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An analysis of the implications of alternative mesh sizes for gillnets and opening dates for the commercial salmon fishing season at West Greenland

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Abstract

A method of calculating the consequences of alternative mesh sizes for gillnets and opening dates of the salmon fishing season at West Greenland is developed. Factors considered in the analysis include: composition of the exploited population, growth, selectivity of gillnets, fishing pattern, and natural mortality. A mesh size of 139-140 mm (stretched) is proposed for opening dates of August 20 to September 1.

Résumé

Une méthode de calcul des conséquences de l'adoption de différents maillages de filets maillants et de différentes dates de commencement de la saison de pêche pour le saumon à l'ouest du Gröenland est présentée. Inclus dans la liste de facteurs considérés sont: la composition de la population exploitée, la croissance, la sélectivité des filets maillants et la mortalité naturelle. Une grandeur de maille de 139-140 mm (étendu) est proposée avec une date d'ouverture entre le 20 aôut et le ler septembre.

Introduction

At its 1980 meeting, the ICES Working Group on North Atlantic Salmon recognized the importance of the mesh size of gillnets used in the West Greenland Salmon fishery on the composition of catches (Anon 1980). An indication of the quantitative impact of varying mesh sizes for monofilament nylon gillets can be gained by examination of catches by research vessels at West Greenland in 1978 and 1979 (Tables 1 and 2). Figure 1 shows a decline in the average percentage of North American origin salmon from 48% to 42.65% to 30% as stretched mesh sizes increase from 127 mm to 140 mm to 155 mm.

The length composition of the catch is also influenced by the mesh size used. Figure 2 shows average fork lengths for North American wild and hatchery origin 1-sea-winter salmon and European origin 1-sea-winter salmon in the catches of Tables 1 and 2. Figure 3 illustrates observed fork length distributions for the 1978 catches, further demonstrating the impact of mesh size on the composition of catches. The impact on mean weights is greater than that on mean lengths.

The possibility of modifying the opening date of the fishery season for salmon at West Greenland from August 10 (as in the base years 1976-77 of the Canada - EEC Fisheries Agreement) has arisen in the context of renewal of this agreement. Since salmon grow rapidly at West Greenland, delaying the season means the same catch in weight can be taken while catching fewer salmon and thus reducing the impact on stocks in home waters.

Salmon originating from both North America and Europe are found in the exploited population at West Greenland, and North American origin salmon are, on the average, shorter (and lighter) than salmon originating in Europe. Thus if the mesh size of gillnets is not changed to correspond to a later season, the composition of catches can be expected to change with a larger proportion of North American origin salmon caught.

This paper presents a method of determining a combination of mesh size and quota corresponding to different opening dates and maintaining constant total mortality for both North American and European origin salmon associated with the catches.

Goal:

1) To estimate the appropriate mesh size and catch quota for seasons starting a) August 20, b) August 25, and c) September 1, to give the same total mortality of North Amercian and European origin salmon as a catch of 1,190 mt in the 1976-77 reference years.

2) To estimate the reduction in catch in numbers resulting from adoption of mesh sizes and opening dates of 1) while retaining a total catch of 1,190 mt.

Factors:

The following factors are explicitly considered:

1) The relative abundance of 1-sea-winter salmon of North American and European origin available to the fishery at West Greenland.

Estimates are based on an assumed constant proportion of North American origin salmon in the exploited population and the implications of possible trends in this proportion during the period August 10 to October 28 are considered.

2) The distribution of length and weight on each date of North American and European origin salmon in the exploited population at West Greenland.

3) The selectivity of gillnets of different mesh sizes in the West Greenland fishery. Two patterns are considered.

4) The pattern of fishing. Two distributions of the catch in weight by day during the season are considered.

5) Catches are adjusted for natural mortality during the interval between the opening date of the West Greenland fishery in the reference years and the proposed opening date.

6) The number of fish encountering the gear but not being retained as catch is estimated in order to give a qualitative indication of the impact of proposed changes on non-catch fishing mortality.

Some simplifying assumptions are adopted, namely:

1) Catches of multi-sea winter salmon are ignored. These represent less than 5% of the total and the impact of proposed changes in mesh sizes and season on their contribution to catches is considered to be much less than on one-sea-winter fish.

2) The size distribution of the exploited salmon population is assumed to be unaffected by fishing. Neglecting this factor is considered to have a negligible influence on the conclusions.

3) Gillnet efficiency is assumed to be 100% at the modal length of selectivity.

Composition of the salmon population at West Greenland

Recaptures at West Greenland of salmon tagged as smolts have demonstrated that salmon originating in Canada, the U.S.A., Scotland, England and Wales, Norway, Iceland, Northern Ireland, Eire, Sweden and France are caught at West Greenland. Both wild and hatchery-reared fish are found in the Greenland catches. Most of the salmon caught at West Greenland originate in Canada and the British Isles (Anon 1974).

Discriminant function analysis of salmon scales taken by research vessel and by the commercial fishery has permitted the proportional composition of the catch and the salmon population at West Greenland to be estimated. Table 3 shows the estimated composition of research vessel and commercial catches.

Table 4 shows the quantity of gillnets of different mesh sizes used by the research vessels. Due to the selectivity of the gear employed, samples collected in 1969-71 and in 1980 overestimate the proportions of North American salmon in the exploited population at W. Greenland. This source of bias is much less important in the 1972-79 samples. Therefore the unweighted average 42.85% North American for 1972-79 is used in this analysis as the main estimate of the percentage of North Amercian fish in the exploited population.

The abundance of salmon at West Greenland can be expected to vary from year to year due to variation in the production of smolts in the countries of origin and variation in migration and the survival of salmon originating in different continents.

Since there is evidence that the proportion of North American salmon in the West Greenland population and catches has increased in the late 1970's when Canadian salmon stocks were rebuilding, the implications of a population composition of 50% North American origin and 50% European origin salmon are considered.

Since the proportion of multi-sea-winter salmon in research vessel catches was only 5% in 1978 and 1979, only the effects of mesh size and season on one-sea-winter salmon are examined.

Figure 4 plots the percentage of North American origin salmon in the combined research vessel catches of Table 3 against the date of capture. There is no systematic trend on the proportion with date. The high observed percentage about November 1 was due to a very large catch in 1974 only which contained an unusually large number of North American origin salmon. This analysis assumes no trend on the percent North American origin salmon in the exploited population. In some years increasing or decreasing trends have, however, been observed.

The distribution of length and weight of population components

Analysis of scale characteristics of salmon caught by research vessels at West Greenland indicates that one-sea-winter salmon of North American origin are, on the average, smaller and lighter than one-sea-winter salmon in the same catches but of European origin. In 1978, for example, the mean weights of one-sea-winter salmon of North American and European origin salmon in research vessel catches were 2.88 kg. and 3.45 kg., respectively. This was attributed by the ICES Working Group on North Atlantic Salmon (Anon 1980) to the earlier date of migration to the sea of European smolts.

The length distributions of one-sea-winter salmon of North American and European origin salmon in research vessel catches are approximately normal. In order to determine the corresponding distributions for the population, it is necessary to make adjustments using the selectivity model discussed below. The population distributions are found to be normally distributed with mean length depending on the date and standard deviations of 3.88 cm for North American origin salmon and 3.49 cm for European origin salmon. These standard deviations correspond to averaging variance estimates derived from research vessel catches in 1978 and 1980 (Table 5).

The mean length of salmon of the two components of the population at West Greenland increases with the date, due to vigorous feeding. Table 6 shows observed mean fork lengths for one-sea-winter salmon in research vessel catches at W. Greenland and the periods of capture. Combining data for all years gives the estimated effective average growth curves for the mean length, L, in centimeters of North Amercian and European components of the exploited population with August 10 as Day 1:

$$L = 62.0791 + 0.049323 \times \text{Day} \qquad \text{(North American)}$$

and

$$L = 67.1467 + 0.038590 \times \text{Day} \qquad \text{(European)}$$

These curves (Figure 5) are adopted in this analysis as estimates of the daily mean length of salmon of these two components encountering commercial fishing gear.

The length-weight relationships

$$\text{Wt (kg)} = -\ 9.6437 + 0.1989 \times L \text{ (cm)} \qquad \text{(North American)}$$

and

$$\text{Wt (kg)} = -23.2597 + 0.3962 \times L \text{ (cm)} \qquad \text{(European)}$$

adopted on this analysis were derived indirectly. Table 7 shows observed mean weights of one-sea-winter salmon of North American and European origin salmon in research vessel catches from different dates for 1969 to 1980. Overall linear regressions (Figure 6) were fitted to North American and European means for all samples combined by period to relate mean weight to date. The regressions were then adjusted according to the regressions for mean length versus date described above (Table 6) so that the mean weight calculated from regression of mean weights on date was the same as the mean weight obtained by first calculating a mean length from the regressions of mean length on date and then applying the length-weight relationship. These relationships differ from what is obtained by regressing mean weights directly on mean lengths and are considered a more reliable basis for the calculations below since opening date is a key variable in the anlaysis. This approach ensures that the calculated mean weight on a given date using a calculated mean length is near the observed value.

Gillnet Selectivity

Selectivity can be defined as any factor that causes size composition of the catch to vary from that of the population (Pope et al. 1975). In this paper, a more restrictive definition is adopted comparing the composition of the catch to the population encountering the gear. The most important factors causing a fish to be caught by a gillnet are its girth behind the operculum and its maximum girth. Those fish with a maximum girth much smaller than that of the lumen of the net pass through while those fish with an operculum girth much larger than the lumen of the net easily escape. Fish with a maximum girth larger than the net lumen and an operculum smaller than the net lumen are likely to be retained by the net for some period of time depending on their velocity and angle of approach to the net (Konda 1966). In the experiments described here, very few fish were caught by tangling in the net.

It is well known that gillnets are highly selective causing the length distribution of catches to differ from that of the population encountering the gear. Hamley (1975) reviews the factors influencing gillnet selectivity, the shapes of selectivity curves for several species and means of estimating selectivity curves. The most reliable methods of estimation involve comparison of gillnet catches with catches by a non-selective gear such as a purse seine or with the composition of a known population encountering the gear. Such comparisons have shown selectivity curves to be somewhat skewed with fish a few centimetres longer than the modal length of selection more likely to be caught than those a few centimetres shorter than the modal length. Hamley also notes a tendency for larger meshed nets to be more efficient in terms of catching more fish per unit of fishing effort. To date, no experiment utilizing these methods has been carried out at Greenland so that it is presently necessary to estimate gillnet selectivity from a comparison of catches by gillnets of different sized meshes. Such indirect estimates require an assumed parametric form of the selectivity curve.

The authors have utilized a method proposed by Holt (1969) to estimate the mesh selectivity of gillnets at West Greenland in a manuscript presented in 1980 to the ICES Working Group. The "normal" selectivity curve adopted has only two parameters which facilitates robust and efficient estimation of the modal length. Problems associated with the skew of selectivities were minimized by considering in the estimation process the range 60 to 73 cm which includes most one-sea-winter salmon. The selectivity for a fish of length L cm of a net of X cm stretched mesh was estimated using research vessel catches with monofilament nylon gillnets in 1978 to be proportional to:

$$\exp - \frac{1}{2}\left(\frac{L - 4.6860 \times X}{8.681}\right)^2$$

Research vessel catches from two sizes of monofilament nylon gillnets in 1980 permit independent estimation of the selectivity curve, again using Holt's method. The frequency distributions of catch in 126 and 142 mm mesh nets are given in Table 8. The cumulative frequency distributions produced straight lines when plotted on probability paper, thus indicating that the catch distribution is roughly normal (Figure 7). This normally distributed catch is consistent with a normal selectivity curve. The deviations from a straight line at the 98 percentile are due to the inclusion of both one-sea-winter and multiple-sea- winter fish in the catches.

The regression line for Holt's method was $Y = -7.9153 + 0.1252 \times L$ with $r^2 = 0.88$ and $F_{1.4} = 30.17$ (significant at less than 1%) (Figure 8).

The estimated selectivity curve is:

$$\exp - \frac{1}{2}\left(\frac{L - 4.7180 \times X}{7.76}\right)^2$$

The variation of points about the regression line is large when one of the length frequencies is small so that length groups with few fish can lead to highly scattered points. To minimize this effect, two centimetre groups were chosen and groups less than 58 cm or greater than 70 cm were excluded from the analysis. This also minimizes the effects of non-normality and skew since the 'tails' are not used in estimation.

Estimated populations were obtained for each mesh size from observed catch in that mesh and estimated selectivity factor for that mesh. The difference between the estimated population and the catch estimates the number of fish encountering that mesh size but escaping. The calculated number of fish encountering the mesh but escaping is 24% for the 126 and 142 mm meshes (Table 8).

Averaging the parameter estimates (mode and variance) from 1978 and 1980 experiments gives the selectivity curve:

$$\exp - \frac{1}{2} \left(\frac{L - 4.7020 \times X}{8.24} \right)^2$$

This curve is adopted for further calculations.

Figure 9 illustrates the estimated selectivity curves for 130, 140 and 150 mm mesh together with the length distributions of 1-sea-winter salmon estimated for August 20. The mesh selection curve for 140 mm mesh has a mode between the modal lengths of the two population components and a wide range of lengths is selected. The modal length for selectivity of 130 mm mesh gillnets is less than the modal length of North American origin salmon and that for 150 mm mesh is greater than the modal length of European origin salmon.

