	24.4	6.4	0.6	1.9	139.3	83.0	—	5
	1960	47.7	14.5	—	16.0	12.4	26.0	0.9	0.6	118.1	70.4	—	4
	1961	31.2	18.1	2.3	18.9	11.8	8.6	0.3	0.5	91.7	60.4	0.2	3
	1962	42.8	8.7	0.4	13.1	9.8	11.3	1.1	1.2	88.4	45.2	0.4	4
	1963	47.5	12.3	0.5	30.1	10.9	16.3	0.1	5.1	122.8	*	*	
Division 3L	1954	106.5	19.7	—	41.5	9.9	—	0.9	—	178.5	65.9	19.5	9
	1955	100.3	15.9	—	36.6	5.0	—	—	—	157.8	43.0	29.7	8
	1956	104.3	17.4	—	50.1	15.0	—	—	0.2	187.0	62.6	31.1	9
	1957	84.1	19.4	—	45.2	10.2	1.6	0.7	—	161.2	60.7	20.2	8
	1958	70.8	8.8	—	17.7	8.1	0.5	—	—	105.9	31.4	6.5	6
	1959	90.2	10.1	0.7	20.4	8.1	2.3	0.7	0.8	133.3	36.5	11.1	8
	1960	101.5	16.2	1.8	21.8	13.2	1.4	5.1	0.8	161.8	49.8	17.8	9
	1961	75.3	13.9	0.6	25.6	21.4	4.5	2.9	1.5	145.7	60.0	15.0	7
	1962	76.4	27.0	0.1	22.2	33.7	2.4	1.5	0.8	164.1	80.8	11.0	7
	1963	77.7	11.1	1.5	29.2	25.7	5.2	4.9	1.1	156.4	*	*	
Total for stock complex	1954	200.8	42.3	—	49.9	10.9	—	0.9	—	304.8	97.9	19.5	18
	1955	170.0	39.4	—	50.2	5.0	—	—	—	264.6	80.1	29.7	15
	1956	183.3	36.3	—	65.3	15.6	—	—	0.2	300.7	98.3	31.1	17
	1957	163.3	45.7	—	54.3	11.1	1.6	0.7	0.1	276.8	96.6	20.7	15
	1958	116.0	48.7	0.6	33.1	19.0	1.7	—	0.5	219.6	100.3	6.5	11
	1959	165.4	55.3	3.9	55.1	38.2	8.9	2.8	3.0	332.6	160.6	11.1	16
	1960	165.9	76.8	13.6	81.6	55.2	66.0	6.1	2.9	468.1	291.7	17.8	15
	1961	125.1	68.5	14.0	90.6	74.6	122.7	4.5	2.4	502.4	366.8	15.2	12
	1962	143.8	81.7	1.2	98.1	100.5	73.8	5.6	3.0	507.7	356.6	11.4	13
	1963	149.9	63.5	2.9	132.6	91.2	42.3	5.5	7.0	494.9	*	*	

*Landings by gears not available for 1963.

Except for some annual variation, there has been little change in the level of total cod landings or in the landings of the major gear components for Division 3L. In Division 3K, however, although total cod landings have not changed substantially, there has been a considerable increase in trawler landings coincident with a decrease in the landings of the Newfoundland inshore fishery (Fig. 1). While there has been a decrease in trawl landings from 3K between

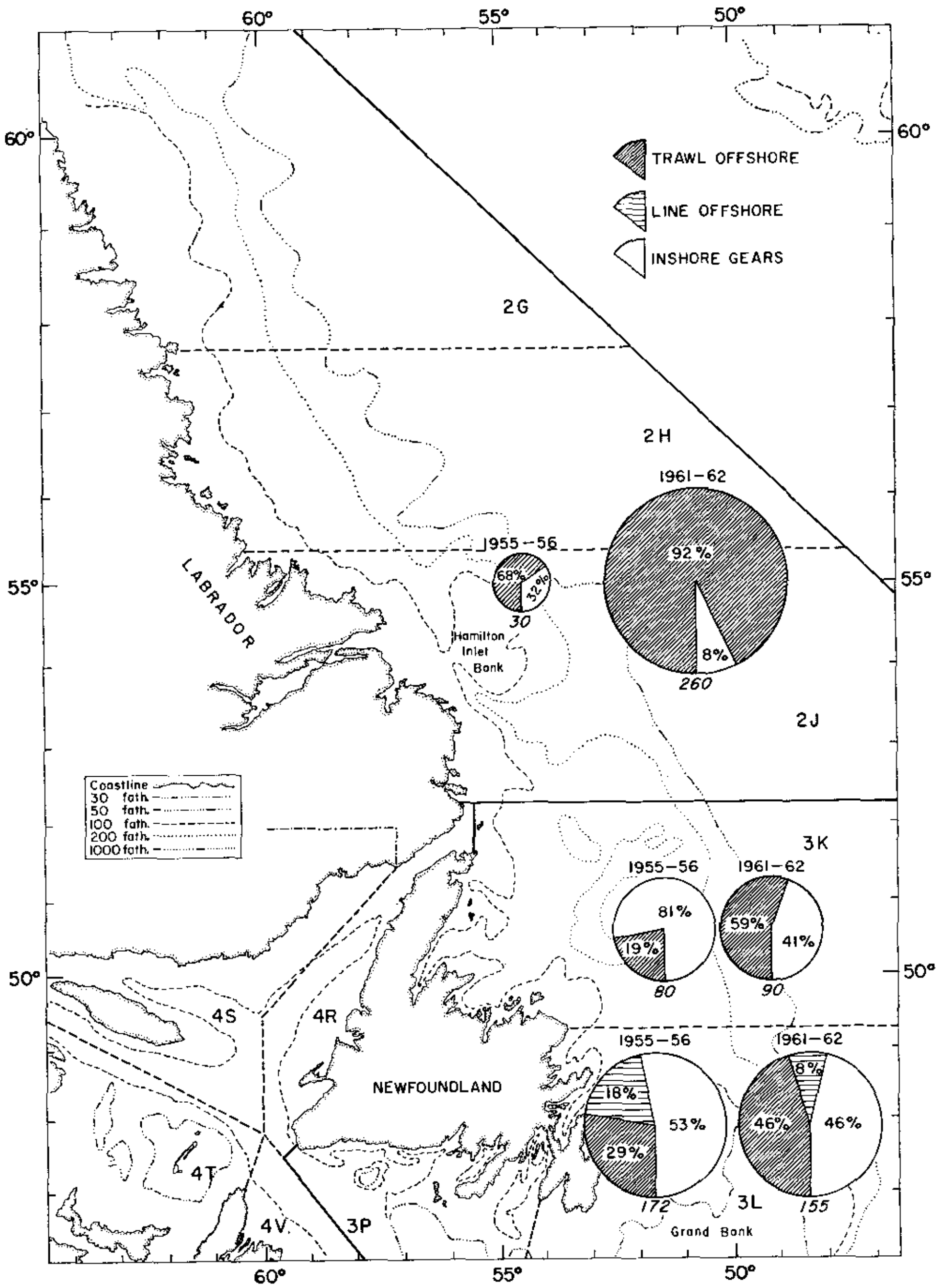

Fig. 1. Map of Subarea 2 and Divisions 3K and 3L showing the average annual distribution of cod landings by gears for 1955–56 and 1961–62.

1959 and 1962, probably attributable to a shift in fishing effort, the decrease in inshore landings is attributed to decreased availability of cod in the coastal waters. Some improvement in the total for 3K is noted for 1963 due mostly to increased landings by Portuguese vessels.

In Subarea 2 (mostly in the Hamilton Inlet Bank area, Division 2J) a very great offshore cod fishery developed between 1959 and 1961 when trawler landings reached a level of almost 250 thousand tons from less than 30 thousand tons annually in 1954 to 1958. The great changes occurred largely as a result of increased effort by trawler fleets of France, Portugal, Spain and USSR.

No significant developments have occurred in the offshore line fishery, carried on largely by Portuguese dory vessels; if anything, the trend in landings has been downward. This offshore fishery is closely parallel to the Newfoundland inshore fishery, in that both are seasonal in nature and both depend on the spring and summer migration of cod from deep water of the continental slope to shallow water where the fishing is carried on.

Trends in Effort and Landings per Unit Effort

The trawl fishery

It is obvious from the foregoing that the changes in landings, particularly by trawlers, are largely due to changes in the amount of effort expended, but changes in the landings per unit effort may also be a contributing factor. In order to distinguish between these causes, both annually and seasonally, estimates were made of the fishing effort (in standard units) expended in each of the three regions (Subarea 2, and Divisions 3K and 3L) for the 1954–62 period. These estimates were calculated by dividing the cod landings of trawlers in each region by standard landing per unit effort (L/E) values, which were obtained from the landing and effort data of selected trawler fleets that fished primarily for cod. The initial calculations were carried out on a monthly basis in order to detect any seasonal trends that might be apparent.

The standard unit of effort selected was the Portuguese otter trawler hour. In order to fill some gaps for months when little or no Portuguese effort was expended and to consolidate the landing per unit effort values in relation to the total landings of cod by trawlers, landing and effort data for Spanish otter trawlers were also used, but after conversion to the standard. In a few instances, i.e. months when neither Portuguese nor Spanish otter trawlers operated in an area, UK and USSR data (for > 1,800-ton trawlers) were used but only where necessary. These data were utilized without conversion, since the few landing per unit effort values available show those fleets as being directly comparable with the Portuguese fleet.

Before standardization the landings per unit effort were calculated on a monthly basis from the landing and effort data of Portuguese and Spanish otter trawlers. In Fig. 2 are shown the comparable landing per unit effort values, based on an expenditure by both fleets of 200 or more hours fishing in each region for each month. For all three regions the points are scattered linearly about a line passing through the origin, the slope of which was arbitrarily chosen as 0.8. The next step was to combine the trawl landings and effort of both fleets for each month in each region, with the effort by Spanish trawlers adjusted by a

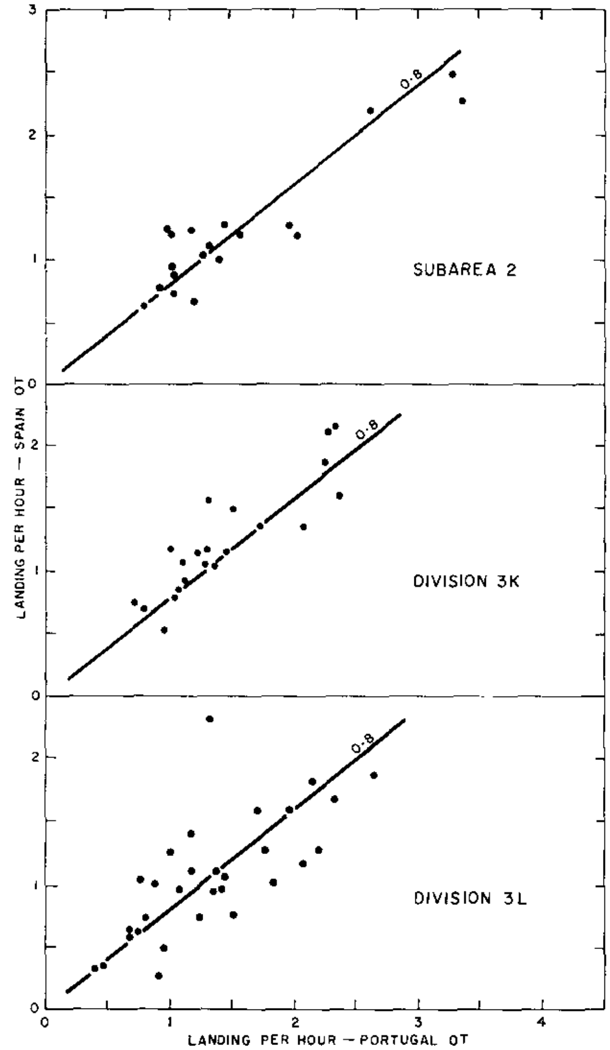

Fig. 2. Cod landings per hour fished (averaged on a monthly basis) for Spanish otter trawlers plotted against the corresponding landings per hour for Portuguese otter trawlers for the period 1955–61.

factor of 0.8. The average landing per hour (standard) in each month was then obtained by dividing the cod landing of both fleets by the adjusted effort. The effort for cod by all trawlers was estimated by dividing the total trawl landings for the month by the standard L/E for that month. The estimation of trawl effort by months has an advantage over the direct method of estimating effort on an annual basis, as carried out by Keir (1959), since it provides the basis for an analysis of trends in the fishery on a seasonal basis.

Subarea 2. Total landings of cod increased greatly between 1959 and 1961 coincident with the increase in trawler landings and effort (Fig. 3). The L/E (standard) declined to an average of about 1 ton per hour fished in 1958 but from 1959 to 1962 it increased to just over 2 tons per hour. When shown on a semi-annual basis, it is apparent that the great increase in landings occurred in the first half of the years 1960 to 1962, when the average L/E was about 3 tons per hour compared with just over 1 ton per hour for the second half of these years. During 1954–59 most of the cod taken in Subarea 2 were caught in the second half of the year, and for this seasonal period the L/E has generally declined from about 1.6 tons per hour in 1954–56 to 1.2 tons per hour in 1961–62. Although this subarea extends along the entire east coast of Labrador about 98% of the annual cod yields is obtained in the southern part of the subarea (Division 2J).

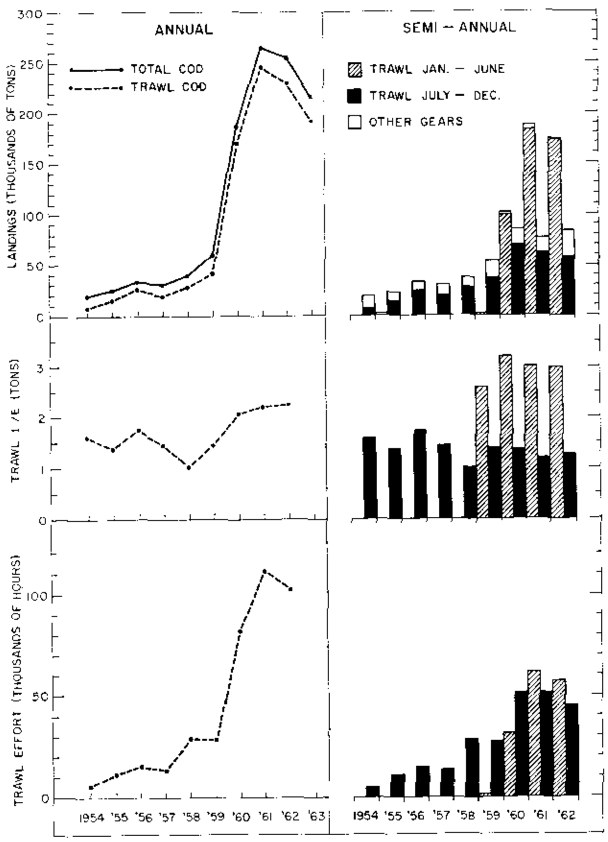

Fig. 3. Subarea 2 cod: landings, effort and landings per unit effort by trawlers, both annually and semi-annually, for the years 1954–62.

Division 3K. On an annual basis total cod landings varied between 75 thousand and 140 thousand tons (Fig. 4), the peak in 1959 having been the result of increased fishing activity by trawlers. The L/E has been relatively stable throughout the period, averaging 1.3–1.6 tons per hour fishing. Seasonally, however, fishing effort by trawlers up to 1958 occurred only in the second half of the year. As in Subarea 2, trawler exploitation of the spring concentrations started in 1959 and continued in 1960 with some decrease in 1961 and 1962, due probably to a shift in effort to the more productive spring concentrations of cod in Subarea 2. The average L/E

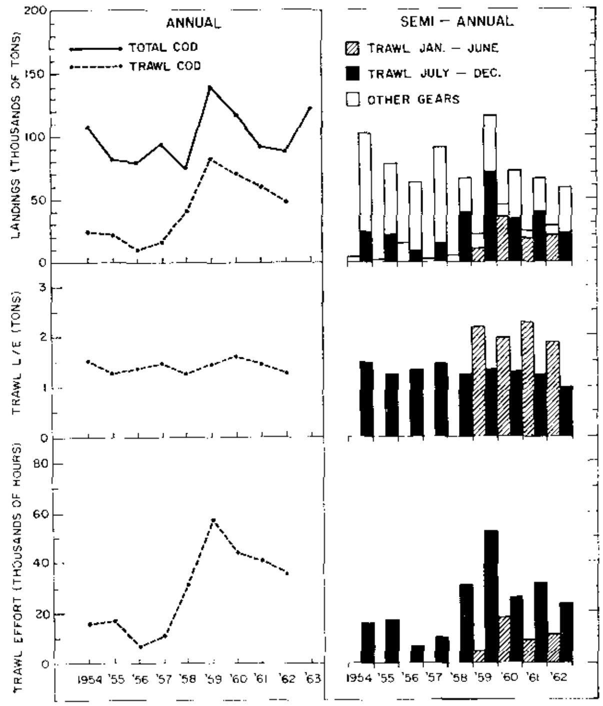

Fig. 4. Division 3K cod: landings, effort and landings per unit effort by trawlers, both annually and semi-annually, for the years 1954–62.

in this division during the first half of the years 1959–62 was about 2 tons per hour compared with a 1.0–1.5 range in L/E for the July–December period of the years 1954–62. Since 1959, however, the L/E for the second half of the year has steadily declined.

Division 3L. The trend in total cod landings has been generally downward with trawlers accounting for about one-third of the annual yields (Fig. 5). The trend in L/E has also been downward from about 1.6 tons per hour in 1954–56 to 1.1 in 1960 with some improvement to 1.4 in 1961 and 1962. Unlike the other 2 regions, trawlers have during the 9 years shown fished in Division 3L in both the January–June and July–December periods. The L/E for the first half of the year was generally more variable than for summer and autumn, in which the trend has been downward from about 1.5 tons per hour during 1954–57 to about 1 ton per hour in more recent years. For the period shown (1954–62) the spring fishery by trawlers has generally been more productive (in terms of L/E) than the fishery in the second half of these years, although the effort was usually higher for the latter.

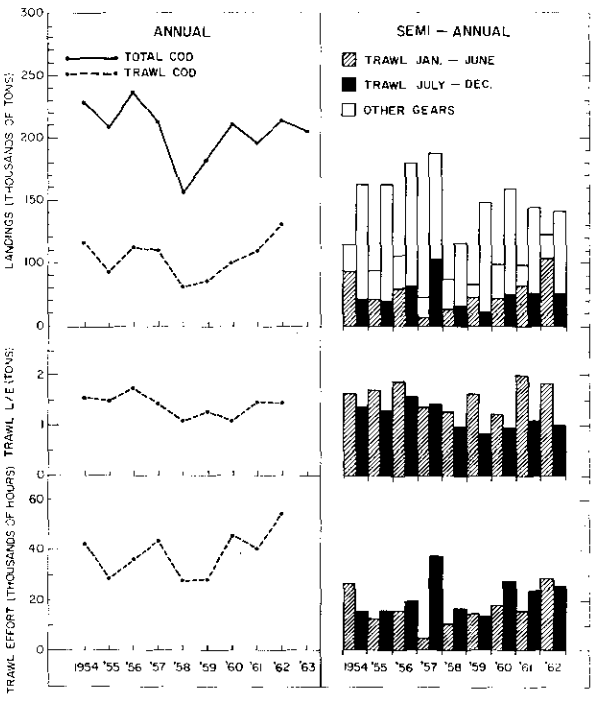

Fig. 5. Division 3L cod: landings, effort and landings per unit effort by trawlers, both annually and semi-annually, for the years 1954–62.

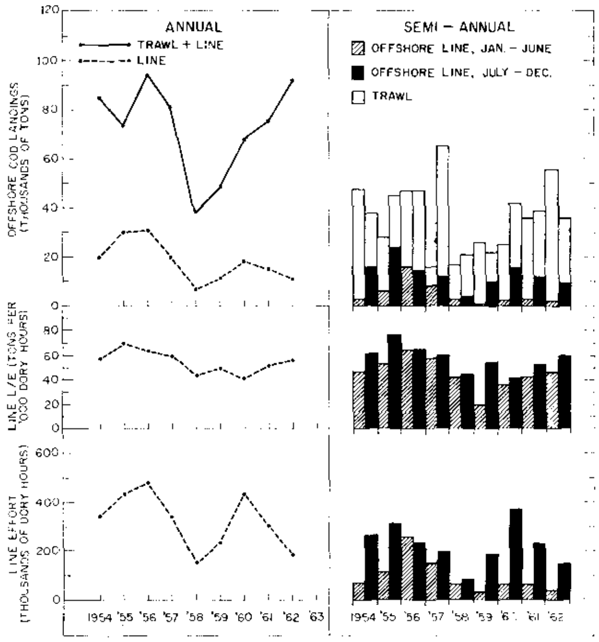

Fig. 6. Landings, effort and landings per unit effort for the offshore line fishery in Division 3L during the period 1954–62.

The offshore line fishery

While the offshore fishery for cod in Subarea 2 and Division 3K is entirely by trawlers (Table 1), about one-quarter of the landings from the offshore cod fishery of Division 3L is obtained by fishing with lines, mostly by a fleet of Portuguese dory vessels. The effort and L/E values shown in Fig. 6 were obtained from the revised Portuguese dory vessel data for 1956–62 given in the Appendices to ICNAF Statistical Bulletin, Vol. 11 and 12. The 1954 and 1955 adjustments were made by applying a conversion factor, based on the revised effort data of 1956, to the previously published unweighted effort data for 1954 and 1955. The effort is expressed in dory hours, i.e. the number of hours the dory fleet is absent from the mother ship times the number of dories.

The trend in landings, L/E and effort for the offshore line fishery has been downward since 1956 with a particularly large decrease in 1958. Although there has been some increase in effort and landings since 1958, the level of L/E has levelled off at just over 40 tons of cod per 1,000 dory hours fished, a decline of about 30% below the 1954–57 level. Considering the data on a semi-annual basis, the line fishery in July–December has generally been slightly more productive than in the first half of the year and in recent years relatively more fishing has occurred in the summer and early autumn than in the spring.

The inshore fishery

The inshore fishery in the three regions under consideration is carried on exclusively by Canadian (Newfoundland) fishermen using a variety of gears (codtraps, handlines, longlines, jiggers, gillnets). Unfortunately with such gear variety and the very widespread distribution of fishermen in hundreds of coastal villages, a good measure of total effort in the inshore fishery is not available. However, estimates of the number of fishermen engaged in the inshore cod fishery have been obtained by the Canadian Department of Fisheries field staff for a number of years. While it does not necessarily follow that changes in the number of fishermen throughout the period under consideration mean corresponding changes in total inshore fishing effort, the data are useful as indicators of trends.

Although an upward trend in inshore cod landings for Subarea 2 is apparent (Fig. 7), the cod yield per man since 1959 is about 25% lower than the average for 1954–57. In Division 3K the number of fishermen has been relatively steady at just over 4,000, but the cod landings (and L/E) have decreased rapidly to a level about 40% below that for the mid-1950's. In Division 3L inshore cod landings are now about 20% lower than in the mid-1950's, despite a 30% increase in the number of fishermen engaged in the inshore cod fishery.

