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Gear selectivity and escapement mortality of Atlantic salmon in drift nets at West Greenland.

by

W.G. Doubleday and D.G. Reddin

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 experiment described here, very few fish were caught by tangling in the net.

There is a portion of the population that dies an a direct or indirect result of fishing activities but it not recorded as catch; termed non-catch fishing mortality. Non-catch fishing mortality in gillnet fisheries for Pacific salmonids has been reviewed by Ricker (1976) and for Atlantic salmon by Ritter et al. (1979). The non-catch mortality due directly to injuries sustained during encounters with nets, or due indirectly to greater susceptibility to predation or disease from those injuries, is termed escapement mortality (Ritter et al. 1979). It has been suggested that some of the survivors of encounters with gillnets may have an impaired spawning potential (Petrova 1964). The extent of the losses is not easy to assess as these fish are not caught and, therefore, their numbers are unknown. This paper utilizes observed length distribution of catches to estimate the length distribution of the population encountering the gear and, hence, the proportion of fish that escape the gear after encountering it.

Theoretical considerations: Inspection of typical size-frequency distributions taken in catches by gillnets of different mesh sizes, indicates that the typical selection curve is similar to the normal distribution (Holt 1963, Regier and Robson 1966) although some positive skew is sometimes noted (Hamley 1975). The fraction of the number of fish retained is thus highest at some central length, and decreases nearly symmetrically to zero for fish much larger, or smaller, than that length. The gear selectivity estimation method utilized in this paper, proposed by Holt (1963), calculates the theoretical length-selection curve of a gillnet when at least two mesh sizes have been fished comparatively.

Notation

$f(x)$ number of fish of length x encountering the experimental gear (assumed equal for all mesh sizes)

$f_1(x)$ number of fish of length x retained by gear 1

$f_2(x)$ number of fish of length x retained by gear 2

$\mu_1 \ \mu_2$ length of maximum selection for gear 1, 2.

$\mu = K \times mesh_i$
K is a constant of proportionality

σ standard deviation of selection curve assumed equal for all experimental gears.

$$f_1(x) = f(x)e^{-\frac{1}{2}\left(\frac{x-\mu_1}{\sigma}\right)^2} \quad \text{or} \quad f(x) = f_1(x)e^{\frac{1}{2}\left(\frac{x-\mu_1}{\sigma}\right)^2}$$

$$f_2(x) = f(x)e^{-\frac{1}{2}\left(\frac{x-\mu_2}{\sigma}\right)^2} \quad \text{or} \quad f(x) = f_2(x)e^{\frac{1}{2}\left(\frac{x-\mu_2}{\sigma}\right)^2}$$

Taking logarithms and subtracting

$$\ln f_2(x) - \ln f_1(x) = \frac{1}{2\sigma^2}\left(2x(\mu_2-\mu_1) + (\mu_1^2-\mu_2^2)\right) \qquad (1)$$

Thus, if a straight line $Y = aX + b$ is fitted to the observed differences $\ln f_2 - \ln f_1$, the parameters σ, μ_1, μ_2 may be estimated from

$$\frac{\mu_2 - \mu_1}{\sigma^2} = a \qquad (2)$$

and $$\frac{\mu_1^2 - \mu_2^2}{2\sigma^2} = b \qquad (3)$$

or $$\frac{K(\text{Mesh}_2 - \text{Mesh}_1)}{\sigma^2} = a \qquad (4)$$

and $$\frac{K^2(\text{Mesh}_2 - \text{Mesh}_1)(\text{Mesh}_2 + \text{Mesh}_1)}{2\sigma^2} = -b \qquad (5)$$

$$\frac{K(\text{Mesh}_2 + \text{Mesh}_1)}{2} = \frac{-b}{a} \qquad (6)$$

$$K = \frac{-b}{a} \times \frac{2}{(\text{Mesh}_2 + \text{Mesh}_1)} \qquad (7)$$

$$\sigma^2 = \frac{(\text{Mesh}_2 - \text{Mesh}_1)}{(\text{Mesh}_2 + \text{Mesh}_1)} \times \frac{-2b}{a^2} \qquad (8)$$

Application to West Greenland.