The impact of using a symmetrical selection curve when the actual curve is skewed is much reduced by limiting consideration to one-sea-winter salmon and by the use of the same selection curve to estimate the size distribution of the population as to calculate catch compositions. To indicate the possible impact of a skewed selectivity curve, an alternative "log-normal" curve with the same modal length and coefficient of variation is utilized for sensitivity calculations. The second curve adopted for further calculations is:

$$\exp - \frac{1}{2} \left(\frac{\ln(L \div 4.7020 \times X)}{8.24 \div (4.7020 \times X)} \right)^2$$

Table 9 compares calculated selectivities for 140 mm mesh gillnets for the "normal" and "log-normal" selectivity models. The two curves are plotted on Figure 10. The modal lengths for the two curves are equal but the skew of the log-normal curve is apparent with differences of a factor of three in the tails. It is unlikely that a mesh selectivity curve much more skewed than the "log-normal" one presented here is consistent with observed research vessel catches of 1-sea-winter salmon at West Greenland. There is, however, a larger observed catch of multi-sea-winter catch than can be explained by the curves adopted. Multi-sea-winter salmon are excluded from this analysis.

Fishing pattern

The distribution of catches during the fishing season varies from year to year. Catch by day for 1976, 77, 79 and 80 were provided by J. Møller Jensen (pers. comm.). In these years, the first 900 mt of the 1190 mt quota were taken in a relatively short period (37 days in 1976, 23 days in 1977 and 1979, and 17 days in 1980). For the purposes of this analysis, two fishing patterns were adopted. The first involves a relatively long season of 57 days based on the average percent catch in weight by day in 1976-77 and the second, a relatively short season of 28 days based on the 1979-80 average. These are presented in Table 10. It is assumed that the relative catch by day is not affected by the opening date of the fishing season.

Natural mortality

At its 1980 meeting, the ICES Working Group adopted instantaneous monthly natural mortality rates of 0.005 and 0.01 to analyze the implications of the salmon fishery at West Greenland. These values are adopted in the current analysis. Estimated catches are therefore adjusted by a factor of 0.99667 or 0.99833 for an opening date of August 20 (ten days later than in the reference years of 1976-77), 0.99501 or 0.99750 for August 25 and 0.99269, or 0.99634 for September 1. This adjustment is necessary to maintain the same total mortality at West Greenland as in the reference period.

Calculation of the effects of alternative mesh sizes and seasons

The calculation of the combined effect of mesh size and season is carried out in three stages. First the composition of the catch on each date is calculated for a given mesh size. The relevant statistics are the mean lengths and proportion by number of the North American and European components and the number of fish of each component encountering the gear but not caught for each fish caught for each component (assuming 100% efficiency of the nets). Next, these relative numbers are transformed to absolute numbers for each season using the length-weight relationships and the fishing patterns and assuming a catch of 355,000 salmon (the calculated catch corresponding to 1,190 mt in 1976-77 from a Canada - EEC scientific meeting report, Brussels, August 1980). Finally, the catch in weight is adjusted for natural mortality and to give a catch in numbers equivalent to 1,190 mt taken by a mesh size giving 42.85% North American origin salmon with the 1976-77 fishing pattern and August 10 opening date.

Table 11 shows the catch in mt and the fraction of North American salmon in the catch for various opening dates, mesh sizes, and fishing patterns for a "normal" selectivity curve with 42.85% North American salmon in the exploited population and 355,000 salmon caught. Table 12 shows the same quantities calculated for a "log-normal" selectivity curve. The calculations leading to Table 11 followed the formulas of Appendix 1 for each date to determine the composition of the daily catch and the daily mean lengths of the continental components in the catch. The catch on weight was then adjusted according to the fishing pattern and scaled to give 355,000 salmon in the total catch.

To reduce computing costs, the calculations leading to Table 12 involved generating relative numbers at length in the exploited population for each continent of origin for every fifth day from August 4 onward. These were then multiplied by the calculated "log-normal" selectivity factors for each cm group for the appropriate mesh size to give a daily catch composition and escapement for every fifth day. From these compositions, mean lengths and percent composition were calculated by summation. The calculated values were then interpolated for each day using the four point Lagrange interpolation formula. Once the daily mean lengths and percentage compositions were obtained, the remaining calculations were identical to the "normal" case.

The mesh sizes in use at W. Greenland in 1976-77 and their relative quantities have not been documented. Therefore, as in previous calculations by Canadian and EEC scientists, it is assumed that the proportion of salmon of North American and European origin in the catch in 1976-77 was the same as the estimated proportions in the exploited population. Therefore, "optimal" mesh sizes and corresponding catches have been estimated for each opening date in order to obtain calculated proportions in the catch equal to proportions in the exploited population. Preliminary analysis showed that quadratic interpolation using calculated values for 130 mm, 140 mm, and 150 mm mesh sizes was sufficiently accurate. This was confirmed by comparing interpolated values with proportions and catches calculated for the estimated optima. Table 13 shows the optimal mesh sizes and catches in weight corresponding to a catch of 355,000 salmon with 42.85% of North American origin. The adoption of the shorter 1979-80 fishing season reduces catches by about 26 mt for both selectivity patterns and the use of the "log-normal" selectivity curve increases catches by about 3 mt. Optimum mesh sizes vary from 137.5 mm to 140.4 mm, depending on opening date, length of season, and selectivity patterns used. For an opening date of August 25, for example, mesh sizes of 139 to 140 mm are estimated to be "optimum".

Comparison of Calculated and Observed Values

Research vessel catches of 1-sea-winter salmon in 1978 and 1979 were used to compare observed quantities with corresponding values calculated from the normal selectivity model. The percent North American 1-sea-winter salmon in the exploited population was assumed to be equal to the observed percentage for that year for all mesh sizes combined. August 20 was adopted as a nominal date of capture to calculate catch compositions for different mesh sizes.

Figure 11 shows calculated and observed percentages of North American origin 1-sea-winter salmon for three mesh sizes in 1978 and 1979. Figure 12 shows calculated and observed mean lengths by continent of origin for the same years. In both cases, there is good agreement between calculated and observed values. This comparison validates the model used.

Adjustment for Natural Mortality and for the 1976-77 Quota.

Table 14 contains estimated catches and escapements for the various combinations of "optimal" mesh sizes and opening dates. The number of fish caught was adjusted to correspond to 364,401 which gives a catch of 1190.00 mt for 138.5 mm mesh with "normal" selectivity, an opening date of August 10 and the 1976-77 fishing pattern. The natural mortality correction corresponds to the opening date as outlined above. Adoption of the 1979-80 fishery pattern results in a loss of about 26 mt if other parameters are held constant. The use of the skewed selectivity curve changes the estimated catch by only one to three metric tons.

Sensitivity to Natural Mortality and Composition of the Exploited Population.

Table 15 compares calculated catch and escapements for "optimal" mesh sizes and the "normal" selectivity pattern and the 1976-77 fishing pattern with alternative natural mortality rates and percent North American origin salmon in the exploited population. Calculated values are insensitive to changes in the natural mortality rate with catches differing by about two metric tons. If the total number of salmon caught is held at the calculated values using 42.85% North American salmon in the population, however, catches are reduced by 14 to 16 mt if the percent North American becomes 50%. Nevertheless, the percent composition of the catch is approximately equal to that of the stock on this case too.

Impact of an Increasing Trend in Proportion of North American Origin Salmon

Although the combined data of Figure 4 show no clear trend in the proportion of North American origin salmon in the exploited population during the fishing season, analysis of recaptures at Greenland in 1972 of salmon tagged as smolts (Møller Jensen 1980) and detailed consideration of the data of Table 6, suggest that an increasing trend may exist, especially during August. It is possible that European origin salmon arrive at West Greenland earlier in the year than their North American counterparts. Since reliable estimates of this possible trend are not available at the time of writing, the authors have limited consideration of this factor to calculating the effects of two scenarios on calculations leading to Table 11 where catches of 355,000 salmon were calculated.

In the first scenario, the percent North American origin salmon is assumed to increase at a constant daily rate from 40% on August 9, to 45% on August 29, and then to remain constant at 45% for the remainder of the fishing season. Table 16 shows calculated catches in metric tons and percent North American origin fish in the catch assuming the "normal" selectivity model and the 1976-77 fishing pattern. The increase in catch in weight for a given mesh size with later seasons is slightly less than that of Table 11. For example, for an opening date of August 25 and 140 mm mesh, it is a factor of 1.046 as opposed to 1.048 in Table 11. The percent North American origin salmon in the catch increases more rapidly with later opening dates in Table 16 than in Table 11. For 140 mm mesh, the increase from August 10 to August 25 is 1.825% as opposed to 0.652% previously calculated. This change could be neutralized by increasing the calculated "optimal" mesh size by about 2 mm.

The second scenario considered was a constant rate of increase from 40% on August 10 to 50% on October 29. For 140 mm mesh and other parameters as in the first scenario, the calcualted values were:

Opening Date	August 10	August 20	August 25	September 1
Catch (mt)	1172.66	1208.18	1226.03	1247.49
Percent NA	42.3015512	43.88131	44.5257448	45.2059222

In this case, the increase in catch corresponding to an opening date of August 25 was a factor of 1.0303 and the increase in percent North American origin salmon was 1.58%. Adoption of a mesh size of 144.9 mm and an August 25 opening date gave a calculated catch of 1271.72 mt with 42.3079868% of North American origin. Thus, a 5 mm increase in mesh size neutralizes the trend and gives a catch 1.0845 times greater than 140 mm mesh with an August 10 opening date.

Analysis of the two scenarios shows that an increase in mesh size of about 2 mm neutralizes the effect of a one percent increase in the North American origin component of the catch while increasing the calculated catch corresponding to 355,000 salmon. The impact of a trend on the population composition is determined mainly by the change in average composition during the 10 to 21-day period of proposed delay in opening the fishing season. Calculated catch compositions changed less than population compositions.

Escapement

Tables 17 and 18 show calculated escapements for the two selectivity models and various mesh sizes, opening dates and fishing patterns. 100% efficiency of gillnets at their length of maximum selection is assumed. In all cases, the calculated total escapement for 140 mm mesh gillnets is about one-half of that for 130 mm or 150 mm mesh. Thus, adoption of mesh sizes near 140 mm can greatly reduce calculated escapements over those associated with the other mesh sizes considered. In the 140 mm case, escapement is about one-seventh of catch in numbers so that, if one half of the escaping fish die, the escapement mortality would be about 7% of the catch.

It should be noted that the method used to estimate gillnet selectivities causes an overestimation of escapement mortality as defined by Anon. 1980 since dropouts and haulback losses are effectively considered to be in the escapement. The above estimate, therefore, includes these classifications of non-catch fishing mortality.

Conclusions:

For opening dates from August 20 to September 1 and adoption of a stretched mesh size of 139-140 mm, the estimated proportions of North American and European origin salmon are the same in the catch as in the exploited population. If the monthly natural mortality rate of 0.01 and percent North American salmon in the exploited population of 42.85% are adopted as the basis to adjust the quota at West Greenland, then the estimated catches giving the same total mortality as a catch of 1,190 mt in the reference years of 1976-77 are:

Opening date	Quota (mt)
August 20	1207 - 1236
August 25	1229 - 1257
September 1	1255 - 1283

Equivalently, if a catch quota of 1,190 mt is retained but the opening date of the season is changed as above with the appropriate mesh size, the reduction in equivalent numbers of salmon killed (adjusting the natural mortality), ignoring escapement mortalities are:

Opening date	Percent Reduction
August 20	1.43 - 3.87
August 25	3.28 - 5.63
September 1	5.46 - 7.82

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APPENDIX 1

Selectivity Calculations, "Normal" Case

Notation and Assumptions

1. Assume that the stock complex is composed of a mixture of n components with normally distributed fork lengths. For component i:
   mean fork length i = M_i
   standard deviation of fork length i = σ_i
   length-weight relationship i = $a_i + b_i \times L$

2. Assume that a gillnet of mesh size X cm. has a "normal" relative mesh selection curve $\exp \frac{-1}{2}\left(\frac{L - k \times X}{\sigma}\right)^2$ at length L, where:
   k is a constant of proportionally
   k x X is the modal length of the selectivity curve, and
   σ is the "standard deviation" of the selection curve.

3. The gillnet is 100% efficient at its modal selection length.

4. No fish encounters the fishing gear more than once and if 1000 fish encounter the gear, then $1000p_i$ fish from component i encounter the gear where p_i is the proportion of component i in the exploited population.

