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EXPERIMENTAL FISHERY WITH SALMON DRIFT NETS OF DIFFERENT MESH SIZES IN THE BALTIC IN THE AUTUMN 1990

by

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ABSTRACT

An experimental fishery with salmon drift nets of the three mesh sizes 160, 170, and 180 mm (stretched mesh) was carried out in the Baltic in the autumn 1990. A total of 2436 salmon, 52 rainbow trout and 49 sea trout were caught in 17 sets. More than 95% of the salmon were meshed either around the gills or further back at the body, while the remainder were retained in other ways. Scale samples showed that salmon caught during their second (A1+) and third (A2+) winter at sea made up 83.2% and 15.5% respectively of the catch in numbers.

The catch per unit effort was highest for 170 mm nets with 176 kg/100 nets, and the figures for 160 and 180 mm nets were 174 and 143 kg/100 nets respectively. Calculations of selection curves according to the Holt model showed the selection coefficient K to be 4.84 and the standard deviation for the normal distribution curve was 10.45. This implied the average selection length to be 77.4 cm for 160 mm meshes, 82.3 cm for 170 mm meshes and 87.1 cm for 180 mm meshes. Because of the unusually high condition factor of the fish during the experimental fishery, these values should probably be adjusted a few centimeters upwards. Model calculations suggested that increases in mesh size would increase total catch slightly, but escapement would increase substantially, 53 to 82%, only after a transition to 180 mm mesh size. The size of the increase in escapement will depend on to what extent fishing effort may increase during the spring, when the fish has grown to a larger size and is more vulnerable to a larger mesh.

Introduction

Hamley (1975) stated that a knowledge of the selectivity of gears used in a fishery is important in order to maximize yield and minimize catch of undersized fish. In the Baltic about 80% of the total offshore catch of salmon, which is equal to 60-70% of the total catch of the Baltic salmon stock, is taken by means of drift nets in the offshore fishery. This clearly shows the importance of gill netting in that area. The selective properties of drift nets used in the Baltic salmon fishery (mesh size 160 mm stretched mesh) were repeatedly examined in the 1960s by comparison with long line catches in the same area (Christensen unpublished). Some of these selectivity curves were later presented by Christensson and Larsson (1979). The 50% retention length of salmon at the lower limit of the selection curve was found to vary in the range of 61-78 cm. Considering the variability of environmental factors and the varying fish condition during the season as well as between seasons, the wide range of 50% retention lengths seemed explicable. Other studies in the Baltic in 1960s showed the salmon catch to be highest near the surface and nets with short strops being superior to nets with long strops in terms of catch (Anon. 1968).

At its meeting in 1989, the International Baltic Sea Fishery Commission discussed an investigation of the selective properties of salmon drift nets with larger mesh sizes than the present minimum, 160 mm (stretched mesh), allowed in the Baltic. The purpose was to examine the effect a larger mesh size would have on the exploitation of salmon in the offshore fishery and the number of spawners in the rivers. Sweden offered to carry out the experimental fishery and the Fishery Board commissioned the Salmon Research Institute to perform the study. The experimental fishery was carried out in the autumn 1990 on board a commercial Swedish salmon vessel. The results from the study are reported here together with conclusions regarding exploitation and escapement at different mesh sizes.

Material and methods

The study was conducted from a chartered Swedish salmon vessel, "Tärnskär" (VY 247). This was a purposebuilt gillnetter, 11.6 m in length with a 140-hp engine and a hydraulic net hauler. In total 17 sets took place in an area around northern Gotland in two separate periods, the first in late September-beginning October and the second in the first half of November 1990, see Fig. 1 and Table 1.

Multifilament nets made of black terylene (Utzon 43) and of the dimensions 400 meshes long x 45 meshes deep were used. The net panel was mounted without strops directly on a 6-mm braided polypopylene headrope that had a float every 2.35 m. All nets had a hanging ratio (headrope length/netting length) of 0.95, the same as that of commercial drift nets. Nets with the nominal mesh sizes 160, 170 and 180 mm (stretched mesh) were used and measurements of meshes were made with an ICES gauge of 4 kg tension while the net was wet. The average mesh size was very close to the nominal with millimeter deviations found in a few meshes. The maximum numbers of nets were 120, 160 and 220 of the three mesh sizes 160, 170 and 180 mm respectively. The number of nets of each mesh size was based on the expected CPUE for the different mesh sizes (Anon. 1988). In order to be able to replace damaged nets, 10 spare nets were kept for each mesh size. The nets were used in gangs of 10, all of the same mesh size, which were kept in a sack when not fishing. When shooting the nets, a gang was randomly chosen and combined with another gang to a fleet of 20 nets with a bouy at each end. This implies that for those sets when all nets were used, we fished with 500 nets in a total of 25 fleets, each fleet containing two randomly chosen gangs of nets. All gangs were marked with mesh size on the floats. An attempt to follow the usage and the individual CPUE for each gang was made by marking with numbered circular brass plates fastened to the headrope. However, within a few sets this system broke down as the numbered plates were rapidly lost, with the result that only the mesh size could be recorded from each gang.

The nets were normally shot between 4.30-7.30 p.m. and hauled between 00-10 a.m. When hauling the nets, the fish were removed one at a time and the mesh size was recorded. It was noted if the fish was caught in mesh number 1 next the headrope, the headmesh, or in the upper or lower half of the net. The fish was classified as to mode of capture:

a. gilled, meshed at the gills;

b. wedged, meshed between the operculum and the point of maximum girth;

c. other, normally tangled.