The data used in this exercise was collected by the m.v. "Atkinson" which operated along the West Greenland coast during August, 1978, and was previously reported by Reddin and Burfitt (1979). Up to 5500m of drift (monofilament gillnets) nets were used in each set, and were arrayed in basic units of 30 nets as follows: 10 monofilament, 127 mm; 10 monofilament 140 mm and 10 monofilament, 155mm. The fish were examined on board ship and the following observations recorded: fork length (FL) - distance from the tip of the snout to the mid-fork of the tail to the nearest centimeter, round weight (RW) - (whole) to the nearest 1/10th of a kilogram, sex and a scale sample.

The 127 and 155mm nets are used to estimate parameters since that pair gave the largest value of μ_2 μ_1. The resulting estimates of K and σ were applied to the 140mm mesh as an independent check on the results.

The regression line for Mesh 2 = 155mm and Mesh 1 = 127mm was $Y = 0.17411 X - 11.504$ with s.e. of a = 0.2348, $R^2 = 0.92$ and $F_{1,5} = 54.99$** (fig.1).

Thus K = 4.6860, s.e. = 0.0392

μ_1 = 59.50cm

μ_2 = 72.63cm

σ^2 = 75.36cm

σ = 8.681cm

The standard error of K was calculated by simulation, assuming independent identically normally distributed residuals about the regression line. The sampling distribution of the estimator of K was normal to a high degree of approximation.

Note that the variation of points about the regression line is large when one of $f_1(x)$ or $f_2(x)$ is small so that length groups with few fish can lead to highly scattered points. To minimize this effect, two cm groups were chosen and groups less than 60cm or greater than 73cm were excluded from the analysis. This also minimizes the eefcts of non-normality and skew since the "tails" are not used in estimation.

The frequency distributions of the catch of the 127, 140 and 155mm mesh nets are given in Table 1. The cumulative frequency distributions produced straight line segments when plotted on probability paper, thus indicating that the catch distribution is roughly normal (Fig. 2). A normally distributed catch is consistent with a normal selectivity curve. The deviations from a straight line at the 96 percentile are due to the inclusion of both one-sea-winter and multiple-sea-winter fish in the catches.

Estimated populations were obtained for each mesh size from the observed catch at that mesh and estimated selectivity for that mesh. The difference between the estimated population and the catch for that mesh estimates the number of fish encountering that mesh size but escaping in the experiment. The observed - calculated catch for 140mm was estimated by averaging the estimated populations obtained for the other two mesh sizes and applying the estimated selection factors for a 140mm net to obtain a calculated catch.

Discussion

While the parameter estimates described are reasonable, the comparison of observed and calculated catches for the 140mm mesh indicates a substantial discrepancy. Observed and predicted catches for fish less than 63 cm and more than 73 cm are in good agreement. There is, however, a substantial deficiency (about 72 fish) in the observed catch of the 140mm net from 64cm to 72cm. Examination of the raw catch data for all mesh sizes in this range shows that for only 2 of 10cm groups is the catch of the 140mm mesh higher than the average of the other two and, in some cases, it is less than either of the others. The authors consider that this is due to chance since the selection curve for the 140mm mesh must peak between the peaks of the selection curves of the remaining nets and the 140mm net is unlikely to be less efficient than both remaining nets in this range.

Mesh sizes 127mm and 140mm caught more fish over 75cm than is consistent with the assumed normal selection curve. Thus, some skew in the selection pattern exists. To compensate for this, non-catch mortality estimates for fish over 75cm are not included in further calculations.

The estimated percentages of the actual catch (of fish up to 75cm) corresponding to fish less than 76cm encountering the gear but not retained were:

Mesh	127	140	155
% not retained	44	12	32

Since the West Greenland fishery utilizes mainly 127mm and 140mm nets, an estimate of 28% for the number of fish encountering the gear and escaping is appropriate for the commercial fishery. This estimate is biased downwards by ignoring the non-retention of previous spawners and by assuming that all fish at mid-point of the selection curve are retained. Growth of fish during the fishing season will cause the percent not retained by a given mesh size to vary seasonally.