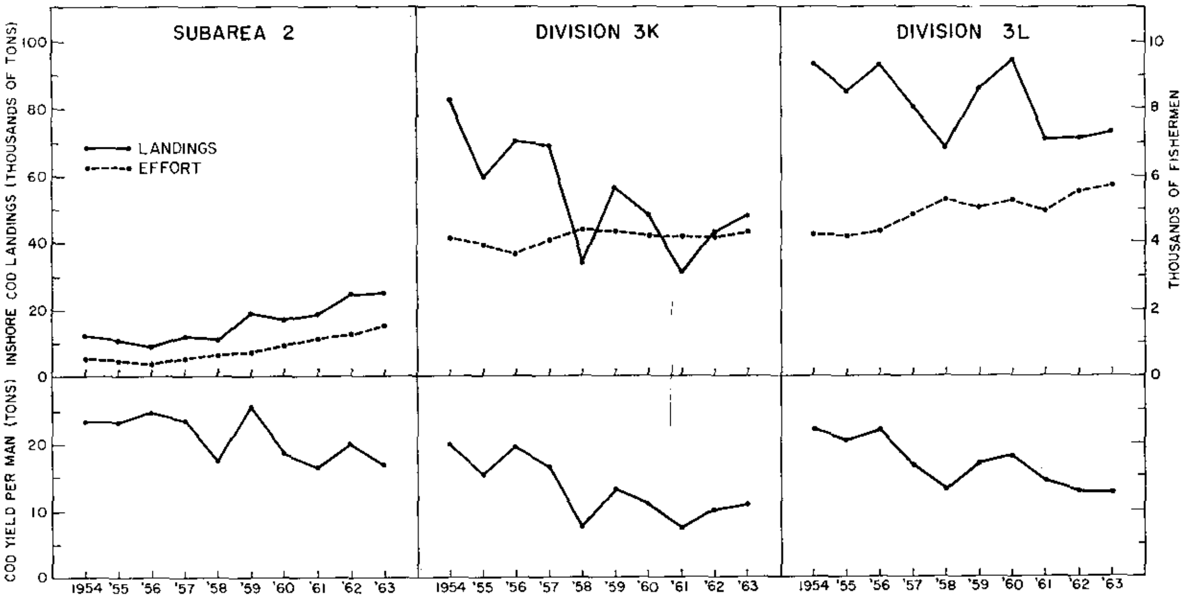

Fig. 7. Landings, effort and landings per unit effort for the inshore fishery in Subarea 2 and Divisions 3K and 3L during 1954–63.

Standardization of Effort

Having obtained a standard unit of effort for the trawl fishery of Subarea 2 and Divisions 3K and 3L (Fig. 3, 4, 5), based on landing and effort statistics of Portuguese and Spanish otter trawlers, the next step was to analyze the available data with a view to standardizing the effort of all major gear components for the fishery on the stock complex. Since the inshore fishery in Divisions 3K and 3L and the offshore line fishery in 3L have been of long standing, the data for these 2 divisions have been combined to represent the fishery on the southern half of the stock complex. The northern part of the stock (Subarea 2) has been treated separately, mainly because of the very recent developments in the offshore trawl fishery.

For the inshore fisheries of Labrador (Subarea 2) and the east coast of Newfoundland (Divisions 3K and 3L), since more than 80%

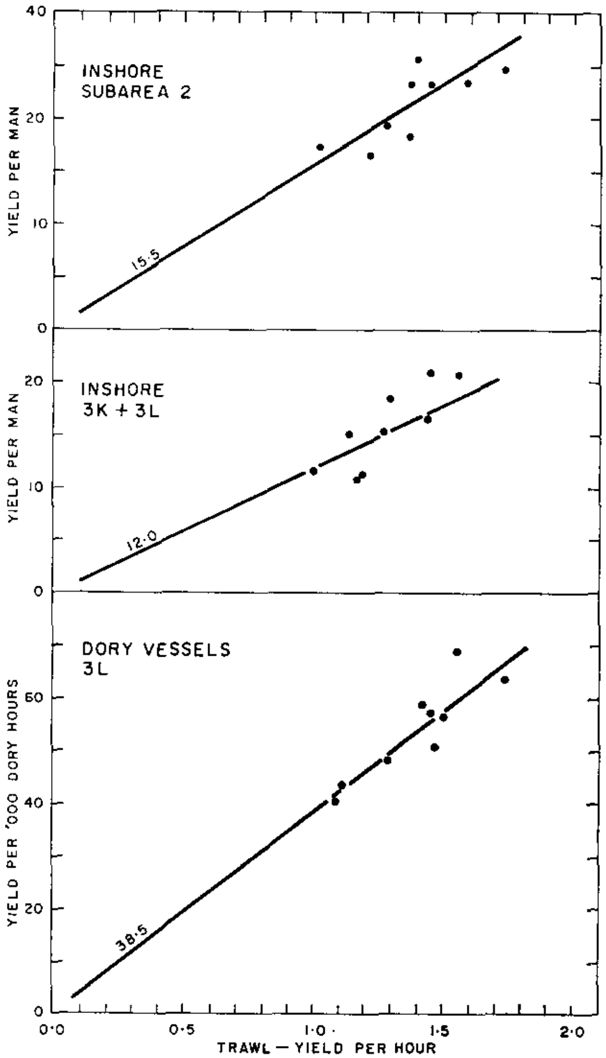

Fig. 8. Cod yields per unit effort for the inshore fishery and for the offshore line fishery plotted against the standard L/E for trawlers in 1954–62.

of the landings are taken in the July–December period, the cod yields per man year are plotted against the standard L/E (landing per hour fished) for trawlers based on the July–December period only (Fig. 8). For the offshore line fishery, on the other hand, since dory vessels fish through the April–October period, the cod landings per 1,000 dory hours are plotted against the standard L/E for trawlers on an annual basis. For all three correlations, a linear trend is indicated and for the sake of consistency the lines were drawn such that they passed through the origin. The effort data for the inshore fishery (number of fishermen) and for the offshore line fishery (thousands of dory hours) were accordingly adjusted by the factors given in Fig. 8. These adjusted effort values were then added to the corresponding estimates of effort by trawlers, and the resultant standardized effort and L/E values for the cod fishery as a whole, together with total cod landings, are shown in Fig. 9, from which a generalized picture of the trends in effort and landing per unit effort (in trawler units) can be obtained.

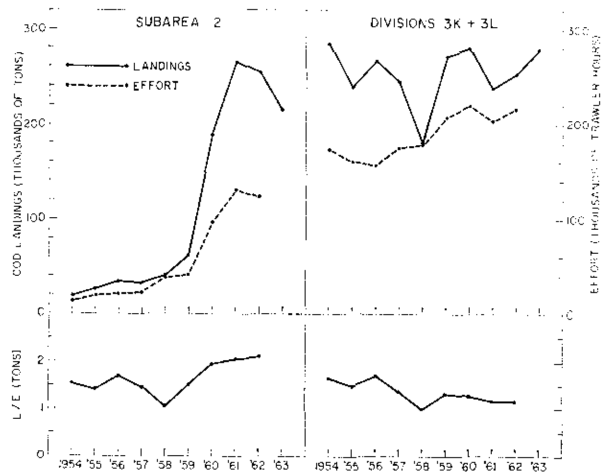

Fig. 9. Subarea 2 and Divisions 3K + 3L cod: landings, effort and L/E in standard trawler units for the period 1954–62.

In Divisions 3K and 3L, while the annual effort has increased by about 30%, cod landings have fluctuated about an annual average of 250 thousand tons, resulting in a gradual decrease in L/E. In Subarea 2, on the other hand, landings, effort and L/E increased very substantially between 1958 and 1961, as the offshore trawl fishery on the spring concentrations of cod developed. Although the landings have decreased since 1961, it is too soon to speculate on future trends. However, in view of reported difficulties with ice in the winter and spring and when the number of old fish has been reduced, landings may fluctuate very widely about a level considerably lower than the peak landings in 1961 and 1962.

An interesting feature of the data both in Subarea 2 and Divisions 3K + 3L is the decline in L/E for 1958. Templeman (1959, 1964) reports that temperature conditions throughout most of the area off the east coast of Newfoundland were somewhat higher than normal in 1958,

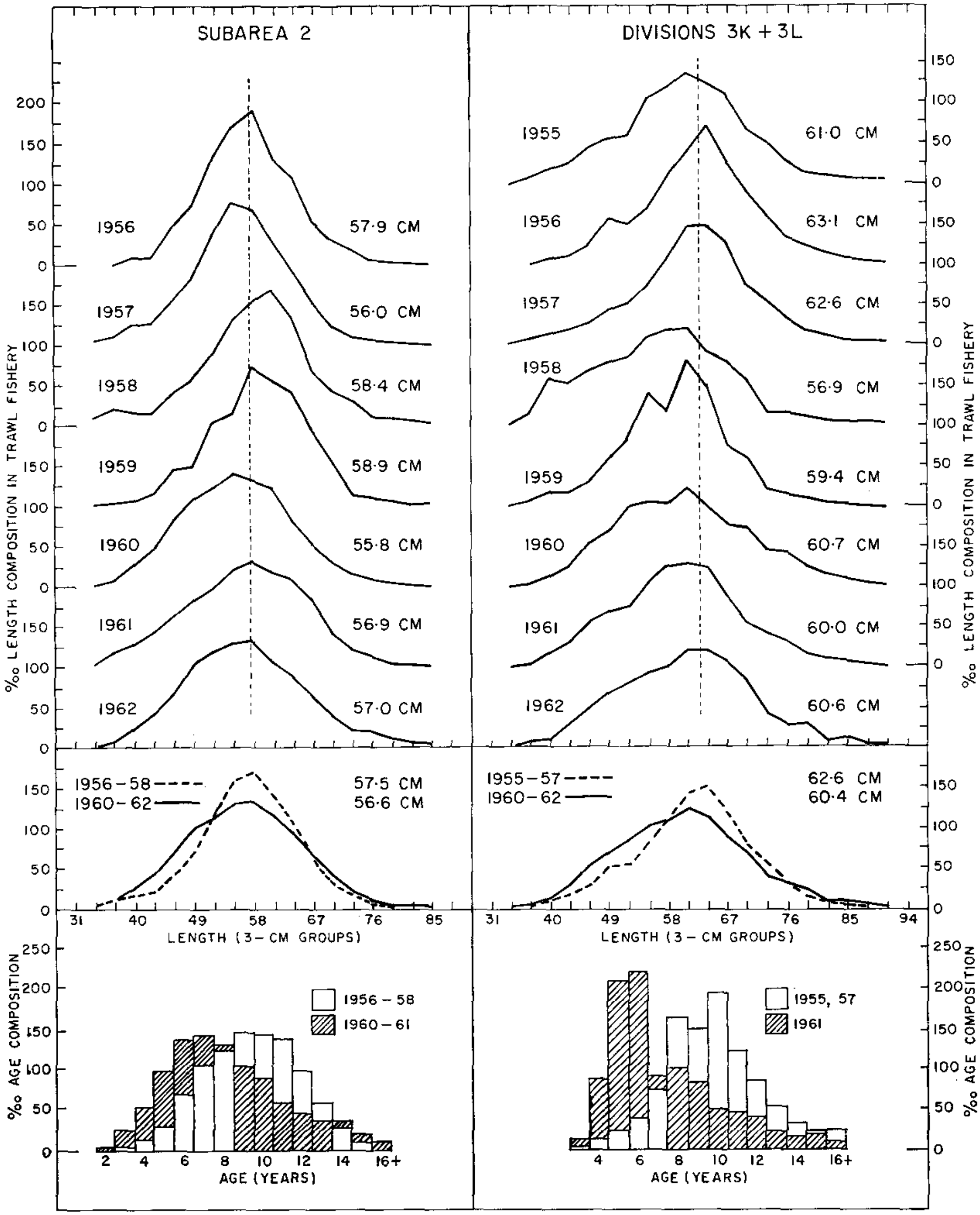

Fig. 10. Trends in length and age composition of cod in the offshore trawl fishery of Divisions 2J and 3K + 3L between 1955 and 1962 (the vertical broken lines represent the average lengths for 2J in 1956–58 and for 3K + 3L in 1955–57).

and this factor probably had the effect of causing the cod to be less concentrated on the fishing grounds than normally.

Length and Age Composition of Catches

The trawl fishery

Length and age composition data have been published annually since 1955 in the ICNAF Sampling Yearbook. While data from several countries with trawlers fishing in the area are available, Portuguese and Spanish data make up the longest series and only these data have been utilized in the present analysis. Data are available for Division 2J from 1956 and for 3K and 3L from 1955. The trawl length frequencies for 2J were sufficiently different from those of the more southerly divisions that they were treated separately, while those of Divisions 3K and 3L were combined because of their consistent similarity in each year of the 1955–62 period. The length frequencies were initially analyzed on a quarterly basis, but differences between the quarterly frequencies within any one year were generally so slight that they were combined after weighting by the quarterly cod landings. The age frequencies were considerably less in number and were simply combined after adjustment of each to the actual number of fish aged.

In Fig. 10 are shown the length compositions of the cod catches (based on Portuguese and Spanish sample data) for Division 2J and Divisions 3K and 3L. Below the annual catch length curves are shown the average length and age compositions in two periods: 1956–58 data are compared with 1960–62 data for Division 2J, and 1955–57 data with 1960–62 for Divisions 3K + 3L. How representative the 1961 age composition for 3K + 3L is of the corresponding length composition is not known, but the 1961 age samples were collected in nearly all months between April and November with no more variation than might be expected. Nevertheless the data indicate that the average length and age of cod have decreased both in 2J and 3K + 3L, the change in age composition being much more pronounced than the change in length composition between the two periods.

The inshore fishery

Although length frequencies for the Canadian inshore cod fishery are not available for long enough a period from Divisions 2J and 3K, regular sampling of catches have been carried out

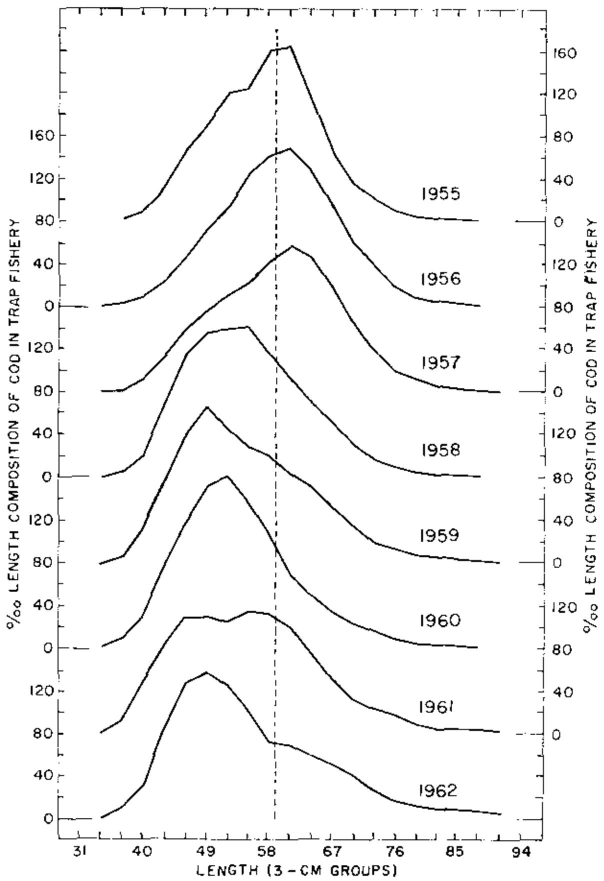

Fig. 11. Changes in length composition of cod landed by the inshore trap fishery in Division 3L between 1955 and 1962 (the vertical broken line represents the average length for 1955–57).

since 1955 by the St. John's Biological Station at two or more fishing ports located in Division 3L, mainly Bonavista and St. John's. Length frequency data for several inshore gears are available in the Sampling Yearbook, but, since the trap fishery in June–August usually accounts for 60–65% of the inshore landings, only data for this important gear are considered here (Fig. 11). From 1955 to 1957 the trap fishery consisted of cod whose average size was 59.3 cm, but in 1958 there was a predominance of smaller cod and this has continued to the present with the average length fluctuating between 53.5 and 55.6 cm during 1958–62. Unpublished age composition data reveal that since 1958 the trap fishery along the east coast of Newfoundland has been largely maintained by fish of ages 4–6 years with a rapid decrease in the number of older fish in the samples. Before 1958, however, fish of ages

7 and 8 were much more prevalent in the samples than at present. The decreased abundance of fish older than 6 years in the inshore trap fishery is attributed to the decreased abundance of these older ages on the offshore fishing grounds as a result of increased effort by trawlers in all areas off the east coast of Newfoundland and southern Labrador in recent years.

Summary and Conclusions

Statistics of landings for the period 1954–62 show that cod landings by trawlers from the stock complex of Subarea 2 and Divisions 3K and 3L have increased substantially since 1958, the greatest increase having occurred in the landings from the southern part of Subarea 2 (Division 2J) in 1960–62. Coincidentally the landings from the offshore line fishery in 3L and from the inshore fishery in 3K and 3L have declined.

Beginning in 1959 a very productive spring fishery developed in the northern divisions (particularly 2J and 3K) and this has resulted in an upward trend in the landing per unit effort in those regions, when the data are considered on an annual basis. However, when considered on a semi-annual basis, the trend in landing per unit effort has been slightly downward for the summer and autumn fishery by trawlers as the fishing effort has generally increased. More pronounced decreases in landing per unit effort are indicated for the offshore line fishery (dory vessels) in Division 3L and for the inshore fishery in all three regions.

In order to better assess the trends in the fishery, the effort and landing per unit effort of the offshore line and inshore fisheries were standardized by converting in terms of trawl units, based on statistics of Portuguese and Spanish otter trawlers. The resultant analysis shows that, while the landings have remained about the same in Divisions 3K + 3L, the effort has increased by about 30%. In Subarea 2, on the other hand, landings and effort and L/E have increased substantially between 1958 and 1961 as the offshore trawl fishery on the spring concentrations developed, but, although landings have since decreased somewhat, it is too soon to speculate on future trends.

Length and age composition data show that there is a tendency toward smaller and younger fish in the catches of trawlers and particularly so in the landings of the inshore fishery. This is attributed to the greatly increased effort by trawlers in recent years, particularly since 1958.

Acknowledgements

The author is indebted to Mr A. M. Fleming of the St. John's Biological Station, who supplied information on the age composition of cod in the inshore fishery between 1955 and 1962, and to Mr B. F. Calvin DeBaie, ICNAF Statistician, who responded to several requests for data, which were otherwise not available at the time.

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The Sea-Bed Drifter[1]

BY ARTHUR J. LEE[2], DEAN F. BUMPUS[3] AND LOUIS M. LAUZIER[4]

Abstract

A simple plastic drifter for obtaining the residual current close to the sea-bed is described. The preliminary results of various investigations based on its use are given.

Introduction

Glass bottom-trailing drift bottles with metal wire "tails" were used in European waters at various times in the years 1904 – 39 and in U.S. waters in 1960 – 61. In recent years we have been making increasing use of drifting plastic objects, known as sea-bed drifters, in order to obtain information about the movements of the water near the sea-bed. The drifters are released in batches at certain points in the sea and trail over the sea-bed, later to be recaptured in the nets of fishermen, or by skin divers, or to be washed ashore and found by members of the public. Rewards are offered for their recovery and return with details of the position and date of finding. The study of this information enables us to construct pictures of the currents near the sea-bed.

The Craig Sea-bed Drifter

The plastic sea-bed drifter was first conceived by Mr R. E. Craig of the Marine Laboratory, Aberdeen, Scotland (Craig, 1962) and the present version of it as used by him is shown in Fig. 1. It consists of a black plastic square, 11.3 cm × 11.3 cm, with a reward notice in the English language inlaid in red. The time and place of release are indicated by a series of punch marks around the edge of the square. Through the middle of the square a white plastic rod, or "tail", 54 cm long and 0.65 cm diam, is fitted: this has a small copper weight attached near its lower end, so that the drifter has slight negative buoyancy and moves over the sea-bed with its "tail" just touching the bottom.

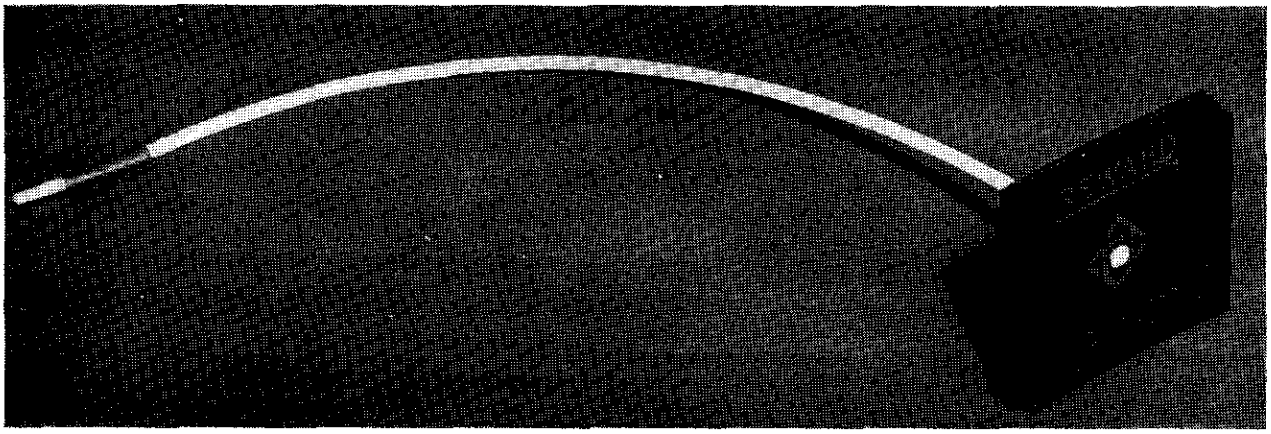

Fig. 1. The Craig Sea-bed Drifter.

