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SELECTION OF SILVER HAKE (*Merluccius bilinearis*) IN KAPRON[1] CODENDS

(A PRELIMINARY REPORT)

Douglas Clay
Department of Environment
Fisheries & Marine Service
Marine Fish Division
Bedford Institute of Oceanography
Dartmouth, Nova Scotia

INTRODUCTION: -

Selection is the variation of length frequency between a true population and what is caught and retained by the fishery. Selectivity is any factor that causes variation. Selectivity is important for two reasons. Firstly, it allows biologists who can rarely study a fish population directly, to use catch statistics more accurately to evaluate actual population numbers. This leads to more accurate assessment techniques and a better understanding of the population. Secondly, selectivity can be used as an important management tool to reduce mortality among juvenile and small fishes and increase the catch efficiency of larger fish.

Factors that affect selection or, in other words, cause fishing mortality to vary with size of the fish can be caused by: - a) differences in time or space, b) differences in the chance of fish of different sizes encountering the gear, and c) differences in the retention of fish of different sizes by the gear.

The present size selection trials were carried out as a joint Canada-Cuba study in August 1977 using the Cuban research vessel Isla de la Juventud (a stern trawler-freezer, 1556 metric tons, 70.3 meters). The silver hake

[1] Kapron is a polyamide synthetic fabric used extensively in codends of the U.S.S.R and Cuban commercial Silver hake fleets.

(Merluccius bilinearis) fishery began in 1963 and was carried on mainly by the U.S.S.R. and more recently by Cuba and Japan. This fishery is primarily a food industry and the harvest has ranged from 2,000 tons to 300,000 tons. There was little direct control or management until 1974 when the first Canadian assessments were begun (Halliday, 1973).

Historically, the Silver hake fishery on the Scotian shelf has used 40 mm codends with 40 mm liners - this in effect would give virtually a 100% retention of all species. The selectivity of Silver hake was affected only by the geographical distribution of the stock, which limited the availability of different year classes. From past assessments (Doubleday and Hunt, 1976) it can be seen there were greater numbers of fish from year classes 2 and 3 in the catch than of year class 1. This indicates there must have been some selection against age group 1 fish (probably due to separate feeding grounds for juveniles and adults) although no absolute selection values can be given. In December, 1976, legislation was set up at a special meeting of ICNAF (Anon, 1976) to limit fishing outside the line shown in Figure 1 to any gear with a codend mesh of 60 mm or over. Inside this line (on the shelf proper) only midwater trawls of 60 mm codend mesh and bottom trawls of 130 mm codend mesh were allowed.

The aim of this joint study is to interpret the effects of the above legislation and explore the possibility of the increasing long-term yield of the Silver hake fishery through optimum effort with appropriate gear type.

Methods:-

The trawl used for this research was a "Spanish Bottom Trawl" (specifications are given in Table 1). The three codends were made of kapron and had mesh sizes of 40 mm, 60 mm and 90 mm. The covered codend method (Davis, 1934) was used with a cover of 20 mm mesh. The alternate tow method of comparing two nets with different codend size could not be considered in these trials because fishing ranged over a very wide geographical area where populations could not be assumed to be similiar.

Initially, a Latin square design was planned. The net sizes were to change with time and alternate between covered and uncovered tows. This was to allow a study of the a) masking effect of the small mesh covers on the codend, b) diurnal fluctuations in populations, and c) difference of selection of the same population by various codend mesh sizes.
Unfortunately the design did not hold throughout the study and only 30 tows were made. These covered a somewhat straight line of nearly 450 km between southwestern Sable Island Bank and LeHave Bank (Figure 1). Of these 30 tows, data were collected from only 23 and of these latter tows only 15 used covers. Only seven tows had Silver hake samples of more than 500 fish total.

Due to this major constraint - the lack of data-analysis has been somewhat limited. Statistical analysis of results cannot take the place of good data. Table 2 and Figure(s) 2a, b, and c shows individual tows and the details collected in this selection experiment.

Treatment of the Data: -

The most important results from such a study are usually: 1) the length at which 50% of the fish are retained by the codend, 2) the selection

factor (50% retention length/mesh size), and 3) the selection range - the difference in length between the 25% retention level and the 75% level. Detailed reviews of analyses of selection data have been carried out by Pope et al (1975) and Holden (1971). Both of these reports came to similiar conclusions on which techniques are best to achieve the above results. They found fitting the selection ogive by maximum likelihood to be the most accurate method of deriving the curve. The tedious calculations associated with this method are not often warranted, as it has been found that fitting the curve by eye gives unbiased estimates (Pope et al, 1975) which are very close (often within 1%) to that obtained by the maximum likelihood method (Holden, 1971). The 50% retention level was calculated by a moving average of 3 points. This gives unbiased estimates of the 50% point but should not be used for any other points (Pope et al, 1975).

The data for each size of codend was pooled wherever possible. This is because: 1) the haul to haul variability is generally a much larger component of the error than any other variable (Pope et al, 1975) and 2) the data were insufficient to obtain a selection ogive from each haul. Pooling of the data was not carried out when the population of two areas were known to be different.

All weights in this study are expressed in kilograms unless otherwise specified and the fish were measured by fork length to the nearest 0.5 cm group (rounded up).

Results and Discussion: -

The length frequency distributions of all species for which adequate data are available are presented in Appendix II. The selectivity ogives for all species for which adequate data are available are presented in Appendix I.

Past Experiments:

The 50% retention levels, selection ranges and selection factors of the three tested mesh sizes are given in Table 3. The mean selection factor found in this experiment is 3.6 and is between the 4.1 value obtained by Gulland (1956) for the European hake (Merluccius merluccius) and the 3.1 average recorded by Clarke (1963) for American studies. The selection ogives of this study and those of Clarke (1954) and Jensen & Hennemuth (1966) have been plotted on probability paper over the selection range and can be found in Appendix III. From these curves it can be seen that for cotton, manila and nylon the selection range tends to increase as the size of the codend mesh increases. For the kapron this does not appear to hold - the selection range decreases as the codend mesh size increases. Figure 3 shows this characteristic of kapron another way. In this figure the fish length of the 50% level is shown versus the codend mesh size. The slope of the line for the kapron net is much steeper than any of the other materials. This indicates that as the codend mesh size is increased the 50% retention point does not increase as fast as would normally be expected. It is, however, a linear relationship.

The difference in selection between nylon and kapron (both polyamide materials) is probably due to the differing abilities to stretch. Kapron has an elongation factor (Holden, 1971) almost 50% greater than nylon used in Canada or polyamide materials used in the U.S.A. The difference between kapron and other materials is not totally unexpected as Boerema (1956) found different materials and different thicknessess

of the same materials greatly altered selection. What was unexpected is the great difference in selection between nylon codends of the same size as found in the two earlier Silver hake selection studies by Clarke (1954) and Jensen & Hennemuth (1966). A possible reason for this difference is the different sources of nylon for codends used in the U.S. East coast fishing fleet in the early 1950's and in the 1960's. In the post war years the nylon codends of the fishing fleet were made of reworked nylon cargo nets (McCracken, personal communication) while in the early 1960's codends were manufactured specifically for the fishing industry from new material. The reworked nylon twine was of a more coarse weave than the newer nylon twines and in all probability would have a very different selection pattern.

