RESTRICTED

INTERNATIONAL COMMISSION FOR THE NORTHWEST ATLANTIC FISHERIES

Serial No.2249
/D.c.8/

ICNAF Res.Doc.69/83

ANNUAL MEETING - JUNE 1969

Assessments of the Effects of Increases in the Mesh Sizes of Trawls on the Cod Fisheries in ICNAF Divisions 3N and 3O

by

A. T. Pinhorn
Fisheries Research Board of Canada
Biological Station, St. John's, Newfoundland

Abstract

Total cod landings were lower in the 1956-64 period than in 1954-55 but then increased steadily to 1966, with a greater than two-fold increase in 1967 attributed to an intensive fishery on the 1964 year-class. Otter trawl and pair trawl were the most important gears and Spain, Portugal and USSR the most important countries. Landings per hour fished were at a high level in 1954-57 but decreased about 50 per cent in 1958-62 followed by an increase to the former level in 1963-67. These changes were attributed to a lack of recruitment of successive year-classes to the fishery in 1958-62. Total effort was slightly lower in 1956-58 than in 1954-55 but returned to the former level in 1959-61. It then decreased 100 per cent in 1962-64 but increased steadily to a high level in 1967. Estimates of total effort based on country were lower than those based on tonnage class.

The greatest long-term gain for otter trawlers was predicted at 5½-inch mesh for the lowest value of E in the 1959-62 period and at 6-inch mesh for the other values of E in the 1959-62 period and for all values of E in the 1963-66 period. The greatest gain to the offshore landings and total landings was predicted at 6-inch mesh for all values of E in both periods.

Immediate losses would have been 10% or less in 1959-62 and 13% or less in 1963-66 for increases from 4- to 5½-inch mesh. The predicted immediate losses were greater at the larger mesh sizes during 1963-66 than 1959-62 due to the larger numbers of smaller fish caught and landed in 1963-66. The same was true in comparing 1959-62 with 1955-58, the greater immediate losses being predicted in 1959-62. The predicted long-term gains at the two higher values of E were greater in 1959-62 than in 1955-58 and in 1963-66 than in 1959-62 because of an increase from 1955-58 to 1963-66 in the proportion of small fish that would have been released by a larger mesh.

The necessity of more adequate sampling of cod catches in 3NO is emphasized.

Introduction

Previous assessments on 3NO cod were reported by Beverton and Hodder (1962) for the 1955-58 period. In view of more recent data on mortality and growth of 3NO cod, it was suggested at the 1968 ICNAF Annual Meeting that "the Research and Statistics Committee should be asked to provide new assessments as soon as practicable" for this area (Report of Meeting of Panel 3, Serial No. 2106). New assessments have been made for 3NO cod based on 1959-62 and 1963-66 combined data and the results are presented in this paper.

Trends in landings, effort and landings per effort during 1954-67

Total landings

Total cod landings from 3NO decreased from about 120 thousand metric tons in 1954-55 to an average level of 60 thousand tons in 1956-64. Landings then increased to 106 thousand tons in 1966, followed by a greater than two-fold increase in 1967 to 220 thousand tons (Table 1 and Fig. 1A).

Otter trawl and pair trawl together accounted for most of the landings with offshore line contributing very little, especially in recent years. Otter trawler landings were high in the early 1950's but decreased to about the level of pair trawler landings until 1964. They then increased steadily in the 1965-67 period, with a two and one-half fold increase in 1967 over 1966. Pair trawler landings remained reasonably stable at about 20-30 thousand tons during 1954-62, after which they increased to about 60 thousand tons in the 1965-67 period. Offshore line landings have decreased since 1959 to a very low level in 1967 (Table 1 and Fig. 1A).

Portugal and Spain were the most important contributors to the total landings until 1960, when USSR entered the fishery. Portuguese landings declined during the entire period while Spanish landings increased after 1962. USSR landings increased after 1964 with a three-fold increase in 1967. Thus, the increase in total landings after 1962 was due to increased landings by Spain and USSR, and the sudden increase in 1967 was mainly due to increased landings by USSR (Table 1 and Fig. 1B).

Total effort and landings per effort

Several methods have been used by various authors to estimate total effort and landings per unit of effort for particular species or combinations of species (Hodder, 1965; Wiles, 1967; May, 1968). Since no comparisons of these different methods have been reported, it was decided to estimate total effort and landings per effort for 3NO cod by several different procedures.

Four methods were used in the present study and these are outlined below:

Method 1. (Effort adjusted by country)

1) Entries for cod landings and hours fished where cod was the main species landed and presumably caught (i.e. cod was greater than 50% of the total fish landed) were selected from the ICNAF Statistical Bulletins for the years 1959-67 and tabulated by gear, country and month for each year. Landings per hour fished were then calculated for each month. In cases where countries reported days fished but not hours fished, the hours were estimated on the basis of the hours per day fished for the countries reporting both.

2) Landings per hour fished for Spanish otter trawlers were then plotted against landings per hour for Spanish pair trawlers for each month in which both fished at least 100 hours. A straight line drawn by eye through the origin gave a conversion factor of 1.2 (Fig. 2A).

3) Spanish pair trawler hours for each month were then adjusted by a factor of 1.2 and added to Spanish otter trawler hours for the corresponding month. The resulting figures were divided into the combined landings of Spanish otter trawlers and pair trawlers for main species cod to produce landings per standard Spanish otter trawler hour for each month.

4) These values were then plotted against landings per hour for (a) USSR otter trawlers, tonnage classes 151-1800, (b) USSR otter trawlers, tonnage class >1800, (c) Canada (Nfld.) otter trawlers, and (d) Portugal dory vessels, producing conversion factors of 0.3, 1.4, 0.6 and 0.033, respectively (Fig. 2, B-D).

5) The effort for these countries (hours fished) for each year was then adjusted by the appropriate factor to standard Spanish otter trawler hours and added to the standard Spanish otter trawler hours derived in (3) above.

6) The total landing of these countries when cod was main species was then divided by the total hours in standard Spanish otter trawler units for each year to produce landings per standard Spanish otter trawler hour. These values were then divided into the total cod landings of all countries and gears regardless of main species to obtain total effort figures for all countries and gears combined in standard Spanish otter trawler units.

This method provides estimates of the total effort expended for cod if all countries landing cod had been fishing primarily for cod. A similar method was used by Hodder (1965) for Subarea 2 and 3K-3L cod, by Wiles (1967) for 4R and 4S cod and by Pinhorn (1969) for 3Pn cod.

<u>Method 2</u>. (Effort adjusted by tonnage class)

Tonnage classes referred to are as follows:

Tonnage Class		1	-	0-50
"	"	2	-	51-150
"	"	3	-	151-500
"	"	4	-	501-900
"	"	5	-	901-1800
"	"	6	-	>1800

1) Entries for cod landings and hours fished where cod was the main species (using the 50% criterion) were selected and tabulated by gear, tonnage class and month for each year. Landings per hour fished were then calculated for each month.

2) Plots of landings per hour fished for otter trawlers yielded no clear relationships between different tonnage classes and thus no conversion factors. Consequently, landings and hours for total groundfish were selected and tabulated by gear, tonnage class and month for each year and landings per hour fished for each month calculated.

