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Minutes of December 1958 Meeting of Scientific Advisers to Panels 4 and 5

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Minutes of December 1958 Meeting

of Scientific Advisers to Panels 4 and 5

The Scientific Advisers to Panels 4 and 5 met in Boston, Mass., on December 2-4, 1958. Dr. Herbert W. Graham acted as Chairman and Dr. J.L. Hart and Dr. R. L. Edwards were appointed reporters. A list of participants is presented in Appendix I.

RECENT ADVANCES IN HADDOCK BIOLOGY

Subarea 5

John B. Colton reported on the results of the Woods Hole Laboratory's larval fish surveys in the general area of the Gulf of Maine and surrounding banks. The main spawning concentrations of haddock (Melanogrammus aeglefinus (L.)) in the years 1953, 1955, and 1956 were in (1) the northeastern part of Georges Bank, (2) on Browns Bank, and (3) in South Channel. Northeast Georges larvae tended to drift south and southwest as they grew. Browns Bank larvae drifted counter clockwise around the Gulf of Maine, and the fate of the South Channel fish was uncertain. Young fish appear to drift in the same manner as drift bottles, and even more exactly as transponding buoys which may be followed day after day. Colton postulated that in the years of survey Georges Bank fish were recruited from Browns Bank. The years of survey were all years of poor recruitment on Georges Bank. Further surveys are needed during years of successful recruitment.

Most surveys were made with Hardy Plankton Recorders towed at the surface and at ten meters. In order to increase the depth of sampling in surveys over a large area in a limited time, it was necessary to devise new samplers. A new sampler was developed and used experimentally in 1958 with several of these samplers being towed simultaneously at different depths. The collections so obtained demonstrated that young haddock tend to be concentrated between 10 and 20 m., day or night. Stratification was relatively marked in deeper waters but less so in shoal water perhaps due to differences in turbulence.

In 1956, extensive mortality of larval silver hake (Merluccius bilinearis (Mitch.)) and yellowtail flounder (Limanda ferruginea (Storer)) was observed off the southern edge of Georges Bank, apparently due to the incursion and mixing of warmer slope water with Georges Bank water. This is the first well documented direct observation of larval fish mortalities associated with increased water temperature in nature. Because of the apparent prevailing drift of larvae of Georges Bank into this area, such phenomena may have an important bearing on the success of haddock year classes and requires further study.

Colton next discussed the results of the trawl surveys of young-of-the-year haddock made in the fall seasons of 1953, 1955, 1956, and 1958. The average fish per tow for each was as follows: 1953--0.7, '55--9.7, '56--1.7, and 1958--14.9. The greatest numbers of zero age group fish were found in depths between 60 and 90 fathoms. The concentrations differed significantly in 1958 when large numbers (up to 300 fish per tow) were found off the eastern edge of Georges Bank, off western Browns Bank and east of Cape Cod. Previously, zero haddock were usually found in the deeper, more central areas of the Gulf of Maine.

Since at least the first three of these surveys were made of poor year classes it is too early to draw any conclusions regarding the relation of the abundance and distributional pattern of young-of-the-year on the bottom to the eggs and larvae or to the commercial yield of the year class.

Clark presented evidence to support an hypothesis that haddock of the Gulf of Maine and contiguous waters are separable into three major stocks: (1) Browns Bank, (2) Georges Bank, east; and (3) Georges Bank, west. The haddock in the Bay of Fundy are considered a mixed group. This breakdown was based on vertebral numbers and tagging returns. The Woods Hole staff has tagged over 9,000 fish since 1953 in connection with the stock and migration study.

The St. Andrews staff, in 1957, tagged more than 2,200 haddock in the Browns-LaHave and Bay of Fundy areas. Returns to date suggest that haddock in the Browns-LaHave area are a relatively discrete stock. Haddock from the Bay of Fundy region were retaken in substantial numbers during winter from the southern Gulf of Maine and Channel regions. The results substantiate earlier conclusions of separate haddock stocks in Subareas 4 and 5.

Subarea 4

The St. Andrews group started a survey program on Nova Scotian (Sable Island, Western, and Emerald) banks in August and September 1953. By far the most abundant fish was the haddock. Smallest haddock, probably '57 year class, were found alone in shallow water (14-20 fathoms), in reduced numbers at intermediate depths, but occurred again along with large haddock in the deeper waters (45+ fathoms). Large numbers of baby haddock, probably '56 and '55 year classes, were caught along with larger fish on top of the banks in intermediate depths (20-45 fathoms).

Preliminary conclusions are that none of the year classes of haddock from '53-'57 are outstanding. Comparative data for other years are lacking, however, and support for this conclusion will have to depend on future measures of recruitment to the commercial fishery.

The cooperative exchange program was reviewed by Martin and Clark (Appendix II). It was agreed that satisfactory progress was being made and that any difficulties that come up could be handled direct.

Subarea 3

Hodder reviewed the history of the haddock fishery in recent years in Subarea 3. The 1949 year class, in the years subsequent to 1953, dominated the fishery, influenced the sizes of fish taken and discarded, and greatly modified Newfoundland's fishing industry. There is no evidence of a good year class in the immediate future on St. Pierre Bank, and, although the 1955 year class is dominant on the Grand Bank, it is actually relatively poor. The dispersal of moderate year classes of haddock in Subarea 3 in the summer months is so extreme as to make fishing unprofitable at this time.

Management of the Haddock Fisheries

Subarea 5

The status of the haddock fishery on Georges Bank is poor. The 1958 year class shows promise but there is no relief in sight until 1960 at the earliest. A suggestion of a 2-year cycle of abundance was a feature of the haddock fishery from 1947 to 1952. However, this pattern has broken down since then and there has been a series of poor year classes.

The present poor condition of the Georges Bank haddock fishery led to a discussion of the importance of knowledge regarding the factors that affect fish populations. For effective management the biologist has an obligation to do more than study the short-term effects of changes in the rate of fishing, for it is vital that he be able to explain and predict the environmental factors that so drastically affect the populations and the long-term influence of fishing on the biology of the stocks. It was accordingly agreed that we continue special efforts to study the effects of fishing and of the environment on recruitment and availability of fishes, especially haddock. It was recommended that an ad hoc committee be set up to consider methods of studying the effects of environment and fishing on recruitment especially of haddock. Taylor (Chairman), Dickie, Hodder, and Walford were appointed and instructed to report back at the June meeting.

Effects of Regulation

Taylor presented a paper on "Recent Variations in Haddock Growth", Appendix III, in which it was shown that the increase in average weight of 2- and 3-year-old haddock following regulation is not due to an increase in growth rate. Other aspects of this study showed that growth rates did differ significantly from one area to another on Georges Bank. It was agreed that growth rate work is basic to the study of the effects of regulation and should be continued.

Taylor presented a paper on "Some Effects of Undetected Trends inEstimating Mortality Coefficients," Taylor and Oberacker, Appendix IV, which assessed the usefulness under various circumstances of the 2 methods (Beverton and Holt, and Paloheimo) in estimating the values of catchability (q) and mortality (M).

Dickie reviewed Holt's method (Appendix V) for estimating benefits of a mesh regulation and pointed out that the method is not more useful in predicting the benefit than methods already being applied because the same assumptions must be made that have already been used.

Dickie presented a paper entitled, "Effects of Possible Mistakes in Age Determination on Age-Composition and Mortality Estimates for Georges Bank Haddock," Appendix VI, in which he showed that errors in age determination could lead to a levelling of apparent year class strength with age, especially in those cases where there are marked differences in year class strength. The Georges Bank data demonstrate a loss of dominance in strong year classes as the fish become older. This could be caused by differentialemigration of the older fish of strong year classes, by relatively more intensive fishing on the stronger year classes, as well as by errors in age determination. A method was described for making the necessary adjustments to correct for such errors. Taylor described studies establishing the validity of scale readings during the time that haddock were producing alternately good and poor year classes.

The subject of a study boat fleet as it applied to assessment of the mesh regulation in Subarea 5 was discussed briefly, and it was agreed to leave the matter open for the present.

Administrative Problems

Medico discussed some of the variations resulting from the use of different synthetic yarns. The problems associated with pre-stretched manila cod ends were explained.

Brackett gave the latest report on the operation of the 10 per cent annual exemption (Appendix VII).

McCracken presented information that Canadian vessels had become dependent on the success of specific year classes for year-round haddock fishing. Recently they have been operating principally on the abundant 1952 year class. The '49 year class was also a dominant year class. The 1955 year class is entering the fishery now, but none of the year classes subsequent to 1952 appear to be outstanding. The proportion of discards varies greatly, depending upon where the fish are being landed and whether they are landed round or gutted. A general value for discards in the summer of 1958 is 9 percent by weight.

Mesh selection experiments with a 5-1/8-inch mesh gave a selection factor of 3.2. Sea trips on commercial trawlers during the summer of 1958 demonstrated that the large mesh nets (4-7/8") released fish under 30 cm. in large numbers.

Martin reported on enforcement of the mesh regulation in Subarea 4. He pointed out the possible administrative needs for a general mesh regulation for haddock for all contiguous Canadian waters.

Subarea 3

Hodder reported on abundance of haddock on the Grand Bank. Catch per unit of effort fell 40 to 50 percent between 1957 and 1958 due to the diminished level of the 1949 year class which was still providing over 50 percent of the landings in 1957. There is wide variation in the growth rates of different year classes. The large 1949 year class had the slowest growth rate of all year classes investigated. The growth rate of all year classes in 1950 was significantly reduced, and this seemed to be due to the unusually low water temperatures on the Grand Bank at that time.

It was noted that some haddock vessels have been fishing in Subarea 3 with cod end mesh sizes as large as 4.6 inches. In general, 4-inch mesh sizes are used for Newfoundland haddock dragging in Subarea 3.

RECENT ADVANCES IN COD STUDIES

Subarea 5

Wise reported that scrod cod (*Gadus callarias* L.) landings at Boston and New Bedford have shown a marked increase in 1958 and appear to be due to one or more successful year classes of fish. The statement was made that Browns Bank and Georges Bank cod are apparently separate stocks. A tagging experiment is planned for March of 1959 to measure the discreteness of these stocks and to determine the degree of homing tendencies. Preliminary work on age of Georges fish shows extremely fast growth and agrees with Schroeder's data for southern New England fish.

Subarea 4

Powles reported on cod tagging at the Magdalen Islands. In July 1957, 1201 cod were tagged. Recaptures were made from the western side of the Laurentian Channel off Cape Breton during December to April following, while in June to November 1958, northeast to Gaspé and the Bay of Chaleur regions. In 1958, 910 cod were tagged earlier, in May. The pattern of returns was similar, but cod migrated north during this year of tagging. All cod were tagged with Petersen discs and Lea tags attached dorsally. Recoveries were of the order of 10 percent for both years.

Size at maturity, spawning season, and fecundity were determined in 1955 and 1956 for cod from Subdivision 4T. In 1955 and 1956, males were 50 percent mature at 50 and 53 cm., respectively; females for the same years were 50 percent mature at 52 and 57 cm., respectively. The spawning season lasted from May to September, with peak spawning at the end of June. The smallest mature cod of 51 cm. produced 200,000 eggs, while the largest specimen of 140 cm. in length carried 12 million ripening eggs.

In feeding studies, it was found that small cod selected a diet of pelagic crustaceans, namely mysids, euphausiids, and amphipods. With increase in size, cod adopted a more varied diet, in which fish and benthic invertebrates became increasingly important. At lengths over 70 cm. pelagic and benthic invertebrates were taken in approximately equal volumes. Herring was the most important fish in the diet of a large cod.

Marcotte reported on the continuation of the survey in the Bay of Chaleur and environs. The survey consisted of 9 stations (3 transects) in the Bay and 6 stations (2 transects) off the tip of Gaspé (Grand River). During the first survey small numbers of cod were rather evenly distributed over the area. Catches close inshore in July were mostly small fish. At the beginning of August cod were abundant at all stations, especially along the northern shore. In October, codfish were still abundant although emigration had begun. Cod move into the Bay as water temperatures rise in late spring. Cod in spawning condition were found throughout the summer, with a maximum in July.

Small codfish were less abundant in 1958 than in 1957. Lower temperatures were observed in 1958 as well as fewer small cod relative to large.