Masking Effect: -

Davis (1934), carried out a detailed study of selection trials in in general and selection of the European hake in particular.

In discussing the covered codend method he stated that [there are] severe limitations [that can] only be accepted with certain reservations owing to the elusive factor of the 'masking' or 'flow' effect of the cover."

Although an initial plan was made to study the masking effect - the poor experimental design and poor data collection for various species makes this virtually impossible.

In an analysis of data for the 40 mm codend it can be seen from Figure 2a that the two tows using covered codends were done in an area adjacent to Emerald Basin (a known juvenile feeding ground) while the two uncovered tows were done 460 km away on southwestern Sable Island Bank (an area known to be predominantly populated by adults). These two pairs of tows can not be assumed to have fished identical populations. For this

reason, the technique of estimating the masking effect during this study, as shown in the Cruise Report (Hare, 1977) is incorrect. When studying the masking effect two possible techniques are used. The first is to compare the length frequency in the covered codend and in the uncovered codend to the assumed total population as caught in the covered codend plus the cover. The method followed by Hare (1977) is a variation of this technique but is only correct if the sampled populations are similiar - the figure (Appendix II) showing the length frequency of Silver hake in the 2 pairs of 40 mm tows will show the great variation between the two populations. The second method that could be used to study the masking effect is to compare the relative fishing efficiency of each individual length group of both samples to a third population - a standard - possibly another mesh size or possibly historical research data. This technique also requires similiar populations to be fished. In effect, due to the data, nothing can be said with regards this problem at present.

In the 90 mm mesh experiment, only one uncovered tow was made, and as Holden (1971) has stated the variation between hauls is greater than the variation between experiments, no attempt can be made to investigate the masking effect. An example of this variation is shown in Figure 4. With the 60 mm codend there are four covered and four uncovered tows to compare. The selection ogive for the covered tows is shown in Appendix I. The selection ogive for the uncovered tows is calculated by assuming the total population of fish caught in the four covered tows is representative of what was fished by the uncovered tows. This ogive is shown in Figure 5. Jensen & Hennemuth (1966) found a masking effect on the 52 mm nylon codend to move the 50% retention point of Silver hake by 10 cm. Gulland (1956) studying the European hake found the masking effect on a 77 mm double sisal codend to move the 50% retention point only 1 cm. A possible indication that stiffer materials (i.e. double sisal) are less

affected by the masking of a cover. As can be seen by Figure 5 the masking of effect with kapron is not large and the 50% retention point moved approximately 1 cm For the purpose of this study, due to the dearth of data, and the indicated small size of the effect of the cover no masking effect correction factor has been used.

The species composition and frequency of occurrence of various fish caught during this study are given in Table(s) 4a, b, & c. These tables point out the percent by-catch of as Silver hake fishery and of a combined Silver hake-Squid fishery. In this 'experimental' fishery, the species selection was very high. Two interesting notes with regards species other than Silver hake are: 1) the cod mesh selection curve in past work usually has a much wider selection range than that found in this experiment, this may be due to the small sample size, and 2) the numbers of juvenile haddock in the covers of both the 60 mm tows and the 90 mm tows are extremely large - the majority of both of these tows took place in southwestern Sable Island Bank, a region historically considered a major haddock fishing ground.

An assessment of the change in yield with an increase in net size has been carried out in Appendix IV. The results are shown in Figure 6.

The use of the larger mesh size appears to be warranted in the light of production estimates for the future. The large numbers of small haddock (0 group) caught during this survey indicate the presence of a viable spawning stock of haddock. As the 50% retention point for hadddock moves almost 10 cm between the 60 mm and 90 mm nets, this stock could have an opportunity to rebuild if it was not subject to by-catch recruitment until approximately 30 cm in length.

For these reasons the author would recommend a minimum mesh size of 90 mm. The 40 mm mesh should not be considered for future agreeements.

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TABLE 1

GEAR SPECIFICATIONS-----ISLA DE LA JUVENTUD

Type of trawl:	Spanish bottom trawl
Foot rope length:	57.9 m
Head rope length:	41.6 m
Head rope height:	6 m
Wing spread:	unknown
Length bridles:	113 m
Type of doors:	Oval
Door weight:	1500 Kg
Door area:	5.5 m^2
Mesh size in wings:	Dry - 204 mm; Wet - 204 mm
Mesh size in body:- square:	Dry - 200 mm; Wet - 200 mm
- middle:	Dry - 150 mm; Wet - 150 mm
- end:	Dry - 123 mm; Wet - 123 mm

Mesh size in codend:

40 mm		60 mm		90 mm	
Dry	Wet	Dry	Wet	Dry	Wet
40.1 mm	40.1 mm	66.1 mm	66.1 mm	90.0 mm	90.0 mm
			66.2 mm		90.2 mm
			66.1 mm		90.2 mm
			66.1 mm		90.2 mm

Liner in codend:	Yes (covering the codend knot)
Mesh size in cover:	Dry - 20 mm; Wet - 20. 1 mm
Chafing gear fitted:	Yes
Rollers on footrope:	No

TABLE 2

DETAILS OF INDIVIDUAL TOWS

DATE	PERIOD	MESH - SIZE	COVER	TOW NO
7-Aug.	1 Hr./night	40 mm	no	4
7-Aug.	1 Hr./night	40 mm	no	5
8-Aug.	1 Hr./night	60 mm	no	6
8-Aug.	1 Hr./day	60 mm	no	7
9-Aug.	2255 Hr./night	60 mm	no	11
9-Aug.	1.0 Hr./day	60 mm	no	12
9-Aug.	2.5 Hr./night	90 mm	no	13
10-Aug.	2.5 Hr./night	90 mm	yes	15
11-Aug.	2.5 Hr./night	60 mm	yes	16
11-Aug.	2.5 Hr./day	60 mm	yes	17
12-Aug.	2.5 Hr./night	60 mm	yes	18
12-Aug.	2.5 Hr./day	60 mm	yes	19
12-Aug.	2.5 Hr./day	60 mm	yes	20
13-Aug.	2.5 Hr./night	90 mm	yes	21
14-Aug.	2.5 Hr./day	90 mm	yes	22
14-Aug.	2.5 Hr./day	90 mm	yes	23
15-Aug.	2.5 Hr./day	90 mm	yes	24
15-Aug.	2.5 Hr./day	90 mm	yes	25
16-Aug.	2.5 Hr./night	90 mm	yes	26
16-Aug.	2.5 Hr./day	90 mm	yes	27
16-Aug.	2.5 Hr./night	90 mm	no	28
17-Aug.	0.5 Hr./night	40 mm	yes	29
18-Aug.	1.0 Hr./night	40 mm	yes	30

TABLE 3

THE SELECTION FACTOR,

SELECTION RANGE AND 50% RETENTION FOR KAPRON CODENDS

MESH SIZE	50% RETENTION POINT (mm) 1	2	SELECTION RANGE (25 - 75%)	SELECTION FACTOR
40 mm	175	177	6.3cm	4.4
60 mm	216	216	1.7cm	3.6
90 mm	260	259	1.9cm	2.9