3) Total groundfish landings per hour fished for otter trawlers, tonnage class 3, were plotted against otter trawlers, tonnage classes 5 and 6, for each month in which each fished at least 100 hours. Straight lines drawn by eye to these points yielded conversion factors of 2.4 for tonnage class 6 and 1.2 for tonnage class 5 (Fig. 3).

4) Hours fished in each month when <u>cod was the main species caught</u> for tonnage classes 5 and 6 were then adjusted to standard tonnage class 3 hours by the appropriate conversion factors and the resulting figures added to unadjusted hours for tonnage class 3. These were then divided into the total landings by trawlers in the three tonnage classes when cod was the main species to provide landings per standard tonnage class 3 hour.

5) These values were then plotted by year against Spanish pair trawler landings per hour, since monthly plots yielded no clear relationships.

the slope of the line by eye through the origin (1.9) was then used to adjust the hours fished in each year by Spanish pair trawlers to standard tonnage class 3 trawler hours (Fig. 3).

6) These adjusted Spanish pair trawler hours were then added to the standard tonnage class 3 trawler hours for each year and the result divided into the total landings by otter trawlers, tonnage classes 3, 5 and 6, and pair trawlers, when cod was main species. This produced landings per standard tonnage class 3 trawler hour for each year. Dividing these values into the total landings by all tonnage classes of otter trawlers and all gears resulted in estimates of total effort for the entire fleet in standard tonnage class 3 trawler hours.

This method provides estimates of the total effort expended for cod in terms of tonnage class 3 hours if all tonnage classes of otter trawlers and all gears landing cod had been fishing primarily for cod.

Method 3. (Effort expressed in terms of one tonnage class)

1) Cod landings and hours for otter trawlers and pair trawlers where cod was the main species were tabulated by tonnage class for each year, after pair trawler hours had been adjusted by 1.9 to tonnage class 3 otter trawler hours. Landings per hour were then calculated for each tonnage class.

2) Landings per hour for tonnage class 3 were divided into the total landings of cod by all tonnage classes of otter trawlers and all gears for each year, resulting in estimates of total effort in standard otter trawler tonnage class 3 hours.

This method provides estimates of total effort expended for cod if all tonnage classes of otter trawlers and all gears landing cod had been fishing primarily for cod with the same efficiency as tonnage class 3 otter trawlers. Thus, the effort measure derived is in the same terms as that derived by Method 2, though the estimating procedures are different. A procedure similar to Method 3 was used by May (1968) for total groundfish in Subareas 2 and 3, except that he used days fished rather than hours fished.

Method 4. (Effort expressed in terms of one country)

1) Landings per standard Spanish otter trawler hour derived from adjusting Spanish pair trawler hours to Spanish otter trawler hours in Method 1 were divided into the total cod landings by all countries and gears to obtain estimates of total effort in standard Spanish trawler units.

This method provides estimates of total effort expended for cod if all countries and gears landing cod had been fishing primarily for cod with the same efficiency as Spanish otter trawlers. A similar method was used by Hodder (1964). Again, this gives effort measures in the same terms as by Method 1, but by different means.

It is evident from Figure 4 that all four methods produced similar trends in total effort and landing per effort, but the actual values were different between Methods 1 and 4 and Methods 2 and 3. Methods 1 and 4 produced almost identical results and this is not surprising since, as can be seen from Figure 1, Spain accounted for most of the landings up to 1966. Methods 2 and 3 also produced almost identical results in terms of absolute fishing effort and landings per effort. Again, this is to be expected since both are based on tonnage class 3 otter trawlers (including pair trawlers), which accounted for most of the landings, at least up to 1966 (Fig. 5).

Landings per hour fished were at a high level in 1954-57 but decreased about 50% in 1958 and remained at this lower level during 1958-62. Landings per hour again increased to the 1954-57 level in 1963 and fluctuated about this higher level during the remainder of the period. Total effort was slightly lower in 1956-58 than in 1954-55 but returned to the former level again in 1959-61. It then decreased 100 per cent to a lower level in 1962-64 but increased steadily to a high level in 1967. The effort in 1967 was about 2-3 times that in 1966.

Tonnage class 3 otter trawlers were used in Figure 4 to estimate total effort by Method 4, since this class contributed most heavily to the total cod landings over the period. However, the trends in landings per hour were somewhat different for the three major tonnage classes and different conclusions regarding trends in effort would be reached by using tonnage classes 5 and 6 instead of 3 (Fig. 5). On the other hand, calculations based on these larger tonnage classes might be of little meaning because of their relatively small contribution to the landings prior to 1966.

Assessments of the effects of increases in mesh sizes of otter trawls

During the 1959-62 period, with the exception of USSR length measurements totalling about 30,000, there were only 1100 length measurements of catches before discards from the commercial cod fishery by all other countries fishing in 3NO. In addition, Canada (Nfld.) obtained about 25,000 length measurements of cod caught on research vessel cruises. Consequently, it was decided to combine USSR commercial length frequencies and Canada (Nfld.) research vessel length frequencies in these assessments to obtain representative length frequencies of the commercial catches before discards in the 1959-62 period.

Similarly, since there were only 3200 and 3700 length measurements of catches before discards in 1963 and 1964, respectively, and no measurements in 1965 and 1966, it was decided to use Canada (Nfld.) research vessel length frequencies totalling 32,000 to derive representative length frequencies of the commercial catches before discards in the 1963-66 period.

Since the Canada (Nfld.) length frequencies were of fish caught with a 41-5 otter trawl with the codend lined with a 1 1/8-inch nylon liner, a 4-inch selection curve was applied to the length frequencies for each year to arrive at a frequency representative of a 4-inch mesh catch, the minimum regulation mesh size in force during both periods. Canada (Nfld.) and USSR frequencies were combined for each year during 1959-62 and the resulting frequency considered to be representative of the commercial catch before discards in 3NO for each year. During the 1963-66 period the Canada (Nfld.) research frequencies alone, adjusted to 4-inch mesh for each year, were considered to be representative of the commercial cod catch before discarding for that year.

Since there were only 5000 length measurements of landings after discards in the 1959-62 period and less than 9000 in 1963-66 and since the numbers of fish measured varied from none in 1960 to 4000 in 1965, it was decided to use a landing frequency derived from the catch frequency used above. Assuming knife-edge discarding between 39-41 cm and 42-44 cm (See Beverton and Hodder (1962)) and by applying a weight-length key to the catch frequency above the discard length, the average weight of fish landed in each year was calculated. From a knowledge of the weight landed by all countries and the average weight of fish landed, the total number landed in each year was calculated. Using the percentage discarded from the catch frequency, the number caught in each year could then be estimated. The catch frequency for each year was then adjusted to the number caught in that year and by combining years, the average catch and landing frequencies for the 1959-62 and 1963-66 periods were derived.

The method used in the assessments for predicting immediate losses and long-term changes was identical to that outlined by Gulland (1961) and as applied by Beverton and Hodder (1962). Total mortality estimate (Z) and growth parameters (L_∞, k, t_o) used for the 1959-62 assessments were from Williamson (1965). Growth parameters used for the 1963-66 assessments were from Wells (1969), while Z was determined from USSR age frequencies for 1965 (ICNAF Sampling Yearbook, Vol. 10). Since it was impossible to separate Z into its natural and fishing components, the same range of values of M was used as in Beverton and Hodder (1962).