The catches taken with #14 and #17 hooks did not obviously differ in length composition, although these data need further analysis. To this end, it was recommended that Clark and McCracken cooperate with Marcotte in applying an analysis similar to that used in mesh selection experiments.

A detailed survey was made of the mesh sizes used in 85 codfish traps as a beginning of mesh selection experiments.

Lacroix presented the results of nine 24-hour cruises made near Grand-Rivière, Gaspé-Sud, Canada, to study daily vertical migrations of euphausiids.

A general pattern of migrations was described, consisting of (a) a dawn descending movement, (b) an absence in the upper 60 meters at mid-day, (c) an evening ascending movement, and (d) a scattering distribution at midnight leading to a stair distribution with a maximum concentration near the surface.

Physical factors causing or modifying migrations are light, temperature, and the state of sea surface. High thermal gredients (at least 1°C./m.) were found to stop the animals in their migrations upwards.

Poulsen presented a report of the cod data recently supplied by Ruivo and Quartin (Appendix VIII). These data include age and size compositions as well as sex ratio information. A dominant 1950 year class appeared in recent Portuguese catches. The group expressed its appreciation for this useful and needed report.

Martin discussed the work (of Yves Jean) carried out in the Gulf of St. Lawrence. Sizes and ages of cod caught and landed by Canada from the northern part of Subdivision 4T have been studied in varied ways. Commercial dragger studies during the period 1948-58 have shown increased landings, decreased catch per unit effort, decreased average age, and increased growth rate. The effects of changes in fishing and in the environment are being assessed. These draggers are now using cod end manila mesh sizes of 4-1/2 to 5 inches. Nine trips to sea on these boats in 1958 have shown that large quantities of small cod, which are observed in survey studies to be present in the area, are escaping from the net. However, discards at sea still amount to about 15 percent by number. A mesh selection experiment with a 5-3/4-inch manila cod end gave a selection factor of 3.3 for cod and 2.1 for plaice.

It was concluded that a 5-1/2-inch mesh would reduce discards to a minimum and that the variability of selection factor experiments makes it difficult to assess effects on the numbers and sizes of cod now landed. With such a mesh size, plaice discards would be greatly reduced with no immediate effect on sizes landed.

It was proposed by Martin that 5-1/2 inch nets be supplied to a few commercial draggers in 1959 in order to measure relative efficiency of various mesh sizes and to gain base-line experience with the use of larger mesh nets. Martin then asked the group for their ideas on a study boat program and the proposed program was discussed. The group endorsed the study boat program and suggested that more than one experimental mesh size be used if the practical difficulties involved could be met.

Subarea 3

Squires presented a preliminary study of the lower landings of cod in 1958 in the trap fishery of Newfoundland, which appeared to be related to hydrographic conditions. These conditions resulted in a short capelin (*Mallotus villosus* (Müller)) season. Cod follow capelin inshore where they are caught in the traps. Further difficulties developed when the bait squid also were not readily available. This handicapped the fall line fishery. Small (1-year) cod were abundant in 1956 and 1958.

An account of some exploratory fishing for shrimp (*Pandalus borealis*) in the Gulf of St. Lawrence and off the Newfoundland coast was presented.

SCALLOPS

Posgay reported on the U.S. scallop fishery and U.S. research on this shellfish. The 1958 catch will be about 2.5 million pounds below 1957 but this is due to decreased effort, not lowered abundance. The catch per unit of effort remains about the same as 1957. Some scallopers were diverted to exploitation of the unusually abundant yellowtail flounder in the area.

Investigation of the annual rings of scallops from the eastern half of Georges Bank, which provides about 70 percent of the total catch on Georges, the Hudson Canyon areas and Block Island, show that the growth rates in all of these areas are almost exactly the same. The growth rate estimated by this method agrees very closely with the growth rate estimated from the recovery of tagged scallops.

An estimation of the natural mortality rate has been made using the ratio of clapper shells to live scallops presented in the fished population. These data give estimates of M ranging from .045 to .162 for the catchable sizes.

An attempt has been made to estimate total mortality rates by analyzing the relative abundance of successive year classes present in the population and by the catch per day of tagged scallops. The relative abundance method gives estimates of Z of about .7 (assuming little variation in year-class strength). The tag return method requires the elapse of more time and return of more tags before returns can be considered to reflect the rate of exploitation. Returns from a preliminary tagging on one of the less heavily fished areas have totalled about 20 percent in the 14 months since their release. A later more extensive tagging has yielded 9 percent returns in 6 months.

The method suggested by Holt (Serial No. 557) for predicting the effect of increasing the mesh size has been applied to the sea scallop data. These calculations predict that postponing the length at first capture from 85 mm., the present cull, to 105 mm. (1.43 years) would lead to an 89 percent benefit if the present fishing mortality is .7 and a benefit of 21 percent if the fishing mortality is .4.

It was recommended that a biological report summarizing evidence for possible benefits of an increased ring size in scallop gear be prepared by the U.S. and distributed prior to the June meeting and that U.S. and Canadian biologists continue their close cooperation in this study.

Dickie reported on sampling on Georges Bank aboard Canadian vessels. Since June 1958, 3 of the 10-minute squares proposed as a basis for statistical reporting were sampled. Records of catch per haul or hour fished indicate differences in the abundance in neighboring areas. However, these differences were reflected largely in the amount of discards, landings per unit of effort varying little in total poundage. With lower catches, the size of 50 percent cull appears to decrease, landings apparently varying mainly with the numbers of different sizes shucked. If this situation is general, it could complicate estimates of abundance from commercial statistics.

The material presented by Dickie suggested that greater shucking power rather than improving the catch per unit effort is necessary to fully utilize the present scallop resource. Posgay pointed out that increasing the catch per unit of effort of larger scallops, by permitting them to grow up, would increase the landed catch per unit of effort with the same shucking power. There was further discussion about the interpretation of Posgay's tagging data and his experimental design for the tagging experiment.

STATISTICS

Clark pointed out that a division of Subdivision 5Z would present the haddock data of Georges Bank more adequately by stocks. It was agreed that a matter of principle was involved and that the question should be passed on to the Committee on Research and Statistics. United States biologists agreed to present the value of a division of Subdivision 5Z at the June meeting.

Clark reported that an annual series presenting the basic haddock data was being prepared, starting with 1956. The 1957 and 1958 data will be published as soon as finished, after which the basic data will be published at the end of each year. It is planned to publish the data prior to 1955 as soon as practical.

PLANS FOR FUTURE MEETINGS

1. It was agreed that two days would be required for the June meeting of Scientific Advisers to Panels 4 and 5. The Executive Secretary was asked to schedule this amount of time out of the week provided for scientific discussions at the annual meeting.

2. Kelly reviewed the work that has been accomplished to date in preparation for the Redfish Symposium, 1959.

3. Wise reported on the plans for the Marking Symposium in 1960. It was agreed that Dr. McCracken should proceed with the publicity phase of the Marking Symposium which is to be covered at the 1959 annual meeting.

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APPENDIX I

List of Participants

CANADA

St. Andrews

Dr. J.L. Hart
Dr. W.R. Martin
Dr. F.D. McCracken
Dr. L.M. Dickie
Mr. P.M. Powles

St. John's

Mr. V.M. Hodder
Mr. H.J. Squires

Dept. of Fisheries, Quebec

Dr. A. Marcotte
Mr. G. Lacroix

ICNAF Headquarters

Dr. E.M. Poulsen
Mr. R.S. Keir

UNITED STATES

USFWS, Washington, D.C.

Dr. L.A. Walford
Mr. J.P. Wise,
representing Mr. H. Eckles

Woods Hole

Dr. H.W. Graham, Chairman
Mr. J.B. Colton, Jr.
Mr. J.R. Clark
Mr. J.P. Wise
Dr. R.L. Edwards
Mr. C.C. Taylor
Mr. J.A. Posgay
Mr. G.F. Kelly

Resource Management (Gloucester)

Mr. L. Brackett
Mr. E. Medico

Observers

Mrs. R.R. Stoddard
Mr. D.A. Oberacker

APPENDIX II

CO-OPERATIVE HADDOCK PROGRAM IN ICNAF SUBAREA 4

Data sent from St. Andrews to Woods Hole

Statistics

Landings from Subdivision 4X by species, months, and type of gear, from January 1, 1956, to January 31, 1958.

Catch per Unit of Effort

Catch per tub for landings at the Lockeport Company from January 1, 1956, to January 31, 1958.

Samples (Sept. & Oct. 1958 samples will be sent to Woods Hole with others for last half of 1958.)

	1956			1957			1958		
Month	No. of Samples	Number Measured	No. of Scales	No. of Samples	Number Measured	No. of Otoliths	No. of Samples	Number Measured	No. of Otoliths
Jan.									
Feb.				1	200	40	1	202	40
Mar.	5	1100	220	4	800	160	3	1160	232
Apr.	1	300	60	1	200	40			
May							2	590	118
June							4	1508	300
July				3	1015	203	6	3327	665
Aug.									
Sept.				1	200	40	5	2600	520
Oct.				1	300	60	1	154	30
Nov.	2	400	80	2	875	175			
Dec.	1	600	120	3	600	120			
Total	9	2400	480	16	4190	838			

Data received by St. Andrews from Woods Hole

Statistics

Massachusetts landings by months from January 1, 1956, to June 30, 1958, with the exception of the month of December 1956.

Interview Records and Summaries - Subdivision 4W

Month	1956 - Number trips	1957 - Number trips	1958 - Number trips
January	2	4	2
February	-	1	2
March	2	1	-
April	6 Summaries only	7	1
May	5 Summaries only	-	2
June	4 Summaries only	6	-
July	1 Summaries only	2	-
August	-	1	
September	-	1	
October	-	7	
November	13	-	
December	6	6	

Samples - Subdivision 4W

	1956						1957				1958			
	Length Frequencies			Otoliths			Frequencies		Otoliths		Frequencies		Otoliths	
Month	Lg.	Scr.	Disc.	Lg.	Scr.	Disc.	Lg.	Scr.	Lg.	Scr.	Lg.	Scr.	Lg.	Scr.
	Number			Number			Number		Number		Number		Number	
Jan.	167	188		20	15		*102	*54	*20		101	112	20	15
Feb.							100	50	20	15	*96		*21	
Mar.	*102			*19										
Apr.	166	219	564	20	20	20	176		35					
May														
June								*62		*15				
July														
Aug.														
Sept.														
Oct.														
Nov.	1013	595		214	124									
Dec.							*97	*118	*20	*14				
Total	1448	1002	564	273	159	20	475	284	95	44				

* Not used as both market categories not sampled or market categories from different areas. Age readings received from January to April of 1956. Otoliths received for all samples following this period.

APPENDIX III

Recent Variations in Haddock Growth

by C.C. Taylor and R.R. Stoddard

The average weight of haddock landed at ages 2 and 3 has increased about 15 percent since mesh regulation (Taylor, P-27, ICNAF, ICES, FAO, Lisbon, 1957). Our interpretation of this as a selection effect of the large mesh has been challenged on the basis that such increase in weight could be due to a change in growth rate.

From Georges Bank subareas G, H, J, and M, back-calculated sizes from 6,392 fish for 1931-1947 year classes were compared to back-calculated sizes of 259 fish taken in 1958. All these fish were taken in Season A and include 3- to 6-year-old fish. The results of these comparisons are summarized in Tables 1 to 3.

Prior to 1947, there were no substantial differences in growth rate in the subareas studied (Table 1).

The 1958 data indicate an increase in growth rate from 1 to 2 centimeters since 1952 in subarea G. Almost no difference in subarea H is evident. In subareas J and M, a slight decrease in growth rate is noted.

Conclusive evidence of variations in growth in recent years must await the reading of additional scale collections taken in the years 1953 to 1957. When this work is completed, it will be possible to trace the growth of individual year classes in the fishery prior to and following the mesh change. This study is expected to be completed prior to the 1959 annual meeting.