Ritter et al. (1979) summarized the literature published to date and concluded the losses from escapement mortality are the most difficult to quantify as the estimates are dependent on being able to determine the number that escape and a mortality rate for the escapees. Thompson et al. (1971); Hunter et al. (1972) presented evidence that an average 73% of sockeye salmon escaping gillnets in Puget Sound on the Pacific Coast died in six days compared with 10% for a control group. Thus, the mortality rate on the escapees could be as high as 60%. For further calculations, it is assumed that 50% of the escapees from encounter with the net die as a result of the encounter.

If this were the case in the Greenland fishery, and Ritter et al. (1979) present evidence suggesting that this is most likely; then, for a catch of 1,200 tonnes at Greenland, 28% or 336 tonnes would escape the gillnets and about 50% of these, or 168 tonnes, would subsequently die. In addition to this loss, there may be an impaired spawning potential in those fish that do return to spawn and, since 75% of the salmon caught at West Greenland are female, the effect could be quite significant (Reddin and Burfitt 1979).

In view of the above calculations, the authors consider that, in the absence of more direct evidence on escapement mortality of salmon in the gillnet fishery at West Greenland, 10% of the catch may be assumed as a minimum estimate for the purposes of assessing the impact of the fishery.

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Table 1: The salmon caught and the population exposed to 127 and 140mm mesh gillnets.

Mesh Size (mm) Length(cm)	127	140	155	Estimated Population 127	140	155	Est. fish encountering gear but not caught 127	140	155	Obs-Calc. Catch 140mm.
52	1	0	0	1.5	0.0	0.0	0.5	0.0	0.0	-0.2
53	1	1	0	1.3	2.9	0.0	0.3	1.9	0.0	0.8
54	1	0	0	1.2	0.0	0.0	0.2	0.0	0.0	-0.2
55	2	0	0	2.3	0.0	0.0	0.3	0.0	0.0	-0.5
56	5	2	0	5.4	3.7	0.0	0.4	1.7	0.0	0.5
57	3	3	0	3.1	4.9	0.0	0.1	1.9	0.0	2.0
58	7	3	1	7.1	4.4	4.1	0.1	1.4	3.1	-0.8
59	5	1	0	5.0	1.3	0.0	0.0	0.3	0.0	-0.9
60	4	9	2	4.0	11.1	5.8	0.0	2.1	3.8	5.0
61	8	12	3	8.1	13.8	7.4	0.1	1.8	4.4	5.3
62	10	10	7	10.4	10.9	14.8	0.4	0.9	7.8	-1.6
63	24	13	6	26.0	13.6	11.1	2.0	0.6	5.1	-4.7
64	15	16	17	17.2	16.3	27.9	2.2	0.3	10.9	-6.1
65	23	14	20	28.1	14.0	29.4	5.1	0.0	9.4	-14.7
66	18	22	28	23.8	22.0	37.5	5.8	0.0	9.5	-8.6
67	18	27	17	26.1	27.4	21.0	8.1	0.4	4.0	3.7
68	20	20	27	32.3	20.8	31.1	12.3	0.8	4.1	-10.5
69	22	9	24	40.0	9.7	26.2	18.0	0.7	2.2	-21.7
70	8	10	20	16.6	11.4	20.9	8.6	1.4	0.9	-6.5
71	6	5	17	14.4	6.1	17.3	8.4	1.1	0.3	-8.1
72	3	5	4	8.5	6.6	4.0	5.5	1.6	0.0	0.2
73	1	0	7	3.4	0.0	7.0	2.4	0.0	0.0	-3.6
74	2	2	2	8.1	3.2	2.0	6.1	1.2	0.0	-1.2
75	1	3	0	4.9	5.4	0.0	3.9	2.4	0.0	-1.6
76	1	0	0	6.1	0.0	0.0	5.1	0.0	0.0	-1.5
77	1	0	0	7.6	0.0	0.0	6.6	0.0	0.0	-1.6
78	0	1	0	0.0	2.8	0.0	0.0	1.8	0.0	1.0
79	0	1	0	0.0	3.3	0.0	0.0	2.3	0.0	1.0
80	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
81	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
82	0	1	0	0.0	6.0	0.0	0.0	5.0	0.0	1.0
83	1	0	1	39.0	0.0	2.0	38.0	0.0	1.0	-2.8
84	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
85	0	0	1	0.0	0.0	2.8	0.0	0.0	1.8	-0.1
86	0	1	1	0.0	15.8	3.3	0.0	14.8	2.3	0.9
87	0	1	1	0.0	20.9	3.9	0.0	19.9	2.9	0.9
	211	192	206	351.50	258.3	279.5	140.5	66.3	73.5	-64.3