Tables 2 and 3 summarize the assessments for 3NO cod during 1959-62 and 1963-66 respectively. Table 4 presents the previous assessments for 1955-58, for which the mesh size in use by commercial trawlers was considered to be 3-inch.

In the 1959-62 period the greatest long-term gain for otter trawl was predicted at 5½-inch mesh for the lowest value of E and at 6-inch mesh for the other values of E. The greatest gain to the offshore line landings and total landings was predicted at 6-inch for all values of E. Immediate losses were 10% or less for increases from 4 to 5½ inches.

In the 1963-66 period greatest predicted long-term gains were at 6-inch mesh for otter trawl, offshore line and total landings for all values of E. Immediate losses were 13% or less for increases from 4- to 5½-inches.

Except for the initial increase to 4½-inch mesh, where the immediate losses were approximately the same in the three periods, the losses would have been less in 1959-62 than in either 1955-58 or 1963-66. The losses in fact would have been very similar in the 1955-58 and 1963-66 periods.

At the lowest value of E the long term changes are very similar for the three periods, although there is a slight difference at mesh sizes 5½ and 6 inch, the 1959-62 and 1963-66 values being slightly higher than the 1955-58 values.

At the two higher values of E the predicted long-term changes (gains) were greatest in the 1963-66 period and least in the 1955-58 period. This was more pronounced at the larger mesh sizes; in fact the differences were small at 4½-inch mesh.

Discussion

Analysis of landing and effort figures indicated a lower landing per unit of effort in the 1958-62 period than in the 1955-57 or the 1963-67 periods. Age and length distributions of research vessel survey cruises in 3NO presented by May (1965) indicated that in the 1955-57 period a succession of year-classes of at least moderate strength entered the fishery. However, in the 1958-62 period only two significant year-classes, 1955 and 1958, entered the fishery. With mortalities as high as those determined for the 3NO fishery (Fig. 8), a series of fairly strong year-classes is necessary to sustain landing per effort at a continuing high level and the decrease in the 1958-62 period was probably caused by a lack of these year-classes. Also, although a decrease in effort may be caused by a decrease in landing per effort and thus a decrease in productivity of a fishery, it is also possible that a decrease in effort can itself cause some decrease in landing per effort related to the lesser efficiency of a smaller fleet in locating concentrations of fish. The increase in landing per effort in 1963 was probably caused by the entrance into the fishery of two good year-classes, 1958 and 1959. Since the ages have not been determined for the survey cruises during the remainder of the period, it is not known whether a succession of strong year-classes occurred here or not.

Total landings in 1967 increased over two-fold compared to 1966 and most of this increase was accounted for by USSR otter trawlers. However, the landing per hour in weight did not change significantly from 1966 and thus the estimates of total effort increased in proportion to the landings. Length frequencies of research vessel survey cruises to 3NO indicated a strong 1964 year-class first captured as 2-year-olds in 1966. In 1967 this year-class produced a peak in the research length frequencies at 36-41 cm (Fig. 6). Also, preliminary analyses of catch per unit of effort data for these survey cruises indicated a significant increase in the numbers caught per hour over 1966, confirming the strength of this year-class. Length frequencies of USSR catches before discards with 4- to 4½-inch meshes indicated a peak at 39-41 cm (Fig. 6), obviously the 1964 year-class. Thus, the increase in landings was accounted for by the greater abundance of the 1964 year-class together with the increase in effort. The fact that the landing per hour in weight did not change is probably explained by the low average weight of these 3-year-old fish. Also, if these fish were being sought for by the commercial fleet, smaller numbers of larger fish would probably be caught than in 1966.

The validity of the results obtained from any mesh assessment depends on the availability of reliable catch and landing frequencies representative of the commercial fleet, and of reliable growth parameters and mortality estimates. In the present study commercial catch frequencies were estimated from research vessel survey data adjusted to a 4-inch mesh. The question therefore arises as to whether the frequencies so derived are representative of the catch by the commercial fleet. The comparisons of research and commercial catch frequencies in Figure 6 indicate that although there is a tendency for the research frequencies to underestimate the proportion of larger fish and overestimate the smaller fish, the agreement is close enough to allow their use in mesh assessments. These differences are probably caused in part by the commercial fleet tending to concentrate their efforts in depths which larger cod are known to inhabit especially at spawning time, whereas research vessel cruises will fish more randomly.

Due to the paucity of length frequencies of landings after discards or discard curves, a knife-edge discard length was chosen, below which it was assumed that all fish caught were discarded. This, of course, is never the case, discarding taking place over a range of sizes.

The point chosen was between 39-41 cm and 42-44 cm. The vertical lines in Figure 7 are drawn at the points below which, if all fish caught were discarded, the number would be approximately equal to the number discarded estimated from comparing the catch and landing curves. Although the landing curves are sometimes based on small numbers of measurements, it does indicate that the discard lengths chosen are in line with the existing data. In fact, it was found that by using discard lengths above or below the length group chosen, the immediate losses and long-term changes were affected very little.

Mortality estimates for 1955-58 and 1963-66 were obtained from commercial age distributions whereas that used in 1959-62 was from research age distributions, there being no commercial ages available during this period (Fig. 8). Since research age distributions represent the entire population while commercial ages represent only that sector of the population captured by the commercial gears, the two sets of mortality estimates need not be comparable and it is desirable to have mortalities based on commercial data.

Average sizes at each age were very similar in the 1959-62 and 1965 periods, while in the 1955-58 period they were greater up to age 5 and less above age 5 (Fig. 8). This explains the small changes in t_c in relation to l_c in Tables 2-4.

The predicted immediate losses were greater at the larger mesh sizes during the 1963-66 period than the 1959-62 period. This was due to the larger numbers of smaller fish caught and landed in 1963-66. Thus an increase in mesh size would release more smaller fish in relation to the total catch than in 1959-62 (Fig. 9). The predicted immediate losses in the 1955-58 period were as high as in the 1963-66 period at comparable mesh sizes but this was mainly because the former assessment was based on 3-inch mesh. If comparable increases are compared (e.g. 3-inch to 4-inch compared with 4-inch to 5-inch), the losses are less in 1955-58 than in the other two periods.

Except at the initial increase to 4½-inch mesh, where very little difference was found, the predicted long-term gains at the two higher values of E were greater in 1959-62 than in 1955-58 and in 1963-66 than in 1959-62. At the lowest value of E there was very little difference in the long-term gains in the three periods. This was because, although the value of E and consequently the proportion of released fish that would have been captured by the larger mesh decreased from 1955-58 to 1963-66 due to a decrease in total mortality, the proportion of small fish that would have been released by a larger mesh increased considerably during the same interval (Fig. 9).

Adequacy of catch sampling

As mentioned above the assessments were hampered by lack of adequate length measurement data, both of catches before discarding and of landings after discarding. Table 5 illustrates this point. Measurements ranged from 20 to 1800 per one million fish landed. The intensity of sampling was about the same in 1955-58 and 1959-62 but only one-third as great in 1963-66.