Total length of each fish was measured to the nearest half centimeter and if the sea was was not to rough, the fish was weighed on either of two spring balances. One was used for fish in the interval 0-5 kg and the other for fish above 5 kg. Girth was measured at the mesh mark (for wedged fish only) to the nearest half centimeter using a tape measure, at the anterior of the dorsal fin (maximum girth) and at the rear of the operculum (opercular girth). A scale sample was taken from each salmon in order to determine age and origin. Whether the fish were of wild or reared origin was determined by the method of Antere and Ikonen (1983). All by catches of fish were recorded, but due to a misunderstanding the registration of birds caught, and above all, the determination to species, was not made. In a similar way the distribution of fish caught at different heights as well as the mode of capture were sometimes recorded with less than appropriate care, as the fish occasionally were so closely gathered in the net that the observer barely had time to register all data.

All data were fed into computer files and the procedures REG and GLM in SAS (SAS 1985) were used for regression and analysis of variance. When making indirect calculations of selectivity curves, the classical Holt (1963) model was used, and the direct calculations based on girth measurements followed Hamley (1975). Catch per unit effort (CPUE) figures were standardized to the length of 160 mm nets, by considering the somewhat longer nets of 170 and 180 mm mesh size.

Results and discussion

Effort

The total fishing effort during the study was 7610 net x nights, see Table 1. Fiftyfive percent of the effort was conducted during period 1 in September and beginning of October and the remaining fortyfive percent during period 2 in November.

Salmon catch

The salmon catch by mesh size and set is shown in Table 2. It was evident that the mean length and its standard deviation varied rather little from set to set. This means that the catches fulfilled the requirements which were established as necessary to calculate selection curves (Anon. 1988). The mean length increased by 3 cm from period 1 to period 2 and the mean length of the summed sample was 74.7 cm. The differences in length between the different mesh sizes were fairly small, see Fig. 2. Only a minor part of the individuals were 60-65 cm in length, which was unusual especially in September. Thirteen undersized salmon, <60cm, were caught or 0.5 % of the total catch. Five of them were caught in 160 mm mesh, three in 170 mm mesh and five in 180 mm mesh. A total of 37 or 1.52% of the salmon were tagged, while 82 or 3.37% lacked an adipose fin.

Height distribution of catch

In contrast to earlier experiences (in Christensen and Larsson, 1979), the catch in the headmesh was rather low, Table 3. Approximate CPUE values during the entire fishery were 9.5 salmon/one million meshes for the headmesh and the corresponding figures for the upper and lower half of the net were 33.9 and 2.7 salmon/one million meshes respectively. Perhaps the absence of strops in our nets together with the unusually large size of the smallest fish may have contributed to the low number of salmon retained in the headmesh. It is also worth noting that the catch in the headmesh decreased considerably from period 1 to period 2. This is consistent with previous observations that the catch in the headmeshes is high primarily in summer and early autumn (Christensen and Larsson 1979). In earlier studies a large proportion of the total catch of undersized salmon was taken in the headmeshes, but as the number of undersized salmon in the autumn 1990 was very low, we have no direct data supporting this observation. However, the size of the salmon retained increased with depth, but the difference in length between fish caught in the headmesh and the lower half of the net was only 5.2 cm.

Age and catch per unit effort

Of 1953 scale samples evaluated, 240 or 12.3% originated from wild salmon, while the remainder came from reared fish. Salmon caught during their second winter at sea (A1+) were completely dominating, as they made up 83.2% of the total catch in numbers, Table 4. Catch per unit effort by mesh size showed a decreasing catch of second winter salmon with increasing mesh size. The catch decreased by 18% from

160 to 170 mm and by 38% from 160 to 180 mm. On the other hand the exploitation of third winter salmon (A2+) seemed to increase from 160 to 170 mm mesh size. When studying these figures, however, it must be remembered that the salmon in the autumn 1990 had grown unusually well (see section selectivity), which increased the exploitation rate at larger mesh sizes. As expected, catch per unit effort was at a maximum early in the autumn with 44.1 salmon/100 nets in 160 mm nets. The catch in numbers was highest in 160 mm nets, but on account of the larger mean weight of salmon in larger meshes, the catch in weight was slightly higher in 170 mm nets. The catch in weight in 180 mm nets was 82.1 % of that in 160 mm nets.

Bycatches

A number of rainbow trout and sea trout were caught, Table 6. They made up 2.0 and 1.9 % of the total catch in numbers and slightly less in weight. Two flounders (Platichthys flesus) were the only other fish retained in the nets. About 39 birds (uncertainty ± 3 birds) were caught, 14 of them during one night. Most of them were guillemots (Uria aalge) and razorbills (Alca torda), but also loons (Gavia spp.) were taken and perhaps other species too. Most of the birds were alive at hauling and many of them could be released without apparent injuries.

Selectivity

Fig. 3 shows the length distribution of salmon caught by the three methods. Gilled fish were as expected larger than wedged fish, but surprisingly they also varied more in size. This evidently depended on the taper of the fish being very marked in the opercular area. Salmon caught by a mesh around the anterior part of the gills will therefore be quite different in size from those meshed around the posterior parts of the opercular area. Fish caught by the "other" method had a very large variation in size, but as only 115 or 4.7% of the total number of salmon were caught by this non selective method, the size selective character of salmon driftnets is very marked.