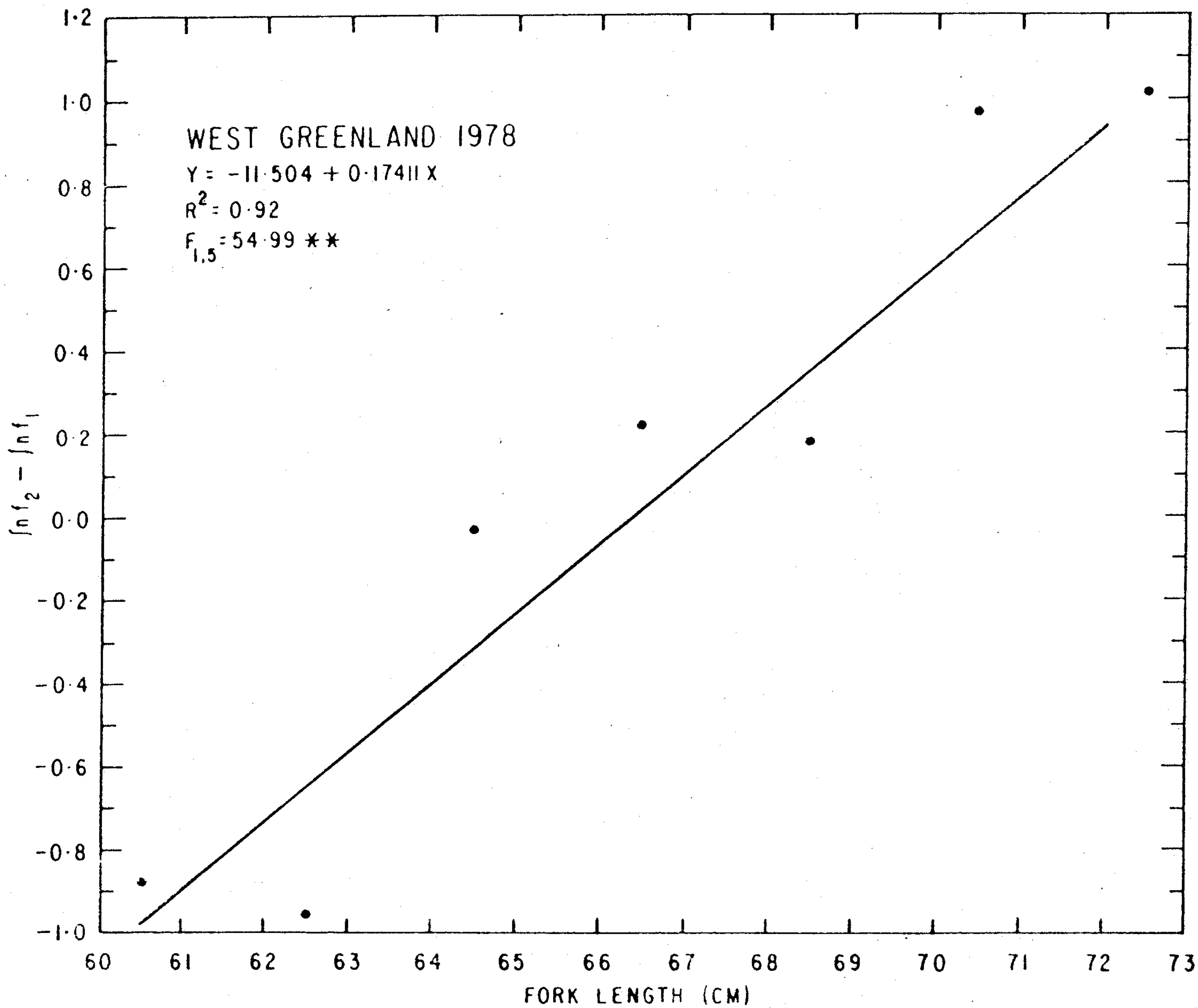

Figure 1. The relationship of the natural logarithms of the catches at length and fork length for Atlantic salmon caught by research vessel at West Greenland in 1978.