1. Fitted by eye
2. Fitted by moving average of 3 points.

Table 4(a)

SPECIES COMPOSITION OF THE 40 mm MESH CODEND

TRAWL (4 TOWS)

COMMON NAME	SCIENTIFIC NAME	WEIGHT[1] (kg)			NUMBER (nil - no data)	FREQUENCY[2]	WEIGHT PER HOUR TOWED
Short-fin Squid	Illex illecebrosus	477	(477)	29.5%	nil	75%	136.3 kg.
Silver hake	Merluccius bilinearis	1094	(1119)	67.7%	3548	100%	312.6 kg.
Witch flounder	Glyptocephalus cynoglossus	1	(1)	0.1%	3	25%	0.3 kg.
American plaice	Hippoglossoides platessoides	2	(2)	0.1%	2	50%	0.6 kg.
Yellowtail	Limanda ferruginea	7	(7)	0.4%	25	50%	2.0 kg.
Summer Flounder	Paralichthys dentatus	0.1	(0.1)	0.1%	2	25%	0.1 kg.
Cod	Gadus morhua	2	(2)	0.1%	2	50%	0.6 kg.
Pollock	Pollachius virens	6	(6)	0.4%	2	50%	1.7 kg.
Haddock	Melanogrammus aeglefinus	8	(8)	0.5%	37	25%	2.3 kg.
Redfish	Sebastes marinus	7	(7)	0.4%	16	50%	2.0 kg.
Red hake	Urophycis chuss	6	(6)	0.4%	25	75%	1.7 kg.
Argentine	Argentina silus	1	(1)	0.1%	4	25%	0.3 kg.
Skate	Raja sp	1	(1)	0.1%	2	50%	0.3 kg.
Angler	Lophius americanus	5	(5)	0.3%	5	100%	1.4 kg.
TOTAL		1617	(1642)				462.2 kg.

% By catch hake fishery	32.3%
% By catch hake-squid fishery	2.8%
% Released by Codend	1.5%

1. First number is the weight in kg. in the codend, the second number in brackets is the total weight caught (includes cover) and the third number is the percent that species makes up of the codend catch of all tows of the same codend size.

2. The percent frequency is the percentage of the tows in which the species was caught.

Table 4(b)

SPECIES COMPOSITION OF THE 60 mm Mesh Codend TRAWL (9 TOWS)

COMMON NAME	SCIENTIFIC NAME	WEIGHT kg.[1]			NUMBER (nil-no data)	FREQUENCY[2]	WEIGHT PER HOUR TOWED
Short-fin Squid	Illex illecebrosus	10,832	(11,034)	83%	nil	100%	555.5 kg.
Silver hake	Merluccius bilinearis	1,303	(1334)	9.9%	5349	100%	66.8 kg.
Witch flounder	Glyptocephalus cynoglossus	14	(14)	0.1%	65	44%	0.7 kg.
American plaice	Hippoglossoides platessoides	34	(36)	0.3%	99	100%	1.7 kg.
Yellowtail	Limanda ferruginea	76	(79)	0.6%	432	100%	3.9 kg.
Summer flounder	Paralichthys dentatus	0.2	(0.5)	0.1%	7	22%	0.1 kg.
Halibut	Hippoglossus hippoglossus	6	(6)	0.1%	1	11%	0.3 kg.
Cod	Gadus morhua	368	(369)	2.8%	236	78%	18.9 kg.
Pollock	Pollachius virens	25	(25)	0.2%	8	11%	1.3 kg.
Haddock	Melanogrammus aeglefinus	154	(169)	1.2%	911	67%	7.9 kg.
Cusk	Brosme brosme	77	(77)	0.6%	12	33%	4.0 kg.
Redfish	Sebastes marinus	0.2	(0.6)	0.1%	16	11%	00.1 kg.
Red hake	Urophycis chuss	44	(45)	0.3%	73	100%	2.3 kg.
Sculpin	Myoxocephalus sp	5	(6)	0.1%	25	33%	0.3 kg.
Wolf-fish	Anarhichas lupus	5	(5)	0.1%	nil	11%	0.3 kg.
Skate	Raja sp	93	(93)	0.7%	88	78%	4.8 kg.
Angler	Lophius americanus	43	(43)	0.3%	9	56%	2.2 kg.
Mackerel	Scomber scomber	0.1	(0.1)	0.1%	1	11%	0.1 kg.
TOTAL		13,080	(13,336)				671.2 kg.

% By catch hake fishery	90.0%
% By catch hake-squid fishery	7.2%
% Released by codend	1.9%

1. First number is the weight in kg. in the codend, the second number in brackets is the total weight caught (includes cover) and the third number is the percent that species makes of the codend catch of all tows of the same codend size.

2. The percent frequency is the percentage of the tows in which the species was caught.

Table 4(c)

SPECIES COMPOSITION OF THE 90 mm MESH CODEND

TRAWL (10 TOWS)

COMMON NAME	SCIENTIFIC NAME	WEIGHT[1] kg.	NUMBER (nil-no data)	FREQUENCY[2]	WEIGHT PER HOUR TOWED
Short-fin Squid	Illex illecebrosus	5380 (7487) 66%	nil	100%	300 kg.
Silver Hake	Merluccius bilinearis	718 (952) 9%	4208	100%	28.6 kg.
Witch flounder	Glyptocephalus cynoglossus	9 (9) .1%	35	50%	0.4 kg.
American plaice	Hippoglossoides platessoides	5 (6) .1%	21	60%	0.3 kg.
Yellowtail	Limanda ferruginea	14 (14) .2%	73	40%	0.6 kg.
Halibut	Hippoglossus hippoglossus	9 (9) .1%	2	20%	0.4 kg.
Cod	Gadus morhua	104 (119) 1%	221	70%	4.8 kg.
Pollock	Pollachius virens	1299 (1353) 16%	927	50%	54.1 kg.
Haddock	Melanogrammus aeglefinus	361 (469) 4%	1395	70%	18.8 kg.
Cusk	Brosme brosme	37 (44) .4%	6	40%	1.8 kg.
Redfish	Sebastes marinus	14 (43) .2%	173	40%	1.8 kg.
Red hake	Urophycis chuss	106 (114) 1%	69	40%	4.6 kg.
Argentine	Argentine silus	- (12) 0.0%	96	40%	0.5 kg.
Wolf-fish	Anarhichas lupus	1 (1.5) .1%	2	20%	0.1 kg.
Skate	Raja sp	29 (30) .4%	41	50%	1.2 kg.
Angler	Lophius americanus	19 (19) .3%	3	30%	0.8 kg.
Mackeral	Scomber scomber	1 (1) .1%	1	10%	0.1 kg.
TOTAL		8106 (10682)			418.9 kg.

% By catch hake fishery	91.1%
% By catch hake-squid fishery	24.8%
% released by codend	24.1%

1. First number is the weight in kg. in the codend, the second number in brackets is the total weight caught (includes cover) and the third number is the percent that species makes of the codend catch of all tows of the same codend size.