Table 1.--Average calculated length at each age for fish captured in subareas G, H, J, and M, 1931-1947 (Season A)

Subarea G

Age at capture	l_1	l_2	l_3	l_4	l_5	l_6	No. of fish
III	18.84	34.49	45.13				277
IV	18.08	31.91	42.52	50.53			304
V	17.96	30.84	41.33	49.08	55.10		158
VI	17.85	30.15	40.41	48.27	54.39	59.32	66
$\bar{x}$	18.18	31.85	42.35	49.29	54.74	59.32	805

Subarea H

Age at capture	l_1	l_2	l_3	l_4	l_5	l_6	No. of fish
III	18.88	34.24	44.73				262
IV	18.73	32.15	42.47	50.02			188
V	17.94	31.43	41.70	49.34	55.32		146
VI	18.02	30.74	40.95	48.77	54.88	59.41	66
$\bar{x}$	18.39	32.14	42.46	49.38	55.10	59.41	662

Subarea J

Age at capture	l_1	l_2	l_3	l_4	l_5	l_6	No. of fish
III	19.50	33.90	44.10				719
IV	18.60	32.30	42.30	49.60			740
V	18.20	31.10	41.00	48.70	54.40		311
VI	17.70	30.50	40.00	47.80	53.50	57.70	140
$\bar{x}$	18.50	31.95	41.85	48.70	53.95	57.70	1910

Subarea M

Age at capture	l_1	l_2	l_3	l_4	l_5	l_6	No. of fish
III	19.80	34.10	44.30				1295
IV	18.90	32.70	42.80	50.10			1028
V	18.30	31.80	41.80	49.10	54.50		511
VI	18.20	31.30	41.10	48.60	54.20	58.50	181
$\bar{x}$	18.80	32.48	42.50	49.27	54.35	58.50	3015

Table 2.--Average calculated length at each age for fish captured in subareas G, H, J, and M, 1958 (Season A)

Subarea G

Age at capture	l_1	l_2	l_3	l_4	l_5	l_6	No. of fish
III	16.40	29.80	40.90				10
IV	18.75	34.95	46.30	53.20			20
V	18.56	32.83	43.28	51.22	56.22		18
VI	16.50	31.42	42.08	50.58	57.17	61.50	12
$\bar{x}$	17.55	32.25	43.14	51.67	56.70	61.50	60

Subarea H

Age at capture	l_1	l_2	l_3	l_4	l_5	l_6	No. of fish
III	17.28	34.43	44.86				7
IV	19.91	36.43	46.87	54.61			23
V	18.33	30.80	42.33	47.33	56.67		15
VI	18.25	31.04	40.54	47.88	54.17	58.62	24
$\bar{x}$	18.44	33.18	43.65	49.94	55.42	58.62	69

Subarea J

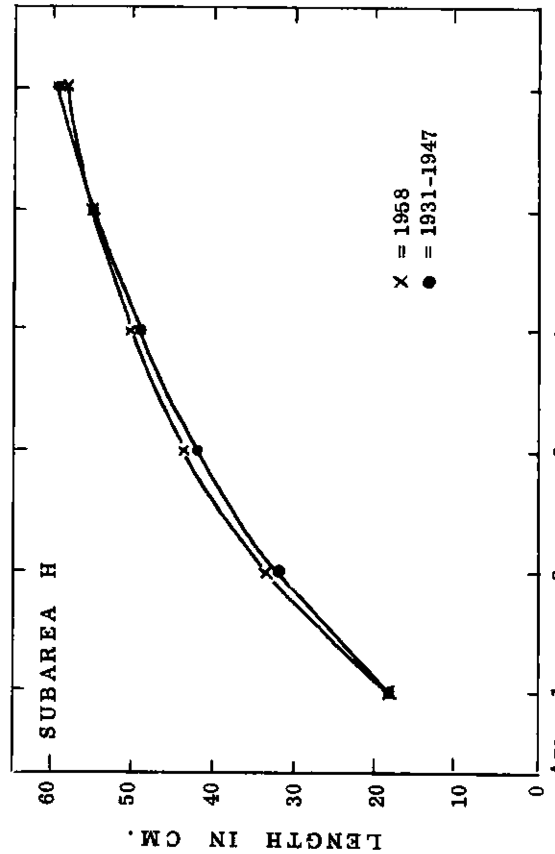
Age at capture	l_1	l_2	l_3	l_4	l_5	l_6	No. of fish
III	20.94	35.94	44.82				17
IV	19.27	30.51	41.14	47.27			37
V	18.41	28.94	39.00	46.59	52.53		17
VI	18.40	31.33	40.87	48.00	52.73	56.33	15
$\bar{x}$	19.26	31.68	41.46	47.29	52.63	56.33	86

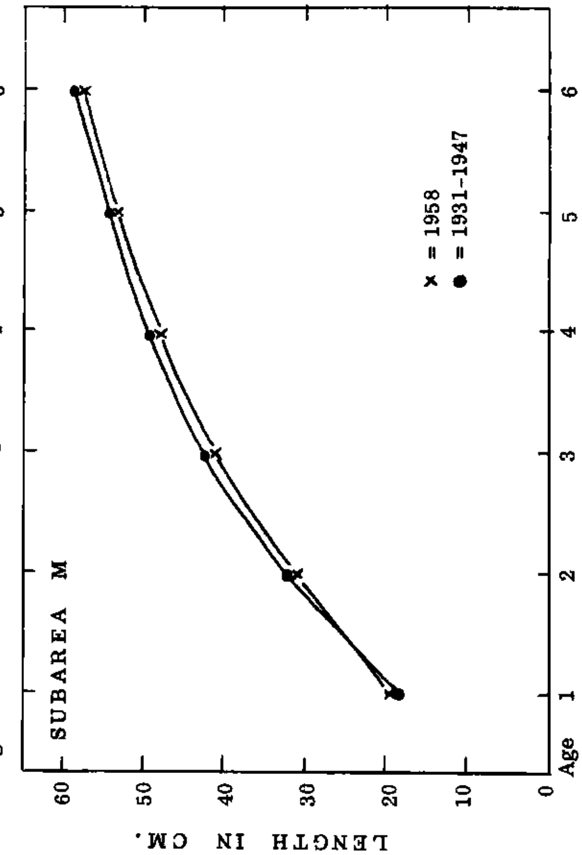
Subarea M

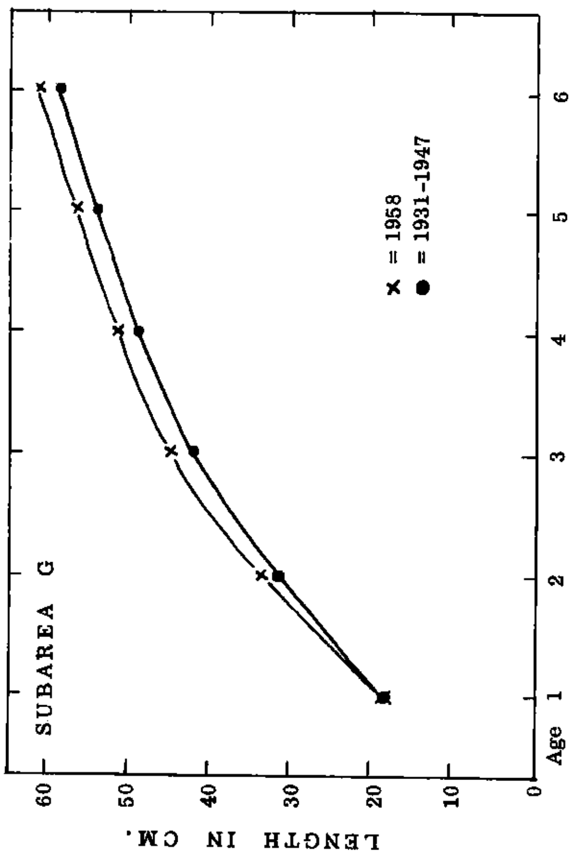
Age at capture	l_1	l_2	l_3	l_4	l_5	l_6	No. of fish
III	21.83	35.33	45.17				6
IV	18.36	31.21	41.64	49.07			14
V	18.44	28.56	38.44	46.78	52.00		9
VI	18.93	31.07	40.40	47.80	54.47	57.33	15
$\bar{x}$	19.39	31.54	41.41	47.88	53.24	57.33	44

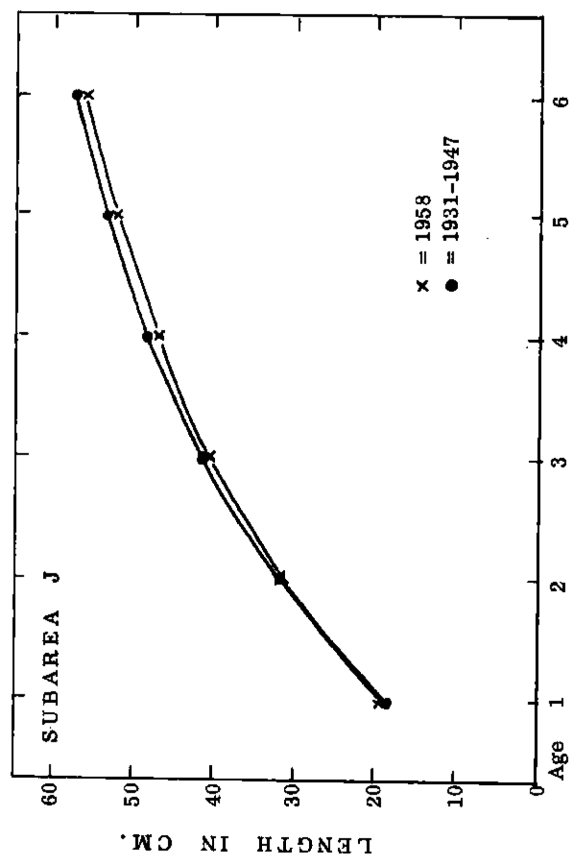
Table 3.--Comparison of average calculated fork length in 1958 to the 1931-1947 average, by subarea (Season A)

Age	Subarea G		Subarea H		Subarea J		Subarea M	
	1958	1931-1947	1958	1931-1947	1958	1931-1947	1958	1931-1947
1	17.55	18.18	18.44	18.39	19.26	18.50	19.39	18.80
2	32.25	31.85	33.18	32.14	31.68	31.95	31.54	32.48
3	43.14	42.35	43.65	42.46	41.46	41.85	41.41	42.50
4	51.67	49.29	49.94	49.38	47.29	48.70	47.88	49.27
5	56.70	54.74	55.42	55.10	52.63	53.95	53.24	54.35
6	61.50	59.32	58.62	59.41	56.33	57.70	57.33	58.50


SUBAREA H
× = 1958
● = 1931-1947
LENGTH IN CM.
Age
0
10
20
30
40
50
60
1
2
3
4
5
6


SUBAREA M
× = 1958
● = 1931-1947
LENGTH IN CM.
Age
0
10
20
30
40
50
60
1
2
3
4
5
6


SUBAREA G
× = 1958
● = 1931-1947
LENGTH IN CM.
Age
0
10
20
30
40
50
60
1
2
3
4
5
6


SUBAREA J
× = 1958
● = 1931-1947
LENGTH IN CM.
Age
0
10
20
30
40
50
60
1
2
3
4
5
6

APPENDIX IV

Some Effects of Undetected Trends in Estimating Mortality Coefficients

by

Clyde C. Taylor and Donald P. Oberacker

Introduction

With adequate statistics on effort and catch by age of fish, it is usually possible to compute the total mortality rate of a fish stock. The separation of total mortality into its components of natural and fishing mortality is a more difficult problem subject to various uncertainties.

Taylor (1958) has estimated natural mortality rates for various ages of Georges Bank haddock, using a method developed by Beverton and Holt (1957). More recently we have applied to the Georges Bank data a method of estimating natural mortality suggested by Paloheimo (1958). The latter method, in general, estimates rates of natural mortality considerably higher than those estimated by Taylor. The magnitude of the discrepancies between the two methods is shown in Table 1.

Table 1. Comparison of estimates of the natural mortality coefficient, M, from data on catch and effort for the Georges Bank haddock fishery, 1932-1950.

Ages Compared	Estimate of M	
	Beverton-Holt Method 1/	Paloheimo Method 2/
2-3	-	-0.100
3-4	-0.170	-0.020
4-5	0.012	0.497
5-6	0.004	0.720
6-7	1.575 3/	1.304
7-8	0.491	0.751

1/ See Taylor, 1958.

2/ The summation is carried from age 9 back to the two ages compared.

3/ Based on first iteration only.

Because of the substantial disagreement in estimates of M resulting from application of the two methods, we have explored a simple theoretical model in which variations in q (see Notation) or M were introduced but which variations were assumed undetected in further treatment of the information on catch and effort.