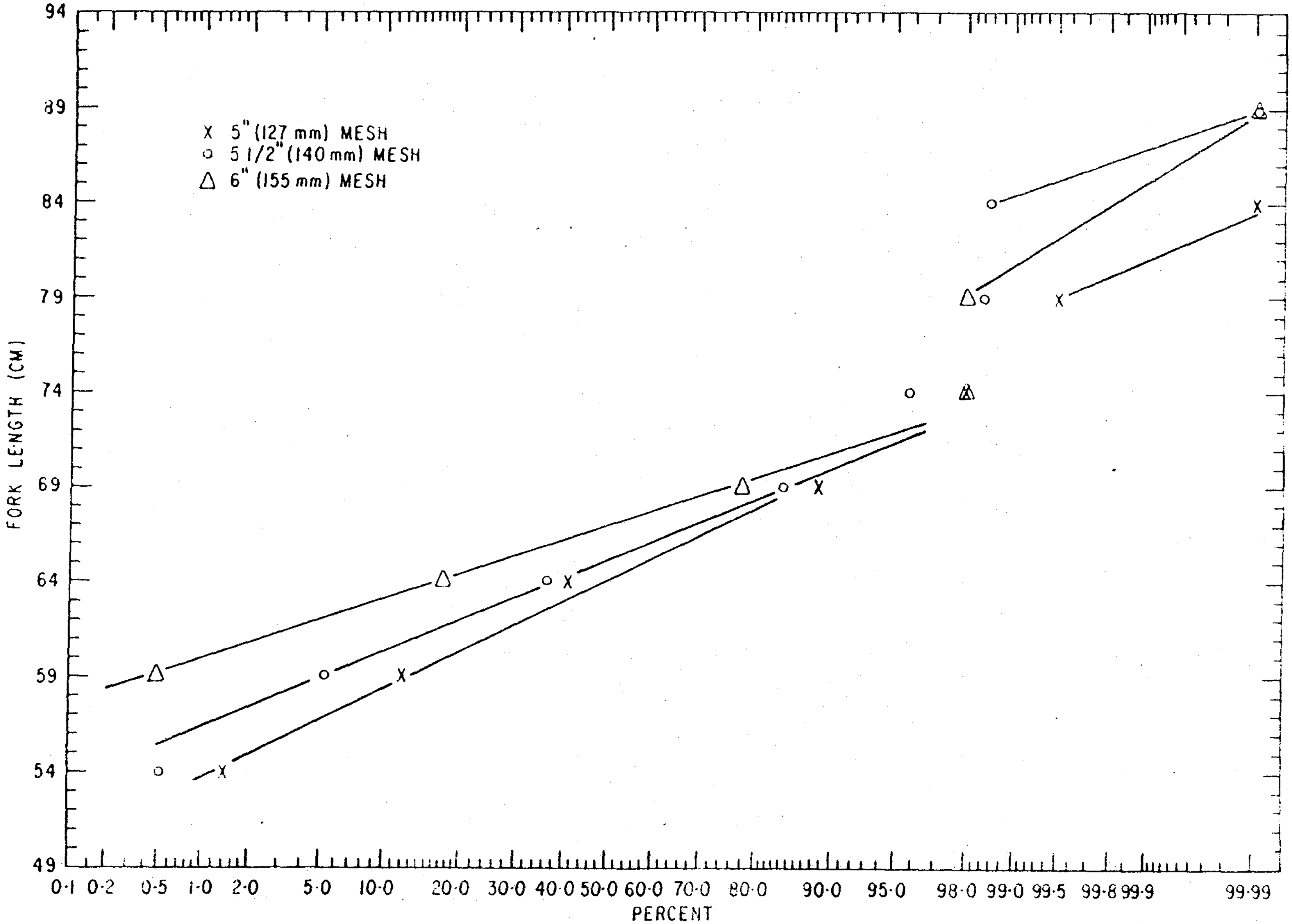

Figure 2. The cumulative catch curve for Atlantic salmon caught by research vessel at West Greenland in 1978.