2. The percent frequency is the percentage of the tows in which the species was caught.

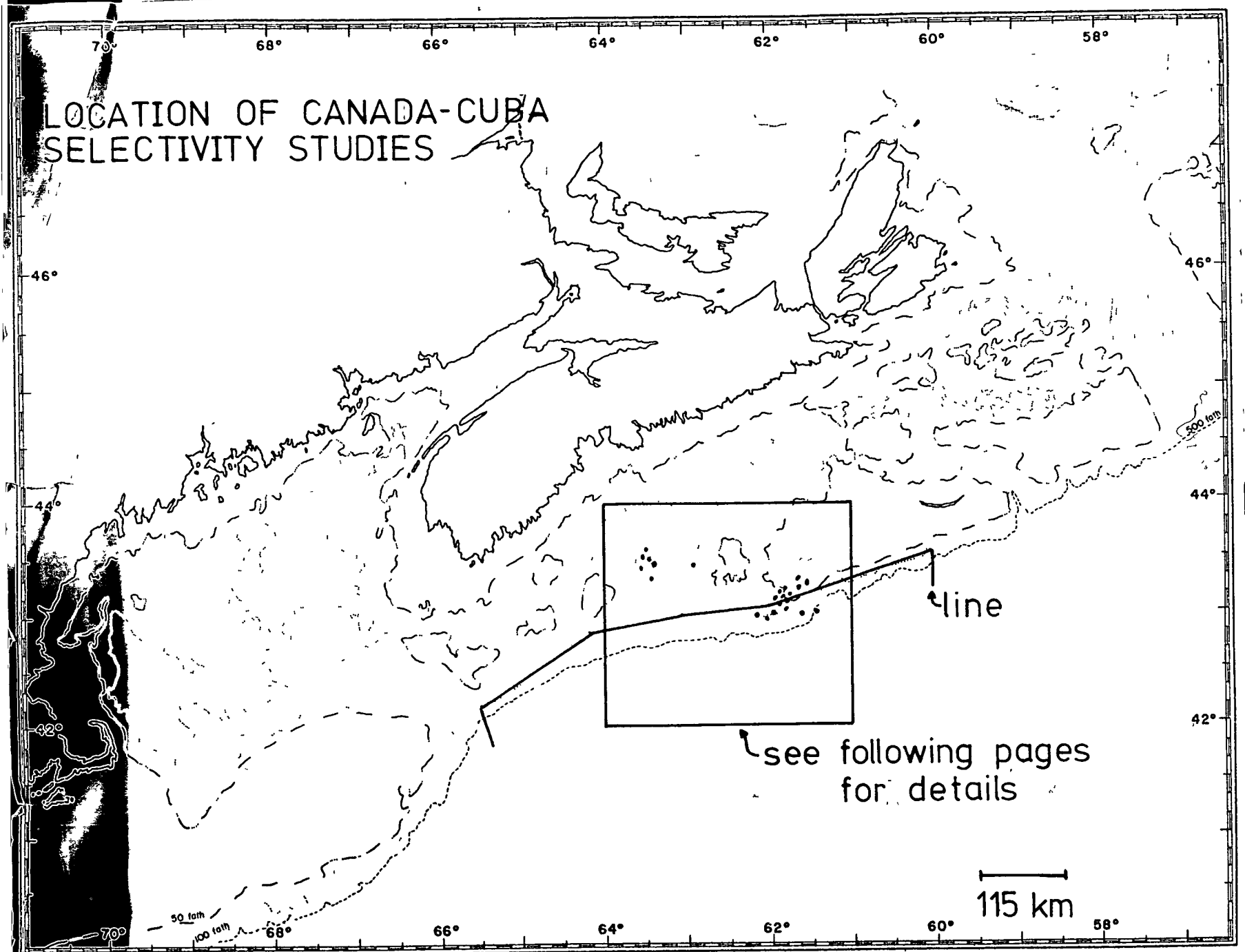
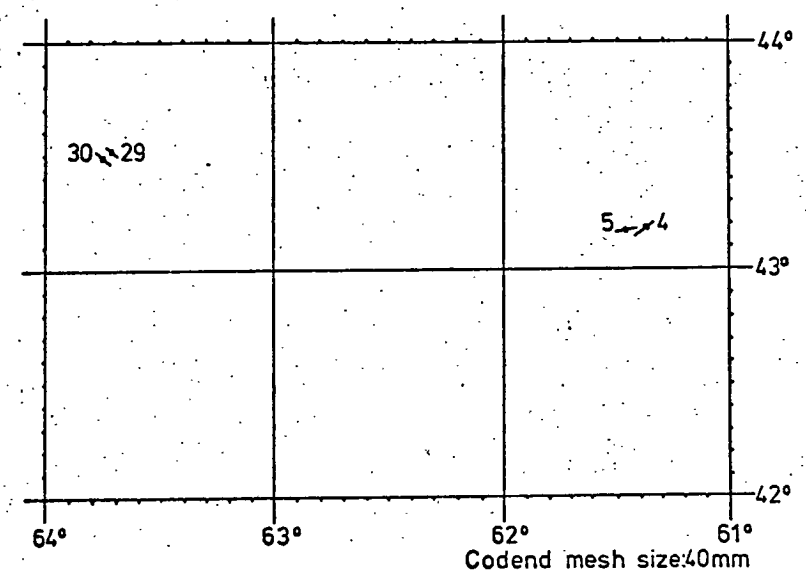


Figure 1

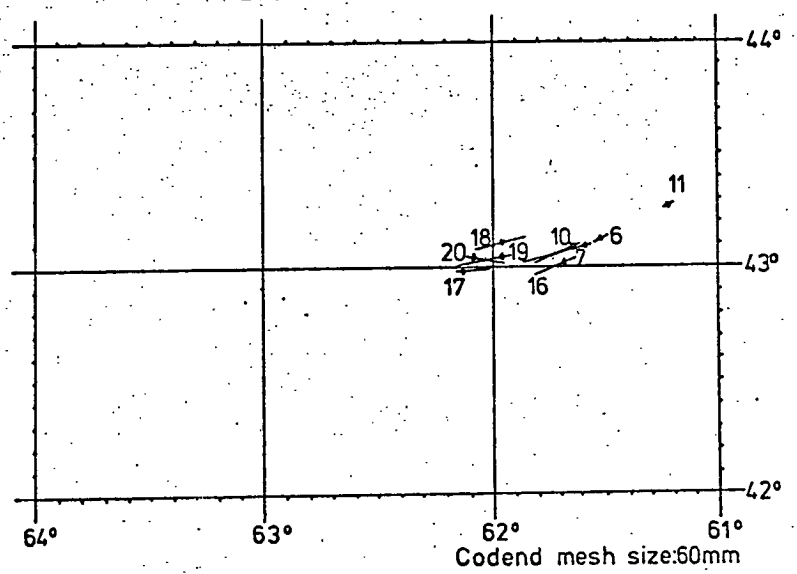
Map of the Scotian shelf with the individual tows marked (dots) and the mesh regulation line indicated. The box corresponds to the areas delineated in Figure(s) 2a,b,c.