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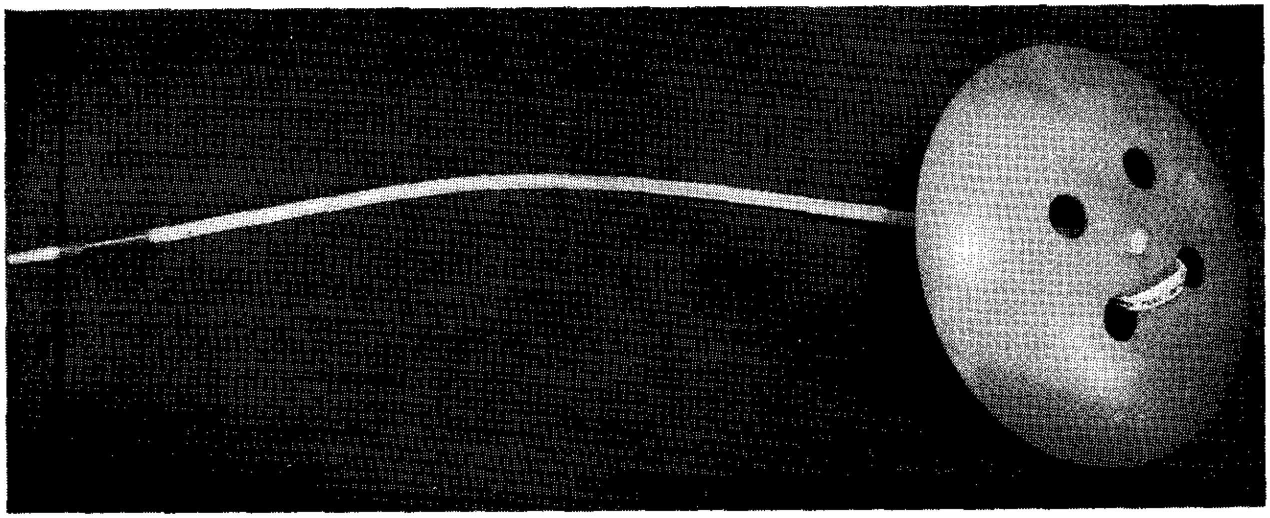

Fig. 2. The Woodhead Sea-bed Drifter as used by U.K. scientists.

The Woodhead Sea-bed Drifter

The drifter most commonly in use at present was developed by Mr P. M. J. Woodhead of the Fisheries Laboratory, Lowestoft, England (Woodhead and Lee, 1960). It is shown in Fig. 2. It resembles a toadstool and has a white polythene rod identical with that now used in the Craig drifter, but instead of a black plate it has a red polyethylene saucer, 18.5 cm diam. The rod is sharpened to a point at its lower end. A copper ferrule is pressed on 6 cm above the point: the red saucer has four holes of 2 cm diam at a distance of 8 cm from its centre. The version used by the Lowestoft laboratory bears, on the saucer, instructions to the finder: these are in English, French, German and Norwegian languages and provision has been made so that alternative languages can be used if required. A serially numbered yellow polyvinyl chloride tag is secured to the saucer and this bears a reward notice in the English language only.

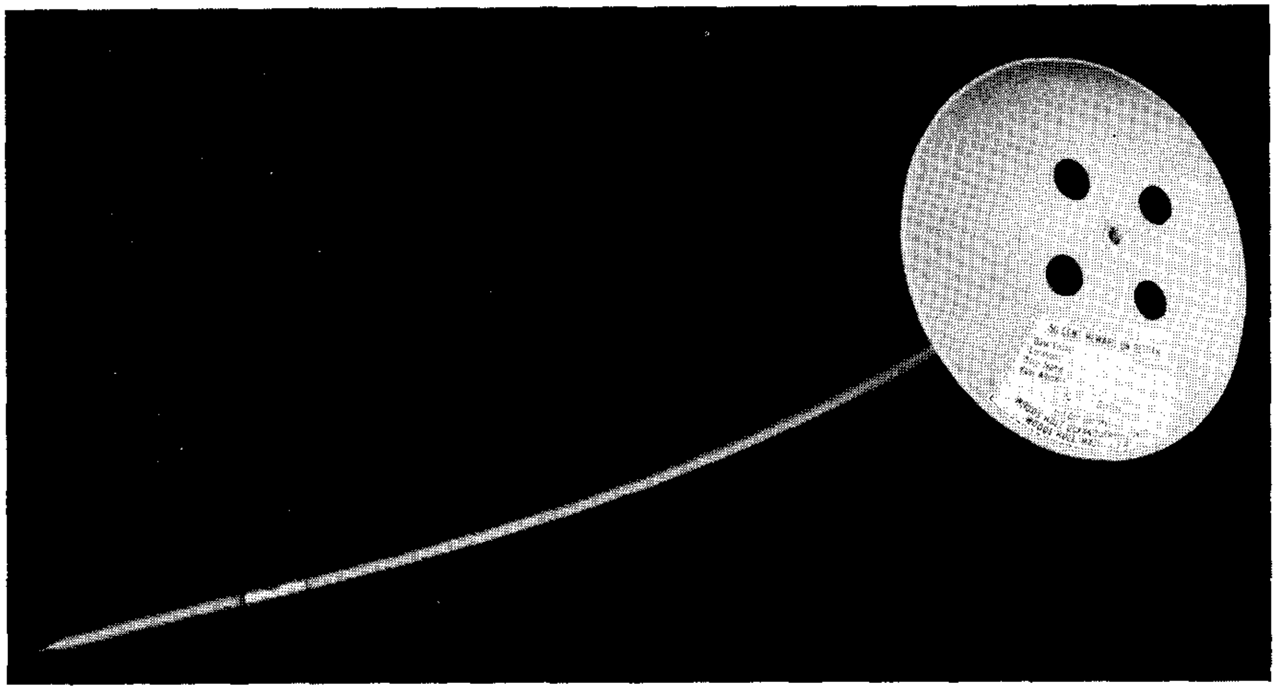

Fig. 3. The Woodhead Sea-bed Drifter as used by U.S. scientists.

The Woodhead version of the sea-bed drifter is also used in Canada and the U.S.A. The U.S. sea-bed drifters have a red stem and a yellow saucer with the serially numbered return labels and instructions in English stuck to the saucer as shown in Fig. 3. The Canadian sea-bed drifters have a red saucer and a white rod, with a serially numbered yellow "spaghetti" tag, similar to the fish tag, secured to the saucer for identification and return instruction purposes. The only printing on the spaghetti tag is: Reward, Ret. Fish. Res. Board St. Andrews, N. B. S–05391.

U. K. Investigations with Sea-bed Drifters

The Craig type of drifter has been used extensively off the east and west coasts of Scotland. These experiments have shown, for example, the presence of a large clockwise bottom eddy in the Moray Firth (Payne, 1963). English workers have made a number of large-scale liberations of the Woodhead type of drifter in the North Sea, Irish Sea, Norwegian Sea and Barents Sea. In the North Sea the rate of recovery has been up to 50% in 12 months and one-tenth of these returns have been drifters which have stranded on beaches. In the Irish Sea the rate of recovery has been 45% in 8 months, of which 95% have been drifters recovered on beaches. Drifters released off the northwest coast of Norway and in the southeastern Barents Sea have only been recovered at the rate of 2% in the first 12 months. It is possible that in these regions the drifters are transported to areas which are not fished and that this accounts for the low recovery rate. Again, most of these releases were made in depths greater than 140 m, so that recaptures by stranding on the shore were less likely in their case. Further, the bobbins on the trawls used in these regions are larger in diameter than those used in the North Sea and the drifters may have passed beneath the groundropes of the trawls and so avoided capture.

The recoveries of the drifters released by the Fisheries Laboratory, Lowestoft in the North Sea and Irish Sea are being analysed by Mr J. W. Ramster of that laboratory and will be reported on by him shortly. At this stage it can be said that he has found that the method of analysis which he has used for the North Sea returns is not so fruitful when applied to the Irish Sea experiments. In the case of the vast volume of North Sea recoveries, some 7,000, he has found it best to group the returns from each release position by 28-day periods, to plot an envelope around all the returns from each release point in each period and to examine the changing geographical distribution of the envelopes so obtained from period to period. In the case of the Irish Sea recoveries, some 480, he has found it best to examine the release and recovery positions and time at liberty of each individual drifter, and to attempt to deduce its track in the light of the recoveries of other drifters from the same release position and from adjacent positions. The Irish Sea investigations have also shown that the duration and strength of the tidal streams must be taken into consideration. In this area the ebb tide lasts longer than the flood and as a result the flood streams are faster than the ebb. Now experiments with the British-made Woodhead drifters in a 20 m long tank, through which water flows at a constant speed, have shown that the drifter speed-to-water speed ratio is not constant but varies with the water speed: at 10 cm/sec it is 0.60 and at 60 cm/sec it is 0.85. This being so, it is possible in an area of irregular tidal streams for a drifter to show a residual movement after a tidal cycle which is not only a function of the residual current but also of the drifter's varying response to tidal streams of different speeds. This difficulty does not arise in an area with regular tidal streams like the North Sea. Despite it, Mr Ramster has been able to deduce the pattern of the bottom currents in spring-summer in the Irish Sea and at all seasons in the North Sea, as will be shown in his forthcoming reports.

Woodhead sea-bed drifters have been used by some other U.K. investigators. Harvey (1963) has made releases in the Menai Straits between Anglesey and North Wales in order to investigate the water movement through them. He finds a southwest-going movement of the bottom water in the straits and a clockwise coastal circulation around Anglesey into Liverpool Bay, but also some movement southwards from the west coast of Anglesey into Cardigan Bay. Perkins *et al.* (1964 *a*, *b* and *c*) have used the drifters in order to determine the movement of silt and hence of "radio-colloidal" effluent in the Solway Firth. They found a movement of the drifters towards the head of the estuary. Robinson (1964 *a* and *b*) has used them in physiographic studies of the coastal region of eastern England between the Humber and the Wash, in particular to determine the direction of transport of material for the construction of onshore and offshore geomorphological features.

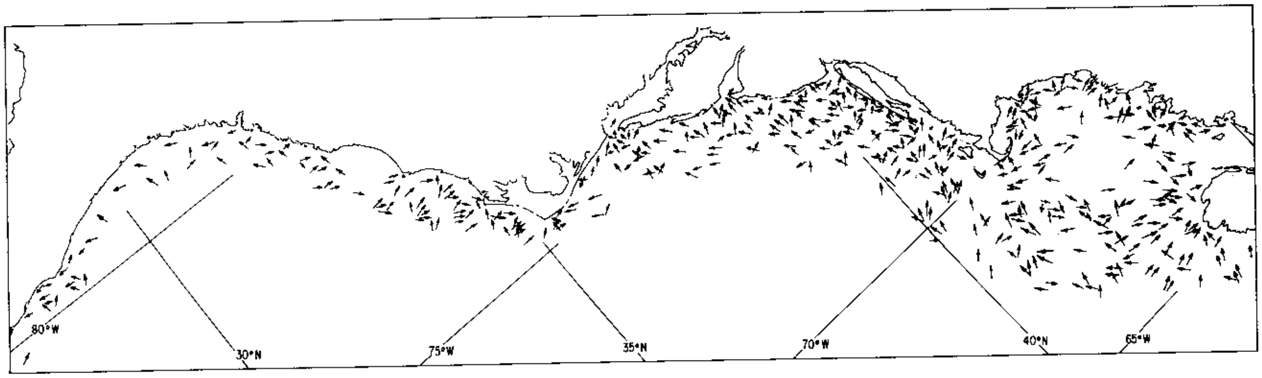

Fig. 4. Direction of bottom drift on the continental shelf between Nova Scotia and Florida.

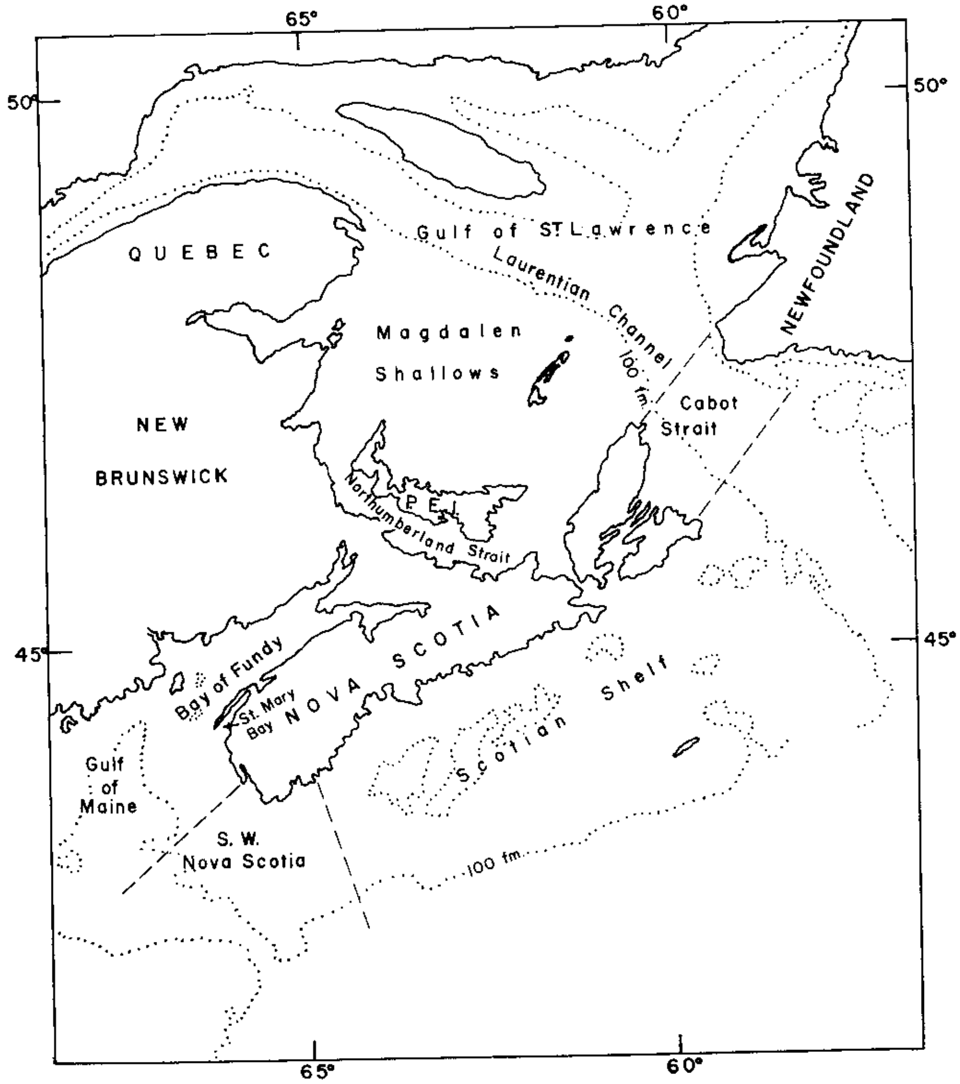

Fig. 5. Areas in which Canadian Sea-bed drifter releases have been made.

TABLE 1. Releases and recoveries of sea-bed drifters along the Canadian Atlantic coast 1961–63.

Area	Releases	At sea		Recoveries ashore		Total	
	no.	*no.*	%	*no.*	%	*no.*	%
Gulf of St. Lawrence exclusive of Northumberland Strait	1,494	192	12.9	53	3.5	245	16.4
Cabot Strait	498	14	2.8	8	1.6	22	4.4
Scotian Shelf	1,179	58	4.9	8	0.7	66	5.6
S. W. Nova Scotia	565	32	5.7	137	24.2	169	29.9
Gulf of Maine – Bay of Fundy exclusive of St. Mary Bay	1,129	87	7.7	387	34.3	474	42.0
Enclosed areas: Northumberland Strait, St. Mary Bay	315	30	9.5	139	44.1	169	53.6
Total	5,180					1,145	22.0

U. S. Investigations

Since 1 April 1961, 24,500 Woodhead sea-bed drifters have been released in U.S. continental shelf waters between Nova Scotia and Florida and in the eastern Gulf of Mexico, with over 16% recovered by mid-August 1964. This is a remarkable recovery rate when one considers that for a similar area only 11% of the surface drift bottles are reported. Figure 4 presents a preliminary diagram of the indicated directions of bottom drift. The rates of drift lie between 0.1 and 0.9 nautical miles per day.

Canadian Investigations

From 1961 to October 1964 more than 8,200 Woodhead sea-bed drifters were released along the Canadian Atlantic coast from the Gulf of St. Lawrence to the Bay of Fundy (Fig. 5). Approximately 70% of all releases originated from cruises. The other releases were made repeatedly at monitor fixed stations mostly in Cabot Strait and Gulf of Maine — Bay of Fundy area. Table 1 shows an overall recovery of 22% and gives a general breakdown of up-to-date recoveries of sea-bed drifters released before January 1964. Each area is characterized by particular percentage recovery, the type of recovery — ashore or at sea — and the rate of recovery, the percentage of all recoveries in a given time.

In the Gulf of St. Lawrence, most of the returns were recovered at sea by draggers and approximately 45% of all the recoveries were made later than 12 months after releases. From the 1961 releases, more than 20% of all the recoveries at sea indicated a south-east drift along the western slopes of the Laurentian Channel over a distance greater than 100 miles. Some of these were found outside the Gulf of St. Lawrence, even on the Scotian Shelf. The drift over long distances averaged 0.4 nautical miles per day. Over the Magdalen Shallows a more variable drift has been inferred with an average speed between 0.3 and 0.7 nautical miles per day. Releases made during 1962 and 1963 in the Gulf of St. Lawrence showed the same general drift pattern.

Drifters were released in Cabot Strait area just before the ice season (February – April) and were intended for recovery in the early spring when the seasonal fishing effort might be at a peak. The low rate of recovery, 4.4%, might indicate that the releases had been too early.

On the Scotian Shelf area, the percentage recovery was relatively low, 5.6%, with most recoveries from draggers. The average drift computed from these recoveries is about 0.7 nautical miles per day and predominantly to the west. As much as 37% of all recoveries were made later than 12 months after the releases.

In the southwest Nova Scotia and Bay of Fundy — Gulf of Maine areas, four times as many drifters were found stranded on beaches as were recovered at sea. In these areas only 13 to 17% of the recoveries were made more than 12 months after the releases. The average drift was 0.6 nautical miles per day, predominantly to the north and northeast. However, drifts of 1.1 nautical miles per day were not uncommon. The recoveries in these two areas suggest a certain amount of upwelling along the southwest coast of Nova Scotia and an "upstream" bottom drift in the Bay of Fundy.

Sea-bed drifter experiments in enclosed areas, northern Northumberland Strait and St. Mary Bay, gave the highest percentage recovery and the quickest returns, 56% within 3 months after release. Most of the recoveries were made along the shore.

In the Gulf of St. Lawrence, Cabot Strait and the Scotian Shelf areas, the fishing effort is seasonal and a large number of recoveries were made more than 12 months after release. Computed drift from recoveries later than 12 months after release could be misleading, particularly if the recoveries were made within 50 miles or so of the release position. This problem does not seem to be so acute in other areas. Shore recoveries are indicators of upwelling and vertical movements, but nevertheless they leave some doubts as to the amount of "true" bottom drift which has occurred.

Summary

Increasing use is being made of two types of plastic sea-bed drifter in European and North American waters. The recovery rate of these drifters is sufficiently high to allow the pattern of currents near the sea-bed and in some places their speed, to be deduced. There are some difficulties in interpreting the recoveries, particularly where the drifters strand on the coast and in areas of irregular tidal streams. To date, however, it has been possible to derive reasonable pictures of the current systems near the sea-bed over wide areas, such as the North Sea and the Irish Sea and along the eastern seaboard of North America from the Gulf of St. Lawrence to Florida, and in addition to use the drifters for special studies in localized situations.

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Heterogeneity Among Samples of the Length and Age Compositions of Commercial Groundfish Landings

BY L. M. DICKIE[1] AND J. E. PALOHEIMO[1]

Introduction

Landings of commercial vessels provide a source of more extensive, hence potentially more representative, samples of the characteristics of fished populations than are afforded by any other device currently in use. Accordingly, a sustained effort is made by various research agencies to collect routine information on the length and age composition of various species as landed by different fishing gears, areas and seasons. Before these data can be confidently used to provide indices of relative abundance of sizes and ages, or as a basis for calculating mortality and growth rates, it is necessary to establish the reliability of estimation of the various characteristics they display.

The regular sampling procedure followed by port samplers in eastern Canada is to obtain data on lengths of about 200 fish and otoliths for ageing for about 40 fish of a particular species from each landing sampled. An attempt is made to select for sampling those vessels which fished in a definable unit area. In most cases landings are sorted into market categories by size at time of landing. In such cases the market categories are sampled roughly in proportion to their representation in the catch, proportion factors being determined later on the basis either of the trip weighout or of weighouts from all vessels landing in a particular port from a particular area during the season. Studies of this sampling program have been mainly concerned with attempts to improve its efficiency; however, they also indicate that there is marked heterogeneity among samples from particular areas and seasons. We report here certain features of the heterogeneity in the length and age compositions of samples of haddock and cod caught commercially over the past 14 years, and their implications for continued study.

Methods and Data

Basically the method used in this study has been the standard χ^2 test comparing the deviations of length or age compositions of individual samples from their general mean (corrected for sample size differences) when the samples are grouped in various ways. However, the calculation of the expected distributions and corresponding χ^2 components from a given set of samples is rather time consuming; and the entire procedure must be repeated for every sub-grouping of a particular set of samples. To obviate these difficulties, which sometimes become serious with the large numbers of samples involved, we have used the system of information statistics which is asymptotically equivalent to the χ^2 statistic. The method of calculation, together with a worked example, is given by Kupperman (1959).

Our application of the method to analysis of the length compositions is illustrated by an example in Table 1. In this Table, as in all the calculations, the original size-frequency distributions for each sample were condensed in order to avoid numerous small numbers. Such condensation also smooths out some of the variation among samples. In the case of haddock, the length observations which were originally compiled into 2-cm size-classes were further grouped into five larger size-classes. Using ICNAF terminology these classes may be described as:

0 – 40.5
42.5 – 46.5
48.5 – 52.5
54.5 – 58.5
60.5 – +

In the cod studies, the original length frequency distributions compiled in 3-cm size-classes were grouped into eight size-classes as follows:

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0 – 46
49 – 52
55 – 58
61 – 64
67 – 70
73 – 76
79 – 82
85 – +

As is shown in the upper part of Table 1, the condensed length compositions for each sample were arranged in a two-way table and the marginal totals obtained. Each entry was then replaced as in the lower part of Table 1 by the product $x ln\ x$, where x is the original frequency or total and $ln\ x$ is its natural logarithm. The approximate χ^2 value is calculated as

$$2[\Sigma\ (x_i ln\ x_i) - \Sigma(x_l\ ln\ x\ ) - \Sigma(x_s ln\ x_s) + (\Sigma\ x_i\ )\ ln\ \ (\Sigma\ x_i\ )]$$

where the subscript i refers to the frequency entries, l to the marginal totals for each length group, and s the totals for each sample. The degrees of freedom are calculated from the product $(n_l\text{–}1)\ (n_s\text{–}1)$ where n_l is the number of length groups and n_s the number of samples used in the calculations. It should be noted that if tables of $x ln\ x$ (e.g., Kullback, 1959) are not available, it is a relatively simple matter to calculate appropriate x log x values using tables of logarithms to the base 10, and to obtain the estimate of χ^2 by multiplying the quantity within the square brackets by (2 × 2.3026) rather than by 2 as in the above equation.

In using this system any sub-sampling from a set of samples requires compilations only of new sets of vertical marginal totals and their $x ln\ x$ values as a prerequisite for calculating χ^2 values. The system therefore readily lends itself to calculation of an overall χ^2, of χ^2 values within particular sub-sets, and by using the sub-set totals, of the χ^2 between sub-sets, for an analysis of the sources of variation among the samples.