Theoretical Considerations

The mean length of fish from component i in the catch is:

$$M_{ci} = \left(\frac{M_i}{\sigma_i^2} + \frac{k \times X}{\sigma^2}\right) \left(\frac{1}{\sigma_i^2} + \frac{1}{\sigma^2}\right)^{-1} \qquad (1)$$

and the variance of the length of fish from component i in the catch is:

$$\sigma^2_{ci} = \left(\frac{1}{\sigma_i^2} + \frac{1}{\sigma^2}\right)^{-1} \qquad (2)$$

The proportion P_{ci} of fish from component i in the catch as a fraction of the number of fish from component i encountering the gear is:

$$P_{ci} = \left(\frac{1}{\sigma_i^2} + \frac{1}{\sigma^2}\right)^{-\frac{1}{2}} \sigma_i^{-1} \exp \frac{-1}{2} \frac{(M_i - k \times X)^2}{\sigma_i^2 \sigma^2} \left(\frac{1}{\sigma_i^2} + \frac{1}{\sigma^2}\right)^{-1} \qquad (3)$$

The mean length of fish escaping the catch from component i, is:

$$M_{ei} = (M_i - P_{ci}M_{ei})/(1 - P_{ci}) \qquad (4)$$

On the average, for each fish encountering the gear, the weight caught is

$$\sum_{i=1}^{n} P_i \times P_{ci}(a_i + b_i \times M_{ci}) \qquad (5)$$

thus, the number of fish E which must encounter the gear to give a daily catch Q is:

$$E = Q/(\sum_{i=1}^{n} P_i P_{ci}(a_i + b_i M_{ci})) \qquad (6)$$

The number of fish caught from component i is thus:

$$EP_i P_{ci} \qquad (7)$$

and the escapement of fish from component i of those encountering the gear is:

$$EP_i(1-P_{ci}) \qquad (8)$$

If the proportion of the escapement dying due to encounter with the gear is M then the total number of fish killed is:

$$EP_i(P_{ci}+ M(1-P_{ci})) \qquad (9)$$

APPENDIX II

Computer Programs Used

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      ∇COMP[⎕]∇
    ∇ COMP
[1]   MLNA←(((LZNA+BLNA×DAY)÷VLNA)+K×MESH÷VMESH)÷((1÷VLNA)+(1÷VMESH))
[2]   MLEU←(((LZEU+BLEU×DAY)÷VLEU)+K×MESH÷VMESH)÷((1÷VLEU)+(1÷VMESH))
[3]   PCNA←((((1÷VLNA)+(1÷VMESH))×VLNA)*¯0.5)×*¯0.5×((MLNA-K×MESH)*2)÷(VLNA+VMESH)
[4]   PCEU←((((1÷VLEU)+(1÷VMESH))×VLEU)*¯0.5)×*¯0.5×((MLEU-K×MESH)*2)÷(VLEU+VMESH)
    ∇
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      ∇SKEWCOMP[⎕]∇
     ∇ SKEWCOMP
[1]    L←39+⍳50
[2]    IDAY←¯10+5×⍳20
[3]    XLEN←⍉(20 50 ρL)
[4]    MLENNA← 50 20 ρLZNA+BLNA×IDAY
[5]    MLENEU← 50 20 ρLZEU+BLEU×IDAY
[6]    APCNA←(1÷(VLNA×○2)*0.5)×*¯0.5×(((XLEN-MLENNA)*2)÷VLNA)+(((⍟XLEN÷K×MESH)×K×MESH)*2)÷VMESH
[7]    APCEU←(1÷(VLEU×○2)*0.5)×*¯0.5×(((XLEN-MLENEU)*2)÷VLEU)+(((⍟XLEN÷K×MESH)×K×MESH)*2)÷VMESH
[8]    VPCNA←+⌿APCNA
[9]    VPCEU←+⌿APCEU
[10]   VMLNA←(+⌿APCNA×XLEN)÷VPCNA
[11]   VMLEU←(+⌿APCEU×XLEN)÷VPCEU
[12]   I←1 ◇ PCNA←⍳0 ◇ PCEU←⍳0 ◇ MLNA←⍳0 ◇ MLEU←⍳0
[13]   DAY5←⌊DAY÷5
[14]   P←(DAY÷5)-DAY5
[15] LOOP:I1←DAY5[I]+1
[16]   I2←I1+1
[17]   I3←I1+2
[18]   I4←I1+3
[19]   Q←P[I]
[20]   Q1←¯1×Q×(¯1+Q)×(¯2+Q)÷6
[21]   Q2←(¯1+Q*2)×(¯2+Q)÷2
[22]   Q3←¯1×Q×(Q+1)×(¯2+Q)÷2
[23]   Q4←Q×(¯1+Q*2)÷6
[24]   PCNA←PCNA,(Q1×VPCNA[I1])+(Q2×VPCNA[I2])+(Q3×VPCNA[I3])+Q4×VPCNA[I4]
[25]   PCEU←PCEU,(Q1×VPCEU[I1])+(Q2×VPCEU[I2])+(Q3×VPCEU[I3])+Q4×VPCEU[I4]
[26]   MLNA←MLNA,(Q1×VMLNA[I1])+(Q2×VMLNA[I2])+(Q3×VMLNA[I3])+Q4×VMLNA[I4]
[27]   MLEU←MLEU,(Q1×VMLEU[I1])+(Q2×VMLEU[I2])+(Q3×VMLEU[I3])+Q4×VMLEU[I4]
[28]   I←I+1
[29]   →(81>I)/LOOP
     ∇
```

```
      ∇CATCH[⎕]∇
     ∇ CATCH FP
[1]    FISHPAT←(ODATE-1)ρ0
[2]    FISHPAT←FISHPAT,FP
[3]    FISHPAT←FISHPAT,(81-ODATE+ρFP)ρ0
[4]    MULT←FISHPAT÷((PCNA×FNA×(WZNA+BWNA×MLNA))+(PCEU×FEU×(WZEU+BWEU×MLEU)))
[5]    NCNA←MULT×PCNA×FNA
[6]    NCEU←MULT×PCEU×FEU
[7]    NENA←MULT×FNA×(1-PCNA)
[8]    NEEU←MULT×FEU×(1-PCEU)
[9]    NUM←+/NCNA+NCEU
[10]   NCNA←NCNA×355000÷NUM
[11]   NCEU←NCEU×355000÷NUM
[12]   NENA←NENA×355000÷NUM
[13]   NEEU←NEEU×355000÷NUM
[14]   FISHPAT←FISHPAT×355÷NUM
     ∇
```

```
      ∇PRINT[⎕]∇
    ∇ PRINT
[1]   ''
[2]   ''
[3]   '<STRETCHED MESH IS >,F5.1,< CM OPENING DATE IS >,I2,< AUG 10 IS DAY 1>' ⎕FMT(MESH;ODATE)
[4]   ''
[5]   'FRACTION NA IS  ';FNA
[6]   'FRACTION EU IS  ';FEU
[7]   'MEAN LEN NA IS  ';LZNA;'  PLUS  ';BLNA;'  TIMES DAY'
[8]   'MEAN LEN EU IS  ';LZEU;'  PLUS  ';BLEU;'  TIMES DAY'
[9]   'MEAN WT NA IS  ';WZNA;'  PLUS  ';BWNA;'  TIMES MLNA'
[10]  'MEAN WT EU IS  ';WZEU;'  PLUS  ';BWEU;'  TIMES MLEU'
[11]  'VLENNA  ';VLNA;'  VLENEU  ';VLEU;'  VMESH  ';VMESH
[12]  'K FOR MESH IS  ';K
[13]  ''
[14]  ''
[15]  'DAY  NCNA   NCEU   NENA   NEEU   CATCH TONS'
[16]  'I3,4F7.0,F8.1' ⎕FMT(DAY;NCNA;NCEU;NENA;NEEU;FISHPAT)
[17]  'TOTAL CATCH NOS NA  ';+/NCNA
[18]  'TOTAL CATCH NOS EU  ';+/NCEU
[19]  'PERCENT NA  ';+/NCNA÷(+/NCNA+NCEU)
[20]  'TOTAL ESC NA  ';+/NENA
[21]  'TOTAL ESC EU  ';+/NEEU
[22]  'TOTAL CATCH NOS  ';+/NCNA+NCEU
[23]  'TOTAL ESC NOS  ';+/NENA+NEEU
[24]  'TOTAL CATCH IN TONS  ';+/FISHPAT
[25]  ''
[26]  ''
[27]  ''
    ∇
```

```
      ∇PRIN[⎕]∇
    ∇ PRIN
[1]   ''
[2]   ''
[3]   '<STRETCHED MESH IS >,F5.1,< CM OPENING DATE IS >,I2,< AUG 10 IS DAY 1>' ⎕FMT(MESH;ODATE)
[4]   ''
[5]   'FRACTION NA IS  ';FNA
[6]   'FRACTION EU IS  ';FEU
[7]   'MEAN LEN NA IS  ';LZNA;'  PLUS  ';BLNA;'  TIMES DAY'
[8]   'MEAN LEN EU IS  ';LZEU;'  PLUS  ';BLEU;'  TIMES DAY'
[9]   'MEAN WT NA IS  ';WZNA;'  PLUS  ';BWNA;'  TIMES MLNA'
[10]  'MEAN WT EU IS  ';WZEU;'  PLUS  ';BWEU;'  TIMES MLEU'
[11]  'VLENNA  ';VLNA;'  VLENEU  ';VLEU;'  VMESH  ';VMESH
[12]  'K FOR MESH IS  ';K
[13]  'TOTAL CATCH NOS NA  ';+/NCNA
[14]  'TOTAL CATCH NOS EU  ';+/NCEU
[15]  'PERCENT NA  ';+/NCNA÷(+/NCNA+NCEU)
[16]  'TOTAL ESC NA  ';+/NENA
[17]  'TOTAL ESC EU  ';+/NEEU
[18]  'TOTAL CATCH NOS  ';+/NCNA+NCEU
[19]  'TOTAL ESC NOS  ';+/NENA+NEEU
[20]  'TOTAL CATCH IN TONS  ';+/FISHPAT
[21]  ''
[22]  ''
[23]  ''
    ∇
```

```
      ∇OPRINT[⎕]∇
    ∇ OPRINT MORT
[1]   Q←1.02648153×⋆MORT×(1-ODATE)÷30
[2]   NCNA←+/NCNA×Q
[3]   NCEU←+/NCEU×Q
[4]   NENA←+/NENA×Q
[5]   NEEU←+/NEEU×Q
[6]   CAT←Q×+/FISHPAT
[7]   NC←NCNA+NCEU
[8]   NE←NENA+NEEU
[9]   'I3,F7.1,F9.2,6F12.0' ⎕FMT(ODATE;MESH;CAT;NCNA;NCEU;NC;NENA;NEEU;NE)
    ∇
```