FIGURE 2.

LOCATION OF TOWS a



LOCATION OF TOWS b



LOCATION OF TOWS c

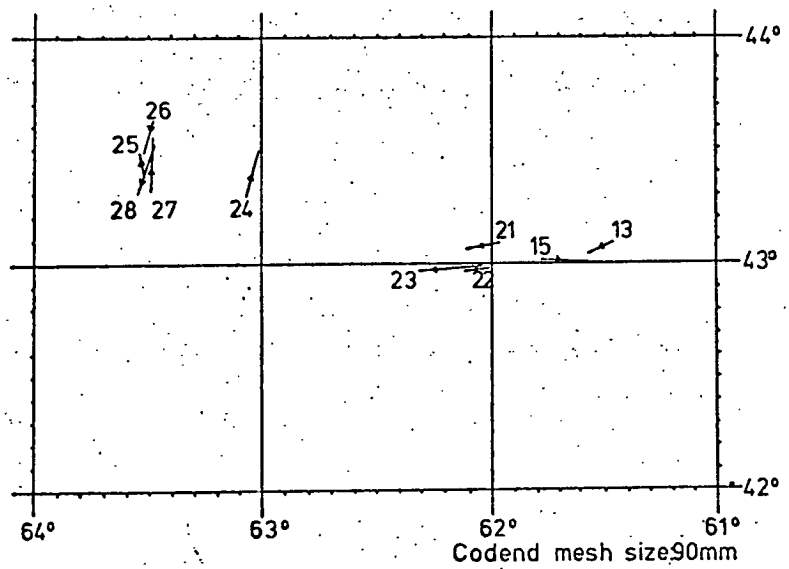


Figure 3

The selectivity of different types of material used in the manufacture of codends. The length in cm at which 50% of the fish are retained in the codend is plotted against the mesh size. The date of the study is indicated after the words nylon.

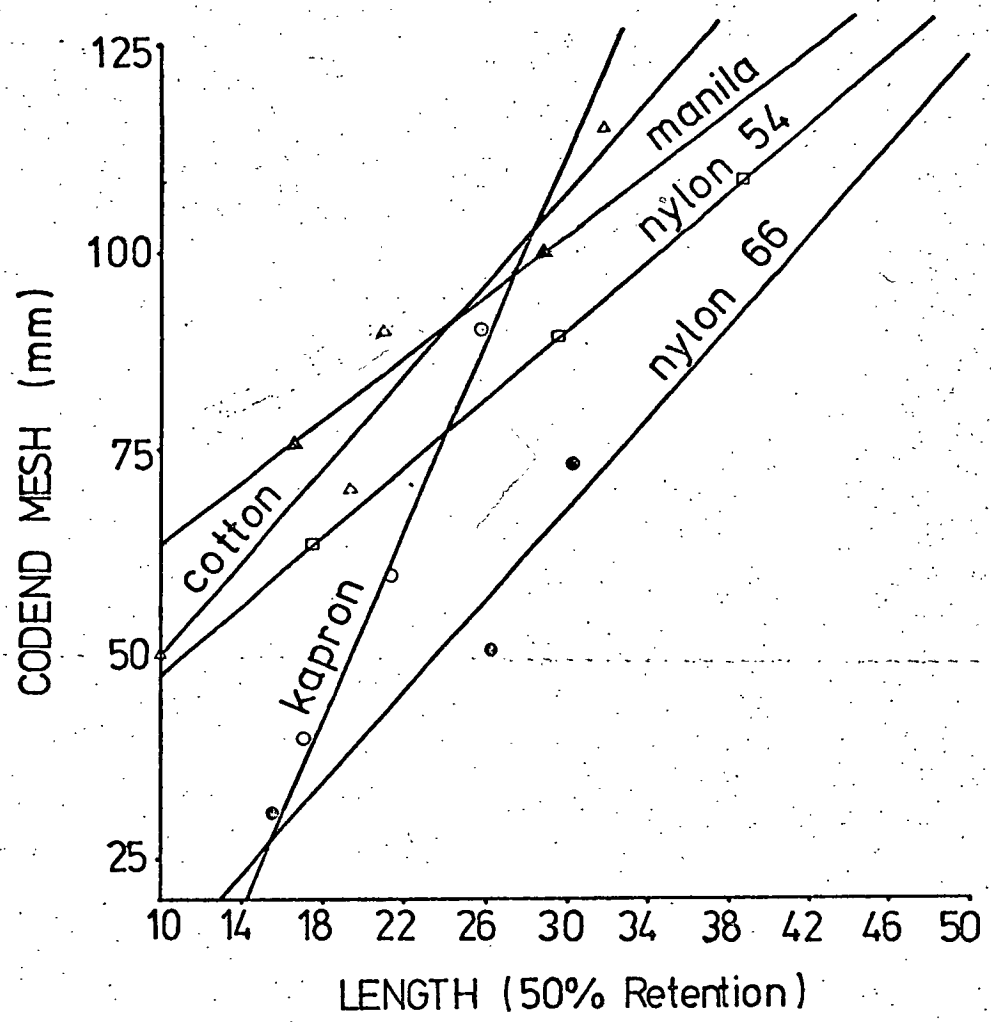


Figure 4

Variation between individual tows of the 90mm covered codend during the experiment.