In addition to the paucity of measurements, sampling was not adequately spread over the fishing season and in some years all measurements were in the same quarter.

Commercial age distributions were totally lacking in the 1959-62 period and only available for 1965 (1200 ages) in the 1963-66 period.

If meaningful assessments for 3NO cod are to be carried out in future, more adequate length and age sampling of the commercial catch must be instituted.

Acknowledgements

The author is grateful to Dr. A. W. May for helpful discussion and suggestions during the course of these assessments and for critically reading the manuscript.

References

Beverton, R.J.H., and V. M. Hodder (Editors). 1962. Report of Working Group of Scientists on Fishery Assessment in Relation to Regulation Problems. Suppl. to ICNAF Annual Proc. Vol. 11.

Gulland, J. A. 1961. The estimation of the effect on catches of changes in gear selectivity. J. Conseil Explor. Mer, 25(2): 204-214.

Hodder, V. M., MS, 1964. Assessments of the effects of fishing and of increases in the mesh sizes of trawls on the major commercial fisheries of the Newfoundland area (ICNAF Subarea 3). Fish. Res. Bd. MS Rept. Biol., No. 801, 166 pp. (mimeo.).

Hodder, V. M. 1965. Trends in the cod fishery off the east coast of Newfoundland and Labrador. ICNAF Res. Bull. No. 2, pp. 31-41.

May, A. W. 1965. The validity of otolith ages of southern Grand Bank cod. ICNAF Res. Bull. No. 2, pp. 19-24.

May, A. W. 1968. Revision of estimated fishing activity for groundfish in ICNAF Subareas 2 and 3, 1959-67, with remarks on some groundfish stocks and fisheries. 1968 ICNAF Annual Meeting, Res. Doc. 68/93, Serial No. 2081.

Pinhorn, A. T. 1969. Fishery and biology of Atlantic cod (Gadus morhua L.) off the southwest coast of Newfoundland. (In press).

Wells, R. 1969. Growth estimates for Grand Bank cod, 1963 and 1965. ICNAF Annual Meeting Document.

Wiles, M. 1967. Trends in the cod fishery in the northeastern Gulf of St. Lawrence during 1953-65 (ICNAF Div. 4R to 4S). ICNAF Annual Meeting, Res. Doc. 67/79, Serial No. 1875.

Williamson, G. R., MS, 1965. Age, growth, sexual maturity and mortality of cod on the Grand Bank of Newfoundland and St. Pierre Bank during 1946-62. Ph.D. thesis, London University, 140 pp.

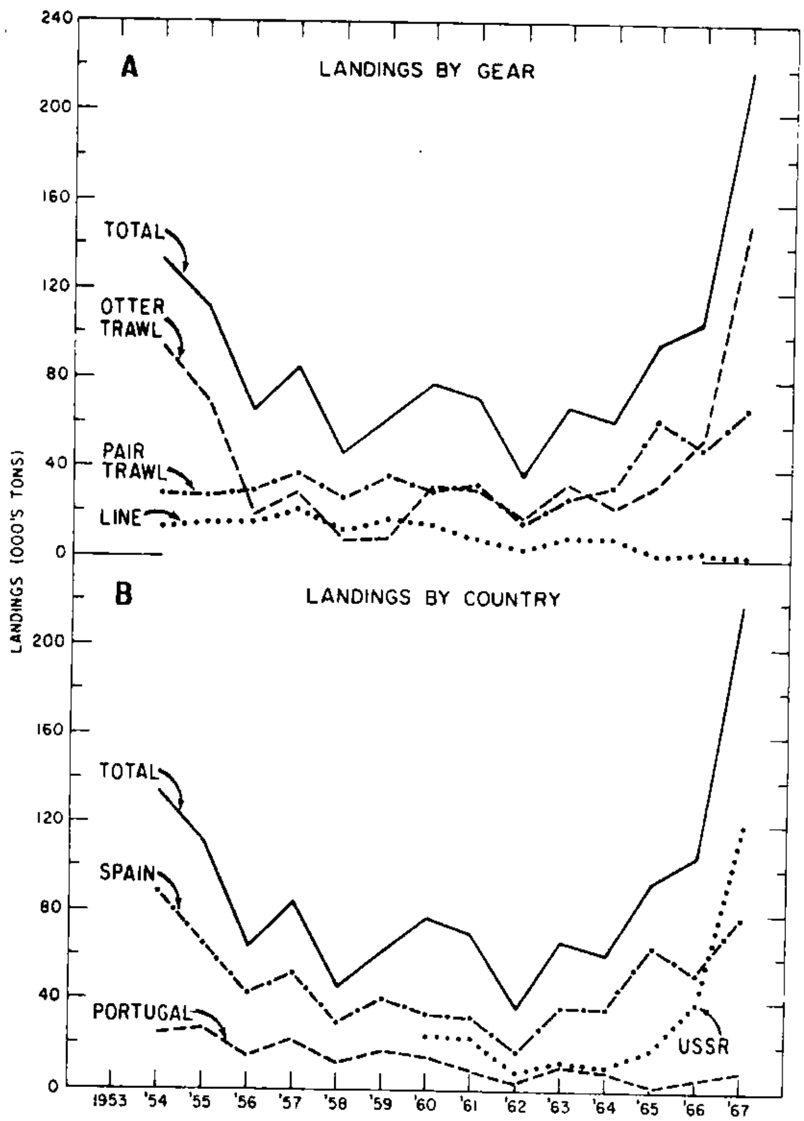

Fig. 1. Landings by gear and country, 3NO, 1954-67. 1953 landings are omitted because of incomplete reporting by divisions.