```
    ∇ ROOT
[1]   A←(0.5×F[1]+F[3])-F[2]
[2]   B←0.5×F[3]-F[1]
[3]   G←F[2]-FNA
[4]   P←(¯1×(((B*2)-4×A×G)*0.5)+B)÷2×A
[5]   'FRAC NA IS    ';(0.5×P×(P-1)×F[1])+((1-P*2)×F[2])+(0.5×P×(P+1)×F[3])
[6]   'MESH SIZE IS    ';14+P
[7]   'CATCH IS    ';(0.5×P×(P-1)×C[1])+((1-P*2)×C[2])+(0.5×P×(P+1)×C[3])
    ∇
```

Table 1. Length, weight and percentage of North American, North American hatchery and European origin Atlantic salmon caught in different mesh sizes at West Greenland in 1978

	Mesh size: Mean 127 mm				Mesh size: Mean 140 mm				Mesh size: Mean 155 mm			
Origin	Fork length (cm)	Whole weight (kg)	Sample size	%	Fork length (cm)	Whole weight (kg)	Sample size	%	Fork length (cm)	Whole weight (kg)	Sample size	%
North American	62.7	2.83	75	35.7	63.7	3.06	73	37.8	65.9	3.26	47	22.2
North American Hatchery	65.0	3.04	9	4.3	65.6	2.95	11	5.7	66.2	3.21	10	4.7
European	66.6	3.40	121	57.6	67.5	3.52	106	54.9	68.3	3.61	151	71.2
Not identified	64.5	2.94	5	2.4	65.7	3.24	3	1.6	67.0	3.03	4	1.9
Total	65.1	3.17	210	100.0	65.9	3.34	193	100.0	67.7	3.50	212	100.0
Sea age 1												
North American	62.2	2.73	72		63.2	2.98	68		65.6	3.25	44	
North American Hatchery	64.9	3.04	9		65.6	3.10	11		66.0	3.32	9	
European	66.6	3.40	121		67.3	3.51	105		68.0	3.63	144	
Sea age 2												
North American	80.0	6.2	2		84.0	7.6	2		86.0	7.4	1	
North American Hatchery	0	0	0		0	0	0		0	0	0	
European	0	0	0		0	0	0		87.0	7.9	1	
Previous spawners												
North American	63.0	2.8	1		61.0	2.6	2		58.0	1.9	1	
European	0	0	0		87.0	7.0	1		84.0	6.4	2	

Table 2 Length, weight and percentage of North American, North American hatchery and European origin Atlantic salmon caught in different mesh sizes at West Greenland in 1979.

	Mesh size Mean 126 mm				Mesh size Mean 142 mm				Mesh size Mean 154 mm			
Origin	Fork length (cm)	Whole weight (kg)	Sample size	%	Fork length (cm)	Whole weight (kg)	Sample size	%	Fork length (cm)	Whole weight (kg)	Sample size	%
North American	62.8	2.96	75	48.4	63.7	3.17	41	35.4	68.8	4.08	16	24.6
North American Hatchery	66.7	3.50	7	4.5	64.3	3.17	7	6.0	69.7	4.23	3	4.6
European	66.4	3.52	67	43.2	66.6	3.61	68	58.6	67.8	3.82	40	61.6
Not identified	64.5	3.00	6	3.9	0	0	0	0	58.5	3.03	6	9.2
Total	64.6	3.24	155	100.0	65.5	3.42	116	100.0	67.6	3.87	65	100.0
Sea age 1												
North American	62.3	2.85	72		63.4	3.05	39		66.1	3.51	14	
North American Hatchery	64.7	3.20	6		64.3	3.17	7		69.7	4.23	3	
European	66.2	3.48	66		66.4	3.55	67		67.3	3.73	39	
Sea age 2												
North American	84.0	8.00	1		70.0	6.60	1		88.0	10.50	1	
North American Hatchery	0	0	0		0	0	0		0	0	0	
European	77.0	5.80	1		83.0	7.50	1		88.0	7.40	1	
Previous spawners												
North American	70.5	4.40	2		67.0	4.10	1		88.0	5.60	1	
European	0	0	0		0	0	0		0	0	0	

Table 3 Percentage (by number) of North American and European salmon in research vessel catches at West Greenland 1969-1980 and from commercial samples 1979-80

Year	Percentage North American wild plus hatchery	95% confidence interval upper	95% confidence interval lower	Percentage North American hatchery fish	Percentage European	95% confidence interval upper	95% confidence interval lower
				RESEARCH			
1969	51	57	44	8	49	56	43
1970	35	43	26	14	65	74	57
1971	34	40	28	5	66	72	60
1972	36	37	34	7	64	66	63
1973	49	59	39	1	51	61	41
1974	43	46	39	6	57	61	54
1975	44	48	40	4	56	60	52
1976	43	48	38	6	57	62	52
1977	-	-	-	-	-	-	-
1978(a)	38	41	34	5	62	66	59
1978(b)	44	47	41	4	56	59	53
1979	47	52	41	5	53	59	48
1980	58	62	54	4	42	46	38
				COMMERCIAL			
1979	50	52	48	4	50	52	48
1980	48	51	45	6	52	55	49

(a) during fishery
(b) includes research samples after fishery closed

Table 4   Gear fished at West Greenland by research vessel.

Year	Ship	Sets	114 mm mesh Multi	114 mm mesh Mono	127 mm mesh Multi	127 mm mesh Mono	140 mm mesh Multi	140 mm mesh Mono	152 mm mesh Multi	152 mm mesh Mono
1969	ATC	16	400		800		909		328	423
1970	ATC	15			497	500	500	500	500	500
1971	ATC	11	495		750	750			750	750
1972	ATC	26				1427				1423
1973										
1974	ADJ	6				750				750
1975	Dana	4				750				750
1976	ADJ	12				854				708
1977										
1978	Atkinson	9				444		444		444
1979	Zagreb	16				569		569		569
1980	ATC	16				1000		998		

Table 5 Characteristics of salmon population at West Greenland.

	1978	1980[1]
NORTH AMERICAN STOCKS		
$\overline{FL}$ (cm) =	63.48	63.83
Variance =	15.98	14.11
EUROPEAN STOCKS		
$\overline{FL}$ (cm) =	67.73	65.60
Variance =	12.83	11.47

1. Subsequent to this analysis revised estimates of 63.23, 11.32, 65.44, 11.55 respectively were obtained for 1980, adjusting for misclassification of some European origin salmon with growth checks on their scales. This analysis has not been revised since the impact, in test calculations, was less than 0.5 mt on the catch in weight and an increase of about 0.2% in the North American origin proportion of the catch.