TABLE 1. Condensed length-frequency distributions of samples of the haddock caught comercially in ICNAF Division 4W(h) (Western Bank) in Feb., Mar., Apr., 1961, and subsequent steps in calculating approximate χ^2 values.

Length groups	Observed frequencies (x_i) in sample no.											
	1	2	3	4	5	6	7	8	9	10	x_l	
cm												
0 –40.5	41	29	43	47	20	...	...	6	3	9	198	
42.5–46.5	80	63	87	82	260	31	120	199	138	158	1218	
48.5–52.5	45	65	44	40	279	144	289	235	153	162	1456	
54.5–58.5	29	37	21	26	127	97	93	111	57	45	643	
60.5+	5	5	5	6	75	60	115	122	32	10	435	
x_s	200	199	200	201	761	332	617	673	383	384	3950	$= \Sigma x_i$
					$(x_i)\ (ln\ x_i)$						$(x_l)\ (ln\ x_l)$	
0 –40.5	152.3	97.7	161.7	181.0	59.9	...	...	10.8	3.3	19.8	1047.1	
42.5–46.5	350.6	261.0	388.5	361.4	1445.8	106.5	574.5	1053.4	680.0	800.0	8653.9	$\Sigma\ (x_l ln\ x_l) =$
48.5–52.5	171.3	271.3	166.5	147.6	1571.1	715.7	1637.6	1283.0	769.7	824.2	10604.5	27106.0
54.5–58.5	97.7	133.6	63.9	84.7	615.2	443.7	421.5	522.8	230.5	171.3	4157.7	
60.5+	8.0	8.0	8.0	10.8	323.8	545.7	245.7	586.1	110.9	23.0	2642.8	
$(x_s)\ (ln\ x_s)$	1059.7	1053.4	1059.7	1066.0	5049.0	1927.3	3964.1	4382.4	2278.1	2285.0	32712.1 =	
						$\Sigma\ (x_s\ ln\ x_s)$	=	24124.7			$(\Sigma\ x_i)\ (ln\ \Sigma\ x_i)$	

$$\chi^2 \simeq 2[\ \Sigma\ (x_i ln\ x_i) - \Sigma\ (x_l\ ln\ x_l) - \Sigma\ (x_s\ ln\ x_s) + \Sigma\ (x_i)\ \ (ln\ \Sigma\ x_i)\ ]$$
$$= 2[\ \ 18921.1 - 27106.0 - 24124.7 + 32712.1]$$
$$= 2[\ \ 402.5] = 805.0$$

$$\chi^2/\text{d.f.} = \frac{805.0}{36} = 22.4 \qquad \text{with d.f.} = (n_l\text{–}1)\ (n_s\text{–}1) = 9 \times 4 = 36$$

Such calculations have been carried out on length compositions of samples of Canadian commercial catches of cod and haddock. A series of samples has been obtained from landings by the summer small otter-trawl fishery for cod in ICNAF Division 4T since it began about 1947. In Table 2 we show calculations carried out on the samples from small otter trawlers (26–55 gross tons) fishing between May and October during the period 1950–63, except 1953 and 1954 when too few samples were taken. A similarly long series is available for haddock fished from Division 4W by larger otter trawlers (150–500 GT) in February, March and April. Available data for the period 1950–63 (i.e., except 1954) are given in Table 3.

TABLE 2. Approximate χ^2 to measure heterogeneity of length compositions among samples of commercial cod catches. Samples are from small Canadian otter trawlers (26–55 GT) fishing in 4T, in two seasons: Season I, May–July; Season II, August–October.

Year	No.	Within unit areas within seasons			Between unit areas within seasons			Within seasons			Between seasons			Overall samples		
	samples	d.f.	χ^2	χ^2/d.f.	d.f.	χ^2	χ^2/d.f.	d.f.	χ^2	χ^2/d.f.	d.f.	χ^2	χ^2/d.f.	d.f.	χ^2	χ^2/d.f.
1950	8	35	251.2	7.2[a]	7	53.8	7.7[a]	42	305.0	7.3[a]	7	56.0	8.0	49	361.0	7.4
1951	18	...	...	...	...	...	...	112	1632.2	14.6	7	79.0	11.3	119	1711.2	14.4
1952	14	...	...	...	...	...	...	84	1125.0	13.4	7	277.4	39.6	91	1402.4	15.4
1955	14	49	225.4	4.6[a]	14	216.4	15.5[a]	84	766.6	9.1	7	2159.2	308.4	91	2925.8	32.1
1956	16	70	641.4	9.2	21	248.0	11.8	91	889.4	9.8	7	113.0	16.1	98	1002.4	10.2
1957	14	63	562.0	8.9	21	134.2	6.4	84	696.2	8.3	7	71.0	10.1	91	767.2	8.4
1958	16	35	350.8	10.0[a]	14	167.0	11.9[a]	98	726.2	7.4	7	32.6	4.7	105	758.8	7.2
1959	13	56	959.4	17.1	21	198.0	9.4	77	1157.4	15.0	7	4.6	0.7	84	1162.0	13.8
1960	11	56	152.9	2.7[a]	7	36.8	5.3[a]	63	523.1	8.3	7	23.0	3.3	70	546.1	7.8
1961	18	91	752.1	8.3	21	342.5	16.3	112	1094.6	9.8	7	128.9	18.4	119	1223.5	10.3
1962	16	56	398.8	7.1	42	461.4	11.0	98	860.2	8.8	7	131.2	18.7	105	991.4	9.4
1963	23	119	424.6	3.6	28	171.4	6.1	147	596.0	4.1	7	38.6	5.5	154	634.6	4.1

[a] one season only

TABLE 3. Approximate χ^2 measures of heterogeneity in length compositions among samples of commercial haddock catches. All samples were from the period Feb., Mar., Apr., and taken from Canadian otter trawlers (151–500 GT) fishing in ICNAF Division 4W.

Year	No.	Within gross tonnage groups within Western Bank			Within Western Bank			Between fishing banks			Overall samples		
	samples	d.f.	χ^2	χ^2/d.f.	d.f.	χ^2	χ^2/d.f.	d.f.	χ^2	χ^2/d.f.	d.f.	χ^2	χ^2/d.f.
1950	4	4	33	8.3	12	54	4.5		...		12	54	4.5
1951	5	4	32	8.1	16	151	9.4		...		16	151	9.4
1952	5	4	57	14.3	16	77	4.8		...		16	77	4.8
1953	6	3	56	18.7	9	76	8.5		...		15	110	7.4
1954	1		...			...			...			...	
1955	7	4	47	11.8	24	234	9.7		...		24	234	9.7
1956	11	8	71	8.9	40	207	5.2		...		40	207	5.2
1957	20	8	55	6.8	52	526	10.1	16	834	52.1	76	1453	19.1
1958	8	4	19	4.7	16	26	1.6	12	74	6.1	28	100	3.6
1959	18	8	66	8.3	56	336	6.0	4	48	12.0	68	427	6.3
1960	13	8	115	14.4	24	525	21.9	16	127	7.9	48	712	14.8
1961	10	8	215	26.9	36	805	22.4		...		36	805	22.4
1962	16	4	271	67.8	12	399	33.3	16	225	14.1	60	918	15.3
1963	12		...		4	39	9.7	8	429	53.6	44	676	15.4

The study was extended to age-length keys derived from otolith readings and lengths of haddock in individual samples for three of the recent years for which sufficient information is available, as well as for 1 year of 4T cod data. Since few otoliths are taken per sample, it was necessary to group age-length data over rather large blocks of the age-length keys, reducing the possibilities of detecting heterogeneity. The results are shown in Table 4.

Results

In assessing variability among samples, the most convenient value is the χ^2/d.f. ratio. This ratio, calculated from Table 1, has been entered on Table 3 with others similarly calculated. The relatively high value for 1961 indicates that the set of length compositions we chose as our example showed near maximum variability for the haddock series. Despite this however, in both the cod and haddock series, the calculated approximate χ^2 and χ^2/d.f. values in Tables 2 and 3 indicate that in almost every case the probability that the length-composition samples arose by chance from homogeneous populations is far less than 1% (maximum χ^2/d.f. values for the 99% probability level for homogeneous populations with this many entries range between about 1.2 and 2.0). The following comparison of the χ^2/d.f. ratios within the annual groupings shows the nature of the contribution of various sampling stratifications to this total heterogeneity.

The cod data in Table 2 show that differences between seasons are an important source of variation. This was anticipated, since seasonal changes in both fish distributions and areas fished

TABLE 4. Approximate χ^2 measures of heterogeneity of age-length keys among samples of various classifications of Canadian commercial groundfish landings.

Cod: Division 4T; OT 26–55 GT; Season I: May–July; Season II: August–October

Year	No. samples	Within seasons d.f.	Within seasons χ^2	Within seasons χ^2/d.f.	Between seasons d.f.	Between seasons χ^2	Between seasons χ^2/d.f.	Overall samples d.f.	Overall samples χ^2	Overall samples χ^2/d.f.
1961	8	24	65	2.7	4	8	2.0	28	73	2.6

Haddock: Division 4W; OT 151–500 GT; in February, March and April

Year	No. samples	Within gross tonnage classes within Western Bank d.f.	χ^2	χ^2/d.f.	Within Western Bank d.f.	χ^2	χ^2/d.f.	Between Banks d.f.	χ^2	χ^2/d.f.	Within season Overall samples d.f.	χ^2	χ^2/d.f.
1960	9	3	27	9.1	9	46	5.2	6	27	4.5	33	82	2.5
1961	9	8	62	7.8	28	132	4.7	..			28	132	4.7
1962	15	8	25	3.1	24	54	2.2	0	0	0	60	110	1.8

have long been recognized and are strikingly illustrated by tagging experiments in the Gulf of St. Lawrence area (Jean, 1963; Martin and Jean, 1964). In view of such variability, sampling programs are usually stratified by months or quarter years within general fishing areas. In the case of the Gulf cod stocks the unusually high χ^2/d.f. value between seasons in 1955 reflects a rather abrupt increase in the proportion of 54–60 cm fish in samples from the August–October period and appears associated with changes in growth rates in the area (Kohler, 1963). Otherwise, the reasons for differences between seasons from year to year are unknown.

Although the between-season component of variation is important, the remaining within-season variation is still relatively very large. Inspection of the detailed data showed that neither season showed consistently higher values than the other. Accordingly, the samples were further stratified within seasons according to unit areas. These smaller areas generally define a particular fishing bank or group of banks and are believed to represent more nearly uniform environments and biological communities. The results indicate that there are highly significant differences between the unit areas, the χ^2/d.f. values associated with them being of the same order of magnitude as the between-season differences. Yet, although this stratification by unit areas reduces the residual χ^2/d.f. ratios by as much as a half, the variation remaining within locality (i.e., unit area) and season is still very large compared with that expected from sampling of a homogeneous population.

The haddock samples (Table 3) are taken from the single spring fishing season, the period when most of the Canadian catch is made from the area. The χ^2/d.f. ratios over all samples indicate heterogeneity of the same order as found in the cod samples. It appears again that there are significant differences among the banks; however, the larger, more important Western Bank shows relative variations of the same order as shown by the overall data. In earlier years most of the fishing was on Western Bank, hence the series of samples primarily reflects variability within it.

A striking feature of the haddock samples is the series of relatively high values for 1960–62. A study of the contribution of various size-groups to the total heterogeneity indicates that the high values for these years are associated with the smallest size-groups of fish (36–40 cm) in the samples, in contrast with the earlier period up to and including 1959 when the main contributor to the heterogeneity appears to have been the large size-groups ($\rhd$50 cm). The increased contribution of this smallest group to overall heterogeneity is associated with a general increase in its relative importance in landings during the same period.

Depths fished by vessels change from time to time and year to year, and complete information is not available for all the sampling. However, from recent years' records it appeared that the two or three tonnage sub-groups within this general ICNAF 151–500 tonnage class of haddock boats tended to fish in different depths. As a further step in the haddock analysis, we have therefore stratified samples by tonnage sub-groups, and note that this grouping is possibly associated with depth stratification. The increase in the χ^2/d.f. ratios for the residual variation indicates that the local variations in length compositions were relatively more important than were the differences between landings by the tonnage sub-classes.

The results of calculations from the age-length keys derived from the otolith readings and lengths of fish in individual samples are summarized in Table 4. As noted above, the large blocks into which it was necessary to group the data make the possibility of detecting heterogeneity very much less than with lengths. Even so, the χ^2/d.f. ratios obtained from these age-length data for both cod and haddock are so much lower than the values for length compositions that we conclude that the measured heterogeneity is reflecting the heterogeneity of the length compositions rather than heterogeneity of growth rates. In fact, the age-length samples examined for cod show scarcely significant heterogeneity.

Discussion

The most striking result of the analyses of both cod and haddock samples is the very high heterogeneity which persists in the finest sub-groupings that we can now make. Furthermore, with both haddock and cod, as the numbers of samples have increased, so too have the χ^2/d.f. ratios. That is, more sampling seems to have turned up more sources of variability. A sampling program with such characteristics cannot be relied upon for estimates of the composition of the fished population.

At the present time we do not have the data which would permit us to judge how much of the apparent local variation is a reflection of the way samples are taken from the ships and how much reflects real biological or fishery heterogeneity. But certain features of population or fishery change known from other sources, such as cod growth changes, or the taking of small haddock, were reflected in the measures of heterogeneity among samples. Furthermore, research-vessel sampling reveals that there are marked local variations in catches from area to area, and increases in sampling in more recent years have been largely in response to increases in the amount of fishing. It is therefore likely that much of the increase in the χ^2/d.f. ratios reflects a greater diversity of population elements exploited by the fisheries.

We conclude that improvement in the estimates of catch composition is not likely to be realized through further stratification or redesigning of sample programs of the sort reported here. More reliable estimates will, in fact, require substantial increases in the numbers of samples taken. Once the expanded program achieves the required stability of the χ^2/d.f. ratios within strata, indicating that all the important sources of variation have been included, the commercial samples together with data from special studies, research-vessel surveys and knowledge of fishery characteristics may be used to infer changes in the exploited stocks.

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Quantitative Distribution and the Seasonal Dynamics of Zooplankton in the Newfoundland Area

BY E. V. VLADIMIRSKAYA [1]

Abstract

Plankton sampling in 1958–61 shows the boreal species, with *Calanus finmarchicus* as the main species, are the most important food zooplankton in the area of the rich Newfoundland commercial fisheries.

The shallow waters of the Newfoundland area represent one of the most important fishing areas of the world. Our task was to study the composition, distribution and seasonal fluctuations of the zooplankton which supply food for a number of commercial fish species.

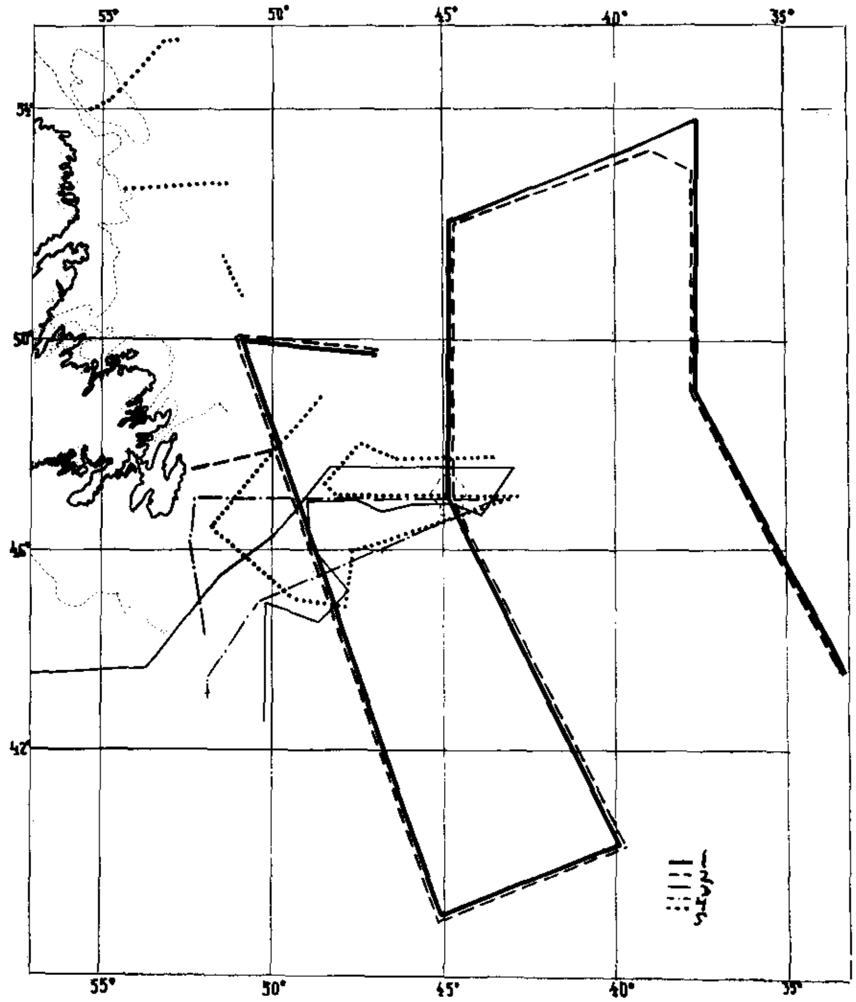

Fig. 1. Cruise routes:
1. R/V M. *Lomonosov*, Cruise II, 6 April–2 May 1958.
2. R/V M. *Lomonosov*, Cruise IV, 4 November–2 December 1958.
3. R/V M. *Lomonosov*, Cruise VII, 17–30 March 1960.
4. R/V M. *Lomonosov*, Cruise XI, 25 September–7 October 1961.
5. R/T *Sevastopol*, Cruise XIV, 7 July–11 August 1959.

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Materials for this study were obtained from plankton samples taken in 1958, 1959, 1960 and 1961, during the International Geophysical Year and the Year of the International Geophysical collaboration, from the R/V *M. Lomonosov* (Cruises II, IV, VII and XI) and the R/T *Sevastopol* (Cruise XIV) (Fig. 1). Plankton was sampled with a No. 38 (38 threads per cm) little Juday net (made of silk gauze) at standard horizontal layers starting from 500 or 1,000 m upward. The quantitative treatment of zooplankton was carried out according to standard methods. The work was started under the guidance of Kusmorskaya (1959, 1960 and 1961) and Kusmorskaya *et al.* (1960).

The area under investigation is rather heterogeneous with regard to its hydrologic regime. Subarctic water masses extend to north and north-east of the Great Newfoundland Bank. The Labrador waters with a high content of biogen elements discharge from the north-west. The southern part of the area is occupied by the warm waters of the North Atlantic current. The area of horizontal transformation (Mamaev, 1960; Istoshin *et al.*, 1960) is situated between the Labrador and subarctic water masses on one side and the North Atlantic water mass on the other.

A complicated system of currents forms water masses of this area which provide favourable chemical conditions for primary productivity. In early spring (March to April) the mass development of phytoplankton and then zooplankton starts in the southern part of the Great

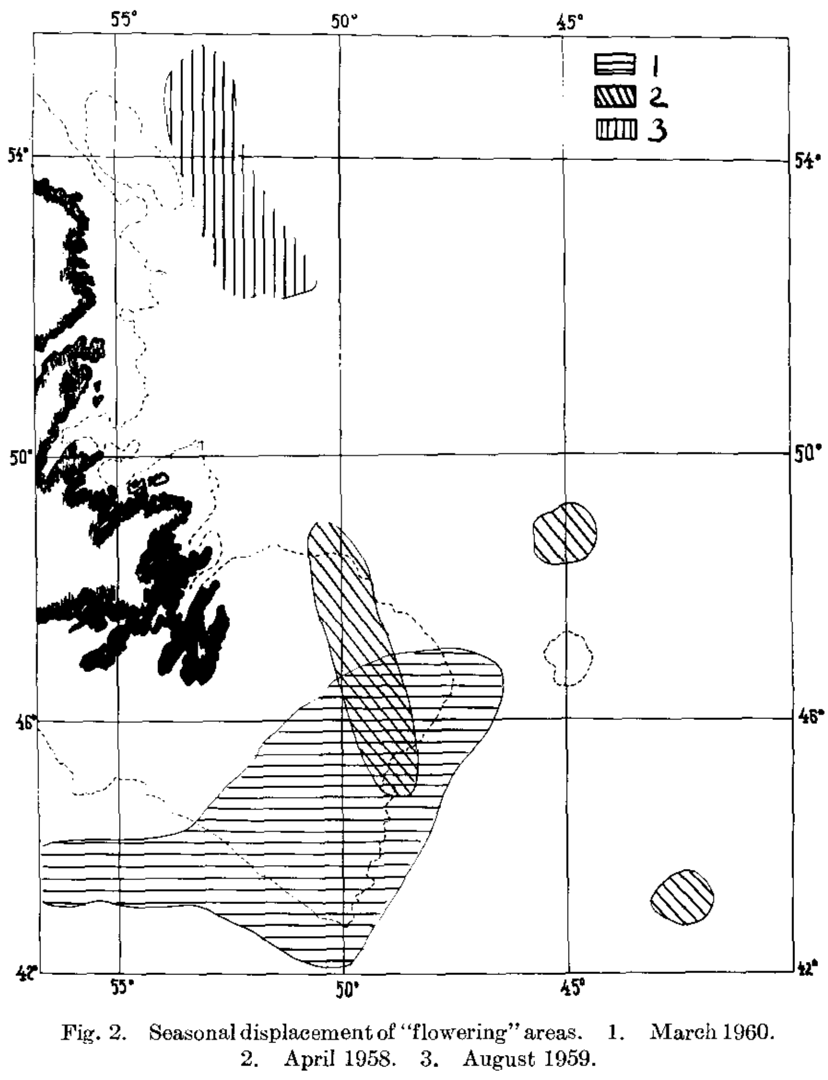

Fig. 2. Seasonal displacement of "flowering" areas. 1. March 1960. 2. April 1958. 3. August 1959.