The gillnet fishery is based on the idea that a fish is caught only if its opercular girth is smaller but maximum girth larger than the mesh perimeter. On account of elasticity of the net material and compression of the fish, the smallest fish retained by the mesh will have a maximum girth which is 5-10% larger than the mesh perimeter (Hamley 1975). In order to find the correct value in our experiments we first calculated the perimeter of the meshes, which were 320, 340 and 360 mm for the different mesh sizes. We then selected wedged salmon where the girth at the netmark was equal to the maximum girth. The maximum girth for these individuals was on average 9% larger than the mesh perimeter. This means that fish with a smaller maximum girth will on the average not be retained in the net. Gilled fish had an opercular girth which was on average 4% larger than the mesh perimeter. Fish with larger opercular girth will therefore not by caught. In order to translate these calculations to fish length, maximum girth (MAXG) and opercular girth (OG) were regressed on fish length, Fig. 4. As the regression equations for MAXG against fish length during period 1 and 2 did not differ ($P>0.05$), all individuals were pooled to one estimate. From the figure can be seen that salmon in the following length intervals will be caught.

Mesh size	Minimum length		Maximum length
160 mm	63.1	-	79.3 cm
170 mm	66.5	-	84.3 cm
180 mm	70.0	-	90.3 cm

The length interval will be strongly dependent on how well-fed the fish is. The condition factor = Weight $/(\text{length})^3$
is the normal measure of how well-fed a fish is. Recaptures from Swedish tagging data 1977-90 were used to calculate the average condition factor during September-October. It was found to be 1.10 for salmon with both weight and length reported. Salmon caught during the experimental fishery had an extremely high condition factor of 1.24, which means that the fish had unusually large girths and therefore unusually short fish were caught in the nets. In order to calculate an average selection interval the following calculations were carried out. It was assumed that salmon

$$\text{Weight} = \text{Constant 1} + \text{Constant 2} * \text{MAXG} * \text{MAXG} * \text{Length}$$

This can be transformed to

$$MAXG = Constant\ 3 + Constant\ 4 * \sqrt{Weight\ /\ Length}$$

For the results from the experimental fishery the regression was the following:

$$MAXG = -2.28 + 171 * \sqrt{Weight\ /\ Length} \qquad R^2 = 0.92 \quad N = 428$$

This equation was assumed to give a measure of maximum girth if weight and length was known. Recaptures of tagged salmon caught in driftnets from September to June in the years 1977-90 were used to calculate an average MAXG, see Fig. 4. The average opercular girth is more difficult to calculate as the connection with fish condition probably is weaker. As opercular girth furthermore only influences the less important, upper border of the selection interval, it was not recalculated. If the calculated average values of MAXG are used, the selection interval will be the following:

Mesh size	Minimum length		Maximum length
160 mm	66	-	(79.3 ?) cm
170 mm	70	-	(84.8 ?) cm
180 mm	74	-	(90.3 ?) cm

Another method of calculating selectivity is to use the method developed by Holt (1963). Knowledge about the length composition of the fish population is not demanded, but instead it is assumed that the selection curves for nets of different mesh sizes have the same height and shape and can be approximated by a normal distribution curve. Calculations for period 1 and 2 separately gave similar results, thus the periods were summed to one final estimate which was based on catch in 5 cm length intervals from 60-95 cm with N $\geq$ 12 in each group. The three calculations gave the following results:

	Average selection length (fish length in cm)			Holt selection coefficients	
	160 mm	170 mm	180 mm	K	SD
Period 1	77.7	82.5	87.4	4.86	9.92
Period 2	75.2	79.9	84.6	4.70	12.38
Total	77.4	82.3	87.1	4.84	10.45

The appearance of the summed estimate is shown in Fig. 5. Presumably the selection curves are slightly too far to the left, towards smaller fish lengths. Probably K-values of about 5 would be more reasonable, which would give average selection lengths of about 80, 85 and 90 cm for the three mesh sizes. These values are in agreement with those calculated earlier (Anon. 1988).

Exploitation and number of spawners

In order to calculate effects of an increased mesh size on catch in the offshore fishery and number of spawners, we used the spreadsheet-model for the Baltic salmon population used by the Baltic Salmon and Trout Assessment Working Group (Anon. 1988). As the model is described in detail in the report of the Working Group, we here discuss the two factors which are changed, namely exploitation rate and weight at catch in the offshore fishery.

Tagging data from the years 1977-90 for salmon were used once more. In total, the material comprised 7870 salmon caught in the driftnet fishery during their second winter at sea (A1+). The lower length limits of the catchability based on girth measurements were used to calculate effects on exploitation. For a change from 160 to 170 mm mesh, fish in the interval 66-70 cm will be influenced by the increase in mesh size. There were 1834 individuals in this interval or 23.2% of the total catch of second winter fish. For a transition to 180 mm and an affected interval of 66-74 cm, the corresponding figure was 3369 salmon or 42.8% of total number. This would be the decrease in exploitation if the salmon did not grow during the fishing season and no non selective long line fishery occurred in November-February. Normally about 20% of the catch is taken by long lines and additionally the salmon saved by the increase in mesh size will be available in that fishery, resulting in an increased CPUE. Furthermore the salmon grow by on average 2-4 cm from September-October to March-April, the time for spawning migration, which means that still more of the salmon will be caught in the spring. In alternative 1 it is calculated that 50% of the original reduction remains, while 65% remains in alternatives 2 and 3. Differences in weight at catch between mesh sizes are assumed equal to those in the experimental fishery.

Salmon caught by driftnets in their third winter increase from on average 77.6 cm in length in September to 86.7 cm in May. This means that their mean length nears the peak of the 170 and 180 mm mesh selection curves at the end of the winter, Fig. 5. On account of the effort peak in September-October, when the average salmon still is closest to the peak of the 160 mm mesh selection interval, the exploitation will decrease, at least slightly, if 180 mm meshes are introduced, see alternative 3. If fishermen on the other hand are able to exert a larger fishing effort during the spring months, the decrease in exploitation of third winter fish will be very small, or none as in alternative 2.