Table 6 Growth in fork length (cm) of Atlantic salmon at West Greenland.

Year	Stock	[1]Periods 1	2	3	4	5	6	7	8	9	10	R^2	Intercept	Slope	F
1969	NA				[2]64.1 (477) 44	65.6 (482) 57									
	E				68.2 (477) 36	68.8 (483) 63									
1970	NA			64.9 (462) 4	64.8 (475) 35	57.0 (486) 1									
	E			67.8 (462) 8	68.7 (474) 63	67.7 (482) 8									
1971	NA			62.4 (463) 4	62.7 (470) 80										
	E			69.2 (463) 8	67.5 (470) 152										
1972	NA	64.6 (434) 120	63.2 (445) 112	65.3 (456) 14	66.2 (474) 18	66.4 (488) 11	64.6 (500) 9					0.24	54.4470	0.02275	1.27 1.4
	E	67.3 (433) 233	67.8 (444) 185	68.7 (458) 36	69.1 (472) 55	69.0 (488) 12	68.8 (499) 16					0.70	57.2866	0.02397	9.44 1.4
1973	NA			62.6 (457) 11	63.4 (470) 5	66.9 (482) 7	65.2 (500) 6	65.0 (514) 3	65.8 (523) 4	63.7 (537) 7	70.0 (558) 1	0.41	43.2286	0.04374	4.24 1.6
	E			68.6 (457) 14	69.7 (473) 3	70.1 (485) 11	70.7 (500) 6	70.0 (514) 3	72.0 (523) 8	73.5 (537) 6		0.81	45.1695	0.051136	21.14 1.5

Table 6 (Cont'd)

Year	Stock	[1]Periods 1	2	3	4	5	6	7	8	9	R^2	Intercept	Slope	F
1974	NA	62.7 (429) 147	64.3 (438) 22	- - -	63.3 (474) 19	61.6 (483) 5	64.8 (504) 10	65.8 (511) 136			0.20	54.1102	0.020373	1.02
	E	67.0 (430) 306	68.6 (438) 36	- - -	69.8 (473) 16	68.1 (485) 12	68.8 (504) 5	71.2 (511) 105			0.47	54.8629	0.029681	3.60 1.4
1975	NA	61.5 (433) 2	61.8 (444) 223											
	E	70.0 (434) 6	67.4 (444) 285											
1976	NA	60.9 (435) 137	59.7 (438) 6	- - -	62.7 (477) 15	63.3 (490) 3	68.0 (497) 3	- - -	63.0 (534) 1	70.5 (545) 2	0.58	30.2535	0.069182	6.95 1.5
	E	65.5 (435) 190	67.6 (438) 22	- - -	66.5 (478) 4	67.9 (485) 9	69.8 (496) 5	74.0 (520) 1	69.0 (533) 1	67.7 (546) 3	0.27	52.3358	0.032896	2.24 1.6
1978	NA		63.8 (449) 162	63.2 (452) 53	- - -	61.8 (484) 8	64.3 (500) 11	69.5 (511) 2	64.0 (530) 1		0.17	48.1109	0.033470	0.82 1.4
	E		67.3 (449) 298	67.6 (453) 73	- - -	68.6 (484) 8	70.2 (500) 10	71.0 (511) 2			0.95	41.6136	0.057001	63.20 1.3
1979	NA		63.2 (446) 115	63.1 (456) 27										
	E	67.4 (437) 4	66.3 (446) 144	67.3 (457) 26										

(Cont'd)

Table 6 (Cont'd)

Year	Stock	Periods[1] 1	2	3	4	5	6	7	8	9	10	R^2	Intercept	Slope	F
1980	NA	61.9	63.5												
		(437)	(443)												
		23	386												
	E	65.2	65.3												
		(437)	(443)												
		15	180												
All Years	NA	62.3	62.8	63.6	63.9	63.2	65.4	66.8	64.3	67.1	70.0	0.76	40.5743	0.049323	24.85
		(434)	(443)	(458)	(474)	(485)	(500)	(517)	(532)	(539)	(558)				1.8
		419	1022	110	214	89	38	141	6	2	1				
	E	67.1	67.2	68.2	68.5	68.6	69.6	71.5	70.5	70.6		0.87	50.3215	0.038590	46.99
		(434)	(443)	(458)	(474)	(485)	(500)	(514)	(528)	(541)					1.7
		728	1144	157	328	125	40	111	9	9					

[1] Periods are:

1 - July 30-August 12 (days 425-438)
2 - August 13-26 (days 439-452)
3 - August 27-September 9 (days 453-466)
4 - September 10-23 (days 467-480)
5 - September 24-October 7 (days 481-494)
6 - October 8 - 21 (days 495-508)
7 - October 22-November 4 (days 509-522)
8 - November 5-18 (days 523-526)
9 - November 19-December 12 (days 527-540)
10 - December 12-25 (days 541-554)

[2] Row 1 - length in cm
Row 2 - ( ) time in days
Row 3 - sample size

Table 7 Growth in weight (kg) of Atlantic salmon at West Greenland.

Year	Stock	[1]Periods 1	2	3	4	5	6	7	8	9	10	Regressions (weight on time) R^2	Intercept	Slope	F
1969	NA				[2]2.95 (477) 44	3.25 (482) 57									
	E				3.62 (477) 36	3.84 (483) 63									
1970	NA			2.80 (462) 4	2.89 (475) 35	2.00 (486) 1									
	E			3.39 (462) 8	3.42 (474) 63	3.55 (482) 8									
1971	NA			2.77 (463) 4	2.65 (470) 80										
	E			3.61 (463) 8	3.36 (470) 153										
1972	NA	2.97 (434) 117	2.74 (445) 112	3.13 (456) 13	3.46 (474) 18	3.49 (488) 11	3.26 (500) 8					0.77	-1.7847	0.01071	13.24 1.4
	E	3.33 (433) 230	3.41 (444) 185	3.60 (458) 35	3.70 (472) 55	3.77 (488) 12	4.22 (499) 14					0.89	-1.7857	0.011719	31.98 1.4
1973	NA	- - -	- - -	2.67 (457) 9	3.47 (470) 3	3.65 (482) 7	3.53 (500) 6	3.43 (514) 3	3.35 (523) 4	3.13 (539) 7	4.00 (558) 1	0.26	0.52353	0.005699	2.11 1.6
	E	- - -	- - -	3.71 (457) 8	3.80 (473) 1	4.57 (485) 11	4.94 (500) 6	3.85 (514) 3	4.72 (523) 8	5.39 (537) 6		0.52	-3.7348	0.016372	5.32 1.4

(Cont'd)

Table 7 (Cont'd)

Year	Stock	[1]Periods 1	2	3	4	5	6	7	8	9	10	Regressions (weight on time) R^2	Intercept	Slope	F
1974	NA	2.79	3.08	-	2.97	3.01	2.98	3.52				0.38	0.92149	0.004516	2.48
		(429)	(438)	-	(474)	(483)	(504)	(511)							1.4
		140	22	-	19	5	10	136							
	E	3.47	3.85	-	4.07	3.95	3.78	4.72				0.47	-0.07477	0.008549	3.55
		(430)	(438)	-	(473)	(485)	(504)	(511)							1,4
		283	36	-	16	12	5	105							
1975	NA	2.10	2.58												
		(433)	(444)												
		2	223												
	E	3.45	3.42												
		(434)	(444)												
		6	284												