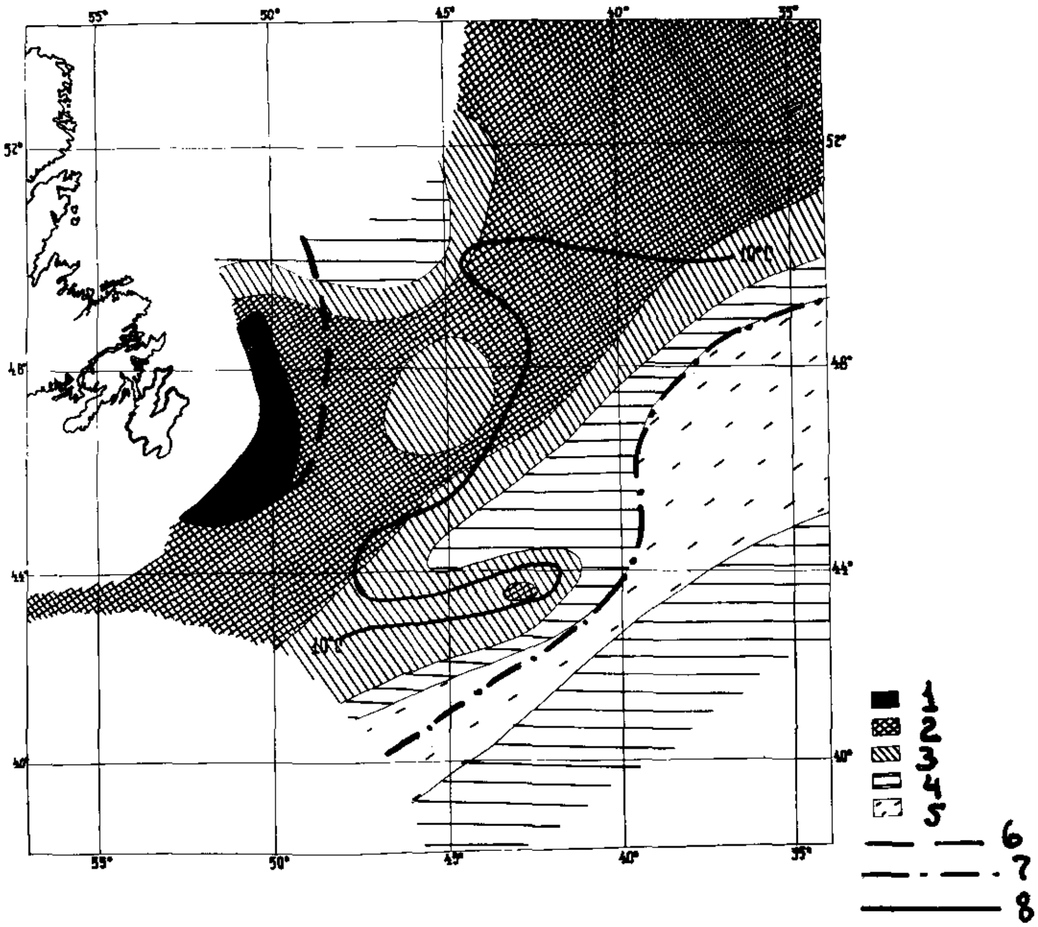

Fig. 3. Quantitative distribution of food zooplankton in mg per cubic meter in the Newfoundland area in the 100–0 m layer. Spring. 1. > 300 mg/m³. 2. 300–200 mg/m³. 3. 200–100 mg/m³. 4. 100–50 mg/³. 5. <50 mg/m³. 6. The north-western border of warm water species distribution. 7. The south-eastern border of arctic organisms distribution. 8. Location of the +10°C surface isotherm.

Newfoundland Bank (Vladimirskaya, 1962). Later the mass development of plankton is observed along the northern slopes of the Bank and in August this process is seen near the Labrador coast (Fig. 2).

The qualitative composition of zooplankton off Newfoundland is rather diverse. Boreal species, characteristic of the subarctic water mass, are predominant in the plankton population on the Great Newfoundland Bank and Flemish Cap. Food zooplankton of the boreal fauna is chiefly represented by *Calanus finmarchicus* (Gunner); in addition, the most abundant species are *Pseudocalanus minutus gracilis* G. O. Sars, *Pareuchaetra norvegica* (Boeck), *Metridia lucens* (Boeck), *Thysanoessa longicaudata* (Kroyer), *Pleuromamma robusta* Dahl, *Tomopteris* sp., *Limacina retroversa* Flemming.

Hydromedusae (mainly *Aglantha digitale*) and *Ctenophora* are the most frequent of the non-food species. A few arctic species such as *Calanus hyperboreus* Kroyer, *Calanus glacialis* Jaschnov, *Limacina helicina*, *Clione limacina*, *Oikopleura labradoriensis* Lohman supplement the boreal varieties on the Banks and their slopes being carried there by the Labrador waters.

Warm water species are brought and distributed by the North Atlantic Current. No

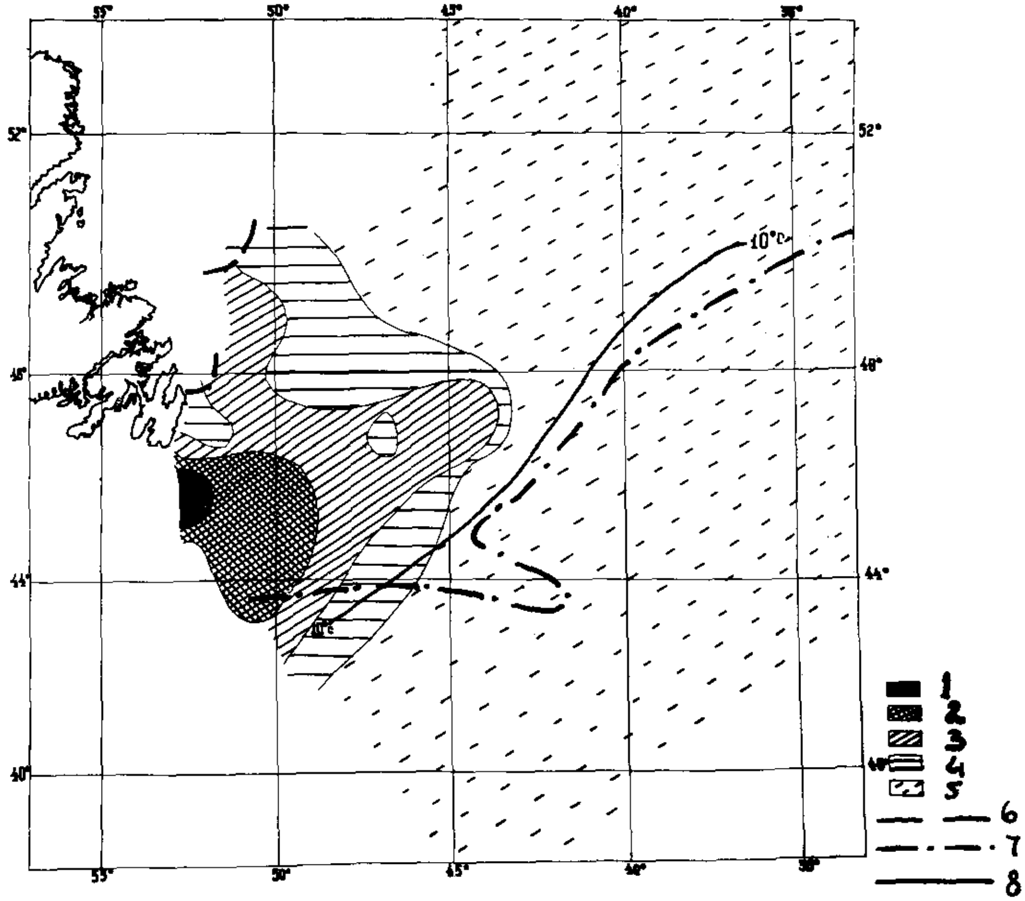

Fig. 4. Quantitative distribution of food zooplankton in mg per cubic meter in the Newfoundland area in the layer 100-0 m. Autumn. 1. > 300 mg/m³. 2. 300–200 mg/m³. 3. 200-100 mg/m³. 4. 100–50 mg/m³. 5. <50 mg/m³. 6. The north-western border of warm water species distribution. 7. The south-eastern border of arctic organisms distribution. 8. Location of the +10°C surface isotherm.

particular species predominates in this current. Although a great diversity of species is observed none of them reaches such mass development as the boreal varieties. Warm water species such as *Calanus Nelgolandicus* (Claus), *Neocalanus gracilis* (Dana), *Nannocalanus minor* (Claus), *Mecynocera clausi* Thompson and various species of *Calocalanus*, *Spinocalanus*, *Pleuromamma*, *Heterorhabdus*, *Euchaeta* are most frequent in the upper layers of the North Atlantic Current.

Of the non-food species, Doliolids and Salps (mainly *Salpae fusiformis* which occurs in spring and totals nearly 700 specimens per haul with a Juday net) are found in large quantities in waters of the North Atlantic Current. The limits of penetration of arctic and warm water species are shown on zooplankton biomass charts (Fig. 3 and 4).

The zone of horizontal transformation represents a zone of intermingling where representatives of boreal and warm water faunas are found together. The +10°C surface isotherm in this zone may be taken as the southern border of mass distribution of boreal species.

In the shallow waters of the Great Newfoundland Bank oceanic organisms are replaced by neritic forms, such as: *Temora longicornis* (Muller), *Pseudocalanus minutus elongatus* (Boeck), *Centropages hamatus* (Lilljeborg) and by various species of *Evadne* and *Pordon*. In addition to the above species considerable amounts of benthic larvae are found in the shallow waters.

The distribution of plankton biomass within the area in question is extremely unequal. The volume of food zooplankton biomass varies from tens to hundreds mg/m³ of water. The largest volume of biomass is characteristic of the Labrador and subarctic water masses. The maximum quantity of food zooplankton is observed in the central shallow area of the Great Newfoundland Bank up to its northern slopes. Waters of the North Atlantic Current area are considerably poorer than those of the subarctic area. The zone of horizontal transformation is the poorest one.

Figures 3 and 4 show the distribution of food zooplankton in respect of two seasons — spring and autumn.

The average volume of food zooplankton biomass in the boreal zone in the 100 – 0 m layer fluctuates from 130 mg/m³ to 350 mg/m³; the maximum biomass volume for the 200 – 0 m layer is 520 mg/m³ and the volume of particular samples is 900 mg/m³. In the zone occupied by the warm water species zooplankton biomass was only 30 – 50 mg/m³, rarely 90 mg/m³. The biomass of *Calanus finmarchicus* represents the base of the total biomass of food zooplankton in the boreal zone, a sizable proportion of the biomass in the central part of the Great Newfoundland Bank shallow waters is represented by neritic forms and larvae of benthic forms.

In summer the biomass zooplankton is considerably higher than in spring; in a number of areas it sometimes exceeds 1,000 mg/m³.

In autumn the distribution of zooplankton is similar in general features to the spring distribution. However, the ratio between arctic, boreal and warm-water species changes considerably at a number of stations.

In autumn the area occupied by arctic species and a proportion of the arctic species biomass in the total amount of food zooplankton both decreases greatly (from 20% to 4%). In autumn,

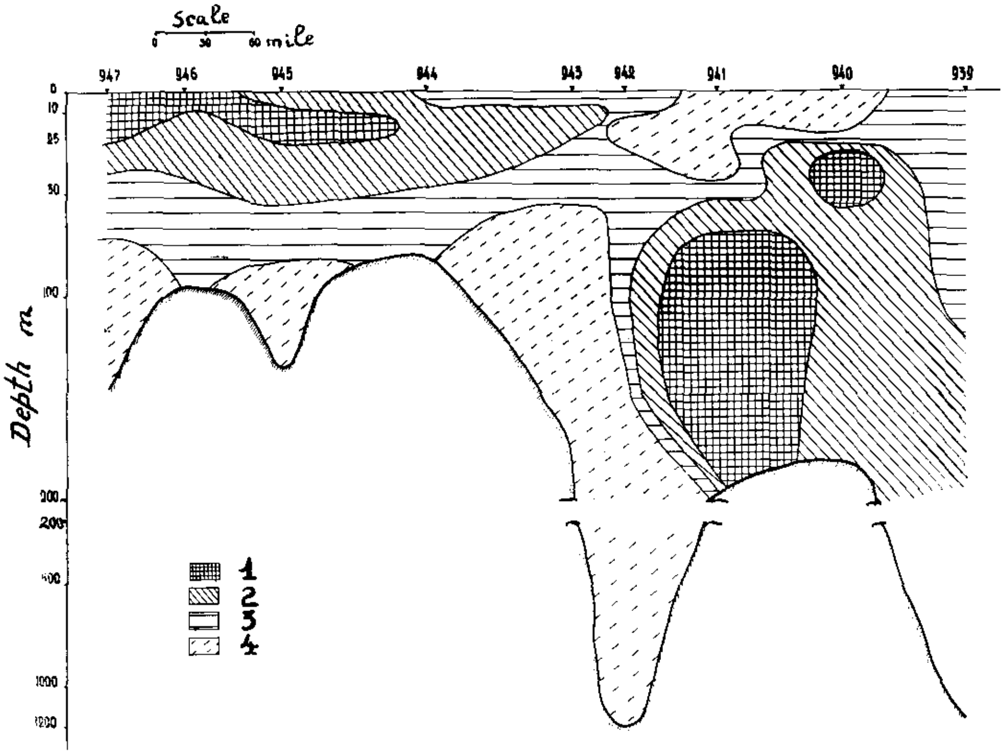

Fig. 5. Vertical distribution of food zooplankton in mg per cubic meter in the Newfoundland area. September 1961. 1. 500–200 mg/m³. 2. 200–100 mg/m³. 3. 100–50 mg/m³. 4. <50 mg/m³.

the area occupied by boreal species remains unchanged, but at some stations their proportion of the total biomass increases due to the presence of arctic species. At other stations, however, the amount of boreal forms decreases because of an increasing proportion of warm-water species.

In autumn warm-water species penetrate farther north and, at some stations, their biomass is considerably higher than in spring.

The total biomass of food zooplankton substantially decreases in autumn. Biomass remains higher than 300 mg/m^3 only in a small area of shallow water on the Great Newfoundland Bank. This may be explained by the presence of neritic forms. Over a large part of the area the biomass is just over 100 mg/m^3, and southwest of the Great Newfoundland Bank the maximum biomass decreases sharply in autumn up to 10 - 20 mg/m^3. The vertical distribution of zooplankton biomass and the ensuing food supply in the various water layers are extremely heterogeneous. In the boreal zone, because of diurnal vertical migrations, a large portion of the zooplankton leave the upper layers in the day time. In winter, the bulk of *Calanus finmarchicus* goes into hibernation, stops migrating and remains below 200 m in the deep water areas. This greatly reduces the food supply of the upper water layers. In shallow water areas, zooplankton inhabit the whole column of water from the bottom to the surface. In these areas, neritic species do not perform day and night mass migrations and the food supply therefore varies slightly during 24 hr. Figure 5 shows the vertical distribution of food zooplankton biomass across the Great Newfoundland Bank and Flemish Cap. In the Flemish Cap area (Station 941), the bulk of *Calanus* is found in the bottom layers and here, the food zooplankton biomass reaches 410 mg/m^3.

In the shallow waters of the Great Newfoundland Bank (Stations 944 - 947) *Calanus finmarchicus* occurs in the 50 - 0 m layer above the bottom water layers with temperatures below 0°C. The diurnal vertical migration is not clearly distinguished in the zone inhabited by warm-water species. Food organisms are most abundant from 0 to 50 m.

There is some difference in the ratio of *Calanus finmarchicus* stages of development in various seasons of a year. In spring, the first and sixth copepoid stages each make up 30% of the population; in summer in the Great Newfoundland Bank area the first and second copepoid stages make up 97% and in the Flemish Cap area the fourth and the fifth stages make up 80% of the population. In autumn, no one stage predominated in the 200 - 0 m layer. Great numbers of the young stages were found in the population. The fourth and the fifth copepoid stages of *Calanus finmarchicus* occurred mainly in the 1,000 - 200 m layer and appeared to be in hibernation.

The distribution of *Calanus finmarchicus* biomass reproduces, in general, the distribution of food zooplankton biomass inhabiting the boreal zone. In spring, *Calanus finmarchicus* made up 40 - 70% of the total food zooplankton biomass in the 200 - 0 m layer; in summer 50% in the 50 - 0 m layer (85 - 90% in a number of samples taken in 500 - 0 and 200 - 0 m layers); in autumn, 60 - 90% in the 100 - 0 m layer and 40 - 84% in the 1,000 - 0 m layer.

Thus, in the Newfoundland area, the boreal fauna with *Calanus finmarchicus* as the main species, forms the basic food zooplankton item and production and the distribution of *Calanus finmarchicus* determines the natural resources.

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Catch/Effort Assessment in Some ICNAF Fisheries

BY R. J. H. BEVERTON[1]

Abstract

Estimates of the possible range of values of mortality, growth and selection size are obtained for the majority of the ICNAF stocks of cod, haddock and redfish. These are used in a modified form of yield-isopleth diagram to obtain an approximate diagnosis of the state of the fisheries in relation to the point of maximum yield.

It is concluded that the level of exploitation in the majority of these ICNAF fisheries is, within limits of the available information, close to or beyond that giving the maximum sustained yield. The only exceptions are haddock of Divisions 4VW and possibly, cod of Subarea 2 (for which no reliable assessment of the effect of the recent big increase in fishing effort is yet possible).

Introduction

The many separate, or partially separate, fisheries of the ICNAF area, some long-established, others of recent origin, with a variety of gears and varying amounts of research data, present a peculiarly complex situation from the point of view of catch/effort assessment. No amount of theoretical manipulation can overcome the lack of reliable estimates of stock abundance or the difficulties of age-determination which are still major obstacles in many of these fisheries. Nevertheless, a considerable amount of information exists which, if allowance is made for the uncertainty attaching to it, can be used to make a rough diagnosis of the state of many of the ICNAF stocks in relation to fishing.

Method

Several authors (Jones, 1957; Holt, 1957, 1962; Beverton, 1963) have developed algebraically simplified forms of the yield equation by replacing age as an explicit variable by length and grouping the remaining parameters as ratios. That for equilibrim catch per recruit which is most convenient for the present purposes, although algebraically identical to the original form (Beverton and Holt, 1957), is

$$Y' = \frac{Y}{R_o W_\infty} = F/M\ (1-c)^{M/K} \sum_{n=o}^{3} \frac{U_n (1-c)^n}{1 + F/M + \frac{{}_nK}{M}} \qquad \ldots (1)$$

where

R_o = number (arbitrary) of recruits at age t_o

$c = L_c/L_\infty$ (where L_c = mean selection length) and the other parameters have their usual meaning. This is the same equation used by Beverton (1963), the derivation of which is given in full in Beverton and Holt (1964), except that E is replaced here by the ratio of fishing to natural mortality (F/M) from the identity

$$F/M \equiv \frac{E}{1-E}. \qquad \ldots (2)$$

For the present purposes F/M is preferable to E since the former is directly proportional to fishing mortality coefficient and hence, to a first approximation, to fishing effort.

Equation (1) shows that the equilibrium relation between catch per recruit and fishing mortality coefficient (in the ratio F/M) is determined by two parameters only, viz: M/K and c ($= L_c/L_\infty$) of which the former can be regarded as an intrinsic biological property of the stock in question, while the latter incorporates (in L_c) the selectivity of the fishing operations.

The theoretical basis of the yield equation contains a number of simplifying assumptions which are too familiar to need further stressing here. Certain of these, such as the assumption of a constant fishing mortality coefficient with age of fish, are clearly unlikely to be exactly true in many of the ICNAF fisheries, especially those exploited by several different fleets and gears. This is accommodated, when using equation (1), by calculating a weighted mean value of L_c and by setting appropriately wide limits to F/M. It will be recalled that an analogous device is adopted in Gulland's (1961*b*) method of mesh assessment, in which the exact value of E cannot be ascertained without detailed knowledge of the trend of F

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TABLE 1

Species	Subarea	Division	1	2	3	4	5	6	7	8	9	10	11	
												F/M		
			L_c cm	L_∞ cm	K	Z	E	M	Decrease in c/u to	M/K	L_c/L_∞	from E/1–E	from decrease in c/u	Source of data for estimates of L_∞ and K
COD	1		55–60	85–90	0.25–0.30	0.35	0.4–0.6	0.14–0.21		0.5–1.0	0.61–0.71	0.7–1.5 (1.4–3.0)		Hansen (Ann. biol., 1959–61)
	2	2HJ	50	65–70	0.3					(0.5–1.0)	0.71–0.77			May *et al.* (1964)
	3	3KL	52	95–105	0.2	0.6	0.42–0.75	0.15–0.35		0.75–1.75	0.49–0.55	0.7–3.0		May *et al.* (1964)
		3M	43	100	0.15						0.43			May *et al.* (1964)
		3NO	40	130	0.12	0.7	0.50–0.79	0.15–0.35		1–2.5	(0.31)	1.0–3.8		May *et al.* (1964)
		3P	46	90–100	0.2	0.6	0.42–0.75	0.15–0.35		0.75–1.75	0.46–0.51	0.7–3.0		May *et al.* (1964)
	4	4X	45	(105)		0.45	0.67–0.89	0.05–0.15			(0.43)	2.0–8.0		
		4T +Vs	50–55	(110–120)	0.10	0.4–0.6	0.50–0.83	0.1–0.2		1–2.0	(0.42–0.50)	1.0–5.0		Kohler (1964)
		4W +V(ex.s)	50	(110)		0.4–0.6	0.50–0.67	0.20			(0.46)	1.0–2.0		
	5		45	105–120	0.16	0.55	0.45–0.82	0.1–0.3	1/5–1/10	0.75–2.0	0.38–0.43	0.8–4.5	1.6–3.5	Schroeder (1930)
HADDOCK	3	3NO	33	55–60	0.22	0.75	0.53–0.80	0.15–0.35		0.75–1.5	0.55–0.60	1.1–4.0		Hodder (pers. comm.)
	4	4X	42	65–70	0.17–0.22	0.45	0.33–0.78	0.1–0.3		0.75–1.5	0.60–0.65	0.5–3.5		U.S. Res. Rept. 1962 (ICNAF)
		4VW	43	65–70	0.17–0.22	0.4–0.6	0.50–0.67	0.2		0.75–1.5	0.61–0.66	1.0–2.0		Hart (pers. comm.)
	5		38	73	0.28	0.6	0.50–0.83	0.1–0.3	1/4–1/8 (1/6–1/7)	0.5–1.0	0.50–0.54	1.0–4.5	1.4–3.6 (2.2–2.9)	Hennemuth (pers. comm.)
REDFISH	1		36	(65)							(0.55)			
	2	2J	32	50–55	$\leq$ 0.1						0.58–0.64			USSR; ICNAF Sampling Yearbook, 1961.
	3	3K	31	(47)							(0.66)			
		3M	29	45	0.12						0.64			USSR; ICNAF Sampling Yearbook, 1961
		3NO	22	40	0.11–0.12					1–2.5	0.55			Sandeman (Hodder; pers. comm.)
		3P	28	43							0.65			
	4	RST	28	(45)	$\leq$ 0.1	0.4	0.25–0.75	0.1–0.3	1/2		(0.62)	0.3–3.0	0.5	Sandeman (Hodder; pers. comm.)
		VWX	23	(42)	$\leq$ 0.1	0.4	0.50–0.83	0.1–0.3			(0.55)	1.0–4.5		
	5	Y	21	38–42	0.09–0.14	0.6	0.50–0.83	0.1–0.3		1–2.5	0.50–0.55	1.0–4.5		Kelly & Wolf (1959)

with age; there too, the difficulty is circumvented by assigning sufficiently broad limits to the range of E used in the calculations.

Other kinds of simplifications are dealt with in a similar way. Thus, the growth pattern of cod in Subareas 1 and 2, with a "step" at about 75–80 cm, is manifestly not in accord with the von Bertalanffy equation or any other simple function. Its effect can, however, be allowed for by setting an appropriate range to L_∞ and hence to c.

Estimates of the ratio M/K are also bound to be uncertain, primarily through lack of knowledge of the mortality rate M but also, where age-determination is unreliable, of the growth parameter K. Although some distinctions can be made between certain groups of stocks, it is necessary to base conclusions on assessments using a fairly wide range of M/K for each stock.