	Present situation	Alternative 1		Alternative 2		Alternative 3
Mesh size	160 mm	170 mm	180 mm	170 mm	180 mm	180 mm
Expl 2 winter	0.73	0.65	0.58	0.62	0.53	0.53
Catch weight 2 w kg	3.5	3.8	4.0	3.8	4.0	4.0
Expl 3 winter	0.95	0.95	0.95	0.95	0.95	0.90

Effects on the catch in the offshore fishery, coastal fishery and escapement are given in the table below. All catch figures are given in tonnes and escapement (excluding grilse) in percent of the number of smolts.

grilse) in percent of the number of smolts.

	Present situation	Alternative 1		Alternative 2		Alternative 3
Mesh size	160 mm	170 mm	180 mm	170 mm	180 mm	180 mm
Offshore catch	3163	3342	3433	3337	3415	3341
Coastal catch	518	629	727	671	797	866
Total catch	3723	4024	4220	4063	4277	4279
Escapement	0.303	0.389	0.464	0.422	0.518	0.552

In all alternatives the catches both overall and in the offshore fishery increase slightly. The increase in the coastal fishery is large, 67%, primarily in alternative 3. Escapement increases by rather small amounts, especially in the transition to 170 mm meshes, and the largest increase occurs in alternative 3 with an increase of 82% from the present situation.

Final conclusions

The attempts to generalize the results from the experimental fishery are made more difficult by the fact that the salmon had unusually high condition factors at the time of the experiment. As salmon below 65 cm in length were scarce, virtually no information was obtained concerning catchability of undersized fish.

The experimental fishery showed nets of 170 and 180 mm mesh size to function well from a technical point of view and it is obvious that the catches would not suffer from an increase in mesh size. A change of mesh size to 170 mm would have relatively small effects, both on catch and escapement. If it is judged as important to decrease the rate of exploitation and increase the number of spawners then only 180 mm mesh size is appropriate. The model calculations also suggest that the catch in the fishery will increase most under this alternative.

References

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Table 1. Details about the experimental fishery. The fishing areas are shown on the map in Fig. 1.

Set nr	Date	Period	Fishing area	Number of nets 160 mm	170 mm	180 mm	Total
1	Sep 16-17	1	1	120	160	220	500
2	Sep 17-18	1	1	120	160	220	500
3	Sep 18-19	1	1	100	140	200	440
4	Sep 23-24	1	1	80	130	190	400
5	Sep 27-28	1	1	80	130	190	400
6	Sep 29-30	1	1	110	130	200	440
7	Sep 30-Oct 1	1	1	90	130	180	400
8	Oct 2-3	1	1	120	160	220	500
9	Oct 3-4	1	1	90	90	140	320
10	Oct 4-5	1	1	90	90	140	320
11	Nov 1-2	2	1	120	160	220	500
12	Nov 2-3	2	1	120	160	220	500
13	Nov 3-4	2	1	120	160	220	500
14	Nov 4-5	2	1	110	160	220	490
15	Nov 9-10	2	2	120	160	220	500
16	Nov 10-11	2	2	80	130	190	400
17	Nov 12-13	2	2	120	160	220	500
Sum period 1				1000	1320	1900	4220
Sum period 2				790	1090	1510	3390
Total				1790	2410	3410	7610

Table 2. Number, mean length and standard deviation (SD) of salmon catch by mesh size and set.

		Mesh size											
		160			170			180			Total		
Period	Set	Length			Length			Length			Length		
		N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD
1	1	59	71.8	8.00	60	73.0	7.25	72	76.9	9.63	191	74.1	8.69
1	2	36	71.4	7.83	48	72.5	7.25	45	76.6	11.3	129	73.6	9.22
1	3	52	69.7	5.17	69	75.2	8.53	83	74.7	7.74	204	73.6	7.77
1	4	36	72.2	6.19	32	76.4	8.90	58	77.1	9.76	126	75.5	8.85
1	5	38	72.3	7.67	51	75.6	7.58	58	76.9	8.33	147	75.3	8.06
1	6	47	70.9	6.60	68	73.9	9.66	73	73.0	6.20	188	72.8	7.77
1	7	53	69.4	5.97	74	71.9	6.96	50	74.7	6.71	177	71.9	6.88
1	8	55	72.3	7.40	81	72.8	6.26	82	75.3	6.79	218	73.6	6.86
1	9	33	71.2	6.40	26	73.6	7.55	24	78.6	9.70	83	74.1	8.31
1	10	30	70.3	5.21	36	71.6	5.39	48	75.3	8.11	114	72.8	6.93
2	11	46	74.1	7.55	50	77.1	7.97	74	77.6	6.72	170	76.5	7.44
2	12	39	75.3	7.18	52	78.2	11.4	79	76.7	8.22	170	76.8	9.11
2	13	29	73.6	9.20	47	77.1	10.4	40	78.6	9.85	116	76.8	10.0
2	14	35	73.6	6.47	54	75.6	7.51	73	75.6	7.56	162	75.2	7.33
2	15	25	74.1	9.68	33	79.7	10.8	28	78.0	6.28	86	77.5	9.41
2	16	11	79.2	10.8	13	78.0	11.2	25	80.4	9.15	49	79.5	9.92
2	17	22	75.8	7.37	37	77.3	8.10	45	78.3	9.67	104	77.4	8.65
Sum Period 1		439	71.1	6.78	545	73.5	7.71	593	75.6	8.39	1577	73.7	7.94
Sum Period 2		207	74.6	8.02	286	77.4	9.50	364	77.4	8.17	857	76.7	8.68
Total		646	72.2	7.38	831	74.9	8.56	957	76.3	8.35	2434	74.7	8.33
Salmon without measured length		2			0			0			2		

Tabell 3. Number, mean length and standard deviation (SD) of salmon caught at different heights in the nets. The catch in the headmesh at the headrope is not included in the catch in the upper half of the net.