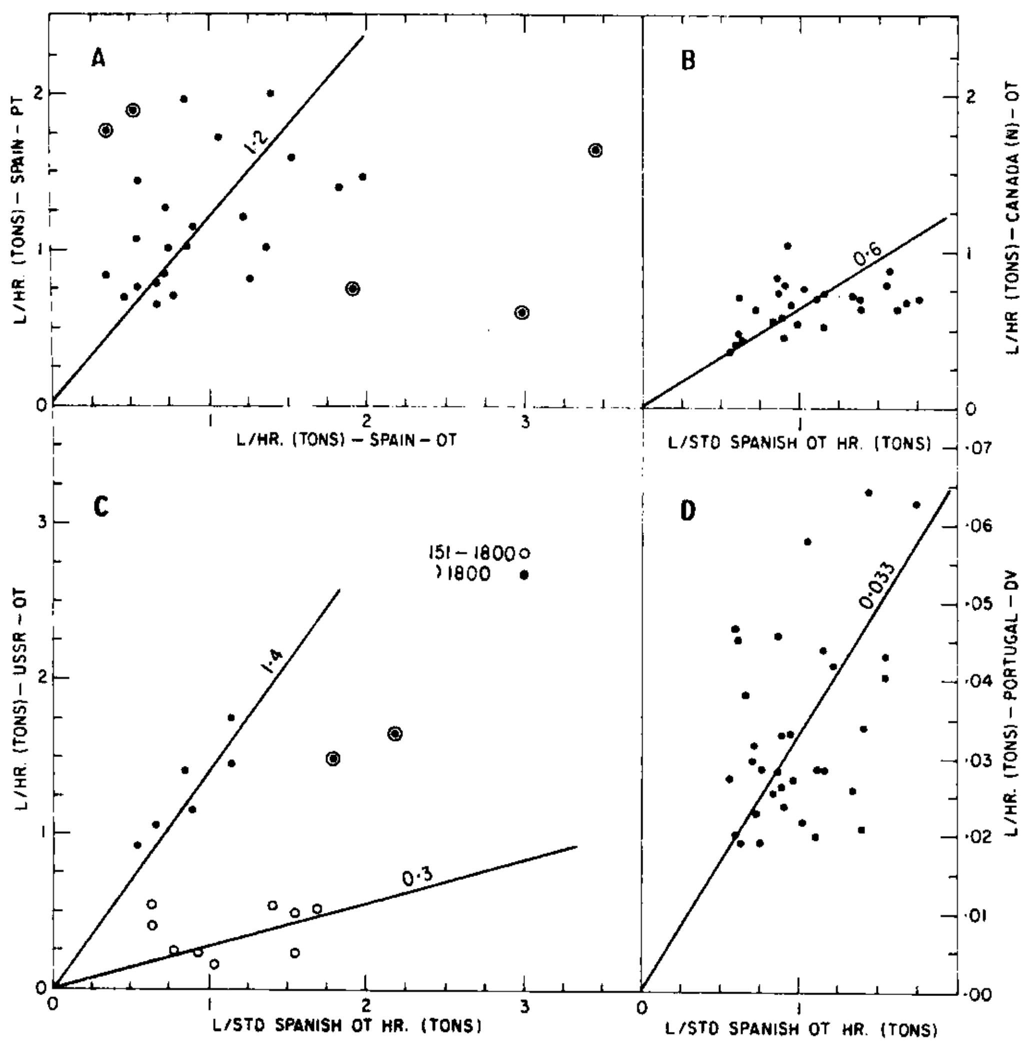

Fig. 2. Plots of main species cod landings per unit effort for the major countries and gears fishing in 3NO, 1959-66, with corresponding straight lines fitted by eye. Circled points were not used in drawing straight lines.

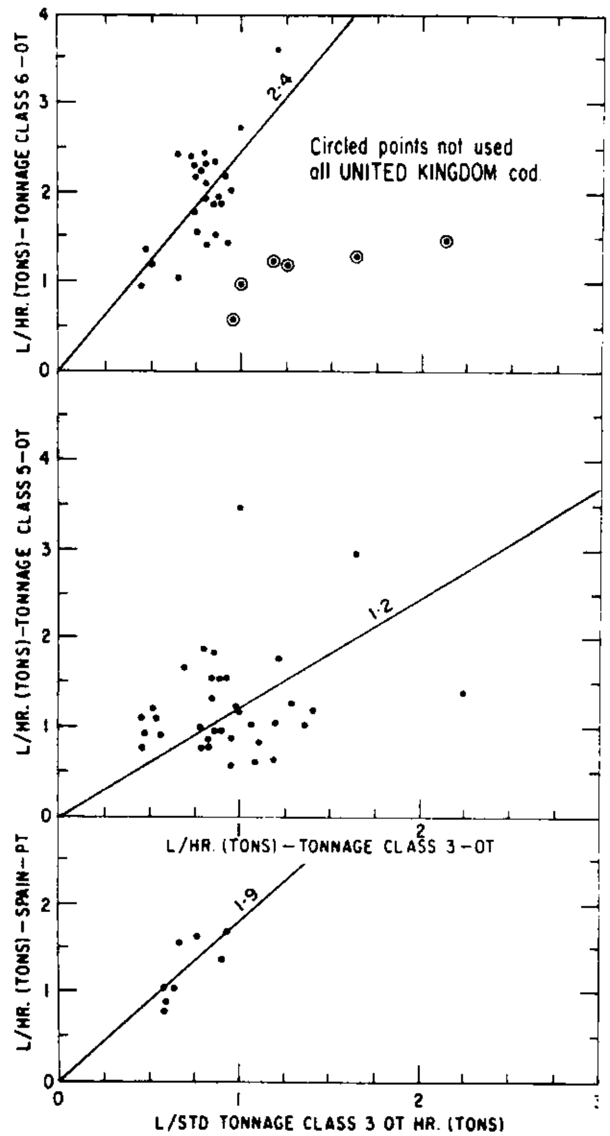

Fig. 3. Plots of total groundfish landings per hour fished for the major otter trawler tonnage classes and for pair trawlers fishing in 3NO, 1959-66, with corresponding straight lines fitted by eye. Circled points were not used in drawing straight lines.

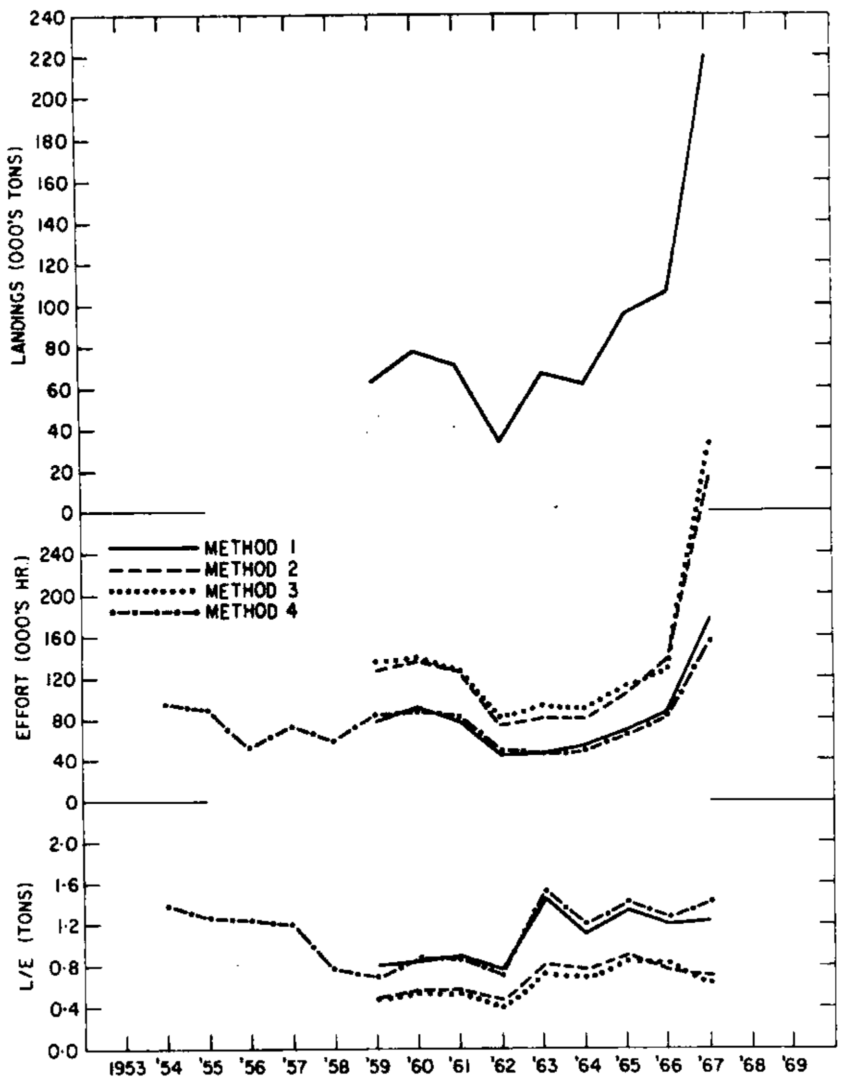

Fig. 4. Landings, effort and landings per unit effort for cod in 3NO, 1954-67. Four methods of estimating landing per unit effort and total effort are compared.