1976	NA	2.43	2.42	-	2.91	3.10	4.37	-	3.50	4.75		0.70	-5.4136	0.017967	11.88
		(435)	(438)	-	(477)	(490)	(497)	-	(534)	(545)					1.5
		137	6	-	15	3	3	-	1	2					
	E	3.05	3.42	-	3.82	4.11	4.54	4.50	5.00	4.73		0.91	-3.53546	0.015633	57.32
		(435)	(438)	-	(478)	(485)	(496)	(520)	(533)	(546)					1.5
		190	22	-	4	9	5	1	1	3					
1978	NA		2.98	2.96	-	2.61	3.15	4.65	3.70			0.38	-3.4711	0.013970	2.48
			(449)	(452)	-	(484)	(500)	(511)	(530)						1.4
			159	53	-	5	11	2	1						
	E		3.48	3.69	-	4.00	4.60	4.50				0.92	-4.1026	0.01701	35.69
			(449)	(453)	-	(484)	(500)	(511)							
			296	72	-	8	10	2							
1979	NA		3.00	3.07											
			(446)	(456)											
			115	27											
	E	4.55	3.53	3.77											
		(437)	(446)	(457)											
		4	143	26											

(Cont'd)

Table 7 (Cont'd)

Year	Stock	[1]Periods 1	2	3	4	5	6	7	8	9	10	Regressions (weight on time) R^2	Intercept	Slope	F
1980	NA	2.89 (437) 23	3.05 (443) 385												
	E	3.27 (437) 15	3.30 (443) 178												
All Years	NA	2.64 (434) 419	2.84 (443) 1022	2.90 (458) 110	3.04 (474) 214	3.02 (485) 89	3.46 (500) 38	3.77 (517) 141	3.93 (532) 6	3.13 (539) 2	4.00 (558) 1	0.74	-1.5738	0.009811	22.4 1.8
	E	3.52 (434) 728	3.49 (443) 1144	3.63 (458) 157	3.68 (474) 328	3.97 (485) 123	4.42 (500) 40	4.39 (514) 111	4.86 (528) 9	5.06 (541) 9		0.94	-3.3222	0.015289	103.94 1.7

[1] Periods:

1. July 30 - August 12 (days 425-438)
2. August 13-26 (days 439-452)
3. August 27 - September 9 (days 453-466)
4. September 10-23 (days 467-480)
5. September 24 - October 7 (days 481-494)
6. October 8 - 21 (days 495-508)
7. October 22-November 4 (days 509-522)
8. November 5 - 18 (days 523-526)
9. November 19 - December 12 (days 527 - 540)

[2] Row 1 - weight in kg
Row 2 - ( ) time in days
Row 3 - Sample size

Table 8 The salmon caught and the population exposed to 126 and 142 mm mesh gillnets at West Greenland in 1980.

Mesh size (mm)	Catch		Estimated Population		Est. fish encountering gear but not caught	
Length (cm)	126	142	126	142	126	142
54	1		1.3		0.3	
55						
56		1		2.7		1.7
57	3	4	3.2	9.2	0.2	5.2
58	7	4	7.1	7.8	0.1	3.8
59	11	6	11.0	10.2	0.0	4.2
60	29	13	29.1	19.5	0.1	6.5
61	29	26	29.6	35.0	0.6	9.0
62	27	32	28.5	39.4	1.5	7.4
63	34	39	37.8	44.5	3.8	5.5
64	29	30	34.4	32.3	5.4	2.3
65	34	34	43.9	35.1	9.9	1.1
66	30	30	42.8	30.2	12.8	0.2
67	19	31	30.5	31.0	11.5	0.0
68	11	27	20.2	27.2	9.2	0.2
69	7	14	14.9	14.5	7.9	0.5
70	12	2	30.2	2.2	18.2	0.2
71	1	8	3.0	9.1	2.0	1.1
72	1	4	3.7	4.9	2.7	0.9
73	1	-	4.6	-	3.6	-
74		3		4.5		1.5
75						
76						
77						
78						
79						
80						
81	1	1	47.1	5.1	46.1	4.1
82		1		6.5		5.5
83		1		8.4		7.4
84						
85						
86	1	1	346.2	20.0	345.2	19.0
87		1		27.6		26.6
Total	288	313	769.1	426.9	481.1	113.9
< 75	286	308	375.8	359.3	89.8	51.3
% not retained					31.4	16.7

24%

TABLE 9

Calculated Gillnet Selectivity
Patterns for salmon with 140mm. mesh

Length	Lognormal	Normal	L. ÷ N.
50	0.08949	0.15800	0.56620
51	0.12510	0.19810	0.63160
52	0.16960	0.24460	0.69340
53	0.22330	0.29770	0.75020
54	0.28600	0.35690	0.80130
55	0.35680	0.42170	0.84600
56	0.43420	0.49100	0.88430
57	0.51600	0.56330	0.91600
58	0.59960	0.63680	0.94160
59	0.68200	0.70940	0.96140
60	0.76020	0.77870	0.97620
61	0.83100	0.84230	0.98660
62	0.89180	0.89770	0.99340
63	0.94030	0.94280	0.99740
64	0.97500	0.97570	0.99930
65	0.99490	0.99500	0.99990
66	0.99980	0.99980	1.00000
67	0.99010	0.98990	1.00000
68	0.96690	0.96590	1.00100
69	0.93180	0.92860	1.00300
70	0.88650	0.87970	1.00800
71	0.83310	0.82120	1.01500
72	0.77390	0.75540	1.02500
73	0.71090	0.68470	1.03800
74	0.64600	0.61150	1.05600
75	0.58100	0.53820	1.08000
76	0.51750	0.46680	1.10900
77	0.45650	0.39890	1.14400
78	0.39910	0.33590	1.18800
79	0.34590	0.27870	1.24100
80	0.29730	0.22790	1.30500
81	0.25340	0.18360	1.38000
82	0.21440	0.14570	1.47100
83	0.18000	0.11400	1.57900
84	0.15010	0.08788	1.70800
85	0.12430	0.06675	1.86200
86	0.10230	0.04996	2.04700
87	0.08362	0.03685	2.26900
88	0.06794	0.02678	2.53700
89	0.05489	0.01918	2.86200

Table 10 Fishing Patterns for Salmon at West Greenland

DAY	FP 76/77	FP 79/80
1	0.17	0.21
2	0.98	1.22
3	1.19	1.48
4	2.62	3.26
5	1.26	1.56
6	3.09	3.83
7	3.33	4.13
8	3.39	4.23
9	7.96	3.36
10	1.85	5.24
11	1.24	4.09
12	1.17	6.03
13	3.45	6.90
14	6.54	6.96
15	4.38	5.43
16	2.74	4.37
17	1.94	6.79
18	1.56	2.94
19	1.70	3.17
20	3.23	4.48
21	3.55	2.91
22	4.57	3.11
23	1.38	1.93
24	0.93	1.67
25	1.60	1.08
26	2.30	3.20
27	7.95	2.20
28	1.48	4.20
29	0.30	
30	1.50	
31	1.49	
32	2.19	
33	1.35	
34	1.32	
35	1.08	
36	0.92	
37	2.85	
38	0.64	
39	0.80	
40	0.35	
41	0.45	
42	0.81	
43	0.72	
44	0.99	
45	0.48	
46	0.71	
47	0.34	
48	0.45	
49	0.45	
50	0.30	
51	0.37	
52	0.37	
53	0.27	
54	0.21	
55	0.31	
56	0.37	
57	0.09	