Period	Headmesh			Upper half			Lower half		
		Length			Length			Length	
	N	Mean	SD	N	Mean	SD	N	Mean	SD
1	27	72.1	6.90	1423	73.5	7.80	125	76.2	9.08
2	2	69.0	1.41	794	76.6	8.56	60	78.9	10.04
Total	29	71.9	6.70	2217	74.6	8.21	185	77.1	9.46
Total %		1.2			91.2			7.6	

Table 4. Age distribution and catch per unit effort (CPUE) by age and mesh size. As scale samples were absent from about 15% of the fish, CPUE only give relative levels.

	160 mm			170 mm			180 mm			Total	
AGE	N	%	CPUE	N	%	CPUE	N	%	CPUE	N	%
A+	3	0.6	0.2	1	0	0	0	0	0	4	0.2
A1+	465	88.9	27.7	543	82.0	22.7	619	80.5	17.2	1627	83.2
A2+	52	9.9	3.1	109	16.5	4.6	142	18.5	4.0	303	15.5
A3+ and older	3	0.6	0.2	9	1.4	0.4	7	0.9	0.2	19	1.0

Table 5. Catch per unit effort (CPUE) in numbers and weight (kg) by mesh size and period. The last line give catch in 170 and 180 mm nets as a percentage of that in 160 mm nets.

Period	160 mm		170 mm		180 mm	
	N	Weight	N	Weight	N	Weight
1	44.1	201	38.9	198	27.7	154
2	26.2	139	24.7	148	21.4	128
Total	36.2	174	32.6	176	24.9	143
Total %	100	100	90.0	101.2	68.8	82.1

Table 6. Catch of rainbow trout and sea trout.

Period	Rainbow trout			Sea trout		
		Length			Length	
	N	Mean	SD	N	Mean	SD
1	36	61.1	9.25	36	67.1	4.71
2	16	61.2	5.12	13	65.5	6.88
Total	52	61.1	8.15	49	66.7	5.34

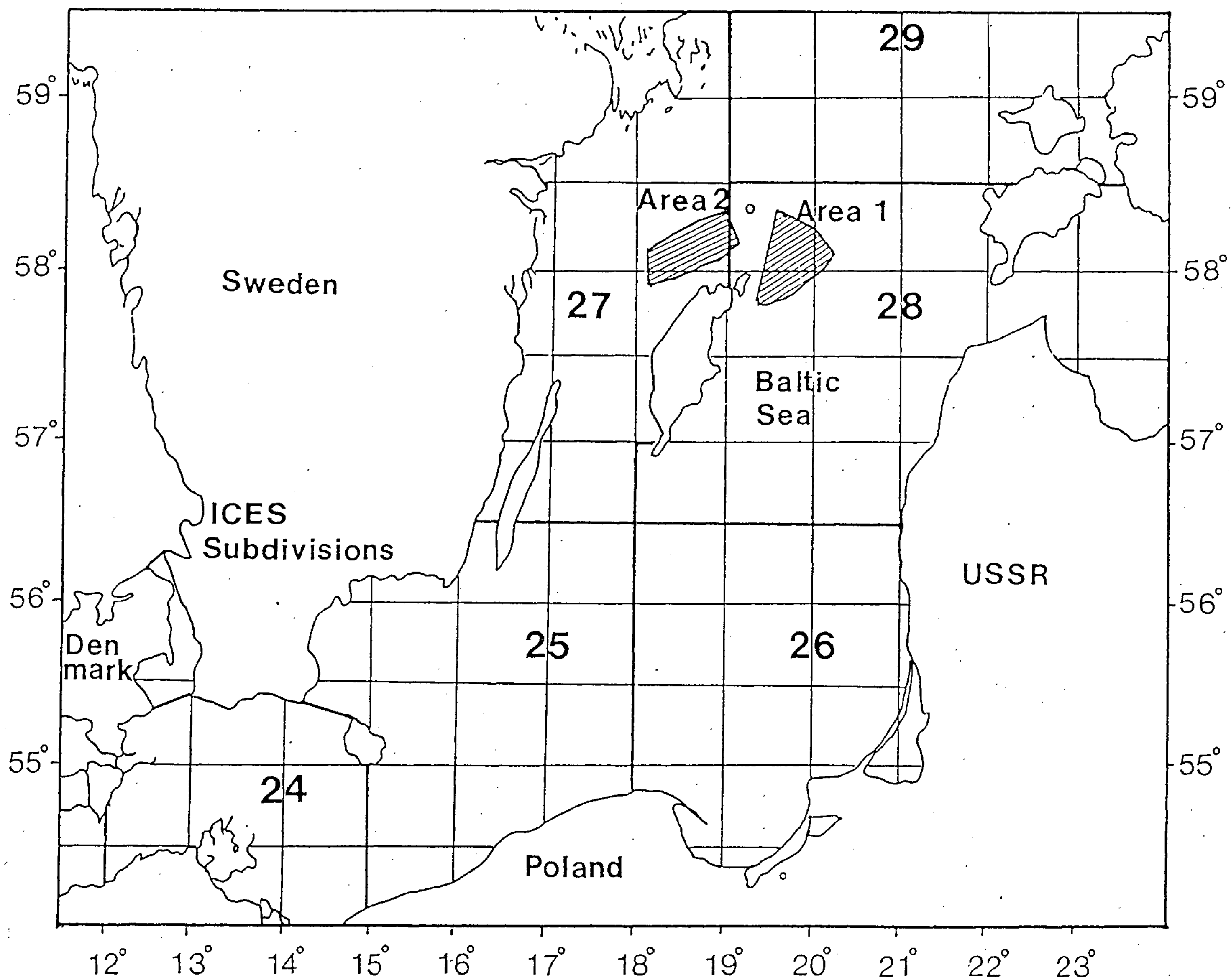

Fig. 1. Area of investigation. Fishing areas are hatched.