Given that it is possible, in certain stocks, to arrive at estimates of the range within which the parameters c and M/K are likely to lie, there remains the problem of determining the current level of fishing intensity, in terms of the magnitude of the ratio F/M. There are two possible ways of doing this. One is to calculate F/M, and its probable range, directly from estimates of F and M (or from E, using equation (2)) obtained by analysis of total mortality in relation to effort, by tagging experiments, or similar means. The other is to use information on the extent to which the abundance of the stock has been reduced by fishing, as judged from the relation between catch per unit effort and fishing effort. It is shown below that this decrease can be interpreted in terms of F/M, and in what follows both methods of estimating F/M are used, according to the kind of information available for the various stocks and fisheries.

Estimates of M/K, c and F/M for certain ICNAF stocks

These are summarized in Table 1, using data from various published sources and some unpublished information kindly supplied at my request by people listed in the last column.

Table 1 is largely self-explanatory, though some supplementary notes to it are given in Appendix 1. Inevitably, the compilation of such a table involves a certain amount of personal interpretation, but as far as possible the ranges of parameter values have been made wide enough to allow for a reasonable margin of uncertainty. It is important to note that estimates of L_c and E (from which c and F/M are calculated), are nearly all taken from the 1961 Assessment Report (Beverton and Hodder, Editors, 1962) and therefore refer to the period 1956–58. No attempt has been made here to allow for trends since that time, except in the case of two stocks. These are cod of Subarea 1, where there is clear evidence of an increase in fishing effort of some 2 to $2\frac{1}{2}$ times since 1957 (ICNAF, 1964); and haddock of Subarea 5, where data up to 1960 have been used (ICNAF, 1963).

Whichever method is used for making catch/-effort assessments from equation (1) and the data of Table 1, it is first necessary to decide on the range of M/K appropriate to each stock. Inspection of column 8 shows that the ranges of M/K can be grouped into four broad categories, as follows:

(a)	M/K = 0.5–1.0	Subarea 1 cod Divs. 2 HJ cod Subarea 5 haddock
(b)	M/K = 0.75–1.5	Div 4X haddock Divs. 4 VW haddock Divs. 3NO haddock
(c)	M/K = 0.75–2.0	Divs. 3KL cod Div. 3P cod Divs. 4T and V (S – Spring) cod Subarea 5 cod
(d)	M/K = 1–2.5	Divs. 4 RST redfish Div. 5Y redfish Divs. 3NO cod.

To some extent this grouping undoubtedly reflects real differences; this is the case where K is large (e.g. 0.25–0.30 in Subarea 1 and 2 cod and Subarea 5 haddock), and for these stocks M/K cannot be much greater than 1.0 without implying a value of M exceeding the observed range of Z. Where K is low, on the other hand, the same degree of uncertainty concerning M means that M/K has to be allowed a correspondingly wide range. This is particularly true for redfish and some cod stocks, though it may well be that the real range of M/K for these is not as large as this.

There are, in fact, indications from other studies (Beverton and Holt, 1959; Beverton, 1963) that M and K in different stocks of the same or related species tend to vary together, thus reducing the spread of their ratio M/K. No attempt has been made here to restrict the range of M/K on this basis, but the guess may be hazarded that as more precise estimates of M and K become available the range of M/K can be made narrower than is listed above. This is particularly the case with the stocks having the lowest K values (groups (c) and (d)), and it is not without significance that in one of these (4T + Vs cod) Dickie (1963) has estimated M to be in the region of 0.1, although the author was careful to stress that confidence limits could not yet be attached to this estimate. The same may prove to be the case for redfish; indeed if the ages of up to 50 years or more not infrequently recorded for this species by several authors are true, M for redfish must be correspondingly low, in accordance with its low K value. So far, however, these stocks have not shown as sensitive a response to changes in fishing effort as would be expected if M were truly low (Gulland, 1961*a*; Assessment Report), but the possibility is still open that special features of redfish distribution are masking the relation between catch per unit effort and stock abundance in this species.

Graphical presentation of catch/effort assessments

The yield equation (1) may be employed in the usual way to construct curves of yield per recruit (as a function of F/M, for given values of *c* and M/K) or yield-isopleth diagrams (with coordinates F/M and *c*, for given values of M/K). Tables of the yield function (1) are now available from which these may be drawn directly (Beverton and Holt, 1964), but the degree of uncertainty of the parameter values for most ICNAF fisheries means that a number of such diagrams would have to be drawn for each fishery.

A useful initial diagnosis of the state of a fishery can, however, be made without knowing the detailed shape of its yield curve or yield-isopleths. The first step is to obtain a rough appreciation of where the present level of exploitation stands in relation to the point of maximum yield. If, therefore, diagnosis is limited to establishing:

(a) whether the present rate of fishing is likely to be greater or less than that which would generate the maximum equilibrium yield (if one exists at a finite rate of fishing); and

(b) if less, whether the equilibrium yield generated by the present rate of fishing lies within, say, 95% or 90% of the maximum on the ascending side of the yield curve,

then a form of yield-isopleth diagram can be constructed which enables all the information for a particular fishery to be combined on a single diagram.

An example is shown in Fig. 1, for the first group of stocks in which M/K lies between 0.5 and 1.0. As in a yield-isopleth diagram, the ordinate is a scale of F/M (proportional to fishing mortality coefficient) and the abscissa is a scale of *c* (proportional to mean selection length), but instead of showing a range of contours of yield, only the locus of the maxima of the constituent yield curves (and the loci of yields which are 95% and 90% of the maxima, see below) are drawn. Thus, the curve forming the upper boundary of the stippled zone defines pairs of values of F/M and *c* generating a maximum yield when M/K = 0.5; that forming the lower boundary defines pairs of F/M and *c* generating a maximum yield when M/K = 1.0. The stippled area can therefore be regarded as the "zone of maximum yield", in as much as any pair of values of *c* and F/M falling within it cannot be distinguished (because of the present uncertainty of the exact value of M/K) from those generating the true maximum yield. The full and broken lines shown above the stippled zone refer to yields which are 95% and 90% of the maxima defined by the upper boundary of the stippled area (i.e. for M/K = 0.5); they therefore refer to points on the ascending limbs of the constituent yield curves at these percentages of the maxima.

If the likely range of *c* and F/M is known for any stock in the first group (M/K = 0.5 to 1.0), these can be drawn directly on this diagram as a rectangle (Fig. 1). The location of this rectangle in relation to the stippled zone and to the 90% and 95% contour lines indicates at once the state of the fishery compared with the requirements for obtaining the maximum yield or these percentages of it on the ascending side of the yield curves, with allowance made for the uncertainty of the true value of M/K. As better or more up-to-date estimates of the likely range of *c* or F/M become available, they can be entered directly on the same diagram simply by modifying the boundaries of the rectangle.

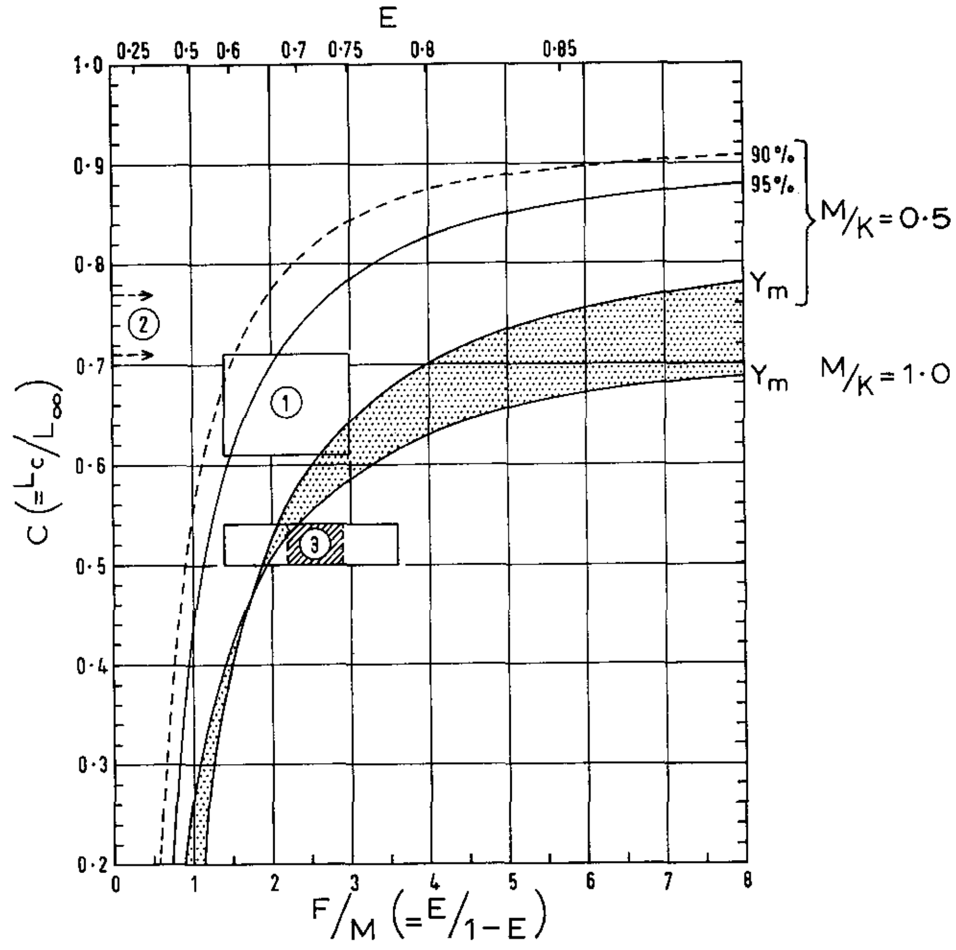

Fig. 1. Catch/effort nomogram for stocks with M/K = 0.5–1.0, namely:
(1) Cod, Subarea 1
(2) Cod, Subarea 2
(3) Haddock, Subarea 5
The stippled zone defines the range of values of F/M (ratio of fishing to natural mortality; approximately proportional to fishing effort) and c (= L_c/L_∞ ; proportional to mean selection length L_c) which generate a maximum in the catch/effort curve, allowing for the uncertainty of the true value of M/K within the range of 0.5–1.0. The actual range of values of c and F/M (Table 1) for cod of Subareas 1 and 2, and Subarea 5 haddock, are shown on the diagram.

The conclusions that may be drawn about the state of the fishery according to the location of values of c and F/M on a diagram such as Fig. 1 may be classified as follows:

	Location of c and F/M	Diagnosis
(i)	Outside the 90% contour (above and left)	Yield has not yet reached 90% of the maximum, and may be less.
(ii)	Between the 90% and 95% contours	Yield has not yet reached 95% of the maximum, but may exceed 90% of it.
(iii)	Between the 95% contour and the stippled zone	Yield has not reached the maximum, but may exceed 95% of it.
(iv)	In the stippled zone	Rate of fishing is close to that generating the maximum yield (on either side), and cannot be distinguished from it within the limits of accuracy of the data.
(v)	Outside the stippled zone (below and right)	Rate of fishing clearly exceeds that generating the maximum yield.

Contour lines referring to the descending side of the constituent yield curves are not shown; this is partly to avoid complicating the diagram, and partly because when once it can be demonstrated that the rate of fishing has exceeded that generating the maximum yield it matters less, from the point of view of regulatory action, by how much the yield has been depressed. It may be noted, however, that the 95% and 90% contour lines on the descending side of the yield curves are roughly the same distance from the locus of the maxima (measured normally to it) as are those on the ascending side. Thus, in the case of Fig. 1, the yield generated by any value of c and F/M in the stippled zone is certainly greater than 95% of the maximum, whether on the ascending or descending sides of the corresponding yield curve.

Two other features of this and similar diagrams for other ranges of M/K (Fig. 4, 5 and 6) need mention. One is that their use for the kind of diagnosis stated above makes no assumption about the form of the relation between fishing mortality coefficient and fishing effort, except that the two should increase or decrease together. If, however, F can be assumed to vary roughly in proportion to effort, then the abscissae of these diagrams can be taken as an approximate scale of fishing effort. This permits certain conclusions to be drawn about changes in catch per unit effort, as will appear later.

The other point is that because the curves shown in these diagrams are the loci of maxima (or percentages of those maxima) in curves of yield as a function of F/M at fixed values of c, they define only one of the two sets of maxima which can be distinguished in a full yield-isopleth diagram. They must therefore be read in the **horizontal direction only,** i.e. parallel to the scale of F/M[2].

Assessments of this kind for stocks in each of the four groups, listed above according to their range of M/K, will now be given.

Assessment for stocks with M/K = 0.5–1.0 (Fig. 1)

(a) Subarea 5 haddock

This is a particularly useful example to begin with, since data of both mortality and the decrease of catch per unit effort with effort are available. The values of E and M from columns 5 and 6 of Table 1 give a wide range of F/M, from 1 to 4.5. It will now be shown that this range of F/M is, however, much wider than is consistent with that which can be deduced from the relation between catch per unit effort and effort for this stock, provided it can be assumed that recruitment has not varied appreciably with stock size.

Figure 2 shows this relation, taken from the U.S. Research Report for 1962. The 1960 effort was 8.5 units, and the catch per unit effort about 10.5 units, which is about one-quarter of the highest observed catch per unit effort even when there was appreciable fishing. If the theoretical catch per unit effort curves for M/K between 0.5

[2]The other set of maxima are those in the curves of yield as a function of c at fixed values of F/M. Their loci are similar in shape to those of Fig. 1 but are displaced upwards (i.e. lie at higher values of L_c/L_∞), and are true eumetric fishing curves corresponding to curve BB′ of Beverton and Holt (1957), fig. 17.14. They would be used to assess catch in relation to selection length (L_c) by this method. In the yield function tables referred to above (Beverton and Holt, 1964) both sets of maxima are shown; the one used here is marked in the above tables by an asterisk, and is tabulated therein more exactly in the supplementary table IIa.

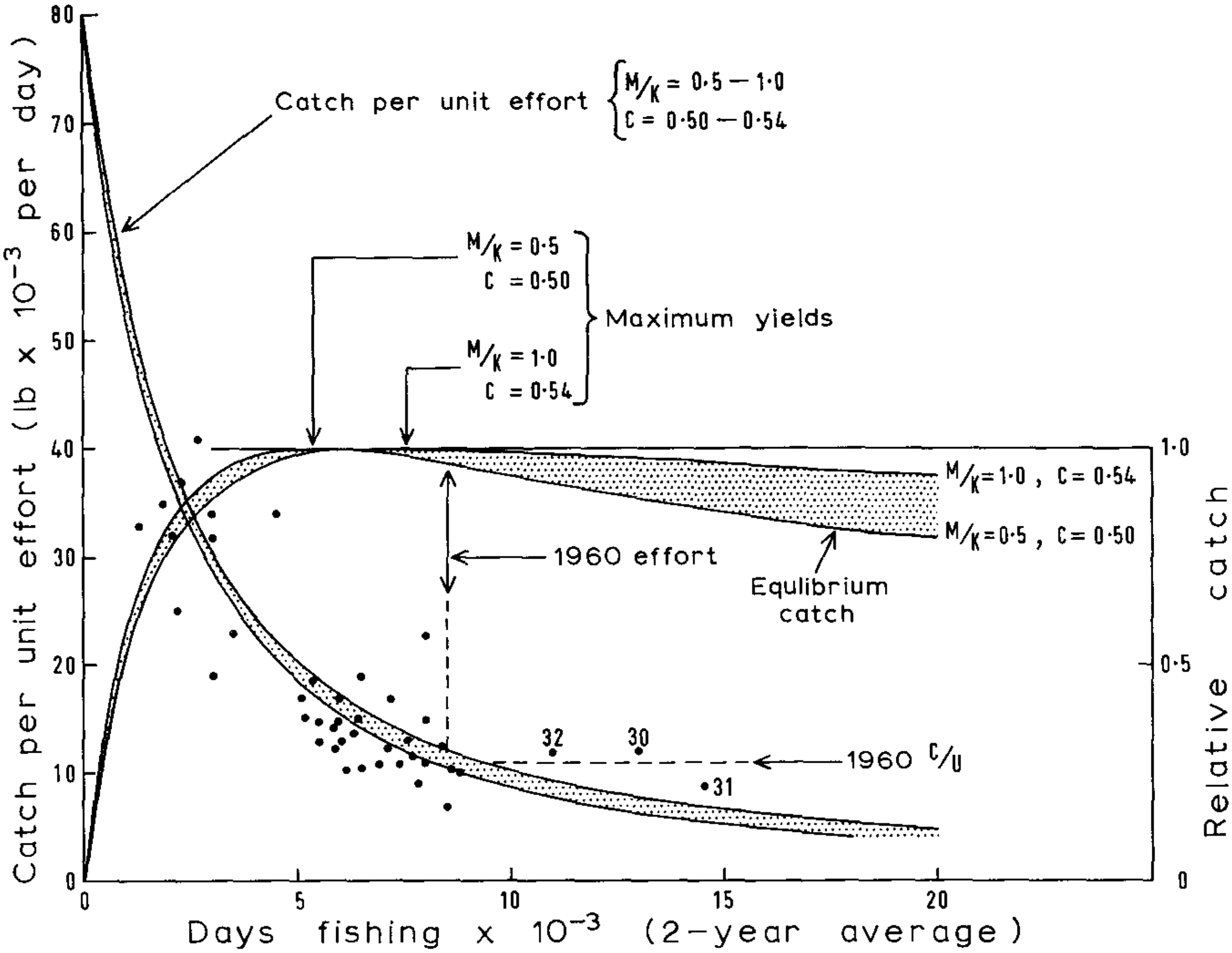

Fig. 2. Plot of catch per unit effort against fishing effort for Subarea 5 haddock (1962 U.S. Res. Rept.). Shown also are the theoretical catch per unit effort/effort curves (left-hand scale) and the corresponding yield/effort curves (right-hand scale) for M/K = 0.5–1.0 and c = 0.50–0.54.

and 1.0, and for c between 0.50 and 0.54 are calculated from equation (1), they appear as the stippled curve in Fig. 2[3]. No great precision can be claimed for this fit; in particular, the high points for the years 1930–32 are aberrant by any simple criterion. Nevertheless, a curvilinear relation is not only to be expected theoretically but has been demonstrated in cases where a wide range of effort and catch per unit effort data are available (e.g. for Icelandic plaice and haddock; Gulland, 1961c). The 1960 catch per unit effort, according to Fig. 2, corresponds to a reduction to between one-sixth and one-seventh of the unexploited c/u; this is doubtless an optimistically precise estimate, but even if a simple linear regression is put through the points it is difficult to conclude that the decrease in stock abundance due to fishing could have been to less than about one-quarter of its original unfished level.

Figure 3(b) shows the relation between these estimates of stock decrease and those of F/M required to generate them. The stippled curve is the decrease of catch per unit effort (expressed

[3]When fitting theoretical curves of catch per unit effort to data as in Fig. 2, both an unexploited value of c/u and a scale relating effort to F/M have to be selected, as judged by the goodness of fit they produce. In Fig. 2 the unexploited c/u is taken as 80 units. For M/K = 0.5, unit F/M ≡ 3.25 units of effort; and for M/K = 1.0, unit F/M ≡ 2.89 units of effort.

as a fraction of the unexploited value) with increasing F/M, for M/K = 0.5–1.0 and c = 0.50–0.54, again calculated from equation (1). Marked on this curve are the extreme values of F/M corresponding to the possible extent of stock decrease, giving:

Fraction of unexploited c/u	**Range of F/M**	
$\frac{1}{4} - \frac{1}{9}$	1.4 – 3.6	(wide range)
$\frac{1}{6} - \frac{1}{7}$	2.2 – 2.9	(narrow range).

The wider of these two ranges of F/M is shown by rectangle ③ of Fig. 1; the narrower by the hatched area within it. From the former it would appear that the 1960 level of effort generated an equilibrium catch which could range from just to the left of the maximum to about 95% of it beyond. The narrower limits would set the catch just below the maximum on its descending side, which is essentially the conclusion reached in the 1962 U.S. Research Report (ICNAF, 1963). These differences in equilibrium catch of a few per cent are clearly of little significance in themselves, but it is important to note that the wider limits of F/M cover a two-fold range, and hence, approximately, a similar range of fishing effort and catch per unit effort.

This example also enables the correspondence between the generalised presentation and the conventional yield curve graphs to be shown. Thus the yield curves for M/K 0.5–1.0; c = 0.50–0.54 are shown in Fig. 2 by the stippled zone, all being adjusted to unit maxima. The exact maxima are shown by the arrows; as expected from the inner hatched area of rectangle ③ in Fig. 1 they are all to the left of the 1960 effort, but the actual

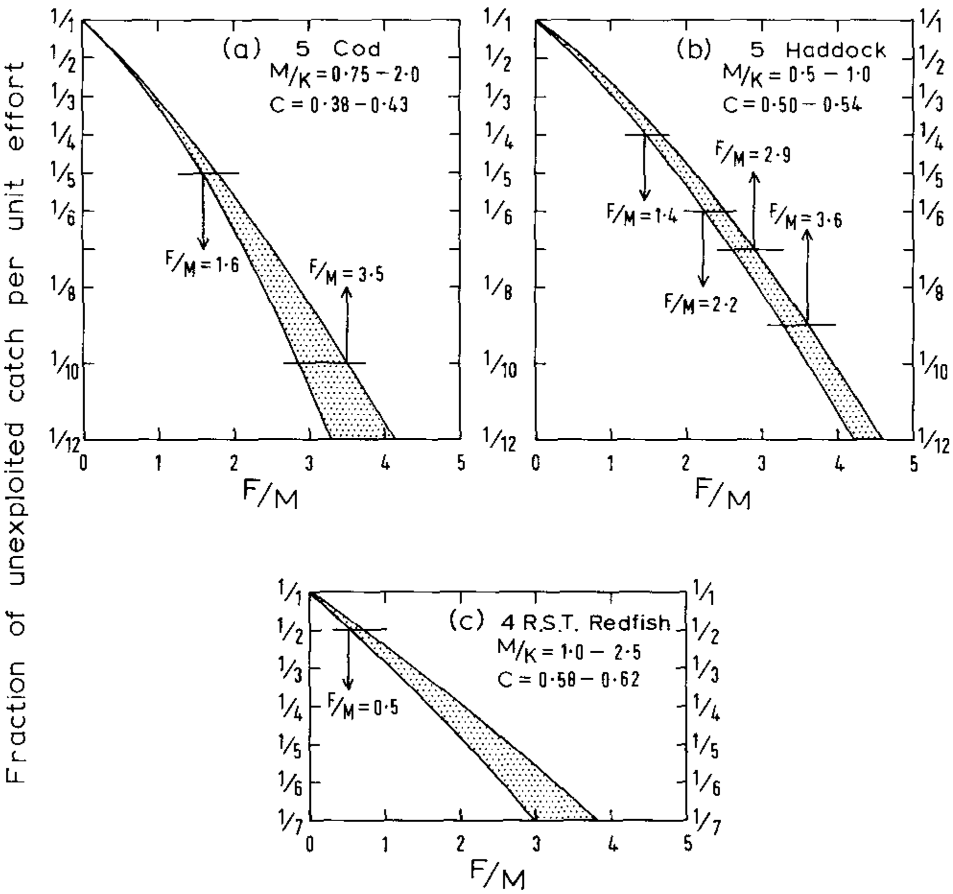

Fig. 3. Graphs showing the theoretical decrease in catch per unit effort (as a fraction of the value in the unexploited stock) as a function of F/M (approximately proportional to fishing effort) for certain stocks. Marked on these graphs are the observed limits of decrease of catch per unit effort and the values of F/M to which they correspond.