Notation

We shall adopt the notation of Paloheimo (1958) where, for one year class:

N_i number of the i-year-old fish at the start of the year

C_i catch in numbers of the i-year-old fish

f_i fishing intensity, the effort per unit area, defined by Paloheimo (1958) as "the total effective effort expended on the i-year-old fish". It is the measure of effort which is linearly related to the instantaneous fishing mortality coefficient, F.

q_i coefficient expressing the fraction of the i-year-old fish caught by one unit of fishing intensity, f; in other words the factor of proportionality linearly relating f to F.

M_i instantaneous natural mortality rate of the i-year-old fish

F_i instantaneous fishing mortality rate of the i-year-old fish

$Z_i = F_i + M$, or $Z_i = q_i f_i + M$, the total instantaneous mortality rate of the i-year-old fish.

The Theoretical Model

Both the Beverton and Holt and the Paloheimo methods of estimating natural mortality require estimates of the total mortality rate at different levels of fishing intensity so that a regression of total mortality on fishing intensity may be determined. The slope of the regression line is the estimate of q, and the intercept on the ordinate is the estimate of M. In a theoretical model it is necessary to establish only two points to determine the regression line and the estimates of q and M. We did this by computing the total mortality at two levels of fishing intensity. The estimates thus obtained were further refined by the iterative procedure common to both methods.

Thus, we considered a year class of 50 million fish at age 1 and computed the catches which would be obtained from it at effort levels of 6,000 days per year and 3,000 days per year under certain variations in q and M at ages 1, 2, and 3. The combinations of data thus obtained provided the necessary information for applying either the Beverton and Holt or the Paloheimo method. In applying these methods, it was assumed that q and M were constant from age 1 to age 10. Values of q and M were then estimated from abundance indices for ages 1 and 2. It should be pointed out that we had determined values for q and M after age 3, when q and M were actually constant, either method would estimate their exact values.

In the four cases considered, q and M varied as follows:

Case 1. q increases from 0.050 per thousand days fished at age 1 to 0.075 at age 2, after which it is constant at 0.100 from ages 3 to 10. M is held constant at 0.10.

Case 2. q decreases from 0.150 at age 1 to 0.125 at age 2, after which it is constant at 0.100 from ages 3 to 10. M is held constant at 0.10.

Case 3. M increases from 0.100 at age 1 to 0.200 at age 2, after which it is constant at 0.400 from ages 3 to 10. q is held constant at 0.10.

Case 4. M decreases from 0.400 at age 1 to 0.200 at age 2, after which it is constant at 0.100 from ages 3 to 10. q is held constant at 0.10.

Results

Table 2 shows the results obtained in estimating q and M by the two methods. The first column of estimates by the Paloheimo method are obtained by summations from age 10 back to ages 1 and 2. In the second column of estimates by the Paloheimo method, the summations are confined to ages 1 and 2 only.

Table 2. Summary of results in applying two methods of estimating natural mortality to a theoretical population in which q and M vary.

Case No.	Age	True Value of q	True Value of M	Beverton-Holt Estimate of q	Beverton-Holt Estimate of M	Paloheimo Estimate of q	Paloheimo Estimate of M	Paloheimo1/ Estimate of q	Paloheimo1/ Estimate of M
1	1	0.050	0.10	2/	2/	0.060	-0.007	0.026	-0.051
	2	0.075	0.10						
	3-10	0.100	0.10						
2	1	0.150	0.10	3/	3/	0.144	0.155	0.135	0.310
	2	0.125	0.10						
	3-10	0.100	0.10						
3	1	0.10	0.10	0.10	0.140	0.089	0.287	0.140	0.145
	2	0.10	0.20						
	3-10	0.10	0.40						
4	1	0.10	0.40	0.10	0.310	0.112	0.157	0.102	0.300
	2	0.10	0.20						
	3-10	0.10	0.10						

1/ Summation restricted to ages 1 and 2 only.
2/ Negative regression slope in first iteration.
3/ Iterations fail to converge.

Discussion

The principle underlying both the Beverton and Holt and the Paloheimo methods of estimating natural mortality is that the total mortality coefficient, Z is a linear function of f, the fishing instensity:

$$Z = qf + M \tag{1}$$

The methods differ in the manner of estimating Z.

To understand why the two methods, both valid in principle, produce different results in practice, to assess their comparative virtues, and to appreciate how the combined use of both methods is useful in indicating trends in M and q which might otherwise not be detected, we shall review their derivations and, in particular, the assumptions on which their application is based.

The Beverton and Holt Method

From Beverton and Holt (1957, equation 13.2, p. 179) we have the mean abundance of a year class in year i:

$$\bar{N}_i = \frac{N_i}{(F + M)_i}\left(1 - e^{-(F + M)_i}\right) \tag{2}$$

and for the same year class in year i + 1:

$$\bar{N}_{i+1} = \frac{N_{i+1}}{(F + M)_{i+1}}\left(1 - e^{-(F + M)_{i+1}}\right) \tag{3}$$

At this point, it simplifies the notation considerably if we face the fact that, at our present stage of knowledge and for all practical applications, we must assume that q and M are the same between two successive years for a year class (Beverton and Holt method) or that they are the same over the period of summation (Paloheimo method). It is true that q and M could be assumed to vary from one year to the next, but this presumes more knowledge than we actually have. Paloheimo (1958) states: "The catchability coefficient, q_i, in the above could be assumed to vary not only with age but also with effort and with changing hydrographic conditions . . . We leave, however, these possibilities as special cases and shall not consider them here." For present purposes, we shall specify this constancy by omitting the subscript i from q and M.

From equation (1) we substitute qf for F in equations (2) and (3). To obtain the ratio of the mean abundance between years i and i + 1, we divide equation (2) by equation (3) and, after taking logarithms of both sides for simplification, we obtain: 1/

$$qf_i + M = \log\left[\frac{C_i/f_i}{C_{i+1}/f_{i+1}}\right] + \log\left[\frac{(qf_i + M)\left(1 - e^{-(qf_{i+1} + M)}\right)}{(qf_{i+1} + M)\left(1 - e^{-(qf_i + M)}\right)}\right] \tag{4}$$

1/ We point out that log x/y = -log y/x. Some authors insist on writing the first term of the Beverton and Holt equation (4) as $-\log \frac{N_{i+1}}{N_i}$. Mathematically, this is unimportant. In actual computations, however, clerks (and mathematicians) will find it much easier to look up the logarithm of 2.00, say rather than -logarithm of 0.50.

An example of the computational method used in applying (4) is given by Taylor (1958).

The Paloheimo Method

The similarity of the Paloheimo method to the Beverton and Holt method is best indicated by starting with the following equation (Paloheimo, 1958, equation 9):

$$\log \frac{N_i}{N_{i+1}} = qf + M \tag{5}$$

where N_i and N_{i+1} are numbers of fish of a year class at the beginnings of years i and i + 1.

The actual mathematical procedures in estimating the N's in equation (5) tend to be obscured by a series of substitutions. It is, however, essential to the proper understanding of equation (5) to write it without substitutional steps. We have, then:

$$N_i = \frac{\Sigma a_i C_i}{1 - e^{-\Sigma(F_i + M)}} \qquad (6)$$

where $a_i = \frac{F_i + M_i}{F_i}$. Substituting $\underline{qf_i}$ for F_i and M for M_i,

$a_i = \frac{qf_i + M}{qf_i}$, so that equation (6) may be written:

$$N_i = \frac{\Sigma\left[\left(\frac{(qf_i + M)}{qf_i}\right) C_i\right]}{1 - e^{-\Sigma(qf_i + M)}} \qquad (7)$$

In the same way, we have:

$$N_{i+1} = \frac{\Sigma\left[\left(\frac{(qf_{i+1} + M)}{qf_{i+1}}\right) C_{i+1}\right]}{1 - e^{-\Sigma(qf_{i+1} + M)}} \qquad (8)$$

Substituting equations (7) and (8) for N_i and N_{i+1} in equation (5), we derive:

$$qf_i + M = \log\left[\frac{\Sigma\left[\frac{C_i}{f_i}(qf_i + M)\right]}{\Sigma\left[\frac{C_{i+1}}{f_{i+1}}(qf_{i+1} + M)\right]}\right] + \log\left[\frac{1 - e^{-\Sigma(qf_{i+1} + M)}}{1 - e^{-\Sigma(qf_i + M)}}\right] \qquad (9)$$

Study of equation (9) and comparison of it to equation (4) are worthwhile because all the computational procedures are evident.

We note, for example, from the first term on the right hand side of (9), that we are not escaping, in any sense, from dealing with the "variability and inaccuracy" of annual catch per unit of fishing intensity data for each age. Further, we see that the second term on the right hand side of equation (9) is a correction term in the same sense as the corresponding term in equation (4).

One further very important matter is revealed by writing (9) in the following manner:

$$qf_i + M = \log\left[\frac{C_n/f_n(qf_n + M)}{\Sigma\left[\frac{C_{i+1}}{f_{i+1}}(qf_{i+1} + M)\right]} + 1\right] + \log\left[\frac{1 - e^{-\Sigma(qf_{i+1} + M)}}{1 - e^{-\Sigma(qf_i + M)}}\right] \qquad (10)$$

where the subscript n denotes the age of the youngest fish included in the data. (Note that $\Sigma a_i C_i = a_n C_n + \Sigma a_{i+1} C_{i+1}$).

We shall refer to equation (10) later in interpreting the high correlation between Z and $\underline{f}$ which apparently results in using the Paloheimo method.

Comparison of Assumptions

Since both the Beverton and Holt and the Paloheimo methods of estimating natural mortality are based on the same population model, the broad assumptions underlying them are common.

In both methods, it is necessary to assume that q and M are the same at corresponding ages. More precisely, it is assumed that at any given age, variations in q and M are normally distributed about a stable mean.

In using equation (4) it is necessary to assume that q and M are the same at two successive ages of a year class. Thus, it is assumed that q and M are the same at ages 3 and 4, say, or at ages 4 and 5. It is never necessary to assume that q and M are the same at ages 3 and 5, however. This is an important difference between this method and the Paloheimo method.

Paloheimo (1958, p. 750) states that it is necessary to assume that q and M are the same at corresponding ages for all year classes. Lacking specific information, however, on the variation of q and M with age (in which case methods of estimating would not be needed), it is necessary to assume that q and M are the same over the entire periods of summation. This accounts, of course, for the bias seen in Table 2, Cases 3 and 4. The estimates of q and M are weighted by events occurring at ages 3 to 10. The Beverton and Holt method, being confined to data at ages 1 and 2 only, estimates values intermediate between the true values for Cases 3 and 4 at ages 1 and 2, as does the Paloheimo method when summation is restricted to ages 1 and 2.

Validity of the Correlation Coefficient

Paloheimo (1958) states: "It is worth while to summarize by noting that in the example worked out the correlation coefficient $r_{z.f}$ between the total instantaneous mortality rate at age 9 and effort is 0.815 when all available data is used and is 0.644 when data on catches only at ages 9 and 10 are used. The corresponding value of $r_{z.f}$ when the Beverton and Holt method is applied was calculated to be 0.51. The increase in the amount of information used appears to bring about a remarkable increase in the accuracy of estimation."

We feel obliged to show that the higher correlation between Z and f obtained in using the Paloheimo method results from a perfectly legitimate mathematical step in the computational procedure used in solving equation (5), which step, however, renders the correlation coefficient an inappropriate measure of accuracy and the resulting correlation coefficient spurious.

Referring to equation (10), we note that the variables correlated are f_i on the left hand side against Z_i, the value of the entire right hand side. We also note that the second term on the right hand side tends to a constant value, especially if summations are restricted to equal periods of time. It has the effect of adding a constant value and therefore little, or no influence on the degree of correlation. We further note that the addition of 1 to the fraction inside the brackets of the first term on the right hand side of (10) also will have no effect on the degree of correlation. (It is standard practice, when dealing with zero values in a correlation involving logarithms, to add 1 to all the observations.) We are left then with:

$$qf_n + M \alpha \log \left[\frac{C_n/f_n\,(qf_n + M)}{\Sigma \frac{(C_{i+1})}{(f_{i+1})}\,(qf_{i+1} + M)} \right] \qquad (11)$$

Let us write (11) as:

$$qf_n + M \,\alpha\, \log(qf_n + M) + \log \left[\frac{C_n/f_n}{\Sigma \left[\left(\frac{C_{i+1}}{f_{i+1}} \right) (qf_{i+1} + M) \right]} \right] \qquad (12)$$

Now since qf + M takes small values, generally much less than 3, the log (qf + M) is almost a linear function of f. It is, therefore, very nearly perfectly correlated with f_i. (The correlation between f_i and log $(qf_i + M)$, using the data in Paloheimo's (1958) Tables I and II is 0.987). It is, moreover, a very substantial part of the total value of the right hand side of (12).