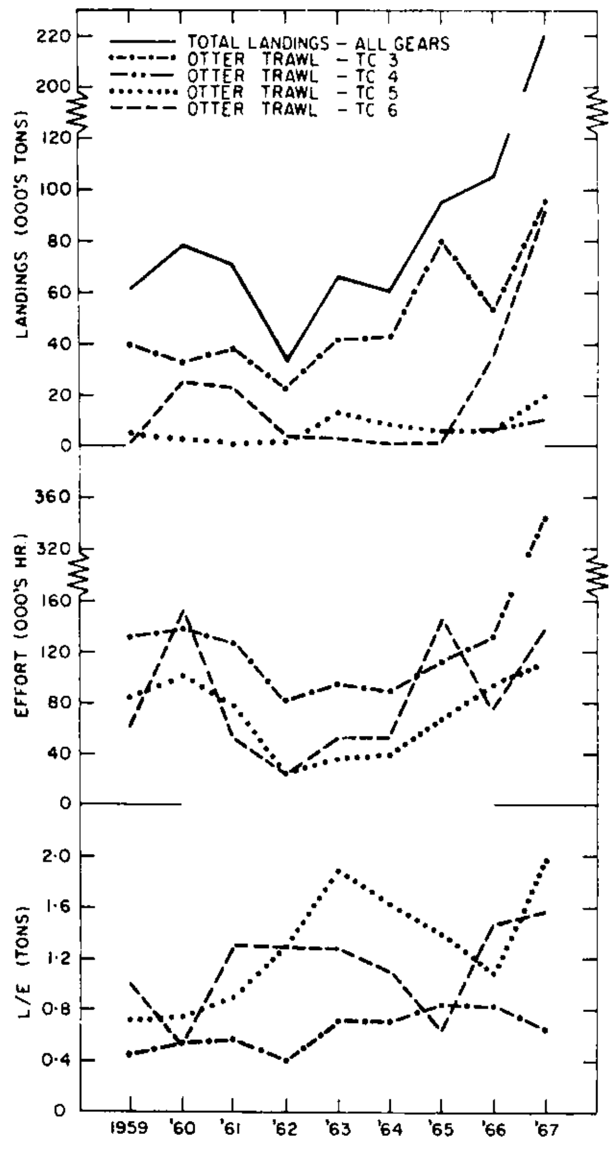

Fig. 5. Landings, effort and landings per unit effort for different tonnage classes of otter trawlers fishing for cod in 3NO, 1959-67.

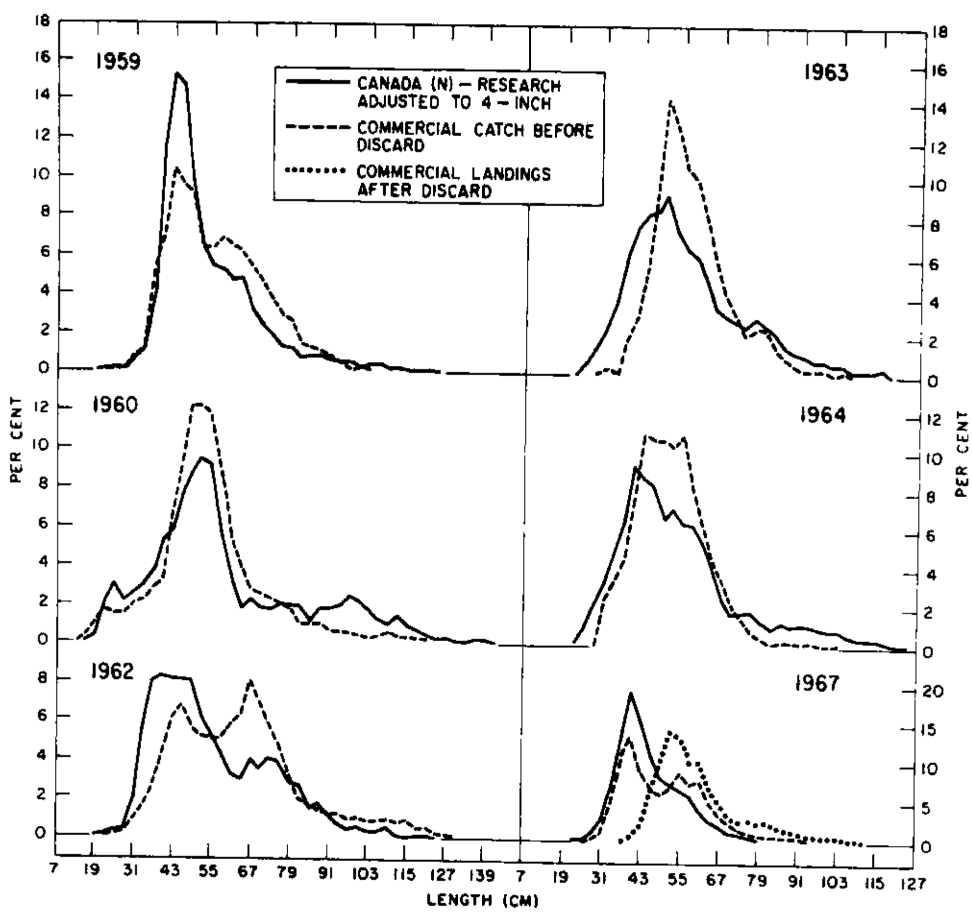

Fig. 6. Comparisons of Canada (Nfld.) research length frequencies adjusted to 4-inch mesh with unadjusted commercial catch frequencies, 3NO, 1959-67. The 1967 commercial landing frequency is shown for comparison.