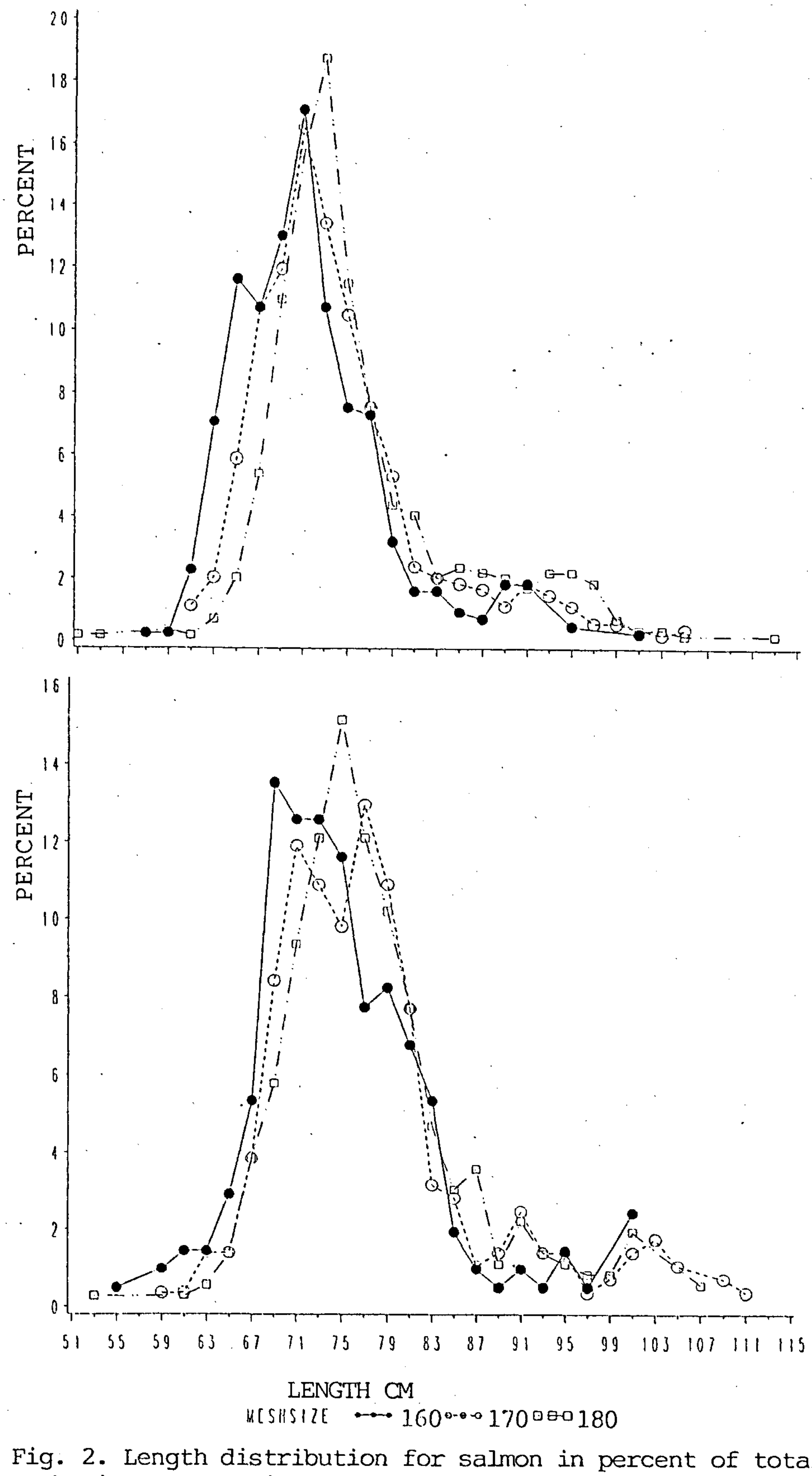

Fig. 2. Length distribution for salmon in percent of total catch by mesh size. a. Period 1. b. Period 2.