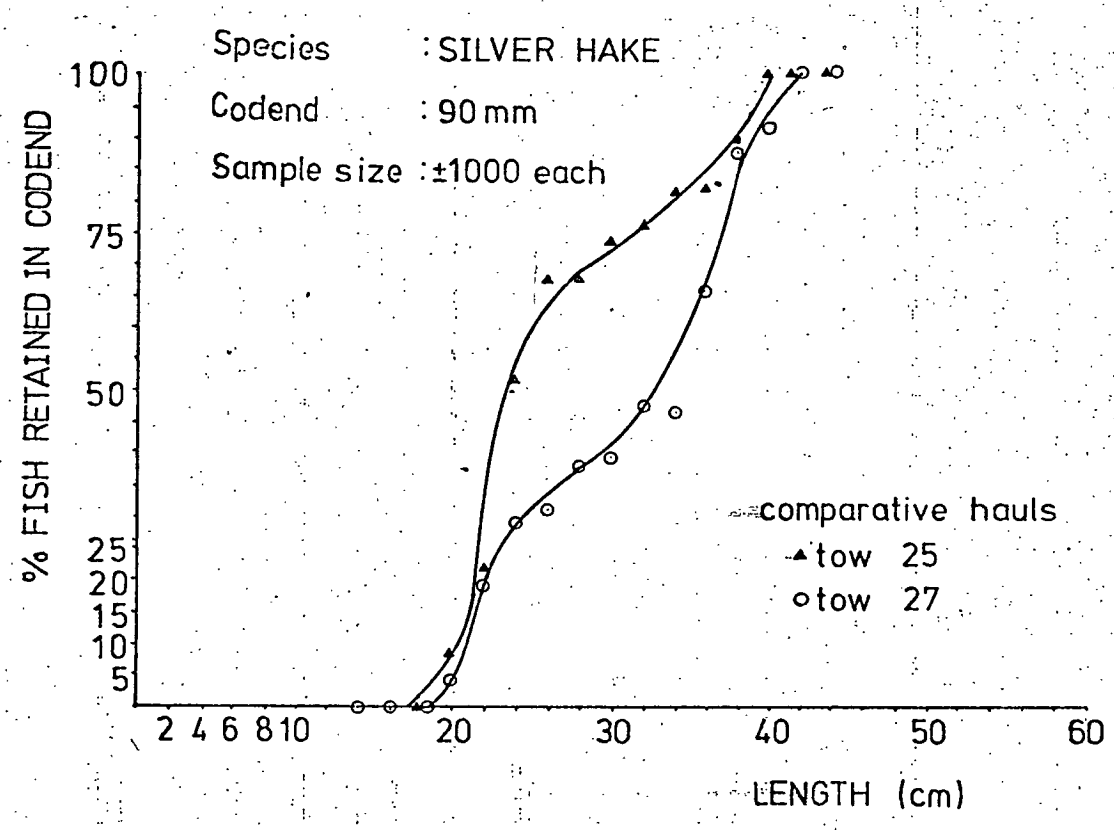


Figure 5

The selection ogives for Silver hake caught in 60 mm kapron codends from covered (x) and uncovered (•) tows.

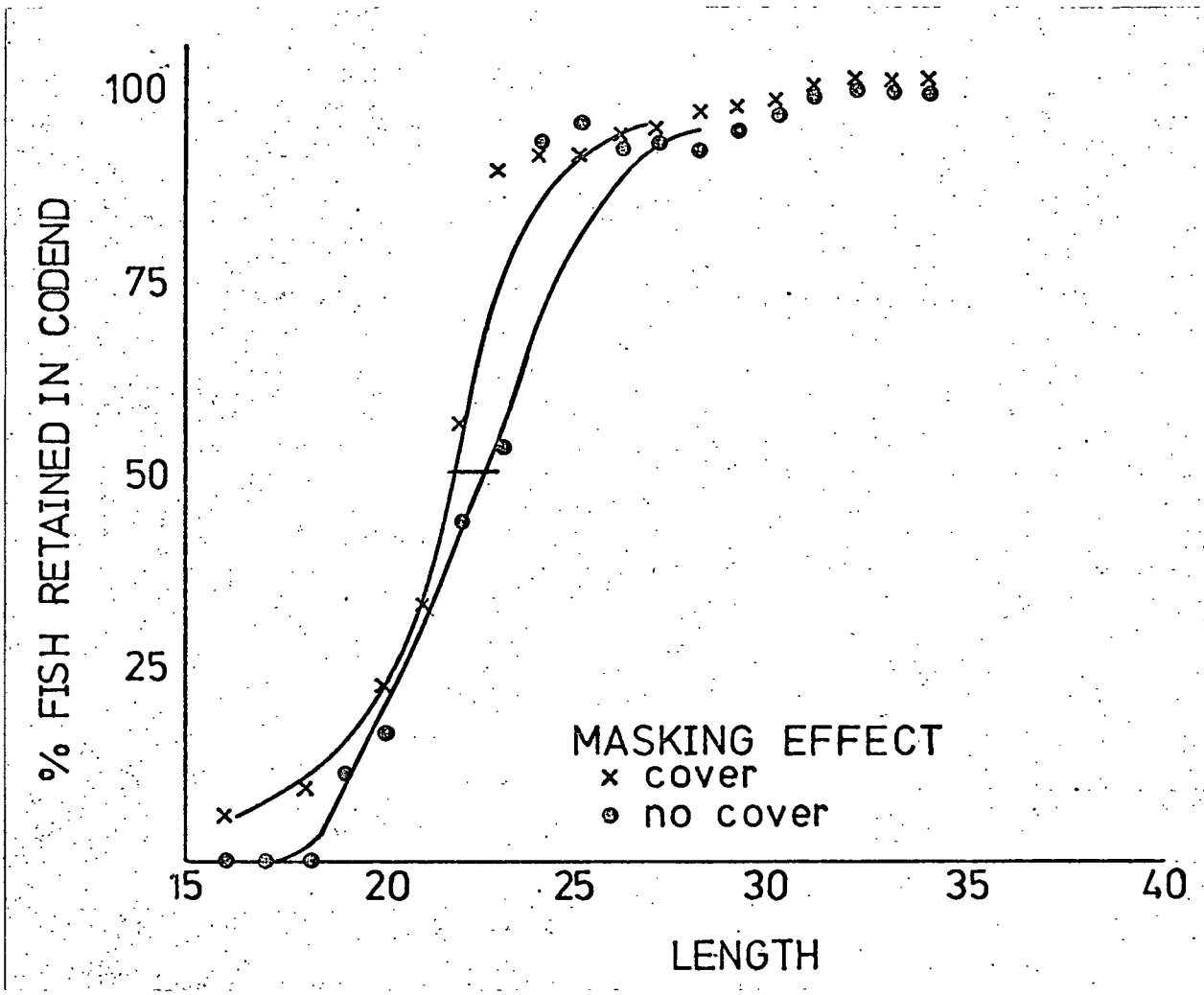
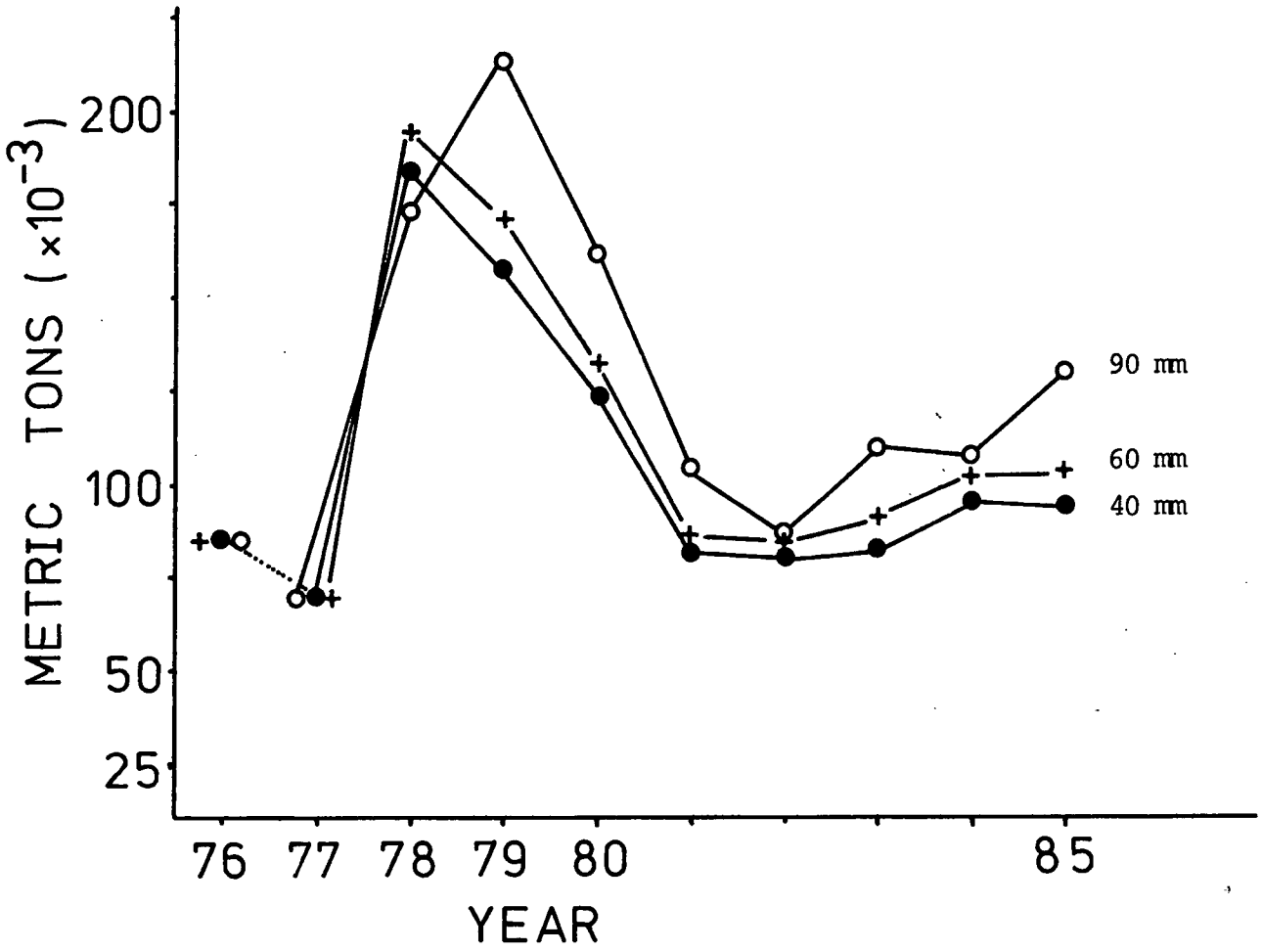