It is clear, therefore, that even if the second term on the right hand side of (12) were a random variable, we should expect some correlation with f because we are always adding to it a value which is a function of f.

The relations indicated in (11) and (12) cut directly to the heart of the matter, but if they are not clear, it is easy to verify them by using the data from Paloheimo's (1958) Tables I and II. Omitting $(qf_i + M)$ from equation (9), we find the correlation between f and Z to be 0.51, or about the same as that found by Paloheimo when applying the Beverton and Holt method to his data. If this is not omitted, the correlation coefficient is 0.83.

The Problem of Undetected Trends

The scope of this study is limited to four cases in which either q or M varies while the other is held constant. Preliminary work only has been done on four additional cases where q and M increase or decrease together or oppositely.

The results summarized in Table II suggest that under certain conditions at least trends in q or M may be detectable. Perhaps the first conclusion one would draw is that when estimates obtained by the two methods do not agree, the discrepancies are due to trends in q or M.

The negative slope obtained by the Beverton and Holt method in Case 1 results from the fact that the catches per day at age 1 are either less than at age 2 (at 3,000 days' fishing) or about the same (at 6,000 days' fishing). Under such circumstances, one would conclude that the fish either are not fully recruited or fully available at age one, and that the method is not applicable. On the other hand, the Paloheimo method, because of the summations, always estimates a larger population at age 1 than at age 2 if there has been any catch at all at age 1. The method "works" even though the resulting estimates are biased.

We are impressed by the fact that the Paloheimo method results in good estimates of q at age 1 in Cases 1 and 2. We find, further, that summing back to ages 2 and 3 from age 10 for the same data gives a good estimate of q at age 2. If we ignore the biased estimates of M which are obtained in this procedure, repeat the iteration for the age 1 and 2 summations holding q constant at its estimated value at age 1 and 2, we quickly converge on an excellent value of M.

The results obtained by the two methods in Cases 3 and 4 are particularly interesting. Very good estimates of q are obtained by both procedures. The Beverton and Holt method, because it is applied to data for the first two years only, gives an average value of M which we consider quite superior to the underestimation or overestimation resulting from the Paloheimo method.

On first inspection, it appeared that one might obtain a superior estimate of M in Cases 3 and 4 by using values of q obtained by the Beverton and Holt method and using these estimates as constants in the Paloheimo method. We found, however, that this procedure results in an estimate of M very nearly the same as that obtained by the Beverton and Holt method.

When the summations in the Paloheimo method are restricted to ages 1 and 2, the results in Cases 3 and 4 are very nearly the same as those obtained by the Beverton and Holt method, as one might expect. The estimate of q is good and an intermediate value of M is obtained. We have already shown that the higher correlation obtained with the Paloheimo method between Z and f is spurious. This should be rather obvious since the data actually put into the equations is the same in both cases.

Summary

Four cases are examined in which either q or M increases or decreases while the other is held constant:

Case 1. When q is increasing from ages 1 to 3 and M is constant, the Beverton and Holt method fails to estimate q or M. The Paloheimo method gives a good approximation of q but underestimates the value of M.

Case 2. When q is decreasing from ages 1 to 3 and M is constant, the Beverton and Holt method fails to converge for the particular values used. The Paloheimo method gives a good approximation of q but overestimates M.

Case 3. When q is held constant and M increases between ages 1 and 3, the Beverton and Holt method estimates q accurately and estimates an average value of M. The Paloheimo method gives a good estimate of q but overestimates M.

Case 4. When q is held constant and M decreases between ages 1 and 3, the Beverton and Holt method estimates q precisely and estimates an intermediate value of M. The Paloheimo method gives a good estimate of q but underestimates M.

It is shown that the higher correlation between the total mortality coefficient, Z, and the fishing intensity, f, must not be interpreted as a superiority of the Paloheimo method.

It is pointed out that discrepancies in results in applying the Beverton and Holt and the Paloheimo methods to the same data are indicative of undetected trends in q or M. Under such conditions and in the cases examined, both methods appear to give good estimates of q. The Beverton and Holt method gives intermediate values of M while the Paloheimo method tends to under or overestimate M.

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APPENDIX V

Method for measuring benefits of the Georges Bank mesh regulation

by

L.M. Dickie

It is important that we should be familiar with the proposals for measuring benefit from the Georges Bank mesh regulation which were proposed by Holt as Document 31, ICNAF Annual Meeting, 1958. This note is drawn up with the limitations of the method most in mind, primarily because a lack of general understanding of the method at the time of its initial presentation may have falsely raised hopes that we could circumvent the difficulties encountered in previous attempts at analysis. It appears that Holt was proposing answers to a different set of questions than those we have been hoping to answer.

In understanding the basis for his "method", one point of notation may help to clear up difficulties, i.e., the symbols

$1-e^{-F}$ = the annual proportion dying (mortality) due to fishing

e^{-F} = the annual survival after fishing

$e^{+F} = \frac{1}{e^{-F}}$ = the annual new survival as a result of a cessation in fishing (like saying "There was 120% survival".)

$e^{F}-1 = \frac{1}{e^{-F}} - 1$ = the annual fraction of fish saved by cessation of fishing (like saying "Survival has improved by 20%".)

If F = .10

$1-e^{-F} = .0952$

$e^{-F} = .9048$

$e^{F} = 1.1052 = \frac{1}{.9048}$

$e^{F}-1 = .1052$

Holt's derivation states:

$$\text{Benefit} = {}_2y(e^{F(t_2-t_1)}-1) - {}_1y \qquad (1)$$

where t_1 and t_2 are the ages at which 50% of fish are taken by the small and large mesh, ${}_2y$ is the fraction of the old total yield which was taken from age t_2 on, and ${}_1y$ = the fraction of the old total yield taken between age t_1 and t_2. If benefit is nil

$${}_2y(e^{F}-1) = {}_1y \qquad (2)$$

That is there is no benefit if the increased survival of fish due to decreased fishing, expressed as a fraction of the former total yield which will be made with the larger mesh, is not greater than the fraction of the old yield made up of sizes between the two mesh sizes (assuming no change in F with change in mesh size).

Put in these terms, Holt's "method" of detecting (or perhaps better "predicting") a benefit is a neat algebraic transformation showing that a benefit must theoretically occur if the old fishing mortality at sizes between the old and new mesh 50% selection points has a particular relation to the yield that used to be made from sizes above and below the proposed new mesh. Specifically, it is a simplified statement of the implications of the Beverton and Holt model that we used for selecting mesh size initially. It therefore can be used to measure benefit only provided that the assumptions we made in the initial prediction do in fact still hold.

It seems to me that this is not the problem that we have been trying to solve. Our primary concern has been to measure the change in yield precisely enough so that we can say whether it has fitted predictions; if so, why? if not, why not? That is, we can detect certain changes in fishing practice and in yield. To date, most of these have worked to the advantage of the fishery in apparently increased yield. The problem is to ascribe the proper part of the increase to the mesh regulation, an approach which implies that we are trying to prove the applicability of our model and the parameters used in it, rather than simply accepting the model and measuring yield.

In relation to this central problem Holt's method leaves us precisely where we have always been. That is, Holt's formulation offers two sources of data for precise measurement of yield:

(1) The long-term average yield above and below the proposed new mesh size. This is implied by his equation for ${}_2Y_1$ and ${}_2Y$ on the bottom of page 1, Document 31, with sufficient years included so that variations in R, the recruitment, average out.

(2) The yield from year-classes of known size, i.e., the same equations calculated for known R.

These alternatives will be recognized as precisely those already suggested. The first was proposed by Graham (1952), and the second has been under discussion by Paloheimo and Taylor. Holt's method therefore suffers the same deficiencies as these do in giving fully satisfactory answers.

Any formulation may therefore be used to measure benefit, provided we can accept the sweeping assumptions made in the initial prediction. If we really wish to test the results, however, we must delve into the assumptions far more deeply than is suggested by Holt's formulation; or at least examine the errors in the data to satisfy ourselves that any such refined proof is impossible. For these purposes, Holt's (Document 31) method is less satisfactory than those currently under study.

A particular weakness of Document 31 is that it neglects any change in F, concomitant with the change in mesh size. This must be considered as part of the result of mesh size, and means that one cannot identify ${}_1y$ and ${}_2y$ before mesh change with ${}_1y^1$ and ${}_2y^1$ after the mesh change. If F increases without a mesh size change, it will generally increase ${}_1y$ at the expense of ${}_2y$. In equation (2), as ${}_1y$ approaches ${}_2y$ in size, an increase in F can decrease expected yield ${}_2y$ appreciably or even nullify benefit and cause a decrease rather than the anticipated increase!

In addition to the assumptions which on page 2 of Document 31 Holt says are implied by his equation, it should be noted that the "method" requires that there be no change in recruitment as a result of the regulation, and no change in growth rate from any cause whatever. These requirements apply equally to Holt's and to other methods, but should be specifically noted as the equation tends to draw attention away from them by requiring measurement only of yields and of fishing mortalities between the two mesh sizes.

In view of the foregoing, it appears that Holt's proposal is not a short-cut solution to the problems we have encountered during the Georges Bank analysis, because we do not yet have sufficient assurance that the estimates of parameters and assumptions used in our predictive models still apply to the fishery. It may prove to be a useful approach when we have proceeded further with our refined analysis of past data, and have made any revisions which our current biological studies suggest are necessary.

APPENDIX VI

Effects of possible mistakes in age determination on age-composition and mortality estimates for Georges Bank haddock

by

L.M. Dickie

Problem: To find out whether or not mistakes in scale-read age determination can account for apparent levelling of abundance of year-classes with age in Georges Bank haddock, and what effect such errors have on mortality rates.

Background: Year-classes 1948, 1950 and 1952 of Georges haddock appeared large while 1947, 1949, 1951 and 1953 appeared small, according to their relative abundance in catches as 2-year-olds. The attached Figure 1 plotted from Taylor's P. 27 (1957) shows that the ratio of abundance at age 2 was roughly 5 to 1. However, by the time each year-class was 7 years of age the initial differences in abundance had disappeared. J.R. Clark in personal communications has suggested that this may result from mistakes in age determinations which, in addition to distortion of age-class abundance, may also result in errors in estimates of mortality rates.

In treating this problem algebraically, Gulland (1955) suggests that a decided distortion of age-classes, which results from mistakes in age-readings, does not necessarily lead to mistakes in mortality rates unless the amount of error in reading changes markedly from age to age.

Plan: In the following account I have used the variation in age determination shown by Kohler and Clark (1958) and other data on the fishery to construct a simplified model of a population like that of Georges Bank haddock. The resulting distortion in age composition is illustrated in Figure 2. Mortality rates may be more or less distorted, depending on the type of calculation used.

Errors in Aging: Kohler and Clark show the degree of variation in determination of age by scales and otoliths for Subarea 5 haddock on the basis of nearly 500 duplicate readings ranging from 2 to 9 years of age. They conclude that there is no bias toward higher or lower age readings by either scales or otoliths, up to about age 8. We may therefore expect that at any one otolith age between 2 and 8 the distribution in ages assigned by scales gives a reasonably good estimate of the distribution of actual scale reading errors at that age. At 8 and above, the distribution of assigned ages cannot be as accurately assigned to a particular true age, but numbers above this are negligible in the fishing anyway.

Table I is constructed from Kohler and Clark's Table II.

In the following model the distribution for ages 2 and 3 is taken directly from Table I. The average for ages 4-7 is used for errors at each of these ages, and the average for 8-9 thereafter.

The Model

Recruitment: We assume that recruitment in alternate years varies in the ratio 5:1 as in Georges Bank haddock. In odd years recruits number 100, in even years 500.