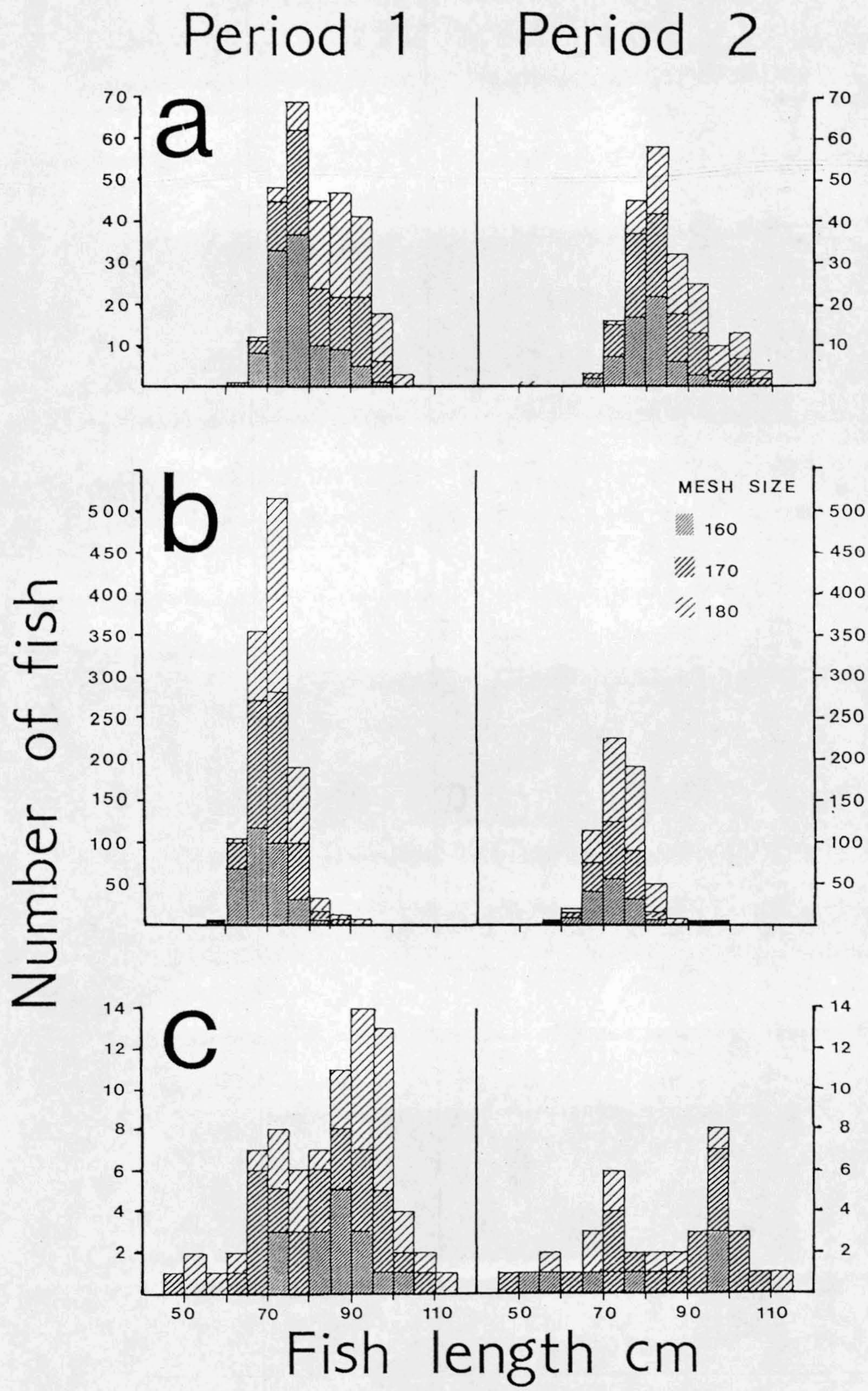

Fig. 3. Length distribution for salmon by mesh size, period and mode of capture. a. Gilled. b. Wedged. c. Other.