Figure 6

Catch estimates for the three codends for the period 1976-1985.



Selectivity ogives for all species of fish for which adequate data are available.

Figure 1. Silver hake 40-60-90 mm
Figure 2. Haddock 60-90 mm
Figure 3. Cod; pollock 90 mm
Figure 4. Redfish 90 mm

Note: 1) The heavy triangle indicates the 50% retention point.

2) The sample size is the total number of fish measured for the distribution, the number in brackets is the number of fish in the codend, the difference is the fish from the cover.

Figure 1

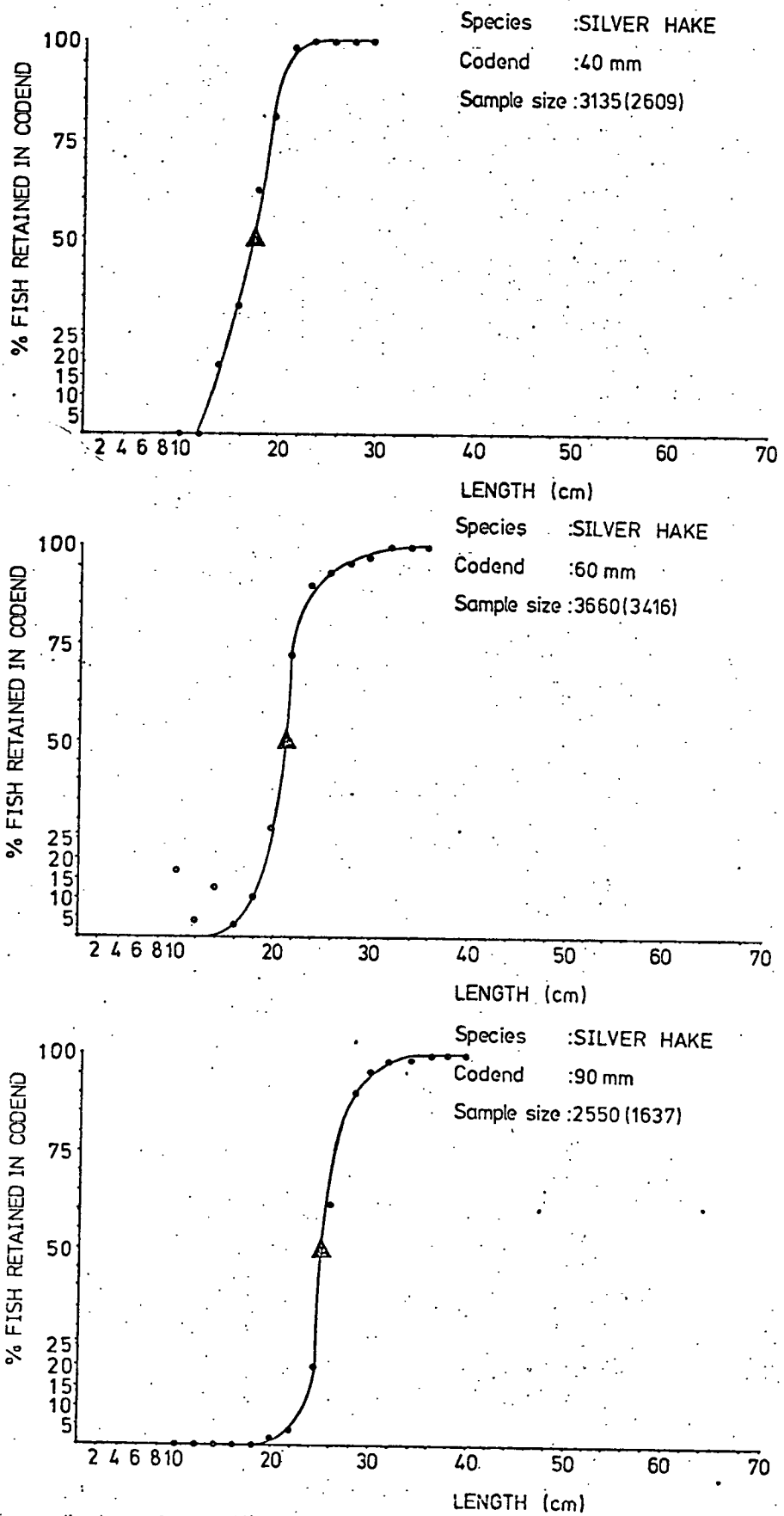
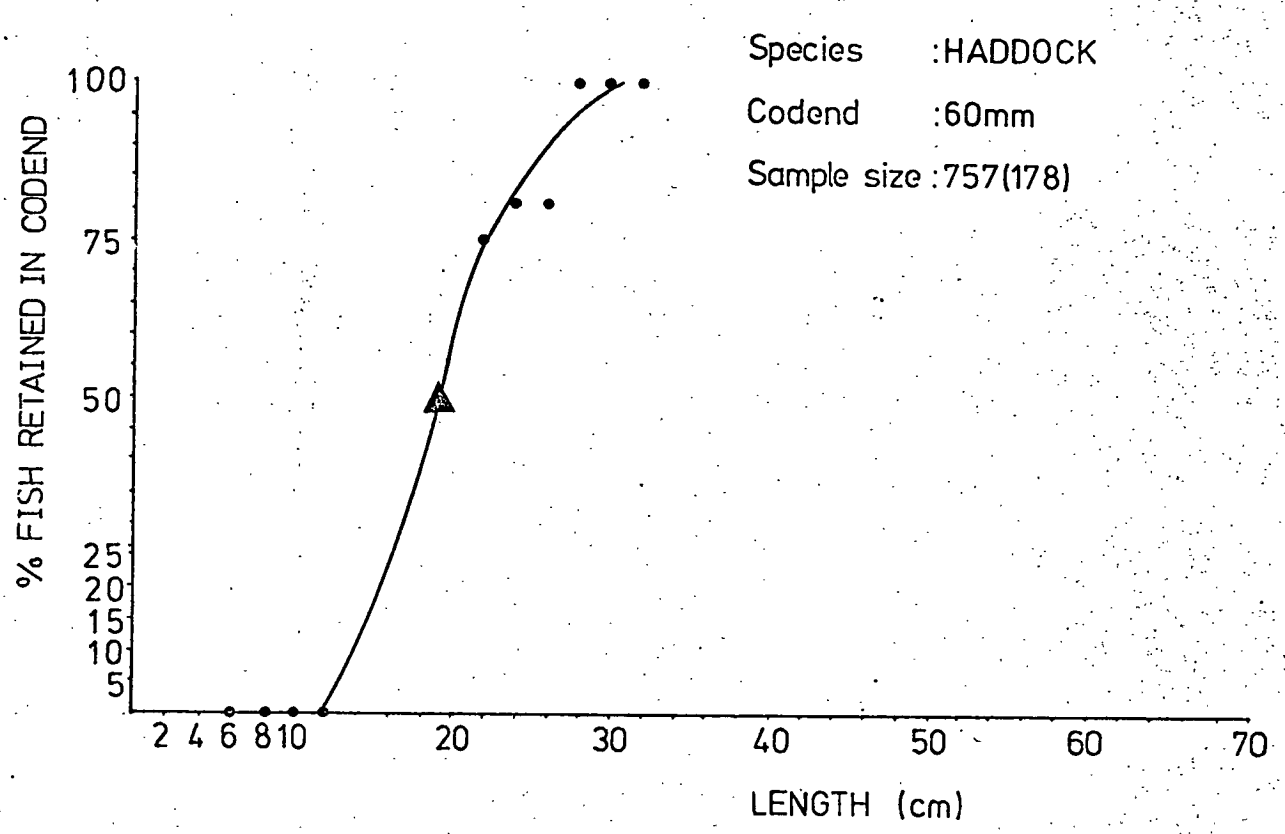