Mortality: The mortality rates are given by Taylor (1958) as approximately

$$F = 0.40 \quad M = 0.20$$

$$\therefore \text{ survival rate } e^{-F+M} = e^{-0.60} = 0.55 \text{ per year.}$$

To simplify calculations we assume survival remains constant from year to year and age to age.

Annual Abundance: ${}_aN_t$ = true abundance of age a at time t

${}_aN_t = {}_{a-1}N_{t-1}\, e^{-(F+M)}$ (F+M constant at all t)

${}_aM_t$ = apparent abundance of age a at time t

$${}_aM_t = {}_{a+2}p_{n-2}\; {}_{a+2}N_t + {}_{a+1}p_{n-1}\; {}_{a+1}N_t + {}_ap_n\; {}_aN_t + {}_{a-1}p_{n+1}\; {}_{a-1}N_t + {}_{a+2}p_{n-2}\; {}_{a+2}N_t$$

where ${}_ap_n$ is the proportion of animals aged "a" which are correctly aged, ${}_{a+1}p_{n-1}$ is the proportion of animals aged "a+1" which were incorrectly identified as one year younger than they were, etc., and values for different p come from Table I.

Table I. Distribution of otolith- and scale-read ages.

Otolith age	Numbers assigned by scale examination to age					
n	n-2	n-1	n	n+1	n+2	Total
2			75	7		82
3		4	15	8	3	30
4		14	76	17	2	109
5	5	19	123	10	2	159
6	1	9	9	5	5	29
7	1	14	21	10		46
8	3	8	9	1	1	22
9	5	7	3			15
						492

	Fraction assigned to each age					
n	p_{n-2}	p_{n-1}	p_n	p_{n+1}	p_{n+2}	
2	0	0	.91	.09	0	1.00
3	0	.13	.50	.27	.10	1.00
4	0	.13	.70	.16	.01	1.00
5	.03	.13	.77	.06	.01	1.00
6	.04	.31	.31	.17	.17	1.00
7	.02	.30	.46	.22	0	1.00
8	.14	.37	.41	.04	.04	1.00
9	.33	.47	.20	0	0	1.00
Adjusted, unweighted average -- ages 4-7	.03	.21	.55	.15	.06	1.00
ages 8-9	.23	.39	.30	.04	.04	1.00

Table II. Model showing effects of mistakes in age determination on age distribution and mortalities in fluctuating stock abundance.

Suppose in Odd years recruitment = 100
" " Even " " = 500

M = 0.20
F = 0.40
$e^{-(F+M)} = e^{-0.60} = 0.55 =$ Ann. Survival

ODD YEARS

N_{t+9} — True age distribution

Age \ Year-class	y+9	y+8	y+7	y+6	y+5	y+4	y+3	y+2	y+1	y+0
2	100									
3		275								
4			30							
5				83						
6					9					
7						25				
8							3			
9								8		
10									1	
Total	100	275	30	83	9	25	3	8	1	

$S_o = \frac{y+8 + \dots + y+1}{y+9 + \dots + y+2} = \frac{434}{533}$

N_{t+9} — Apparent age distribution

Age	y+9	y+8	y+7	y+6	y+5	y+4	y+3	y+2	y+1	y+0
2	91	9								
3	36	138	74	27						
4	1	6	16	5	2					
5		3	17	46	12	5				
6				2	5	2				
7				1	5	14	4	1		
8					1	1	1			
9						2	3	2	1	
10									1	
Total	128	156	107	81	25	24	8	3	2	

$S_o^1 = \frac{y+8 + \dots + y+1}{y+9 + \dots + y+2} = \frac{406}{532}$

EVEN YEARS

N_{t+10} — True age distribution

Age	y+9	y+8	y+7	y+6	y+5	y+4	y+3	y+2	y+1	y+0
2	500									
3		55								
4			151							
5				17						
6					46					
7						5				
8							14			
9								2		
10									4	
Total	500	55	151	17	46	5	14	2	4	

$S_e = \frac{294}{790}$

$S = \frac{434 + 294}{533 + 790}$

$= \frac{728}{1323} = 0.55$

N_{t+10} — Apparent age distribution

Age	y+9	y+8	y+7	y+6	y+5	y+4	y+3	y+2	y+1	y+0
2	455	45								
3	7	28	15	5						
4	4	32	83	23	9					
5		1	4	9	3					
6			1	10	25	7	3			
7					1	3	1			
8					3	6	4	1		
9							1	1		
10							1	2	1	
Total	466	106	103	47	41	16	10	4	1	

$S_e^1 = \frac{328}{793}$

$S = \frac{406 + 323}{532 + 793}$

$= \frac{729}{1325} = 0.55$

Results

Age distribution: Table II shows the balanced true and apparent age distributions for odd years when recruitment is 100 and for even years when it is 500 after the alternation of strong and weak classes has been going on in the fishery for 9 and 10 years. Figure 2 illustrates the results graphically, and shows the degree of distortion which takes place.

Mortality: In calculating effects on mortality, we may use Jackson's (1939) method

$$\frac{y+8 + y+7 + \ldots + y}{y+9 + y+8 + \ldots + y+1} = S = \text{survival rate} = e^{-(F+M)}$$

provided we add the distribution over the two-year cycle of recruitment fluctuations (i.e., average S_o and S_e, the survival rates for odd and even years).

Thus for the true population:

$$S_{N_t} = \frac{(275 + 30 + \ldots + 1) + (55 + 151 + \ldots + 4)}{(100 + 275 + \ldots + 8) + (500 + 55 + \ldots + 2)} = \frac{434 + 294}{533 + 790}$$

$$= \frac{728}{1323} \approx 0.55 \text{ (as used for the model)}$$

For the population sample (apparent population)

$$S_{M_t} = \frac{(156 + 107 + \ldots + 2) + (106 + 103 + \ldots + 1)}{(128 + 156 + \ldots + 3) + (466 + 106 + \ldots + 4)} = \frac{406 + 323}{532 + 593}$$

$$= \frac{729}{1325} = 0.55$$

In the analysis of Georges Bank and other recent data, however, we are unable to use an overall average such as is given by Jackson's method. The approach is rather to compare the strength of a year-class at the beginning of two successive years, and to average results over a series of comparisons. Table III shows the survival rate estimates which will be obtained using this type of computation.

Table III. Apparent mortalities from single age-class comparisons when there have been mistakes in age readings -- for data see Table II.

Age comparison	Strong Year-Classes		Weak Year-Classes	
	Apparent ratio of initial abundance	Apparent survival rate	Apparent ratio of initial abundance	Apparent survival rate
1 - 2 $\left(\frac{y+8}{y+9}\right)$	156/466	0.34	106/128	0.83
2 - 3	103/156	0.66	107/106	1.01
3 - 4	81/103	0.79	47/107	0.44
4 - 5	41/81	0.51	25/47	0.53
5 - 6	24/41	0.59	16/25	0.64
6 - 7	10/24	0.42	8/16	0.50
7 - 8	3/10	0.30	4/8	0.50
Average		0.52		0.64
Overall average		0.58		

Conclusions:

1) The apparent changes in the relative strengths of year-classes of haddock with age may be due entirely to mistakes in age readings.

2) Distortions in age composition will not affect the overall estimates of survival (or mortality) rates, provided we use averages of a sufficiently long series of data and combine information over several cycles of strong and weak year-classes as was suggested by Gulland (1955).

In the actual analysis, however, averages are taken over varying periods of time and different age groups. It is obvious that in such a situation serious errors in the estimation of mortalities and year-class strengths could arise.

It appears that some correction for mistakes in age reading is essential at an early stage in the analysis, especially of incomplete data.

Addendum: It may be a relatively simple task to reconstruct an accurate age frequency diagram for Georges Bank haddock from available data. Suppose we wish to calculate

${}^{y}_{a}N$ for "a" when "y" is a strong year-class following ${}^{y-1}_{a}N$

which was a weak year-class, such that

$${}^{y}_{a}N : {}^{y-1}_{a}N : : 5 : 1$$

Since $${}^{y}_{a}N_t = {}^{y}_{a-1}N_{t-1}e^{-(F_{t-1}+M_{t-1})}$$

Then at 2 years of age

$${}^{y}_{2}M_t = {}_2p_n\,{}^{y}_{2}N_t + {}_3p_{n-1}\,{}^{y-1}_{2}N_{t-1}\,(e^{-(F+M)})$$

$$= (0.91 \times 5) + (0.13 \times 1 \times 0.55)$$

$$= 4.55 + 0.07 = 4.62$$

$$= 0.98 + 0.02 = 1.00$$

Therefore, at 2 years of age the contribution made by the older year-class to the apparent relative abundance is only about 2%, negligible in comparison with other errors. The second term of the equation may be dropped and

$${}^{y}_{2}M_t = {}_2p_n\,{}^{y}_{2}N_t \quad \text{for this particular situation.}$$

The true abundance

$${}^{y}_{2}N_t = \frac{1}{{}_2p_n}\,{}^{y}_{2}M_t = N_1$$

Since the "true" total mortality rate may be obtained from an overall average of the distorted age distribution and the initial relative abundance obtained as given here, we may use these data together with Table I to calculate true age distributions.

i.e. $${}^{y}_{3}N_{t+1} = N_1\,e^{-(F+M)}$$ For the next year-class (y-1) entering at age 2

$$ {}^{y-1}_{2}N_{t+1} = \frac{1}{{}_2p_n} \left({}^{y-1}_{2}M_t - {}_3p_{n-1} \; {}^{y}_{3}N_{t+1} \right) $$

This may be checked with the sampled number at age 3 in year t+1

$$ {}^{y}_{3}N_{t+1} = \frac{1}{{}_3p_n} \left({}^{y}_{3}M_{t+1} - {}_2p_{n+1} \; {}^{y-1}_{2}N_{t+1} - {}_4p_{n-1} \; {}^{y+1}_{4}N_{t+1} \right) $$

in which the last term may be omitted as negligible as in the case above.

etc.

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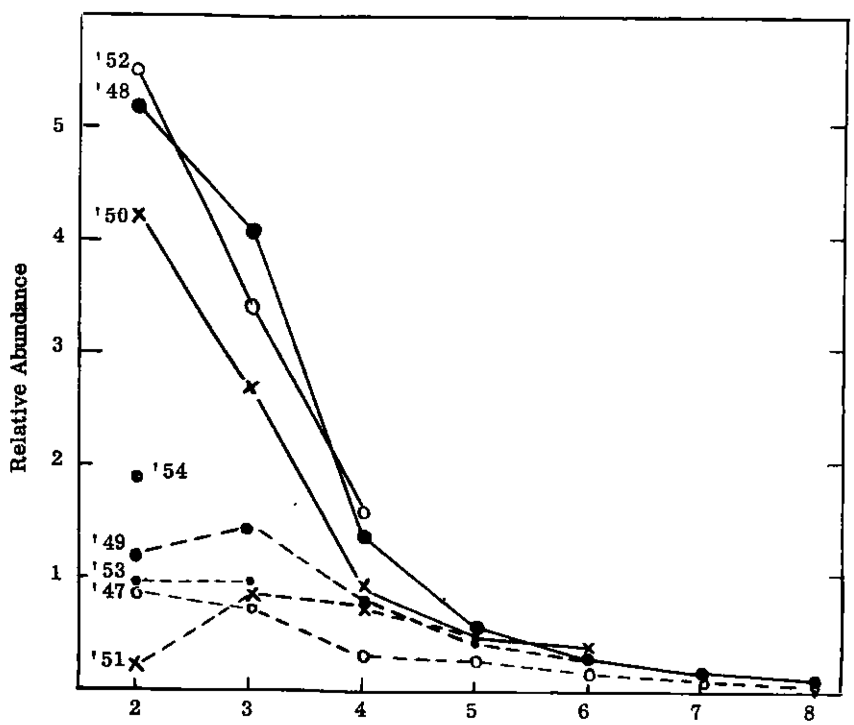

Figure 1. Relative strength of successive year-classes of Georges Bank haddock. (Data from Taylor, P. 27 (1957)).