Table 11. Calculated Catches (mt) (upper figure) and Fraction North American origin Salmon in the Catch (lower figure) for different mesh sizes, opening dates and fishing patterns assuming a "normal" selectivity curve and 42.85% North American origin salmon in the exploited population.

Opening Date	Fishing Pattern	Mesh Size (mm)		
		130.0	140.0	150.0
August 10	76-77	1082.13	1173.1391	1266.7759
		0.47156233	0.42143816	0.37755859
	79-80	1061.35	1151.9378	1245.2282
		0.46941101	0.4189884	0.37486235
August 20	76-77	1119.3298	1210.9493	1305.0697
		0.47542803	0.42581944	0.38236002
	79-80	1098.5659	1189.7768	1283.5619
		0.4733586	0.42344531	0.37973056
August 25	76-77	1137.8868	1229.8067	1324.1641
		0.47730292	0.42795655	0.38471344
	79-80	1117.1307	1208.6479	1302.6756
		0.47527478	0.42562083	0.38211816
September 1	76-77	1160.1197	1252.3954	1347.0329
		0.47950163	0.43047359	0.38749528
	79-80	1139.3724	1231.2525	1325.5671
		0.4775234	0.42818444	0.38494167

Table 12. Calculated Catches (mt) (upper figure) and fraction North American Salmon in the Catch (lower figure) for different mesh sizes, opening dates and fishing patterns assuming a "Log-normal" selectivity curve and 42.85% North American origin salmon in the exploited population.

Opening Date	Fishing Pattern	Mesh Size (mm) 130.0	140.0	150.0
August 10	76-77	1093.4443 0.48139166	1180.2325 0.41518305	1284.2419 0.34487399
	79-80	1072.2558 0.47889621	1159.1619 0.41152344	1263.3067 0.34024062
August 20	76-77	1131.3856 0.48589514	1217.779 0.4217356	1321.363 0.35311003
	79-80	1110.162 0.4835726	1196.7109 0.41825267	1300.4661 0.34862707
August 25	76-77	1150.3483 0.48802691	1236.5228 0.42488956	1339.8741 0.3571243
	79-80	1129.105 0.48579013	1215.4534 0.42149534	1318.9938 0.35271876
September 1	76-77	1173.1004 0.49048067	1258.9934 0.42856667	1362.0476 0.36184801
	79-80	1151.8316 0.48834612	1237.9203 0.42527911	1341.1848 0.35753714

Table 13. Optimum Mesh Size and Catch of 355 000 Salmon
Fishing Pattern 1976-77

OPENING DATE	NORMAL		SKEWED	
	MESH (mm)	CATCH (mt)	MESH (mm)	CATCH (mt)
August 10	138.5	1159.43	138.0	1161.84
August 20	139.4	1205.62	139.0	1208.16
August 25	140.0	1228.71	139.4	1231.31
September 1	140.4	1256.42	140.0	1259.09

Fishing Pattern 1979-80

OPENING DATE	NORMAL		SKEWED	
	MESH (mm)	CATCH (mt)	MESH (mm)	CATCH (mt)
August 10	138.0	1133.73	137.5	1136.13
August 20	138.9	1179.87	138.5	1182.40
August 25	139.4	1202.94	138.9	1205.52
September 1	140.0	1230.62	139.5	1233.27

Table 14. "Optimal" Mesh Sizes, Catches and Escapements

OPENING DATE	MESH (mm)	CATCH (mt)	CATCH NA	CATCH EU	TOTAL	ESC NA	ESC EU	TOTAL
"Normal" Selectivity, 1976-77 Fishing Pattern								
August 10	138.5	1190.00	156171	208230	364401	19632	26242	45875
August 20	139.4	1233.18	155672	207516	363188	19369	25939	45308
August 25	140.0	1256.08	155170	207414	362583	19405	25421	44826
September 1	140.4	1280.41	155106	206753	361859	19099	25587	44686
"Normal" Selectivity, 1979-80 Fishing Pattern								
August 10	138.0	1163.60	156176	208225	364401	19592	26200	45791
August 20	138.9	1206.81	155677	207511	363188	19325	25892	45217
August 25	139.4	1228.78	155342	207242	362583	19250	25616	44866
September 1	140.0	1255.04	154942	206917	361859	19162	25290	44451
"Log-normal" Selectivity, 1976-77 Fishing Pattern								
August 10	138.0	1192.25	156302	208099	364401	21594	29165	50759
August 20	139.0	1236.23	155603	207585	363188	21378	28460	49838
August 25	139.4	1257.16	155497	207087	362583	21095	28438	49533
September 1	140.0	1283.32	155081	206778	361859	20970	28025	48995
"Log-normal" Selectivity, 1979-80 Fishing Pattern								
August 10	137.5	1165.89	156311	208090	364401	21539	29114	50653
August 20	138.5	1209.90	155610	207578	363188	21323	28400	49723
August 25	138.9	1230.85	155505	207078	362583	21035	28377	49411
September 1	139.5	1257.03	155087	206772	361859	20910	27959	48869

Table 15. Sensitives of Estimates Using "Normal" Selectivity and 1976-77 Fishing Pattern

M	% NA	CATCH (mt)	CATCH NA	CATCH EU	TOTAL	ESC NA	ESC EU	TOTAL
		Opening Date: August 10 Mesh: 138.5 mm						
0.010	42.85	1190.00	156171	208230	364401	19632	26242	45875
0.005	42.85	1190.00	156171	208230	364401	19632	26242	45875
0.010	50.00	1176.01	182225	182176	364401	22909	22957	45866
0.005	50.00	1176.01	182225	182176	364401	22909	22957	45866
		Opening Date: August 20 Mesh: 139.4 mm						
0.010	42.85	1233.14	155672	207516	363188	19369	25939	45308
0.005	42.85	1235.23	155932	207862	363794	19401	25983	45384
0.010	50.00	1218.48	181640	181549	363188	22601	22692	45292
0.005	50.00	1220.51	181943	181851	363794	22638	22730	45368
		Opening Date: August 25 Mesh 140.0 mm						
0.010	42.85	1256.08	155170	207414	362583	19405	25421	44826
0.005	42.85	1259.22	155558	207933	363491	19453	25484	44938
0.010	50.00	1240.59	181089	181494	362583	22647	22242	44890
0.005	50.00	1243.69	181543	181949	363491	22704	22298	45002
		Opening Date: September 1 Mesh 140.4 mm						