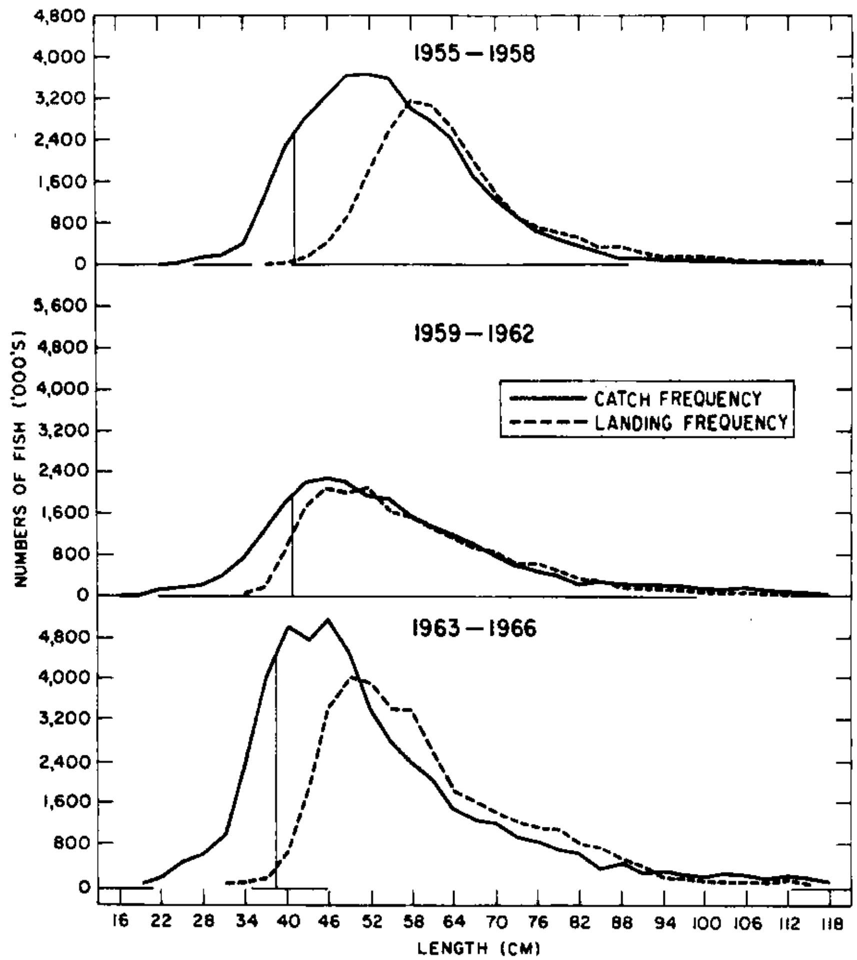

Fig. 7. Length frequencies of cod catches before discards and cod landings after discards, 3NO, 1955-58, 1959-62 and 1963-66. Catch frequencies: 1955-58 - determined from commercial measurements; 1959-62 - determined by combining Canada (Nfld.) research measurements adjusted to 4-inch mesh and USSR measurements; 1963-66 - determined from Canada (Nfld.) research measurements adjusted to 4-inch mesh only. Landing frequencies: determined from commercial measurements in each year.

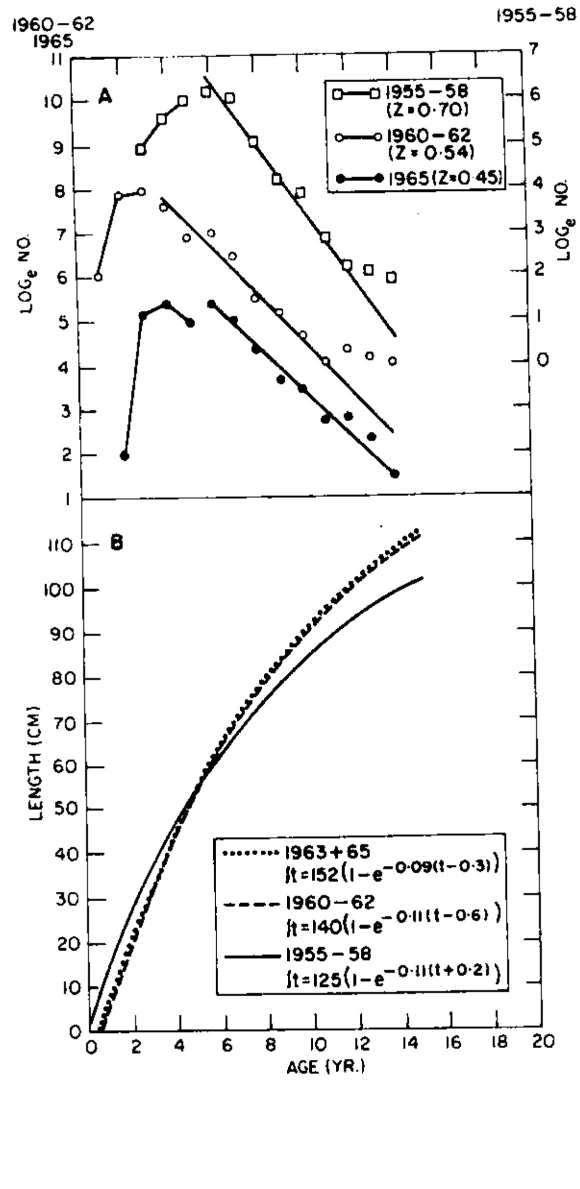

Fig. 8. A. Plots of natural logarithms of the age composition data used in estimating total mortality coefficients. B. Growth curves used to estimate growth parameters.

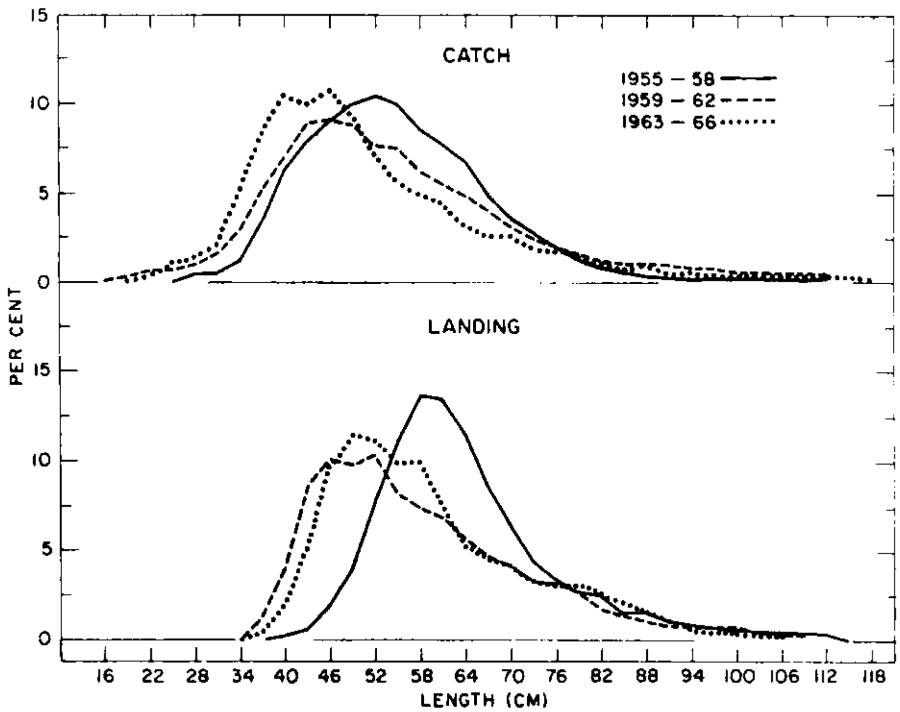

Fig. 9. Length frequencies of cod catches before discards and landings after discards, 3NO, 1955-58, 1959-62 and 1963-66.

Table 1. Cod landings by country and gear, 3NO, 1954-67.