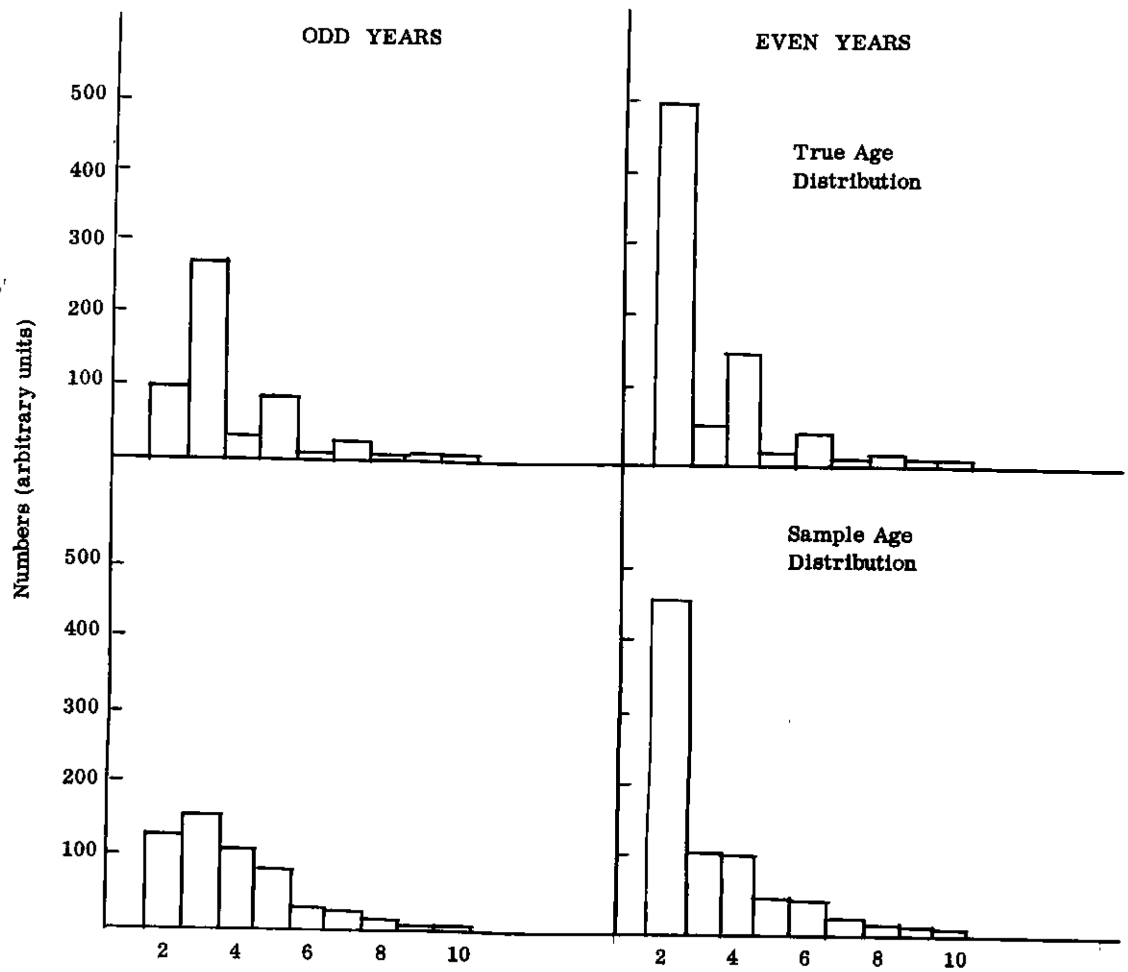

Figure 2. The age composition of a stock in odd and even numbered years, having recruitment at age 2 oscillating from 100 in odd years to 500 in even years, and distortions introduced by mistakes in age reading of the samples. (Note resemblance of lower left to Fig. 6 of Graham, 1952, even though recruitment is complete at age 2 in the model.)

APPENDIX VII

ICNAF MESH REGULATION
OPERATION OF 10% ANNUAL EXEMPTION

October 1, 1957, through September 30, 1958

The United States Bureau of Commercial Fisheries, Fish and Wildlife Service, issued 27 exemption certificates to U.S. vessels during the one-year period. The certificates were issued by months as follows:

Month	Certificates
October 1957	6
November	3
December	2
January 1958	4
February	7
March	2
April	1
May	1
August	1

The tonnage classes of the vessels are as follows:

Gross Tons	Class	Number of vessels
0 - 25	OTS	1
26 - 50	OTS	4
51 - 100	OTM	12
101 - 150	OTM	2
151 - 200	OTL	7
Over 200	OTL	1
		27

The twenty-seven (27) vessels landed a total of 23,178,654 pounds of fish from ICNAF Subarea 5 on 628 trips.

Analysis of these landings shows 2,452,737 pounds of haddock landed on 534 trips, with a range of landings per trip from 15 to 113,000 pounds. There were 147 trips with more than 5,000 pounds and more than 10% haddock.

Cod landings were made on 539 trips to ICNAF Subarea 5, with a total catch of 470,953 pounds. The cod landings range from 10 to 20,650 pounds. Only 15 trips had more than 5,000 pounds and over 10% cod.

The principal species landed by the exempted vessels during the period was redfish. A total catch of 7,333,365 pounds was landed from Subarea 5, representing the 265 trips on which this species was caught. This leaves 363 trips (total 628) on which no redfish was taken.

Other species caught by the exempted vessels included halibut, white hake, cusk, pollock, flounders, and whiting (silver hake). Total catch of these species amounted to 12,921,329 pounds.

Age- and Length-Composition of Cod (Gadus callarias L.) caught in Subarea 4 in 1956-58

(Preliminary Report)

by

Mario Ruivo and Glicinia V. Quartin

Samples of cod have been taken since 1956 from Portuguese trawlers fishing in Subarea 4, especially in the Subdivisions 4R and 4T (Gulf of St. Lawrence).

The cod-end mesh size of the trawls used has been around 117 mm.

In 1956 the samples were taken from the marketable fish, i.e. after discard, in 1957 and 1958 from the cod as caught, i.e. before discard.

Tables 1-3 give the position of each sample and the kind of observations made.

In order to facilitate the study related samples were grouped by subdivisions and months (Tables 4-6).

The results obtained as far as size- and age-composition and sex-ratio are concerned are summarized in Tables 7-15.

The results are circulated in the present more preliminary form for information and discussion. A more detailed report will be presented at the 1959 Annual Meeting of ICNAF.

Table 1. At-sea-samples of cod caught by trawl in 1956.

SAMPLE NUMBER	MONTH	SUBDIVISION	POSITION	NO. OF SPECIMENS	LENGTHS	WEIGHTS	SEXES	MATURITY	OTOLITHS OR SCALES COLLECTED	AGES DE-TERMINED	1ST MATURITY	PARASITES
					INDICATE BELOW OBSERVATIONS MADE							
1	27-III-56	4R	48°10'N 59°40'W	125	+		+	+	OT (100)	+	+	+
2	30-III-56	4R	47°43'N 59°30'W	75	+	+	+	+	OT	+	+	+
3	31-III-56	4R	47°59'N 59°31'W	100	+		+	+	OT	+	+	
4	1-IV-56	4R	47°59'N 59°31'W	62	+		+	+	OT	+	+	+
5	3-IV-56	4V	46°25'N 59°20'W	125	+		+	+	OT (100)	+	+	+
6	4-IV-56	4V	46°20'N 59°22'W	100	+	+	+	+	OT	+	+	
7	6-IV-56	4V	46°38'N 59°35'W	125	+		+	+	OT (100)	+	+	+
8	7-IV-56	4V	46°35'N 59°25'W	200	+		+					
9	16-IV-56	4T	47°10'N 60°16'W	300	+		+					
10	17-IV-56	4T	47°16'N 60°17'W	150	+		+	+	OT (100)	+	+	+
11	18-IV-56	4T	47°10'N 60°15'W	75	+	+	+	+	OT	+	+	+
12	19-IV-56	4T	47°30'N 60°28'W	300	+		+					
13	20-IV-56	4T	47°40'N 60°35'W	125	+		+	+	OT (100)	+	+	+
14	21-IV-56	4T	47°36'N 60°35'W	25	+	+	+	+	OT	+	+	
15	22-IV-56	4S	47°52'N 60°38'W	300	+		+					
16	28-III-56	4R	48°05'N 59°45'W	277	+		+					

TABLE 2 - 1957

SAMPLE NUMBER	MONTH	SUBDIVISION	POSITION	NO. OF SPECIMENS	LENGTHS	WEIGHTS	SEXES	MATURITY	OTOLITHS OR SCALES COLLECTED	AGES DE-TERMINED	1ST MATURITY	PARASITES
1	18-III-57	4V	46°19'N 58°55'W	100					OT			
2	20-III-57	4R	48°25'N 59°28'W	100					OT			
3	22-III-57	4R	48°19'N 59°34'W	100	+		+	+	OT	+	+	+
4	25-III-57	4T	47°24'N 60°26'W	100	+		+	+	OT	+	+	+
5	29-III-57	4V	47°19'N 60°13'W	100	+		+	+	OT	+	+	+
6	30-III-57	4V	46°16'N 58°56'W	100	+		+	+	OT	+	+	+
7	31-III-57	4V	46°03'N 58°53'W	≈360	+		+					

(continued)

Table 2 (continued)

8	2-IV-57	4V	46°36' N 59°30' W	100								
9	5-IV-57	4V	46°12' N 58°50' W	100	+		+	+	OT	+	+	+
10	7-IV-57	4V	45°59' N 58°28' W	≈ 180	+		+					
11	15-IV-57	4R	48°07' N 59°20' W	100	+		+		OT			
12	16-IV-57	4R	48°03' N 59°27' W	100								
13	17-IV-57	4R	47°59' N 59°58' W	100								

TABLE 3 - 1958

1	25-III-58	4V	46°48' N 59°44' W	50	+		+	+	OT	+	+	+
2	26-III-58	4V	46°30' N 59°25' W	50	+		+	+	OT	+	+	+
3	27-III-58	4R	48°32' N 59°21' W	50	+		+	+	OT	+	+	+
4	28-III-58	4R	48°32' N 59°36' W	50	+		+					
5	29-III-58	4R	48°19' N 59°34' W	50	+	+	+	+	OT	+	+	+
6	30-III-58	4R	48°17' N 59°34' W	100	+		+	+	OT	+	+	+
7	31-III-58	4R	48°21' N 59°39' W	100	+	+	+	+	OT	+	+	+
8	1-IV-58	4R	48°21' N 59°39' W	300	+		+					
9	2-IV-58	4R	48°05' N 59°38' W	50	+		+	+	OT	+	+	+
10	3-IV-58	4R	47°40' N 59°25' W	50	+		+	+	OT	+	+	+
11	5-IV-58	4R	48°24' N 59°45' W	100	+		+	+	OT	+	+	+
12	7-IV-58	4R	48°21' N 59°45' W	100	+		+	+	OT	+	+	+
13	9-IV-58	4R	48°39' N 59°40' W	190	+		+					
14	11-IV-58	4T	48°03' N 60°10' W	100	+		+	+	OT	+	+	+
15	13-IV-58	4R	48°12' N 59°40' W	100	+		+	+	OT	+	+	+
16	14-IV-58	4R	47°45' N 59°28' W	100	+		+	+	OT	+	+	+
17	18-IV-58	4T	47°42' N 60°37' W	100	+		+	+	OT	+	+	+
18	20-IV-58	4T	47°35' N 60°32' W	100	+		+	+	OT	+	+	+
19	22-IV-58	4V	47°04' N 60°10' W	100	+		+	+	OT	+	+	

Sample-Groups

Sample Group	Sample Number	Subdivision	Date
	TABLE 4 - 1956		
A	1-2-3-4	4R	27-III/1-IV-56
B	5-6	4V	3/4-IV-56
C	7	4V	6-IV-56
D	10-11-13-14	4T	17-21-IV-56
	TABLE 5 - 1957		
A	3	4R	22-III-57
B	4	4T	25-III-57
C	5-6-8-9	4V	29-III/5-IV-57
D	11-12-13	4R	15-IV/17-IV-57
	TABLE 6 - 1958		
A	1-2	4V	25/26-III-58
B	3-5-6-7	4R	27/31-III-58
C	9-10-11-12-15-16	4R	2/14-IV-58
D	14-17-18	4T	11/20-IV-58
E	19	4V	22-IV-58

Cod. Subarea 4, March-April. Age-distribution, mean lengths and sex ratio, sample-groups A, B, C, and D. Subdivisions and numbers investigated in ( ).