0.010	42.85	1280.41	155106	206753	361859	19099	25587	44686
0.005	42.85	1284.90	155650	207478	363128	19166	25677	44843
0.010	50.00	1264.06	180978	180881	361859	22286	22384	44669
0.005	50.00	1268.49	181613	181515	363128	22364	22462	44826

Table 16. Calculated Catches (mt) (upper figure) and Fraction North American origin salmon in the catch (lower figure) for different mesh sizes and opening dates assuming a "normal" selectivity pattern and an increasing proportion North American origin salmon with Data in the Exploited Population (see text, scenario one)

Opening Date	Mesh size (mm)		
	130	140	150
August 10	1080.56 0.4811182662	1171.21 0.430972746	1264.53 0.38685835
August 20	1116.07 0.495195081	1206.96 0.445290666	1300.43361 0.401247811
August 25	1134.18 0.498882198	1229.29 0.449223511	1318.95 0.40535543
September 1	1156.14442 0.501315418	1247.60 0.451993292	1341.53 0.40840665

Table 17. Calculated Escapement of Salmon for various mesh sizes and Opening Dates and Fishing Patterns assuming a "normal" selectivity curve and 42.85% North American origin salmon in the exploited population.

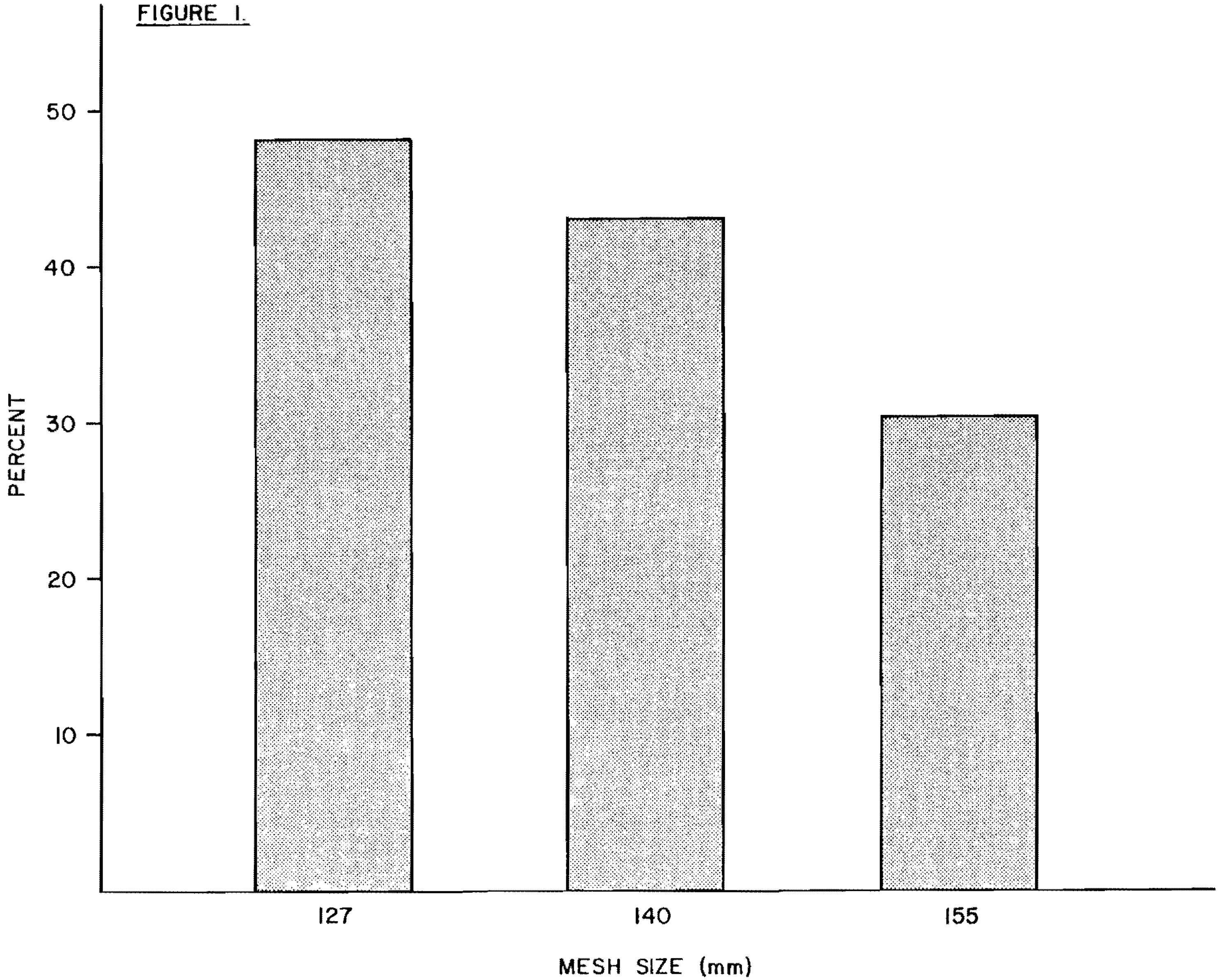
			Mesh Size (mm)		
Opening Date	Fishing Pattern	Origin	130	140	150
August 10	76-77	NA	20781	21124	51654
		Eu	63392	22323	26688
	79-80	NA	19727	21945	54263
		Eu	60204	21388	27935
August 20	76-77	NA	22629	19629	46977
		Eu	69059	23958	24429
	79-80	NA	21338	20275	49389
		Eu	65623	22854	25467
August 25	76-77	NA	23709	18999	44775
		Eu	72053	24889	23441
	79-80	NA	22295	19557	47090
		Eu	68487	23699	24378
September 1	76-77	NA	25146	18347	42249
		Eu	75792	26105	22377
	79-80	NA	23580	18798	44449
		Eu	72064	24810	23196

Table 18. Calculated Escapement of Salmon for various mesh sizes and Opening Dates and Fishing Patterns assuming a "log-normal" selectivity curve and 42.85% North American origin salmon in the exploited population.

Opening Date	Fishing Pattern	Origin	Mesh Size (mm) 130	140	150
August 10	76-77	NA	21487	25498	77267
		Eu	72478	22974	33771
	79-80	NA	20148	26938	81760
		Eu	68624	21863	35925
August 20	76-77	NA	23830	22882	69226
		Eu	79332	24914	29870
	79-80	NA	22153	24048	73353
		Eu	75172	23583	31660
August 25	76-77	NA	25223	21759	65457
		Eu	82957	26029	28169
	79-80	NA	23373	22788	69407
		Eu	78636	24589	29787
September 1	76-77	NA	27096	20573	61148
		Eu	87488	27474	26335
	79-80	NA	25032	21437	64890
		Eu	82967	25923	27775

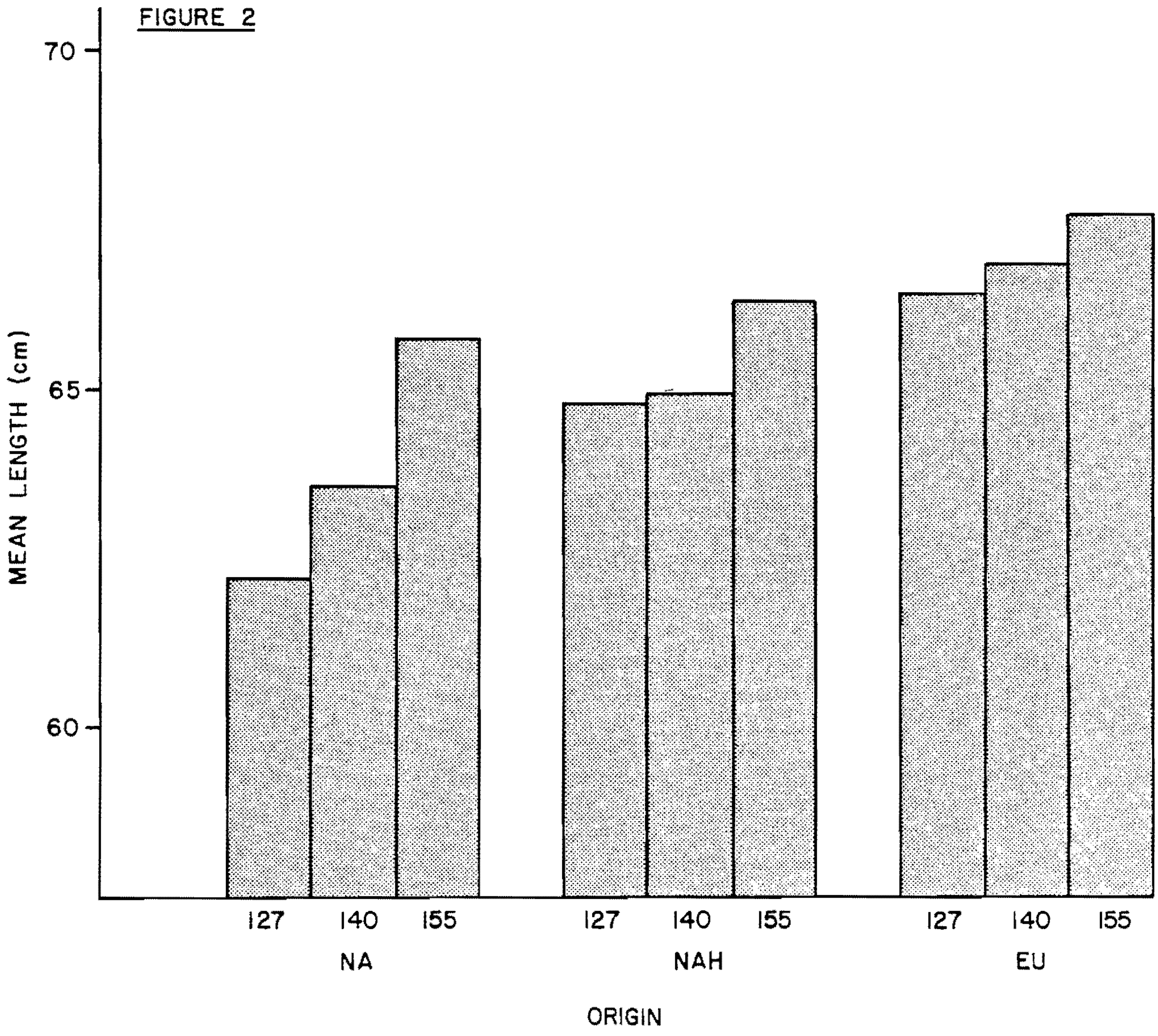
Percentage of North American Origin Salmon in Research Vessel Catches at West Greenland in Gillnets of Three Mesh Sizes (average of 1978 and 1979 observations)

FIGURE 1.



Mean Fork Lengths of Salmon of North American (NA),
North American Hatchery (NAH),
and European (EU) origin
in Research Vessel Catches
(1978 and 1979)

FIGURE 2



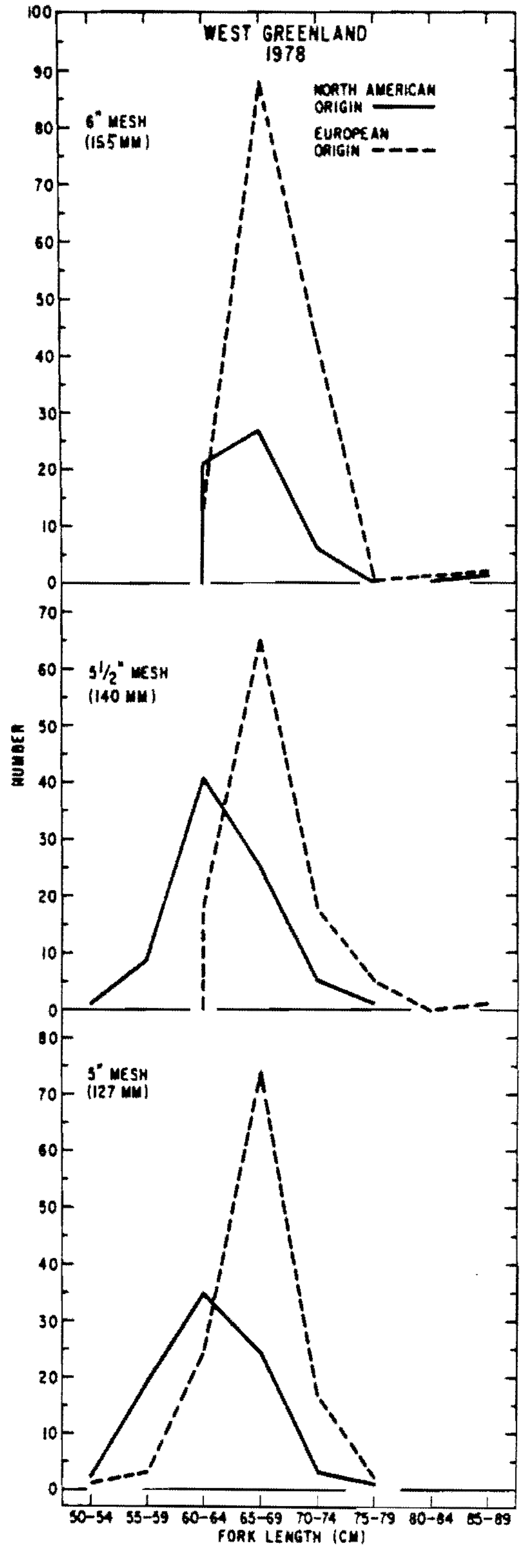
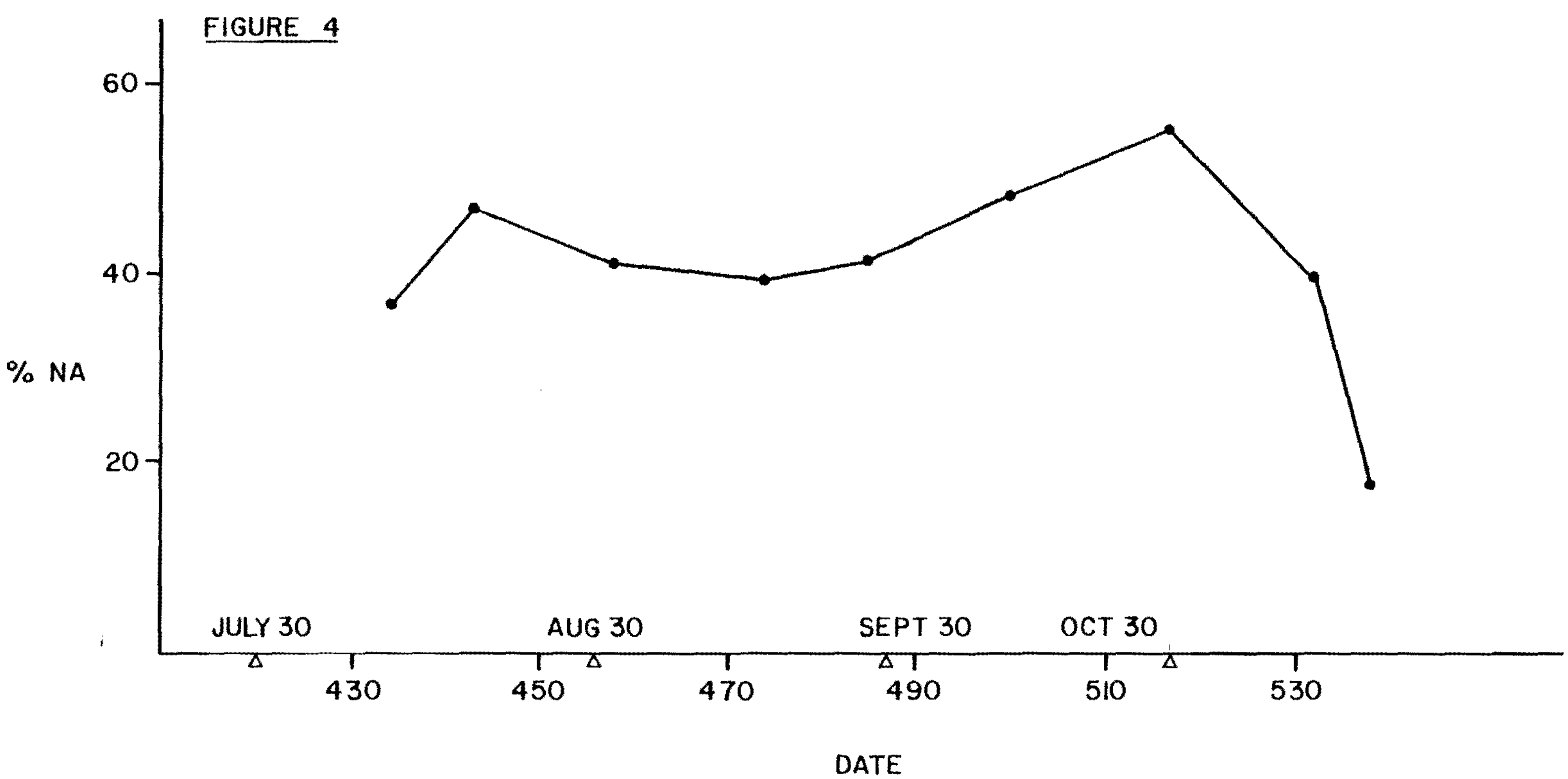


Fig. 3. The fork length distribution of European and North American origin salmon caught in 127, 140 and 155 mm mesh at West Greenland, 1978.

Seasonal Variations of Percent North American Origin Salmon
in Research Vessel Catches
(1969-1980 combined)



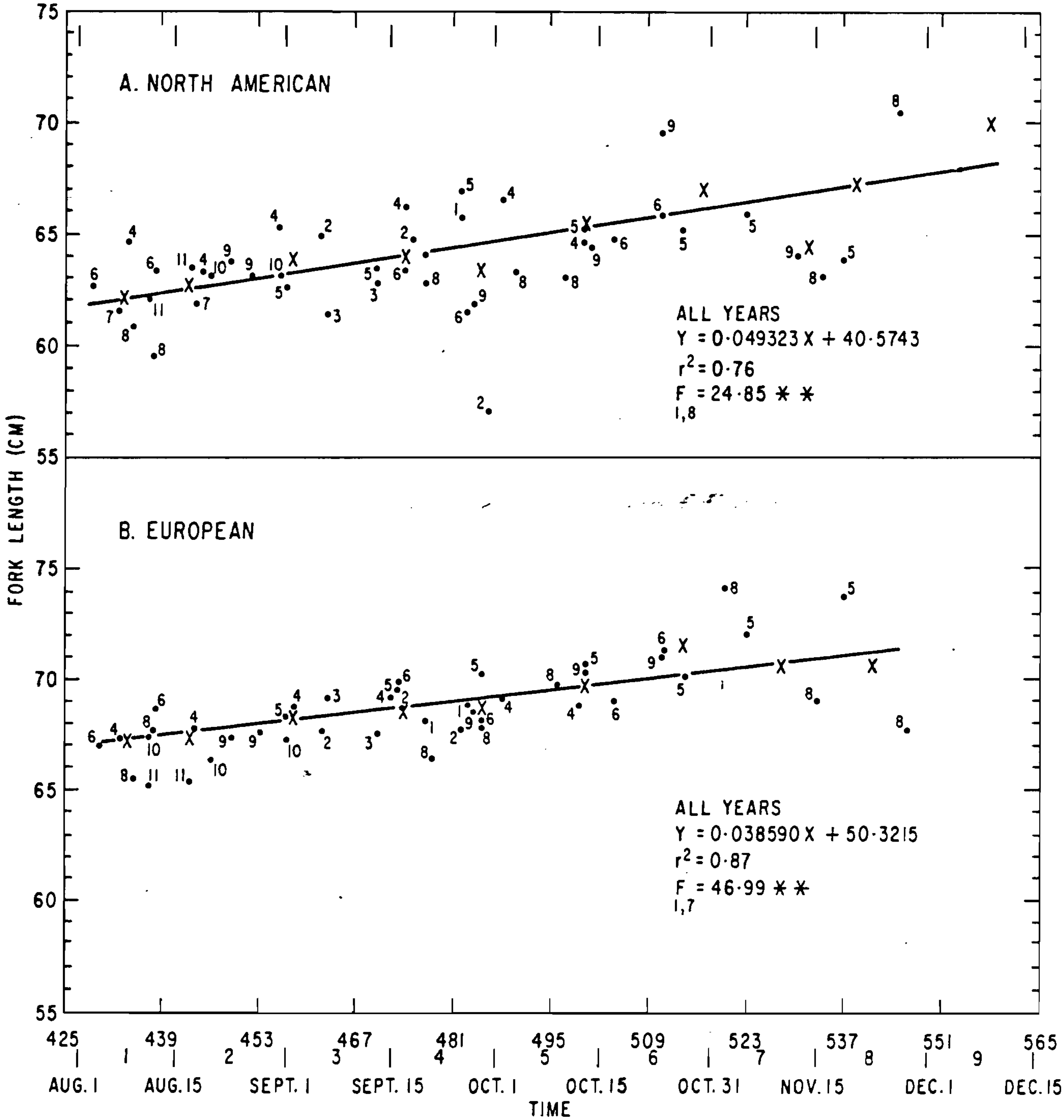


Figure 5 Observed mean fork lengths by year (.) of North American and European origin one-sea-winter salmon in research vessel catches at West Greenland on various dates and years. Lines are fitted to period means (x).

Years: 1-1969, 2-1970, 3-1971, 4-1972, 5-1973, 6-1974, 7-1975, 8-1976, 9-1978, 10-1979, 11-1980.

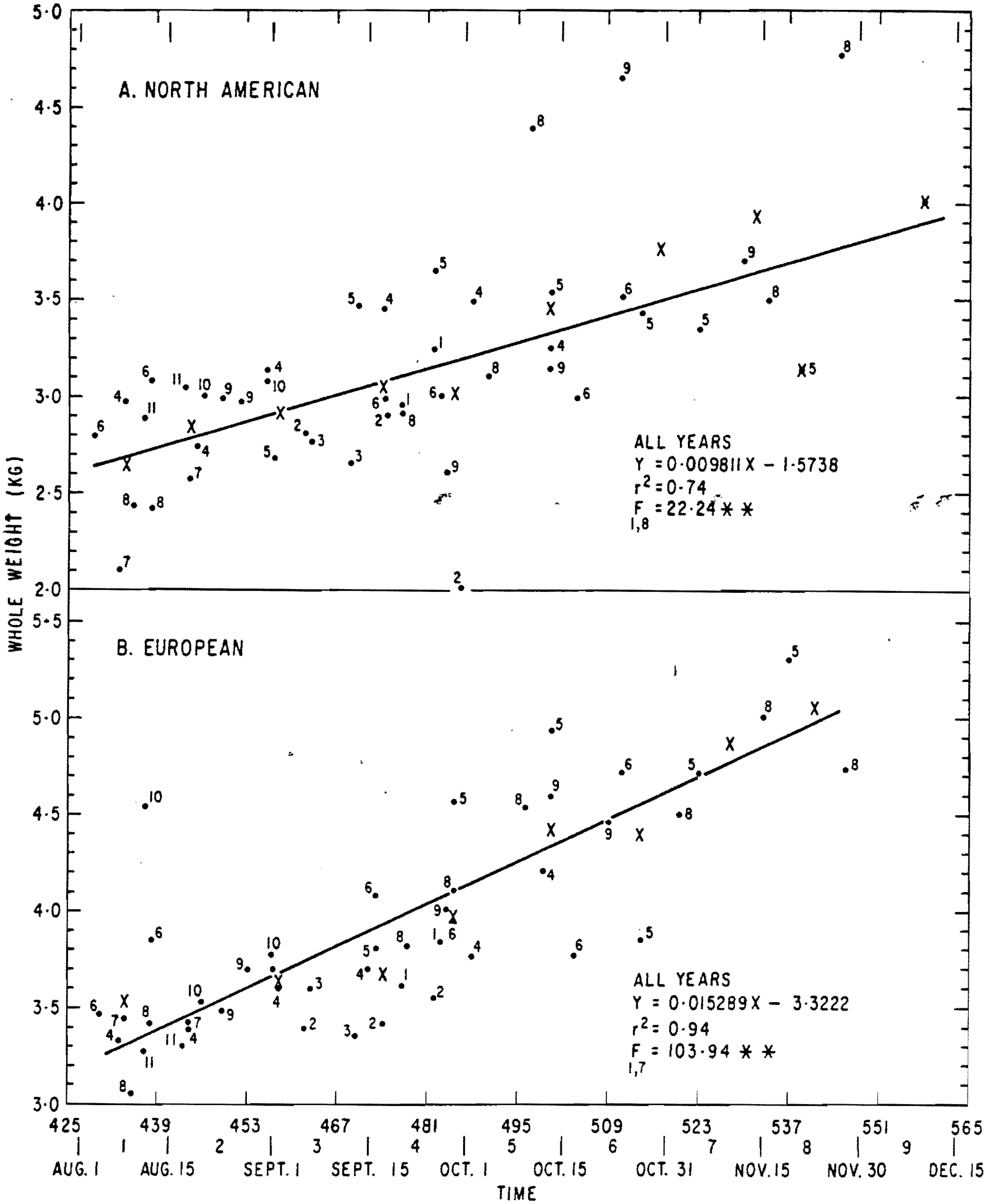


Figure 6 Observed mean whole weights by year (.) of North American and European origin one-sea-winter salmon in research vessel catches at West Greenland on various dates and years. Lines are fitted to period means (x).

Years: 1-1969, 2-1970, 3-1971, 4-1972, 5-1973, 6-1974, 7-1975, 8-1976, 9-1978, 10-1979, 11-1980.

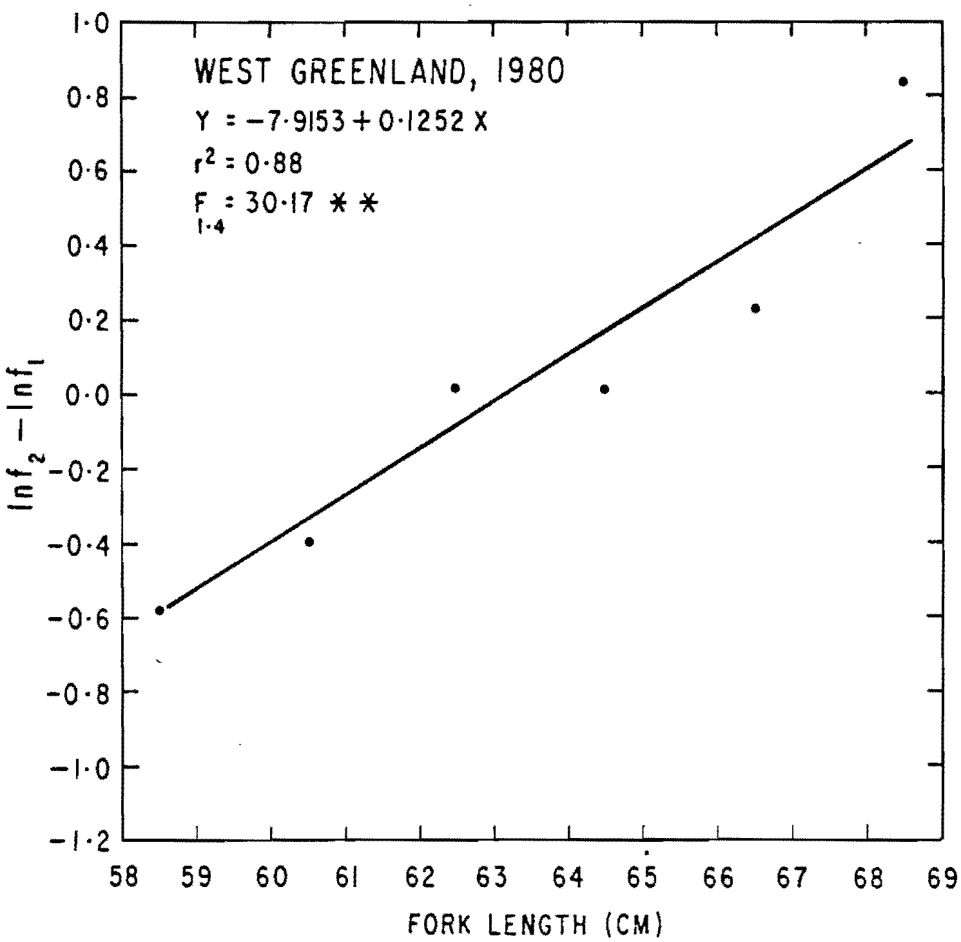


Fig. 7. The relationship of the natural logarithms of the catches at length and fork length for Atlantic salmon caught by research vessel drift gillnetting at West Greenland in 1980.

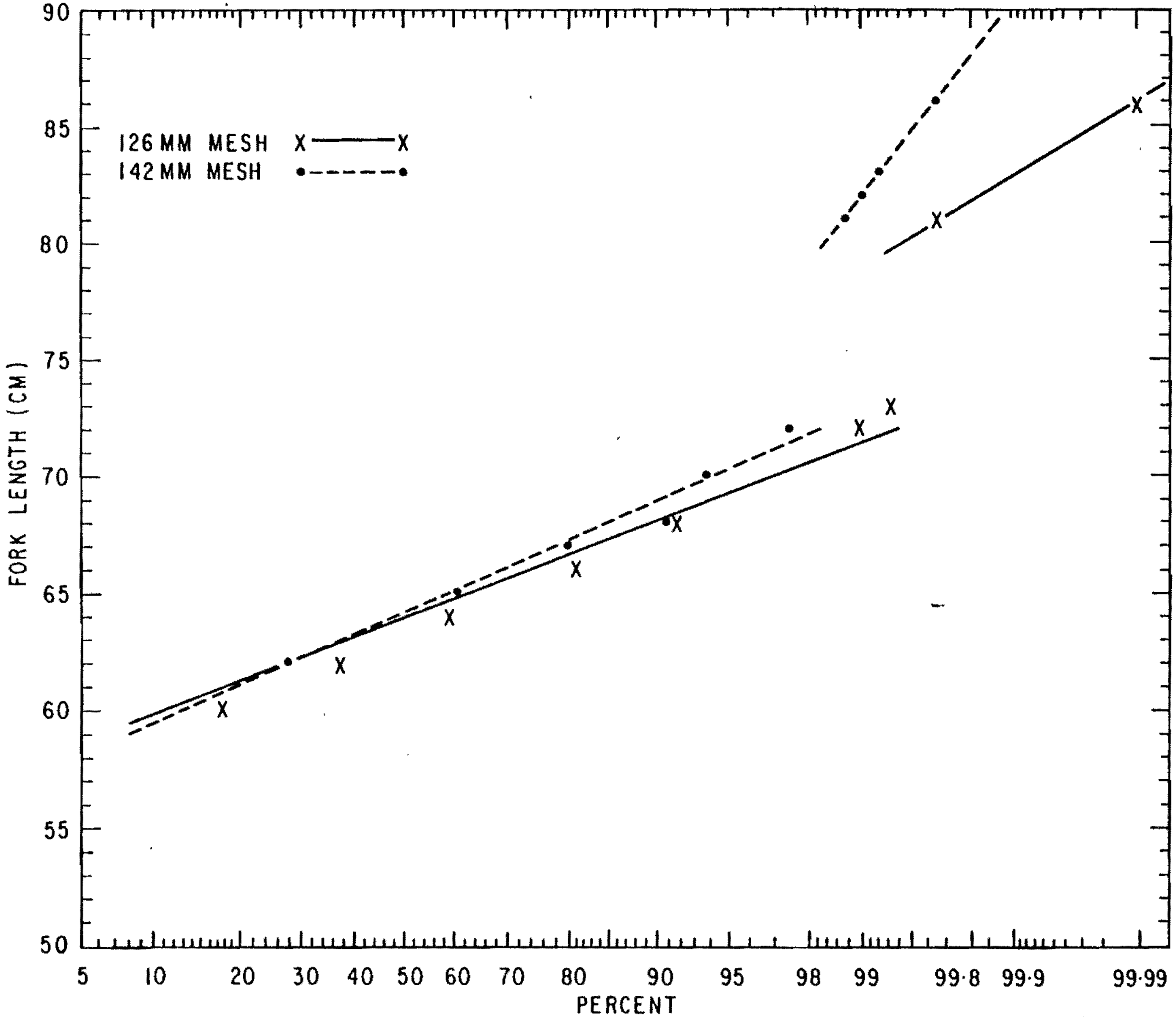


Fig. 8 The cumulative catch curve for Atlantic salmon caught in research vessel drift gillnets at West Greenland in 1980.

Figure 9: Gillnet Selectivity Curves (Upper x 0.1) for 130, 140, and 150mm mesh and length distributions of North American and European 1-SW fish in the exploited population, August 20.

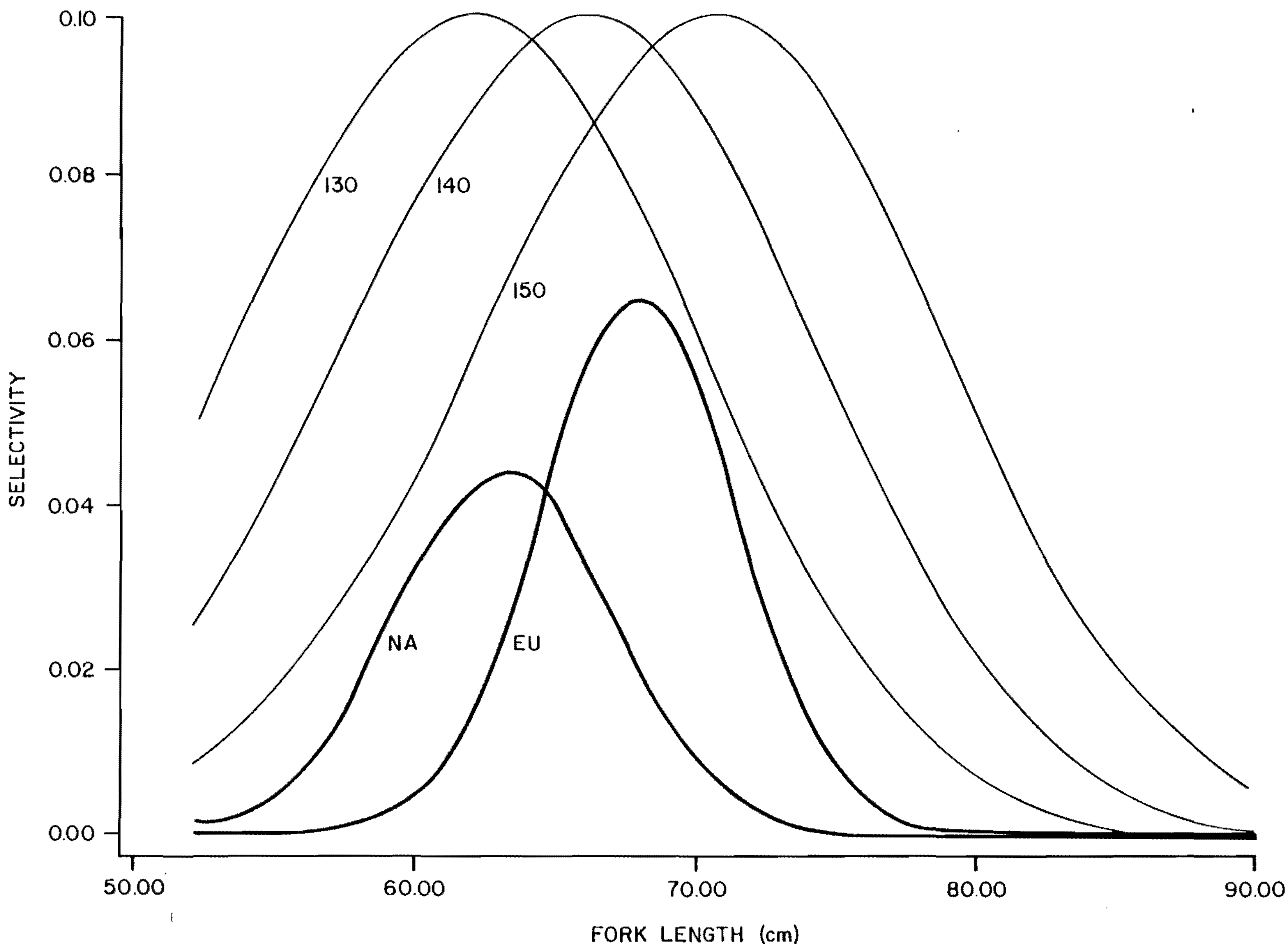
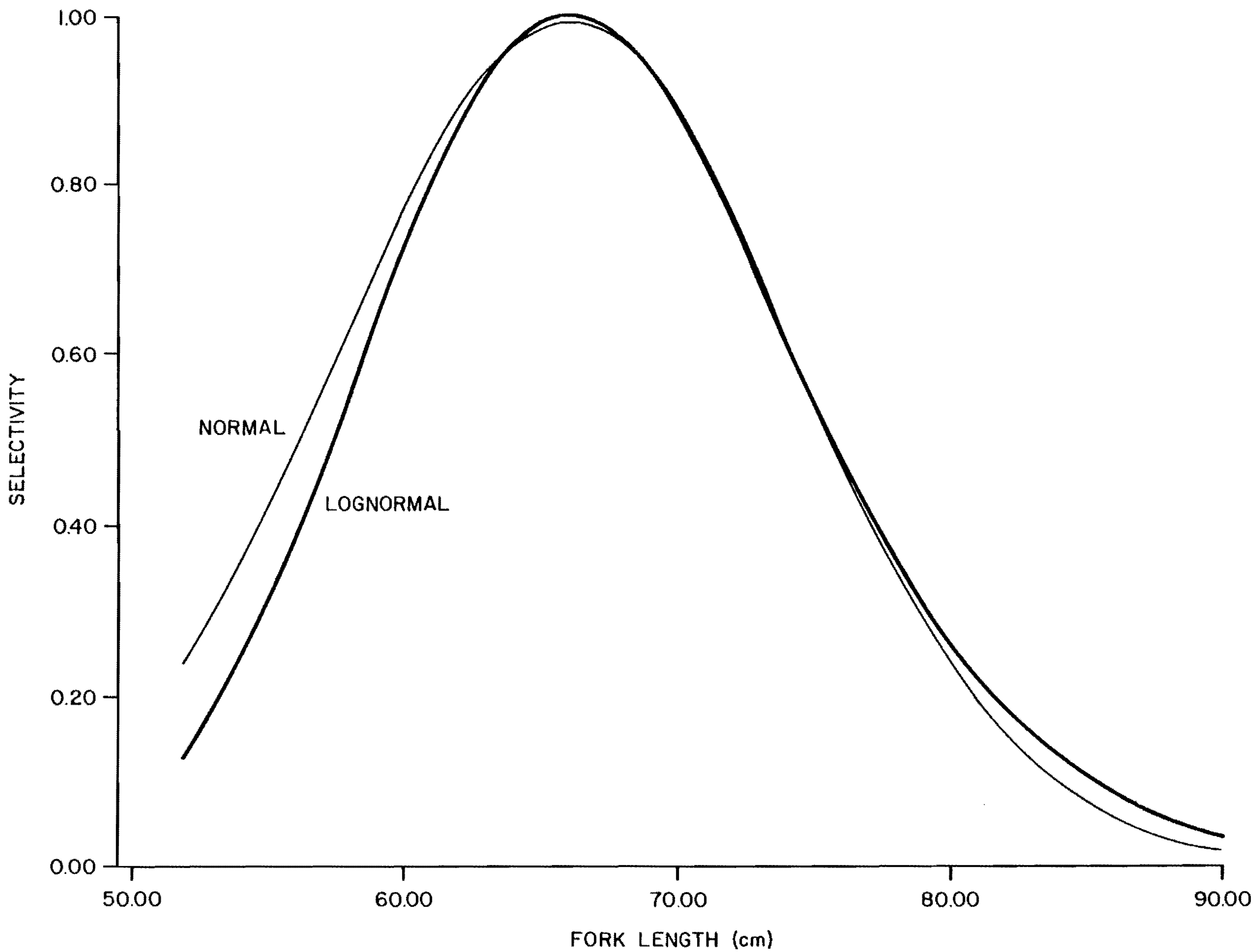
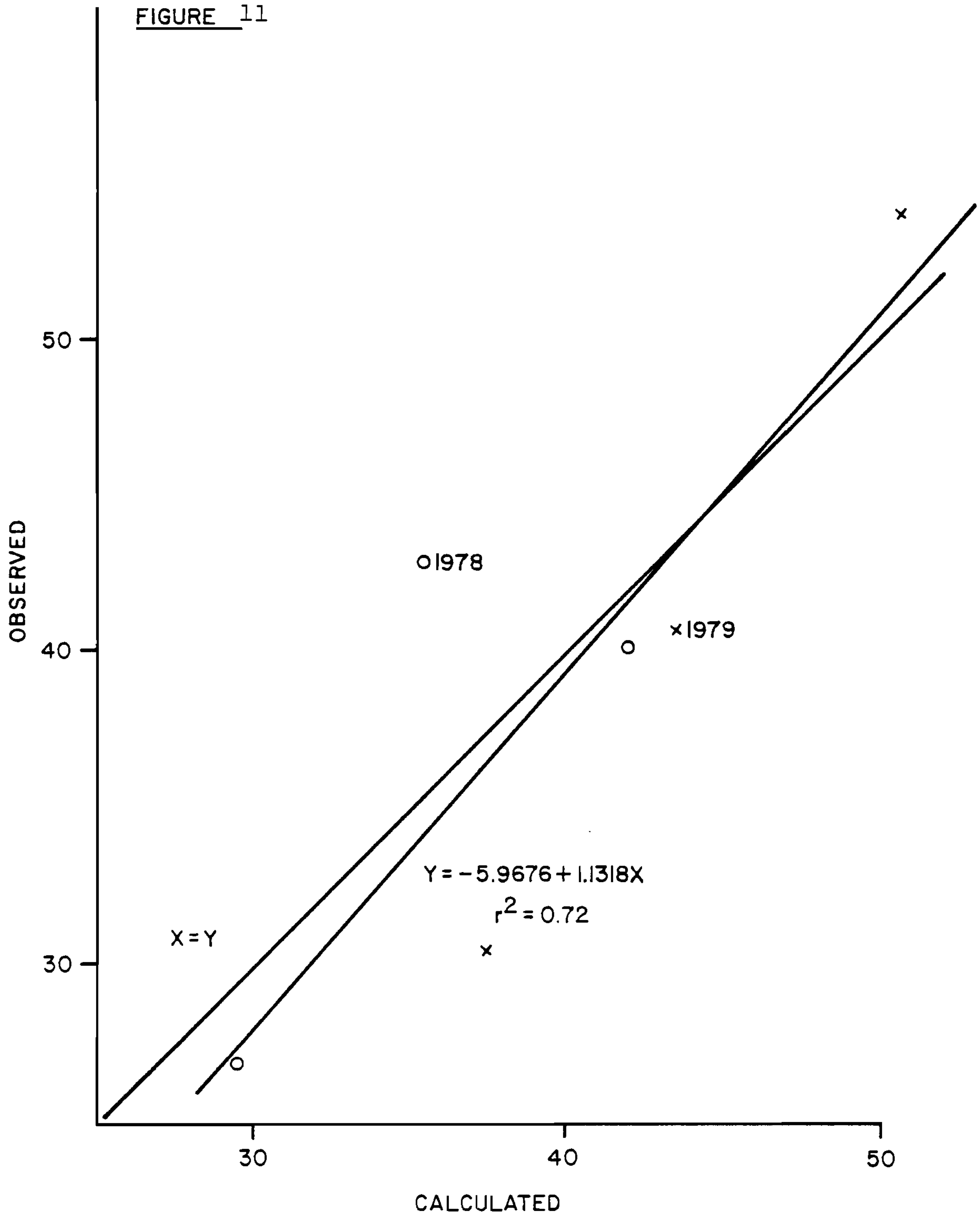


Figure 10: Normal and Lognormal Selectivity Curves for 140mm Mesh



Calculated and Observed % North American Origin Salmon
in Research Vessel Catches (1-SW)

FIGURE 11



Calculated and Observed Mean Lengths of 1-SW Salmon
in Research Vessel Catches

FIGURE 12