Year	Otter trawl														Pair trawl	DV	LL	Total
	Can. M	Can. N	Fran. (M)	Port.	Spain	USSR	UK	USA	FSTP	Italy	Germ.	Pold.	Ice.	Total	Spain	Port.	Can. M	All gears
1954	8,456	5,530	3,033	15,910	59,933	-	-	-	-	-	-	-	-	92,862	28,741	9,860	3,401	134,864
1955	2,098	1,511	13,658	14,782	36,860	-	595	3	-	-	-	-	-	69,507	28,127	12,929	2,444	113,007
1956	3,220	1,808	417	176	11,678	-	971	2	-	-	-	-	-	18,272	30,946	15,329	335	64,882
1957	4,912	4,152	1,985	910	15,167	-	219	-	-	-	-	-	-	27,345	36,823	20,830	577	85,575
1958	2,009	2,381	53	37	2,984	-	-	-	-	-	65	-	-	7,529	26,452	11,571	422	45,974
1959	1,345	2,091	191	587	3,883	48	809	6	-	-	-	-	-	8,960	36,111	17,143	156	62,370
1960	1,008	2,167	328	286	3,227	24,204	1,053	-	409	1	-	-	-	32,683	30,745	14,061	233	77,722
1961	2,179	3,123	128	131	476	22,854	724	2	923	-	52	-	-	30,592	31,808	8,928	126	71,454
1962	983	2,073	-	31	2,370	7,971	1,699	2	420	-	-	12	-	15,561	15,043	3,622	179	34,405
1963	1,416	3,566	994	832	11,611	10,184	2,869	-	873	-	-	42	-	32,387	26,021	9,172	97	67,677
1964	826	2,007	2,491	192	5,308	9,504	1,526	-	297	-	-	-	-	22,151	31,876	7,903	51	61,981
1965	298	3,896	2,715	216	2,142	17,166	2,529	-	363	-	2,177	77	34	31,613	62,510	1,476	36	95,635
1966	1,018	5,464	750	2,613	2,941	39,023	1,172	-	121	-	-	765	11	53,878	49,592	2,457	19	105,946
1967	470	2,987	1,906	7,971	9,471	118,905	4,721	-	101	-	-	3,545	-	150,077	68,477	1,732	22	220,308
Total	30,238	42,756	28,649	44,674	168,051	249,859	18,887	15	3,507	1	2,294	4,441	45	593,417	503,272	137,013	8,098	1,241,800

37,498 tons not reported by ICNAF division not included above.

Table 2. Summary of assessments for 3NO cod, 1959-62.
Offshore line unadjusted.

Mesh size change (inches) From 4 to	l_c (cm) 35.16	t_c (yr) 3.22	Gear group	Percentage change in 1959-62 landings: Immediate loss	Long-term change for			
					0.44	0.63	0.81	E
					0.24	0.34	0.44	F
					0.30	0.20	0.10	M
4½	39.16	3.58	Trawl	-1.73	+3.45	+5.82	+8.15	
			Line	0	+5.27	+7.68	+10.05	
			Total	-1.42	+3.78	+6.15	+8.49	
5	43.19	3.95	Trawl	-4.55	+6.17	+11.37	+16.69	
			Line	0	+11.23	+16.68	+22.25	
			Total	-3.72	+7.09	+12.34	+17.70	
5½	49.10	4.48	Trawl	-10.43	+8.52	+18.75	+29.77	
			Line	0	+21.63	+33.10	+45.45	
			Total	-8.54	+10.89	+21.35	+32.61	
6	52.81	4.91	Trawl	-16.26	+8.23	+21.91	+37.19	
			Line	0	+29.24	+45.58	+63.83	
			Total	-13.31	+12.04	+26.20	+42.02	

Table 3. **Summary** of assessments for 3NO cod, 1963-66.
Offshore line unadjusted.

Mesh size change (inches) From 4 to	l_c (cm) 33.21	t_c (yr) 3.08	Gear group	Percentage change in 1963-66 landings: Immediate loss	Long-term change for 0.33 E, 0.15 F, 0.30 M	0.56 E, 0.25 F, 0.20 M	0.78 E, 0.35 F, 0.10 M
4½	38.01	3.54	Trawl	-2.35	+3.35	+7.40	+11.60
			Line	0	+5.84	+9.98	+14.29
			Total	-2.20	+3.52	+7.56	+11.78
5	42.60	3.99	Trawl	-6.06	+5.92	+14.87	+24.58
			Line	0	+12.75	+22.28	+32.62
			Total	-5.67	+6.36	+15.35	+25.10
5½	48.44	4.60	Trawl	-13.26	+7.63	+24.36	+43.54
			Line	0	+24.08	+43.37	+63.48
			Total	-12.42	+8.67	+25.56	+44.93
6	52.73	5.07	Trawl	-19.90	+7.81	+31.22	+59.09
			Line	0	+34.59	+63.82	+98.62
			Total	-18.62	+9.53	+33.32	+61.64

Table 4. Summary of assessments for 3NO cod, 1955-58. Offshore line unadjusted.

Mesh size change	l_c	t_c	Gear group	Percentage change in 1955-58 landings				
				Immediate loss	Long-term change for			
					0.57	0.71	0.87	E
(inches)	(cm)	(yr)			0.40	0.50	0.60	F
From 3 to	39.2	3.2			0.30	0.20	0.10	M
4	41.3	3.4	Trawl	-1.3	+2.7	+3.7	+4.8	
			Line	0	+4.0	+5.0	+6.1	
			Total	-1.0	+3.0	+4.0	+5.1	
4½	43.1	3.6	Trawl	-3.2	+4.3	+6.3	+8.5	
			Line	0	+7.5	+9.5	+11.8	
			Total	-2.5	+5.0	+7.0	+9.2	
5	45.5	3.9	Trawl	-6.6	+5.6	+9.1	+13.1	
			Line	0	+12.2	+15.7	+19.7	
			Total	-5.2	+7.0	+10.5	+14.5	
5½	49.6	4.3	Trawl	-14.3	+6.2	+12.7	+20.2	
			Line	0	+20.5	+26.9	+34.4	
			Total	-11.3	+9.2	+15.7	+23.3	
6	53.3	4.8	Trawl	-22.5	+4.7	+14.2	+25.7	
			Line	0	+27.2	+36.7	+48.1	
			Total	-17.8	+9.4	+18.9	+30.4	

Table 5. List of length measurements of catches and landings of 3NO cod, 1955-66.

Year	Before discard	After discard	Total	Estimated number landed ('000)	Number measured per 1,000,000 fish landed
1955	8,076	1,522	9,598	44,582	215
1956	3,499	1,000	4,499	18,666	241
1957	8,027	3,825	11,852	11,811	1,003
1958	1,320	1,656	2,976	15,722	189
1955-58	20,922	8,003	28,925	90,781	319
1959	6,351	683	7,034	22,447	313
1960	9,839	-	9,839	28,217	349
1961	194	1,434	1,628	20,962	78
1962	14,249	3,043	17,292	9,513	1,818
1959-62	30,633	5,160	35,793	81,139	441
1963	3,196	2,820	6,016	20,958	287
1964	3,744	666	4,410	23,177	190
1965	-	4,040	4,040	37,720	107
1966	-	1,145	1,145	58,457	20
1963-66	6,940	8,671	15,611	140,312	111
1967	9,327	1,618	10,945	-	-