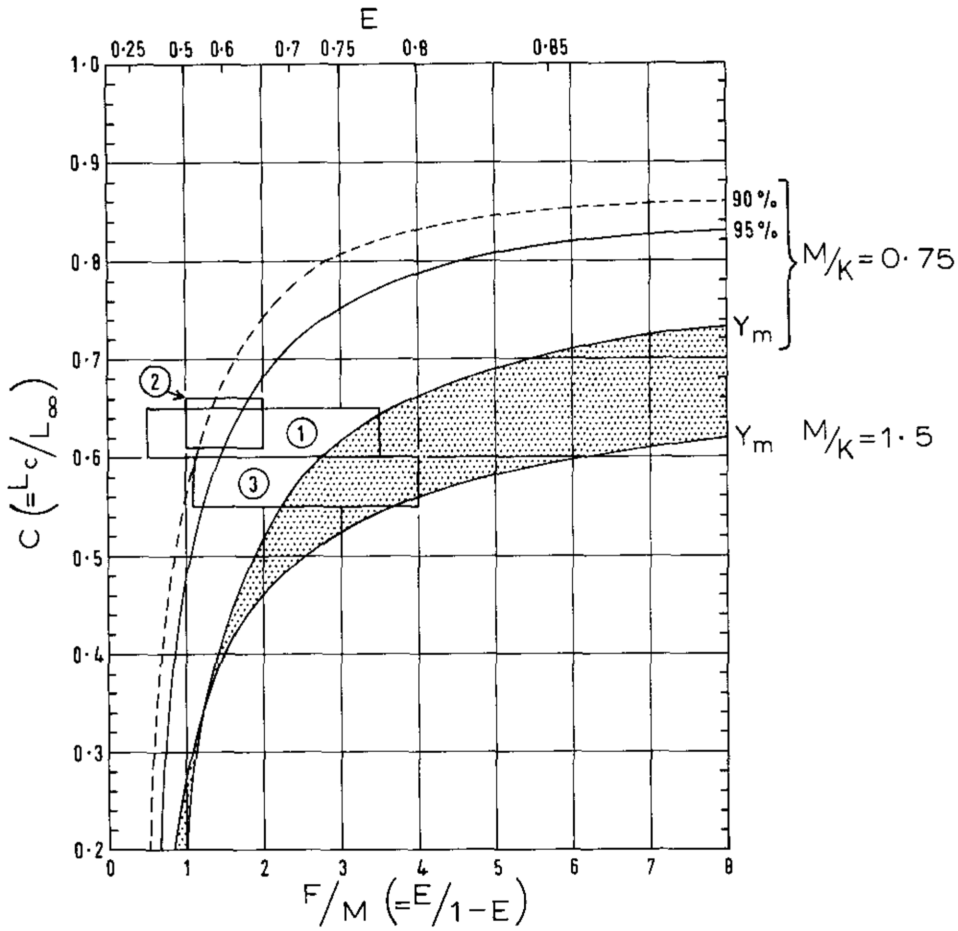

Fig. 4. Catch/effort nomogram for stocks with M/K = 0.75–1.5, namely:
(1) Haddock, Div. 4X
(2) Haddock, Divs. 4VW
(3) Haddock, Divs. 3NO

yields at that effort are only a few per cent below the maxima.

(b) **Subareas 1 and 2 cod**

These are characterised by relatively low values of L_∞ (and hence high values of c), the range here allowing for the "stepped" character of the growth curve of these stocks. In the case of Subarea 2, the different growth parameters for fish of Divs. 2H and 2J reported by May *et al.* (1964) have been combined in a simple value of c by weighting according to the catch taken in each Subdivision. The range of M is not known for Subarea 2 cod, but May *et al.* report no difference in longevity compared with stocks in adjacent areas, and it seems reasonable to assign to them provisionally the same range of M/K as for Subarea 1 cod. The limits of c and F/M for Subarea 1 cod (Table 1), the latter allowing for the increase in fishing effort since 1957, are shown by the rectangle ① in Fig 1. Nearly all of it lies inside the 90% contour, even at the lowest value of M/K = 0.5, and much of it inside the 95% contour. The lower right-hand corner overlaps into the maximum yield zone, from which it may be concluded that if the true F/M is at the upper end of the possible range, and c at the lower end, the present level of exploitation may already have reached that giving the maximum sustainable yield.

Although there has been a massive increase in fishing effort in Subarea 2 in recent years, the period is too short to give a reliable measure of the depletion it has caused, and no direct estimates of fishing and natural mortality are yet available. Therefore, in Fig. 1, only the limits of c are shown, unbounded to the right. These are, however, high, because of the limited span of growth in the Labrador stock. This means that the yield curves for this fishery are likely to be very flat-topped and, as can be seen from Fig. 1, fairly intense fishing would be needed to reach the maximum yield. Indeed, it may well be that the decline in catch per unit effort which would be the inevitable accompaniment of major increases in fishing effort would, for economic reasons, restrict exploitation in this stock to levels below that required to reach the theoretical maximum yield.

Assessments for stocks with M/K = 0.75–1.5 (Fig. 4)

All the remaining haddock stocks (Divs. 3NO, 4X and 4VW) fall into this group, because they all have K values appreciably lower than that of Subarea 5 haddock and there is no direct evidence to show whether M is correspondingly lower. They all have somewhat higher c values than Subarea 5 haddock, partly because they have lower L_∞'s and partly because L_c is higher (Divs. 4X and 4VW). The zones of c and F/M for these stocks are shown in Fig. 4. None extends beyond the zone of maximum yield. Division 3NO haddock is nearest to this, however, and a knowledge of recent trends in fishing effort on this stock and their interpretation is clearly important here.

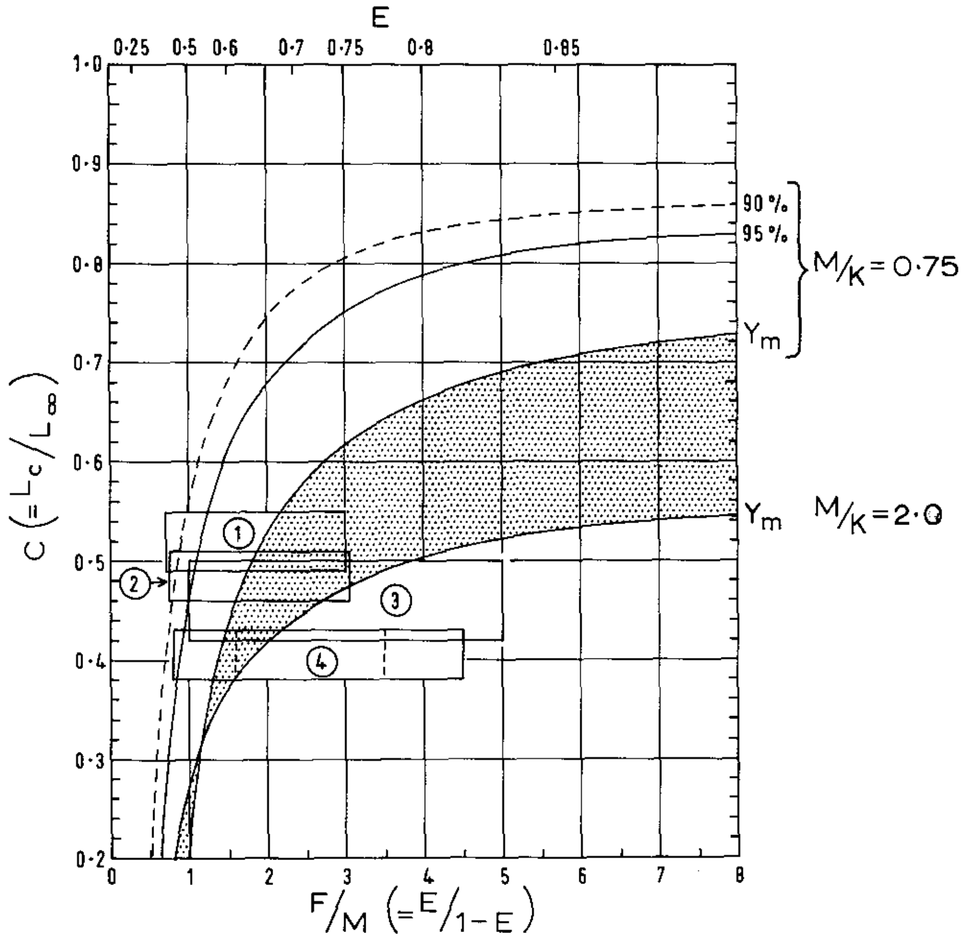

Fig. 5. Catch/effort nomogram for stocks with M/K = 0.75–2.0, namely:
(1) Cod, Divs. 3KL
(2) Cod, Div. 3P
(3) Cod, Divs. 4T + Vs
(4) Cod, Subarea 5

Assessments for stocks with M/K = 0.75–2.0 (Fig. 5)

Included here are the cod stocks with values of K in the intermediate range 0.15–0.25 (Divs. 3KL, 3P and Subarea 5), and also one with a low K (Div. 4T + Vs; K = 0.10) but in which the upper limit of M can reasonably be set at about 0.20. Two distinct growth curves in each of the Divs. 3KL and 3P have been reported by May *et al.* (1964); weighted mean values of L_∞ have therefore been used to estimate *c*, as in the case of Divs. 2HJ. From Fig. 5 it would appear that in neither Divs. 3KL nor 3P cod is it likely that the 1958 level of effort had appreciably exceeded that giving the maximum catch, though in both it might have reached it.

The range of F/M for Div. 4T + Vs cod is based on that of Z for the years 1956–58 (0.4–0.6, Assessment Report, Beverton and Hodder, 1962) and the later estimates of F (0.3–0.5) obtained by Dickie (1964) from tagging experiments. An upper limit of M in the region of 0.20 is indicated from the fact that the estimate of Z in the preceding period 1951–54 was itself only 0.24 (Assessment Report, Beverton and Hodder, 1962). These values give the rather wide range of F/M shown in Fig. 5 of 1–5, which spans the zone of maximum yield and extends beyond it on both sides.

Just as evidence of the relation between catch per unit effort and effort can be used to narrow the likely range of F/M in Subarea 5 haddock, so can it also in Subarea 5 cod. Thus Fig. 8.2. of the Assessment Report (Beverton and Hodder, 1962) suggests that the decline in abundance of this stock attributable to fishing has been even greater than that of the haddock; the 1958 level

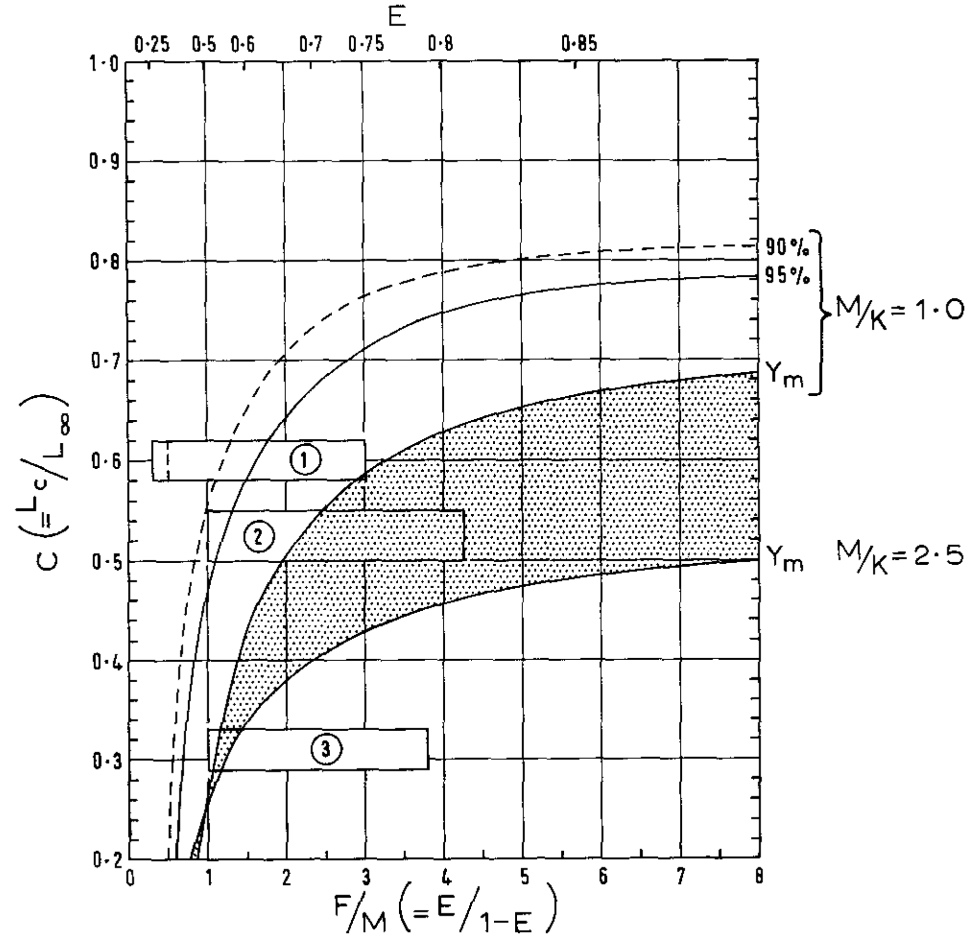

Fig. 6. Catch /effort nomogram for stocks with M/K = 1.0–2.5, namely:
(1) Redfish, Divs. 4RST
(2) Redfish, Div. 5Y
(3) Cod, Divs. 3NO

of catch per unit effort would seem to be something between one-fifth and one-tenth of the unexploited level. Figure 3(a) shows that these limits correspond to a range of F/M from 1.6 to 3.5, and this is indicated in Fig. 5 by the broken lines. With this narrower range of F/M it appears that by 1958 the level of effort was either about equal to that generating the maximum yield or had exceeded it—perhaps by as much as two-fold.

Assessments for stocks with M/K = 1.0–2.5 (Fig. 6)

This last group comprises the stocks with the lowest K values. These include Divs. 3 NO cod and redfish of Divs. 4 RST and 5Y, all of which have K values in the region of 0.1. Again, the lack of precise estimates of M means that M/K for these stocks has for the time being to be allowed a wide possible range up to 2.5. Figure 6 shows the zones of *c* and F/M for these stocks. Only that for Divs. 3NO cod extends to well beyond the zone of maximum yield, due to the low *c* value for this stock, generated by a very high L_∞ (130 cm); in this case it therefore appears that the 1958 level of effort may well have exceeded by a considerable margin that corresponding to the maximum yield.

Changes in catch per unit effort due to fishing do not emerge clearly in these stocks, though in the case of Divs. 4RST redfish it is concluded in the Assessment Report (Beverton and Hodder, 1962) that the stock has probably been reduced to at least a half by fishing. From Fig. 3(c) this reduction corresponds to a minimum value of F/M = 0.5, which raises slightly the lower limit of F/M (as shown by the broken line of rectangle ① in Fig. 6) but does not materially alter the diagnosis.

Summary

(i) An algebraically simplified form of yield equation is used in which equilibrium yield per recruit is expressed in terms of three parameters only, viz:

- F/M (incorporating the amount of fishing, as F)
- L_c/L_∞ (incorporating the selectivity of fishing, as L_c)
- M/K (the ratio of the natural mortality and growth coefficients; an intrinsic biological characteristic of the stock in question).

(ii) From a survey of the information available in the 1961 Assessment Report, supplemented by published and unpublished data from other sources, estimates of the likely range of these parameters are obtained for the majority of the ICNAF cod, haddock and redfish fisheries (Table 1).

(iii) These estimates are used in the simplified yield equation to make a rough diagnosis by graphical means of the level of exploitation of those stocks during 1956–58 (and more recently in two instances) in relation to the requirements for obtaining the maximum equilibrium yield.

(iv) From this analysis the following conclusions emerge:

(a) In only three stocks was the fishing effort during this period (1956–58) clearly below that giving the maximum yield.
These are:
cod of Subareas 1 and 2 (Fig. 1)
haddock of Divs. 4VW (Fig. 4).

(b) A number of stocks were then, or have since become, fished at an intensity equal to or a little below, but not appreciably above, that giving the maximum yield.
These are:
cod of Subarea 1 (Fig. 1) and Divs. 3KL and 3P (Fig. 5)
haddock of Divs. 3NO and 4X (Fig. 4)
redfish of Divs. 4 RST and 5Y (Fig. 6).
The effect of the big increase in fishing effort since 1958 on the level of exploitation of **Subarea 2 cod** cannot yet be assessed.

(c) In the remaining stocks dealt with here the possible rate of fishing during the period 1956–58 spanned that giving the maximum yield and extended well beyond it. These are:
cod of Divs. 3NO (Fig. 6), 4T + Vs (Fig. 5), and Subarea 5 (Fig. 5).
haddock of Subarea 5. (Fig. 1 and 2).

In none of these can it therefore be established, on the evidence considered here, that the fishing effort had clearly exceeded that giving the maximum yield; but in all except cod of Div. 4T + Vs it is more likely than not to have done so, particularly in Divs. 3NO cod.

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Appendix

Supplementary notes to Table 1.

Column 1. (L_c).

Since the method does not take account of a variation of F with age (as probably occurs, for example, in multiple-gear fisheries), the value of L is an average of the mean selection lengths for the constituent gears and fleets, or both, weighted by their respective catches. The data are taken from the length compositions of the commercial catches given in the 1961 Assessment Report, and therefore refer for the most part to the period 1956–58.

Columns 2 and 3 (L_∞ *and* K)

These are taken from published growth data, or from unpublished estimates kindly provided by personal communication. Sources are given in the last column. Values of L_∞ in parenthesis are based, in the absence of growth data, on the maximum length of fish in length compositions of commercial catches.

Columns 4, 5 and 6 (Z, E *and* M)

These are taken from the Assessment Report except in the case of M for Div. 4T + Vs cod, which is from Dickie (1964). The values of Z and E therefore refer to the period 1956–58.

Column 7

Estimates of the decrease in catch per unit effort from the unexploited level, due to fishing, are based on data from the Assessment Report, except in the case of Subarea 5 haddock which is taken from the 1962 U.S. Research Report. As is described in the text, the extent of the decrease in catch per unit effort can be interpreted in terms of F/M, giving the estimates of this ratio tabulated in column 11.

Columns 8 and 9 (M/K *and* L_c/L_∞)

These are calculated from the estimates of the component parameters given in columns 1, 2, 3 and 6.

Columns 10 and 11 (*F/M*)

Two sets of values of F/M are given. One (column 10) is calculated from the values of E in column 5, from the identity

$$F/M \equiv \frac{E}{1 - E}$$

The other (column 11) is estimated from the decrease in catch per unit effort of column 7, as described in the text.

The range of F/M for Subarea 1 cod shown in parenthesis in column 10 (1.4–3.0) allows for an increase of fishing effort since 1958 of 2 to $2\frac{1}{2}$ times.

A Note on the Relation Between the Mortality Rate and the Duration of Life in an Exploited Fish Population

Abstract

Expressions for the mean and upper limiting values for samples from the exponential distribution provide methods of evaluating the fishable life-span and the total mortality coefficient when there are few data for the relative numbers of older age-groups in the stock and catch.

In constructing theoretical population models for assessment of stocks and yields, differential equations for rate of yield must be integrated over the fishable life-span. The lower limit of the fishable life-span is determined by the pattern of recruitment and the selectivity of the gear. The upper limit may be determined by escape of fish from the gear, as with gill-nets, or by emigration from the exploited area, but in a closed fishery using trawls and similar gears it is effectively that to which the formulations adopted for mortality and growth functions are held to be valid.

If the function used to express growth in weight is an asymptotic one, little error can be introduced by extrapolating it, so long as the mortality function is valid. In practice average weight can often be determined fairly satisfactorily at ages for which data on mortality are quite inadequate, and we therefore concentrate attention on estimation of the latter quantity.

Several authors have considered the relation between mortality rate and "life-span" in fishes. Life-span is dimensionally the same as the reciprocal of the total mortality coefficient and Beverton and Holt (1959) and Beverton (1963) used an index of it (the oldest group in published age-distributions) to compare with growth and maturity parameters in studying the inter- and intra-specific relations of these with natural mortality. Tauti (1947) derived a deterministic expression for total mortality in terms of the "average" (strictly, the median) age (a), and of oldest age (b) of fish in a sample of given size n, which, in terms of the instantaneous coefficient Z, is

$$\frac{1 - e^{-Z\,(b - a + 1)}}{e^{-Z(b - a)}\left(1 - e^{-Z}\right)} = \frac{n}{2}$$

Kurita (1948) discussed the limitations and application of this equation, indicated how intrinsic errors might be compensated, and suggested that Z would be better estimated from the average of the survival rates from a number of samples.

Beverton (1963) pointed out that in certain stocks the mortality increases with age and survival is thus well described by the Gompertz equation. In this case the oldest fish in the population at any time, or in samples, is not very sensitive to population or sample size (being related to loglog n). For various reasons, however, the simple exponential has advantage and is sufficient as a model for mortality and lifespan estimation, at least for the post-recruit phase of fish populations.

It is therefore necessary to consider the limiting values for the exponential distribution. The fundamental theory was given by Kendall (1955) in his review of Gumbell, (1954) and the results are as follows:

$$\text{Suppose } f(x) = 1 - \exp.\,(-x)\ [\,x \geqslant o\,] \qquad (1)$$

where $f(x)$ is the probability that a given observation has a value equal to or less than x. Let y be the largest value of x in a sample of size n, and put

$$y = v + ln(n)$$

Then it is shown that the distribution of y has zero mode, mean = 0.577 (Euler's constant)

and standard deviation $= \dfrac{\Pi}{\sqrt{6}} = 1.28$

In a series of samples of size n then the mean largest value is

$$\bar{y} = 0.577 + ln(n) \qquad (2)$$

The average proportion of fish younger than t years in the exploited phase of a fish population for which the total mortality coefficient Z is constant is

$$\frac{R' \int_{t_c}^{t} e^{-Z(t-t_c)}\,dt}{R' \int_{t}^{\infty} e^{-Z(t-t_c)}\,dt} = 1 - e^{-Z(t-t_c)} \qquad (3)$$

so that

$$x \equiv Z(t - t_c)$$

and hence

$$_n\bar{t}_L = \frac{0.577 + ln(n)}{Z} + t_c \qquad (4)$$

where $_n\bar{t}_L$ is the mean age of the oldest fish in a series of samples of size n.