Year-class	Age-Group	A (4R) ♂♂♀♀ (333)		B (4V) ♂♂♀♀ (199)		C (4V) ♂♂♀♀ (100)		D (4T) ♂♂♀♀ (298)	
		%	m.l. cm	%	m.l. cm	%	m.l. cm	%	m.l. cm
				TABLE 7 - 1956					
1953	III	-	-	0.5	41.0	-	-	-	-
52	IV	1.5	46.4	11.6	46.6	-	-	1.0	44.3
51	V	6.9	47.6	13.1	49.7	1.0	69.0	3.7	55.2
1950	VI	17.1	52.9	48.7	54.1	-	-	25.8	57.2
49	VII	16.2	56.2	17.1	56.5	1.0	60.0	22.8	60.0
48	VIII	19.5	60.9	3.5	55.0	18.0	76.2	17.1	68.2
47	IX	15.0	67.1	3.5	68.0	11.0	77.5	16.1	70.7
46	X	8.1	68.7	1.0	69.0	26.0	83.8	7.1	75.6
1945	XI	2.1	76.6	-	-	8.0	79.1	1.7	75.3
44	XII	3.0	71.4	-	-	14.0	84.7	3.0	77.1
43	XIII	0.9	75.8	-	-	8.0	80.5	1.3	73.5
42	XIV	4.8	81.6	-	-	2.0	83.0	-	-
41	XV	3.0	78.3	0.5	80.0	4.0	80.0	0.3	79.0
1940	XVI	1.2	81.5	0.5	85.0	6.0	85.0	-	-
39	XVII	0.3	79.0	-	-	-	-	-	-
38	XVIII	0.3	72.0	-	-	1.0	89.0	-	-
		♂♂ = 45.9%		♂♂ = 54.8%		♂♂ = 45.0%		♂♂ = 51.7%	

TABLE 8 - 1957

Year-Class	Age-Group	A (4R) ♂♂♀♀ (100) %	A m.l. cm	B (4T) ♂♂♀♀ (98) %	B m.l. cm	C (4V) ♂♂♀♀ (398) %	C m.l. cm	D (4R) ♂♂♀♀ (299) %	D m.l. cm
1954	III	-	-	-	-	0.3	43.0	1.0	32.8
53	IV	1.0	48.0	4.1	46.3	3.8	45.5	10.4	41.5
52	V	6.0	50.8	20.4	50.4	12.1	48.4	26.8	45.7
51	VI	11.0	55.4	10.2	54.3	9.0	54.9	17.4	50.2
1950	VII	30.0	56.8	17.3	60.9	23.9	60.0	17.1	57.9
49	VIII	14.0	59.6	13.3	65.9	19.6	65.0	13.7	61.4
48	IX	22.0	63.9	10.2	71.5	7.8	69.5	7.0	67.3
47	X	10.0	67.3	17.3	78.2	7.5	74.4	3.7	71.6
46	XI	3.0	72.3	4.1	74.5	4.8	77.9	1.7	82.8
1945	XII	1.0	58.0	-	-	4.8	79.7	0.3	93.0
44	XIII	1.0	86.0	-	-	1.3	79.1	0.3	71.0
43	XIV	-	-	-	-	0.8	75.3	0.3	91.0
42	XV	1.0	80.0	2.1	86.0	1.8	86.5	-	-
41	XVI	-	-	1.1	76.0	1.3	89.9	-	-
1940	XVII	-	-	-	-	0.8	92.8	0.3	-
39	XVIII	-	-	-	-	-	-	-	105.0
38	XIX	-	-	-	-	-	-	-	-
37	XX	-	-	-	-	-	-	-	-
36	XXI	-	-	-	-	0.5	87.5	-	-
		♂♂ = 49.0%		♂♂ = 43.9%		♂♂ = 53.8%		♂♂ = 52.2%	

TABLE 9 - 1958

Year-Class	Age-Group	A (4V) ♂♂♀♀ (99) %	A m.l. cm	B (4R) ♂♂♀♀ (297) %	B m.l. cm	C (4R) ♂♂♀♀ (496) %	C m.l. cm	D (4T) ♂♂♀♀ (299) %	D m.l. cm	E (4V) ♂♂♀♀ (99) %	E m.l. cm
1955	III	1.0	39.0	0.3	36.0	0.6	38.0	-	-	-	-
54	IV	6.1	44.0	3.7	42.1	8.7	42.8	6.0	41.5	4.0	46.5
53	V	22.2	48.2	10.4	48.3	23.6	48.4	19.1	49.2	15.2	50.4
52	VI	20.2	55.6	18.9	50.2	22.8	50.5	20.4	52.6	28.3	53.4
51	VII	14.1	61.9	16.2	55.8	13.7	55.7	10.4	57.2	12.1	56.4
1950	VIII	13.1	66.4	12.5	60.3	10.3	60.4	18.7	61.8	20.2	62.1
49	IX	8.1	71.0	8.8	63.5	8.3	60.8	10.4	63.2	8.1	66.4
48	X	6.1	76.9	11.5	67.1	5.6	65.8	7.0	67.4	5.1	73.2
47	XI	3.0	74.7	9.1	71.0	3.4	68.1	4.7	68.2	4.0	66.6
46	XII	1.0	84.0	2.4	74.7	1.2	71.4	2.0	73.9	2.0	69.5
1945	XIII	1.0	71.0	2.0	77.0	0.4	80.5	0.7	68.0	1.0	84.0
44	XIV	1.0	80.0	1.4	72.0	0.6	75.0	-	-	-	-
43	XV	1.0	88.0	0.3	70.0	0.2	90.0	0.3	68.0	-	-
42	XVI	2.0	78.5	0.7	86.0	0.2	87.0	-	-	-	-
41	XVII	-	-	1.4	79.4	0.4	82.0	0.3	85.0	-	-
1940	XVIII	-	-	0.3	145(?)	-	-	-	-	-	-
39	XIX	-	-	0.3	118(?)	-	-	-	-	-	-
		♂♂ = 47.5%		♂♂ = 49.5%		♂♂ = 49.0%		♂♂ = 50.2%		♂♂ = 46.5%	

Cod. Subarea 4. March-April. Size-composition, sample-groups A, B, C, D, and E. Subdivisions and numbers in ( ).

TABLE 10 - 1956

Length Group cm	A (4R) %	B (4V) %	C (4V) %	D (4T) %
32	-	-	-	-
37	-	-	-	-
42	2.4	4.5	-	0.7
47	9.3	17.1	1.0	0.7
52	17.7	37.7	-	13.1
57	17.7	27.1	-	23.2
62	19.2	8.5	3.0	18.8
67	9.3	2.0	9.0	14.1
72	6.6	0.5	11.0	11.7
77	7.8	0.5	18.0	8.4
82	4.8	1.5	26.0	7.0
87	3.0	0.5	18.0	1.0
92	1.2	-	5.0	1.3
97	0.3	-	7.0	-
102	0.6	-	2.0	-

TABLE 11 - 1957

Length Group cm	A (4R) % (100)	B (4T) % (98)	C (4V) % (398)	D (4R) % (299)
32	-	-	-	1.0
37	-	-	-	4.7
42	-	1.1	3.5	16.0
47	7.0	10.2	5.5	17.7
52	19.0	20.4	12.1	17.4
57	25.0	12.2	19.4	15.4
62	25.0	13.3	17.8	14.4
67	11.0	6.1	11.6	4.3
72	7.0	15.3	11.6	4.0
77	2.0	9.2	7.3	1.7
82	1.0	7.1	4.0	1.3
87	2.0	3.1	3.8	0.7
92	-	-	2.0	1.0
97	-	2.1	0.3	-
102	-	-	0.5	-
107	-	-	0.5	0.3
112	-	-	-	-
117	-	-	0.3	-

TABLE 12 - 1958

Length Group cm	A (4V) % (99)	B (4R) % (297)	C (4R) % (496)	D (4T) % (299)	E (4V) % (99)
32	1.0	-	-	0.3	-
37	3.0	1.4	2.2	2.0	1.0
42	7.0	6.1	10.3	5.7	2.0
47	8.1	11.8	22.8	12.0	12.1
52	17.2	17.8	23.4	23.4	20.2
57	14.1	16.2	14.1	17.4	25.3
62	12.2	20.5	14.7	16.4	17.2
67	15.2	10.8	7.1	13.7	13.1
72	8.1	5.4	2.0	5.4	5.1
77	4.0	2.7	1.6	2.0	1.0
82	5.1	2.7	1.0	0.3	3.0
87	4.0	3.0	0.6	1.0	-
92	1.0	1.0	0.2	-	-

TABLE 13. Cod. Subarea 4. 1956. Size-composition and sex ratio of Samples No. 16 - 28 March, Subdivision 4R, No. 8 - 7 April, 4V, No. 9 - 16 April, 4T, No. 12 - 19 April, and No. 15 - 22 April, 4S.

Length	16 (4R)			8 (4V)		9 (4T)			12 (4T)			15 (4S)		
Group cm	Morning	Afternoon	Night	Morning	Afternoon	Morning	Afternoon	Night	Morning	Afternoon	Night	Morning	Afternoon	Night
42	2.0	2.0	2.6	3.0	4.0	-	-	-	-	4.0	1.0	-	-	-
47	6.1	5.1	5.3	24.0	26.0	-	3.0	1.0	-	11.0	1.0	3.0	1.0	-
52	6.1	14.3	17.1	26.0	26.0	7.0	7.0	10.0	15.0	17.0	18.0	8.0	2.0	6.0
57	18.4	14.3	14.5	27.0	27.0	16.0	26.0	24.0	15.0	27.0	17.0	20.0	14.0	12.0
62	19.4	20.4	10.5	15.0	12.0	15.0	19.0	16.0	18.0	14.0	17.0	16.0	11.0	14.0
67	8.2	13.3	11.8	3.0	3.0	11.0	18.0	14.0	14.0	9.0	12.0	14.0	12.0	13.0
72	14.3	17.4	14.5	2.0	2.0	11.0	11.0	13.0	14.0	8.0	16.0	13.0	16.0	14.0
77	11.2	7.1	7.9	-	-	13.0	7.0	4.0	9.0	3.0	7.0	9.0	18.0	13.0
82	4.1	2.0	6.6	-	-	11.0	6.0	10.0	13.0	6.0	7.0	7.0	16.0	8.0
87	2.0	1.0	-	-	-	9.0	-	4.0	1.0	1.0	2.0	4.0	6.0	10.0
92	3.1	1.0	6.6	-	-	5.0	3.0	4.0	1.0	-	1.0	4.0	4.0	7.0
97	5.1	2.0	2.6	-	-	-	-	-	-	-	1.0	2.0	-	3.0
102	-	-	-	-	-	-	-	-	-	-	-	-	-	-
107	-	-	-	-	-	1.0	-	-	-	-	-	-	-	-
112	-	-	-	-	-	1.0	-	-	-	-	-	-	-	-
	98	98	98	100	100	100	100	100	100	100	100	100	100	100
% ♂♂	47.0	55.1	62.2	58.0	51.0	51.0	48.0	54.0	49.0	54.0	48.0	44.0	44.0	39.0

TABLE 14. Cod. Subdivision 4V. 1957. Size-composition and sex-ratio of samples No. 5 - 29 March and No. 9 - 5 April.

Length	5		9
Group	(135)	(135)	(184)
cm	Day	Night	Night
42	0.6	0.6	8.2
47	1.1	2.8	29.3
52	5.6	6.1	28.3
57	20.0	23.8	19.6
62	27.2	33.3	10.3
67	26.1	17.2	3.3
72	10.5	6.7	-
77	6.1	5.0	-
82	0.6	1.7	1.1
87	0.6	1.1	-
92	1.1	0.6	-
97	0.6	1.1	-
	68	79	91
% ♂	50.4	57.8	49.5

TABLE 15. Cod. Subdivision 4R. 1958. Size-composition and sex-ratio of sample No. 4 - 28 March.

Length	4	
Group	Day	Night
cm	%(147)	%(147)
27	1.4	-
32	0.7	-
37	6.8	3.4
42	8.8	6.8
47	9.5	13.6
52	16.3	23.1
57	12.9	5.4
62	20.4	22.4
67	9.5	11.6
72	6.1	11.6
77	4.8	2.0
82	2.0	-
87	0.7	-

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