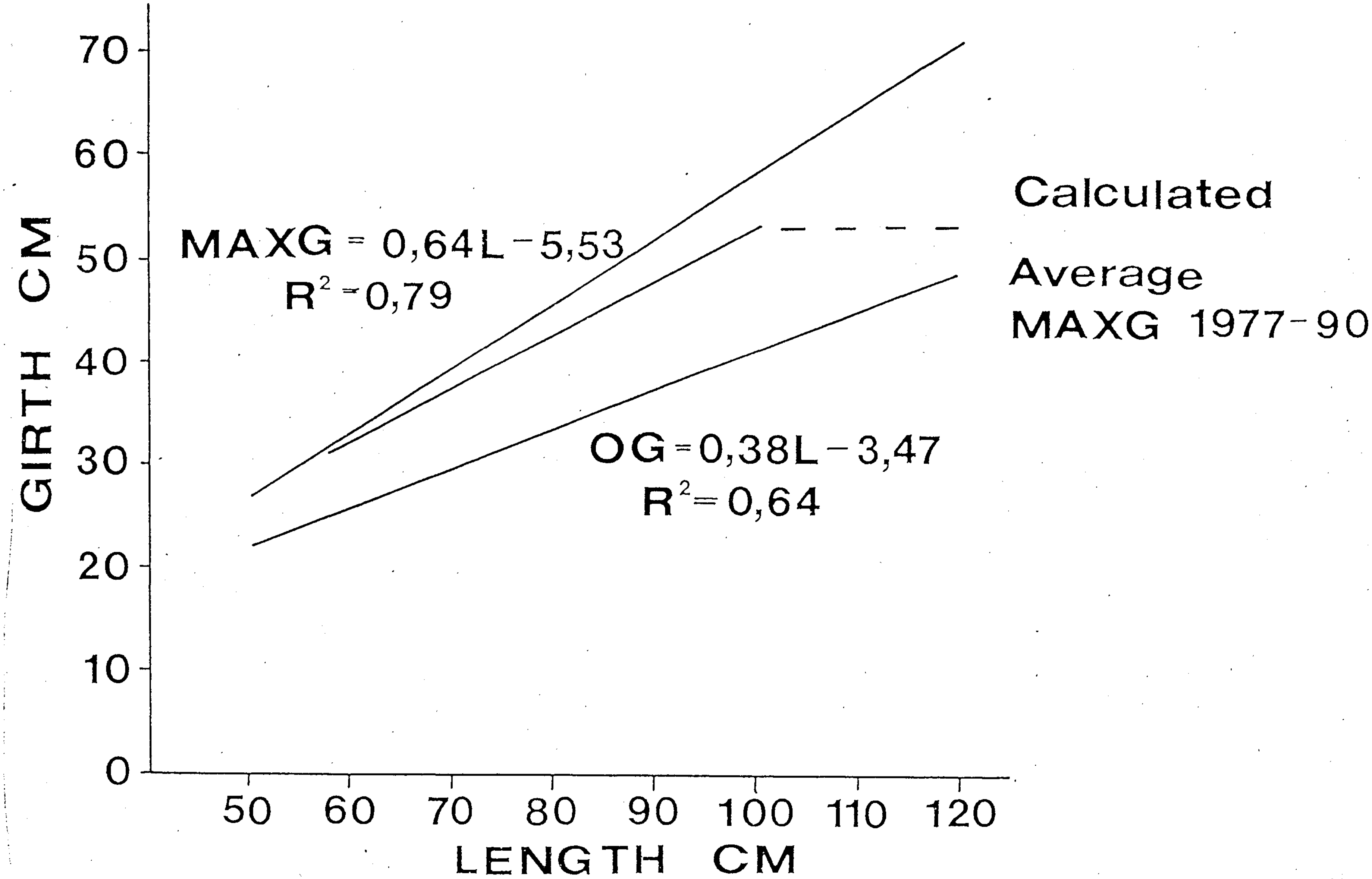

Fig. 4. Regression lines of maximum (MAXG) and opercular (OG) girth on salmon length for the experimental fishery and calculated average MAXG in 1977-90. Further details about the calculations are given in the text.

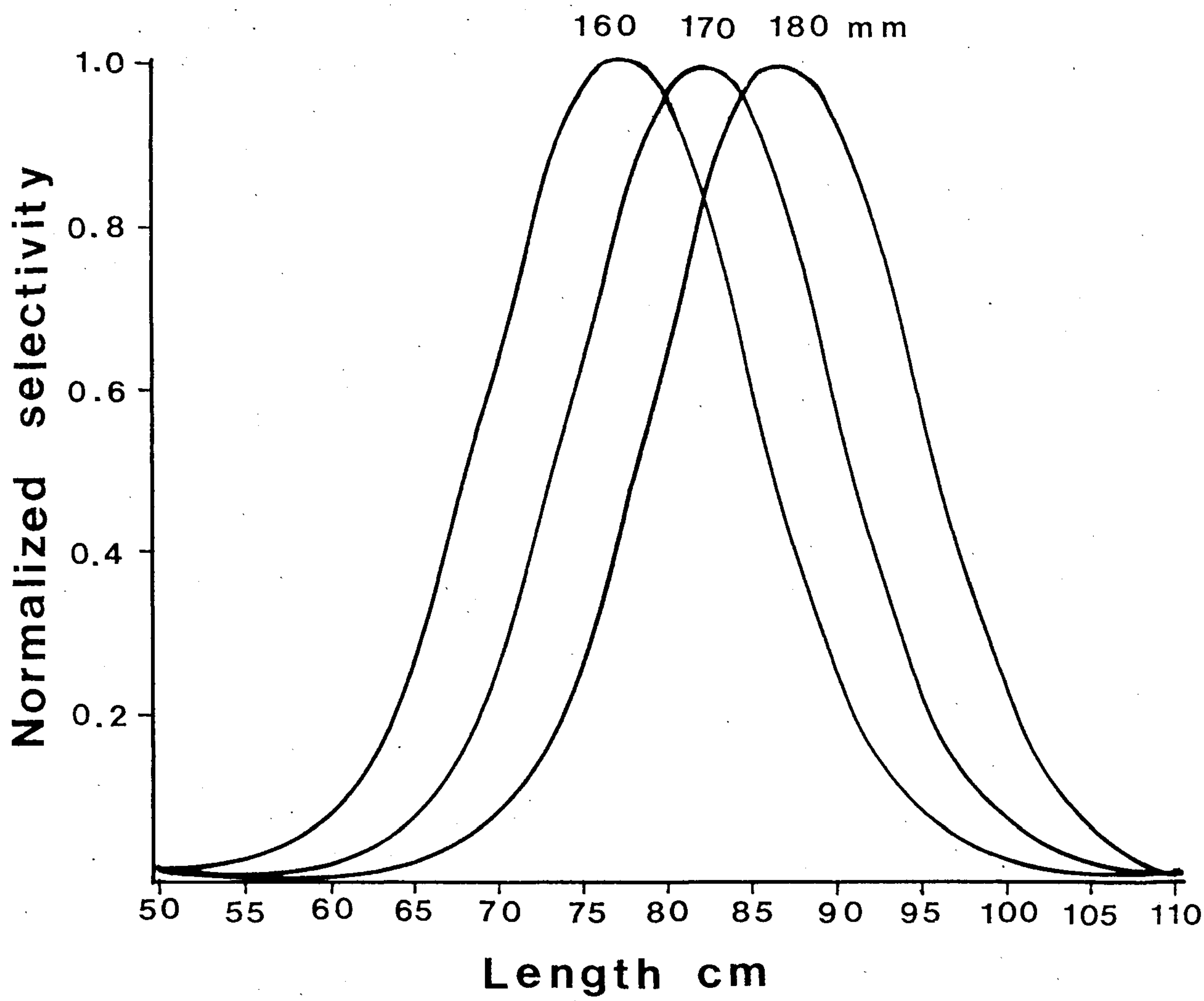

Fig. 5. Selection curves by mesh size as estimated by the Holt model.