The whole fish population present at a given time may be regarded as one of a sample of an infinite number of possible populations existing in a sequence of points in time. The mean age of the oldest fish in the population is therefore

$$\bar{t}_L = \frac{0.577 + ln(\bar{N})}{Z} + t_c \qquad (5)$$

where $\bar{N}$ is the mean size of the exploited population. If there is no upper limit to the exploited life-span, this is given by

$$\bar{N} = R'/Z$$

From (4) and (5) we have the relation between $\bar{t}_L$ and $_n\bar{t}_L$, thus

$$\bar{t}_L = {_n\bar{t}_L} + \frac{1}{Z} ln(\bar{N}/n) \qquad (6)$$

Other relations are

$$\text{modal value of } {_nt_L} = \frac{ln\ (n)}{Z} + t_c \qquad (7)$$

$$\text{and S.D. } ({_n\bar{t}_L}) = \frac{1.28}{Z} \qquad (8)$$

As an example we may take the plaice stock of the Southern North Sea between the first and second world wars, which had a recruitment of about 2.8×10^8 annually at age 3.7 years and a total mortality rate of 0.83 (Beverton and Holt, 1957). Then

$$\bar{t}_L = \frac{0.577 + ln\,[(2.8 \times 10^8)\,0.83]}{0.83} + 3.7$$

$$\simeq 28 \text{ years}$$

Application. If it is observed that at low ages the exponential function represents the age composition of the catch, and that the theoretical values of $_n\bar{t}_L$ calculated from (4) using the estimate of Z in that age range agree with the observed values of $_n\bar{t}_L$ in samples, then it could be assumed that the same total mortality coefficient holds for the higher ages up to the limit given by equation (5), and this limit taken as t_L in yield equations.

Conversely, if there is difficulty in determining the age of the larger fish, a point in the upper region of the growth curve may roughly be determined by finding the mean size of the largest fish in samples and calling this the mean size at the mean greatest age given by equation (4), assuming that the value of Z determined for the younger fish holds throughout the life-span.

The mean of the exponential series may also be used, in conjunction with the limit of the series, to estimate Z when there are insufficient data to calculate mortality coefficients in the usual way. Beverton and Holt (1958) showed that if the potential life-span is unlimited the mean age of all fish older than any age t_x years is given by

$$_x\bar{T} = t_x + \frac{\int_{t_x}^{\infty} t.e^{-Z(t-t_x)}\,dt}{\int_{t_x}^{\infty} e^{-Z(t-t_x)}\,dt} = t_x + \frac{1}{Z} \qquad (9)$$

which gives a direct solution for Z if the mean age of fish above any arbitrary age t_x in the population is known. If data for the ages of the oldest fish in samples are to be used we need the expression for mean age of fish above age t_x and less than some upper limit t_u which is

$$\overline{T}_u = t_x + \frac{\int_{t_x}^{t_u} t.e^{-Z(t-t_x)}\,dt}{\int_{t_x}^{t_u} e^{-Z(t-t_x)}\,dt} =$$

$$\frac{t_x - t_u\, e^{-Z(t_u-t_x)}}{1 - e^{-Z(t_u-t_x)}} + \frac{1}{Z} \qquad (10)$$

Writing, in the special case, ${}_n\overline{t}_L$ for t_u, and substituting from equation (4) gives

$${}_x\overline{T}_L = \frac{t_x - n\ {}_n\overline{t}_L\ /\ 1.78\ n}{1 - {}_n\overline{t}_L\ /\ 1.78\ n} + \frac{1}{Z} \qquad (11)$$

which again permits solution for Z.

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Homogeneity of Age-Length Frequencies Among Months and Quarters of the Year for Haddock Caught on Georges Bank, 1962

This study of samples of age-length frequencies of haddock landings from Georges Bank, 1962, was undertaken to determine the degree of homogeneity among months and quarters within the calendar year. This is of some interest because of the economies in collection, analysis, and publication which can be achieved by condensation of sample age-length data.

The age-frequencies were aggregated by 5-cm length intervals, because expected values for the standard 2-cm intervals were, on the average, too low for valid analysis. The frequencies of the younger and older age groups within a given 5-cm interval were combined for the same reason, when expected values were less than five.

Among Months Within Quarters of Year

The expected age-frequency for each month within the quarter,

$$E_{ij} = (\sum_i 0_{ij}/\sum_j\sum_i 0_{ij})\ (\sum_j 0_{ij}),\ \text{where}$$

0_{ij} = number of fish observed in the i^{th} month of age j,

$i = 1, 2, 3$ months,

$j = 1, 2, \ldots, m$ ages.

Noting that $\sum_i O_{ij} = \sum_i E_{ij}$, as required, the index of dispersion (Hoel, 1954) for each month,

$$\chi^2_i = \sum_j ((O_{ij} - E_{ij})^2 / E_{ij}),$$

with m-1 degrees of freedom.

The data and calculations are summarized by quarters in Table 1. There were five quarters, out of 32 tested, for which the χ^2 index was significant. Four of the five were associated with large deviations within the 2 and 3 year age groups.

TABLE 1. Analysis of homogeneity of age distributions of haddock caught on Georges Bank in 1962 by 5-cm intervals

Length class cm	Age range	D.F.	χ^2 values, Months within quarter: 1	2	3	4	Months within year
35–39	2–3	3	2.89	4.60	1.06	1.67	34.32[a]
40–44	2–4	6	4.90	31.30[a]	12.72[a]	6.84	187.02[a]
45–49	2–5	9	6.95	3.32	21.28[a]	11.38	141.35[a]
50–54	3–6	9	3.60	6.85	11.24	15.29	185.49[a]
55–59	3–7	12	10.38	21.72[a]	3.99	25.90[a]	193.52[a]
60–64	4–8	12	5.86	12.73	5.43	3.49	121.97[a]
65–69	6–8	6	5.22	5.64	4.84	6.90	25.31
70–74	7–9+	6	2.67	3.34	3.67	7.30	13.84

[a]Indicates probability (χ^2) <.05

Among Months Within the Year

Using the above procedure with i = 1, 2, ... , 12 months, the dispersion among months within the year was calculated (Table 1, last column).

The indices for six of the eight length groups were significant, the two nonsignificant indices being in the two largest length groups.

Conclusion

The rather low incidence of heterogeneity found among months within quarters, indicates that recruitment of age-groups is gradual and that aggregating age-length frequencies by quarters of the years would not form biased age-length keys. The large amount of heterogeneity among months within the year precludes annual aggregation for purposes of estimating age composition of catch, unless, of course, proportional sampling was employed.

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Sawing of Otoliths as Mechanical Aid for Otolith Reading

The usual method of preparing a section of an otolith for viewing the ring structure is to break or cut it.

Bedford (1964) described a grinding-polishing machine developed at the Lowestoft laboratory for obtaining an almost standard section of at least one-half of the otolith. This section crosses the centre of the otolith and guarantees a good flat surface for viewing the otolith satisfactorily

At the Institut für Seefischerei, Hamburg, we no longer break otoliths but, for 10 years, we have sawed otoliths using a special machine (Fig. 1). We are convinced that this method has a number of advantages.

1. We obtain from one otolith **two** almost standard sections with very flat surfaces without striations, because the section passes through the centre more or less accurately (as a guiding mark we use the "V" shaped interruption of the sulcus acusticus), and the saw-blade is only 0.07 mm thick. The sawn otolith can be read without any further preparation (no xylene). No striations and no dust impair the reading.
2. We only need one otolith from each fish. This means reduction of personnel and work. We need only one man at the fish market for collecting otoliths (a second man is not needed for the paper bags). Each otolith represents

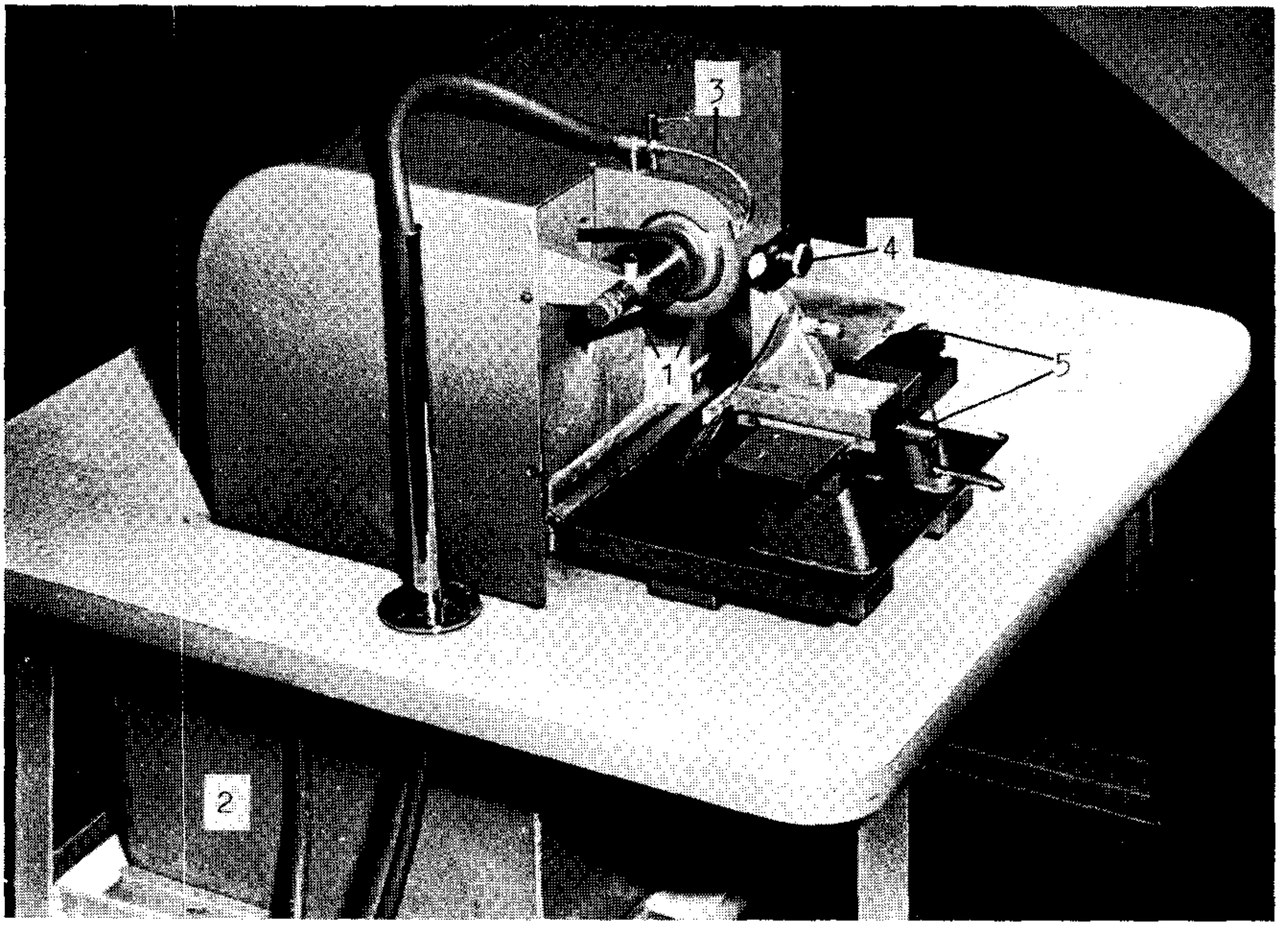

Fig. 1. An otolith sawing machine. 1. Saw-blade and rubber belt; 2. water pump; 3. water feed-pipe; 4. holding device for otolith; 5. two spindles.

a fish and is put into the appropriate hole of an otolith box according to the length of the fish. After sampling or upon returning to the laboratory, the otoliths are put into paper bags. All otoliths of fishes of equal length are put into one paper bag (saving of bags). Before sawing, the otoliths of each cm-group are numbered twice on the concave side, in order to be able to recognize the two halves of each otolith after sawing. To save time the last otolith from each paper bag is not numbered.

3. We saw the otolith from the concave side. If the section does not cross the centre a small, thin slice may be cut off. Just before the otolith is totally sawn, it breaks. The small very flat fracture at the sulcus acusticus does not hamper the reading of the otolith.

4. The details of the machine (Fig. 1) are:

   Motor 0.18 kw, 0.25 hp, 1,400 rpm

   Power transmission to the sawing device by means of a rubber belt (Fig. 1.1). Gear-ratio 1:2.5, i.e. revolution of the saw blade 2.5 times the revolution of the motor.

   Saw-blade (Fig. 1.1) copper-beryllium, diameter 73 mm, 0.07 mm thick. The outer edge of the blade is impregnated with diamond-dust (Winter Diamantkorn D 30 B). The diamond-dust mixed with olive-oil is pressed into the outer edge of the saw-blade by means of a grooved steel-roll, while the machine is running. One carat diamond-dust is sufficient for about 6,000 otoliths. Replace saw-blade after each 600–800 otoliths. Reimpregnate with diamond-dust after each 250–300 otoliths.

   Water-pump (Fig. 1.2) with rotating water feeding and continuously flowing water during sawing (Fig. 1.3).

   Holding-device for otoliths (Fig. 1.4) operating in 4 directions by 2 spindles (Fig. 1.5).

   Sawing performance 300–400 per day

5. Based on our experience in otolith exchange programs, we suggest, for future exchanges, (1) that only sawn otoliths, not broken ones, be used for exchange, since only a completely smooth surface permits a satisfactory and quick judgment and (2) that otoliths for exchange and also from recaptured tagged fish should only be mailed well-packed in strong boxes and not in unprotected envelopes where the risk of receiving only otolith powder is very great.

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Difficulties in Interpreting Trends in Cod and Haddock Landings from the Eastern Scotian Shelf

Measurement of the effects of fishing on stocks of fish requires association of data on catches with data on the amounts and kinds of fishing effort expended in catching them. To obtain the necessary data on eastern Canadian fisheries, scientists have set up and maintain a log-book record system in which the vessel skipper or a deputy is asked to supply detailed records of actual operations and estimated catches. The information so obtained constitutes a basic statistical series available for research purposes. From it are derived additional series. At the second level, the log-book effort data are summarized by trips and associated with trip landings statistics collected by the Department of Fisheries. Finally, the trip catch and effort records are summarized by types of gear, main species sought, month and area fished. This third series is supplied to ICNAF where it is published in association with similar series supplied by other countries. The resulting ICNAF statistical series provides a means of following trends in the fisheries, but a review of recent records illustrates the difficulties of using them to differentiate among the various factors which may be responsible for the trends.

Figure 1 illustrates trends in the important haddock and cod fisheries of the eastern Scotian Shelf (ICNAF Divisions 4V–W) as revealed by the ICNAF statistical series. Annual total landings of haddock (top panel, Fig. 1A) have been relatively constant at an average of about 25,000 metric tons although there is some indication of a gradual upward trend. Canada's share of this catch has been increasing steadily with the increased use of otter trawlers. The United States landed important quantities up to the mid 1950's; since 1958, non-Canadian landings have again increased, with increased activity by Spanish vessels fishing mainly in summer. Their primary interest is in the cod fishery, haddock being taken only incidentally.

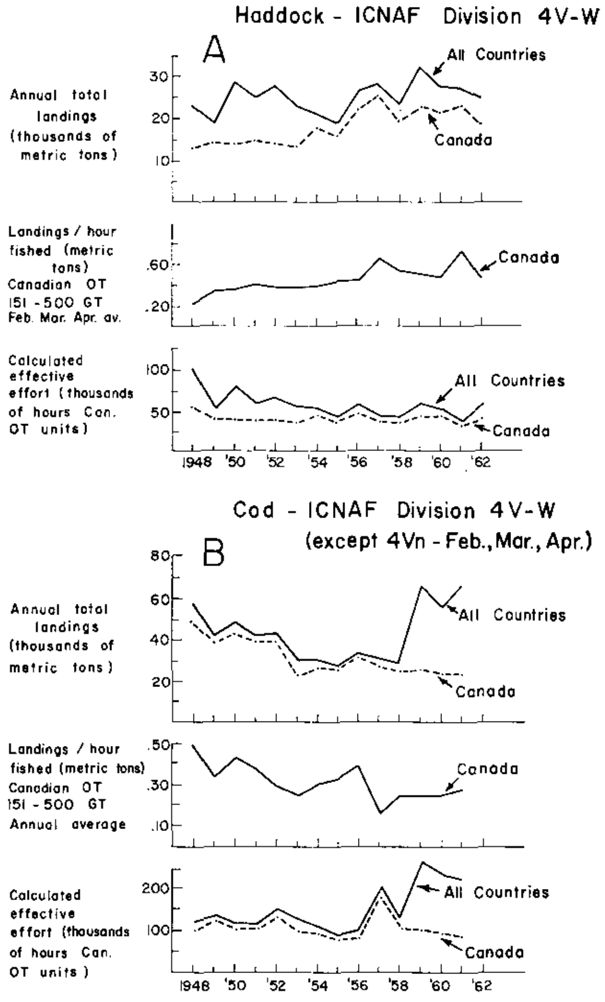

Fig. 1. Trends in haddock and cod fisheries, ICNAF Divisions 4V–W.

The average landings of haddock per hour fished by large Canadian otter trawlers during

February, March and April, when haddock fishing in the area is pursued most vigorously, show (middle panel, Fig. 1A) a slight upward trend, indicative of an increased availability of haddock to the fishing units. This increase is in almost direct proportion to the landings increase so that calculated total effective effort (i.e., total landings divided by landings per unit effort) for haddock, in large otter-trawl units (lower panel, Fig. 1A), has remained almost constant over the past 15 years.

The trends of landings by the cod fishery of the area are rather different (Fig. 1B). Up to 1959, landings were almost wholly by Canada, and from 1948 to 1958 dropped steadily, largely because of the steady decline in Canadian dory-schooner fishing. Landings increased sharply in 1959 with the appearance of Spanish vessels, but the Canadian landing has continued its downward trend. Annual average landing of cod per hour fished shows a downward trend, again almost in proportion to total landings. The resulting estimate of annual total effort for cod by the Canadian fishery also remains relatively constant throughout the period.

Changes in catch or landings per unit effort, reflecting relative availability, are often equated with relative abundance change and studied for possible relations to fishery and environmental effects. Such reasoning applied to these fisheries would suggest that between 1948 and 1962 there was a decrease in abundance of cod and an increase in abundance of haddock. In the absence of major fishing effort changes, we might then investigate the possible influence of environmental factors; and, in fact, a correspondence between temperature trends and the ratio of total annual haddock to cod landings over a rather long period has been noted by McLellan and Lauzier (1956). However, in this fishery, which is now dominated by the catches of otter trawlers, the same vessels land significant amounts of both species from a single trip, although the proportion of each one may be very different from trip to trip. To date, we are unable to distinguish from any of our records between trips intended for haddock and those intended for cod. Therefore, the same trips are used to calculate catch per unit effort for each species. But if fishermen are able to direct their efforts to one species or the other, our measures of fishing success may have a different relation to the relative abundance of the two species at different times. Under such conditions, one might equally interpret the opposite trends of landings per hour to represent a situation in which fishermen direct their efforts towards the catching of the species of their choice. That is, the slight upward trend for haddock might then simply reflect increasing market preferability for them rather than an actual abundance change.

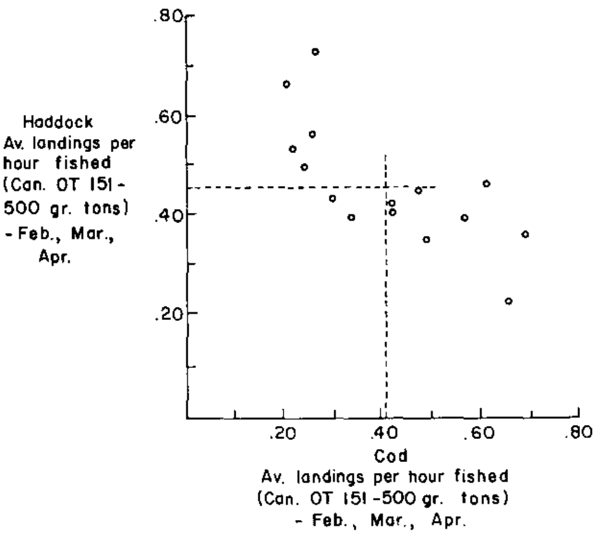

Fig. 2. Relative availability of cod and haddock to Canadian large otter trawlers in ICNAF Divisions 4V–W, Feb., Mar., Apr., 1948–62.

This second possible interpretation is supported if we consider catch per hour fished for the first quarter of the year for both haddock and cod. The two are plotted in Fig. 2 in which the opposite trends of Fig. 1A and B become an inverse relation with slope about –1.00 with a correlation coefficient of 0.73. That is, a change in landings per unit effort of one species is almost exactly made up for by a change in the landings of the other, a result which would be expected in the case that the fisherman's objective is simply to bring in a certain total catch of fish, irrespective of species, but during his operations he directs his efforts rather specifically for the one species or the other. Further support for the view that the changes in fishing practices are reflected prominently in the landings data comes from the studies of species associations in individual commercial catches reported by Paloheimo (1963). His tables suggest that, for 1957, the year in which landings per unit effort for cod dropped most sharply, simultaneous with a rise in landings per unit effort for haddock, the rank correlations of cod and haddock in catches took higher negative values than for the following year. That is, the trips which landed haddock and cod were better separated than in the following year. The lower landings per hour calculated for the otter-trawl-caught cod may, therefore, have resulted from fewer trips made specifically for cod. Since, however, the total cod landings did not show a drop in 1957, the individual trips which were actually cod trips must, on the whole, have been rather good ones, although this does not emerge from the averaged statistical series.

Considerations of this sort show that, while the overall statistics reflect trends in fishing success, it is virtually impossible, at least in this case, to use them to distinguish the influence of fishery operations from real changes in the stocks. This kind of limitation in the interpretation of fishery trends has, of course, been frequently recognized. What seems noteworthy in this case is that the data which suggest the opposite relative abundance changes are the same as those which may be used to suggest the fishery interactions. Similar interactions undoubtedly occur in fisheries data from other fisheries, species and areas, but their expression cannot be detected so simply. Where they are important, it is obvious that to measure the extent of stock changes separate from those in fishing objectives and operations, we require, in addition to data on catch, fishing time and positions, at least two additional types of statistical data. First, records of the intention of the skipper to fish for one species or the other at various times during his trip and how effectively he is able to implement this intention. Second, more detailed information on the actual distribution of different species on the grounds. The first information might be obtainable from log records, although it more likely requires specific first-hand study. The second could only be obtained by extensive research-vessel samplings, such as by combined echo-sounder and fishing surveys.

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INTERNATIONAL COMMISSION FOR THE NORTHWEST ATLANTIC FISHERIES

THE COMMISSION IN BRIEF

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

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

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

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

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

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

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

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

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TEXT

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

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

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

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

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

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

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

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

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

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ABSTRACT

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

TABLES

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

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

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

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

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

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

It was reported that (Collins, 1960) the . . .;
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Where more than one paper by the same author(s) have appeared in one year, reference should be given as follows:

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King and Pierce 1943*a*, 1952)

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

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