Species :SILVER HAKE
Codend :40 mm
Sample size :3135(2609)
% FISH RETAINED IN CODEND
100
75
50
25
20
15
10
5
2 4 6 8 10
20
30
40
50
60
70
LENGTH (cm)
Species :SILVER HAKE
Codend :60 mm
Sample size :3660(3416)
% FISH RETAINED IN CODEND
LENGTH (cm)
Species :SILVER HAKE
Codend :90 mm
Sample size :2550 (1637)
% FISH RETAINED IN CODEND
LENGTH (cm)

Figure 2


Species :HADDOCK
Codend :60mm
Sample size :757(178)
% FISH RETAINED IN CODEND
100
75
50
25
20
15
10
5
2 4 6 8 10
20
30
40
50
60
70
LENGTH (cm)

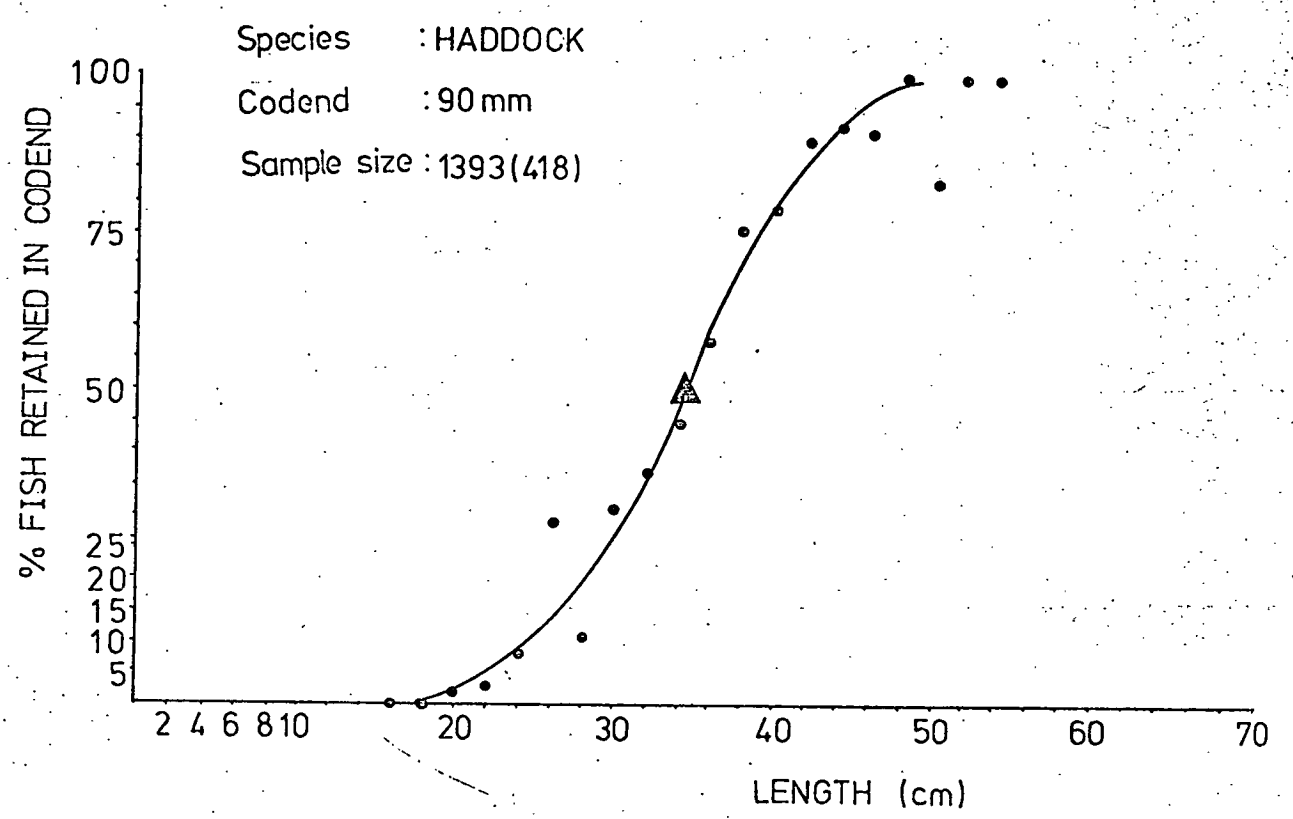
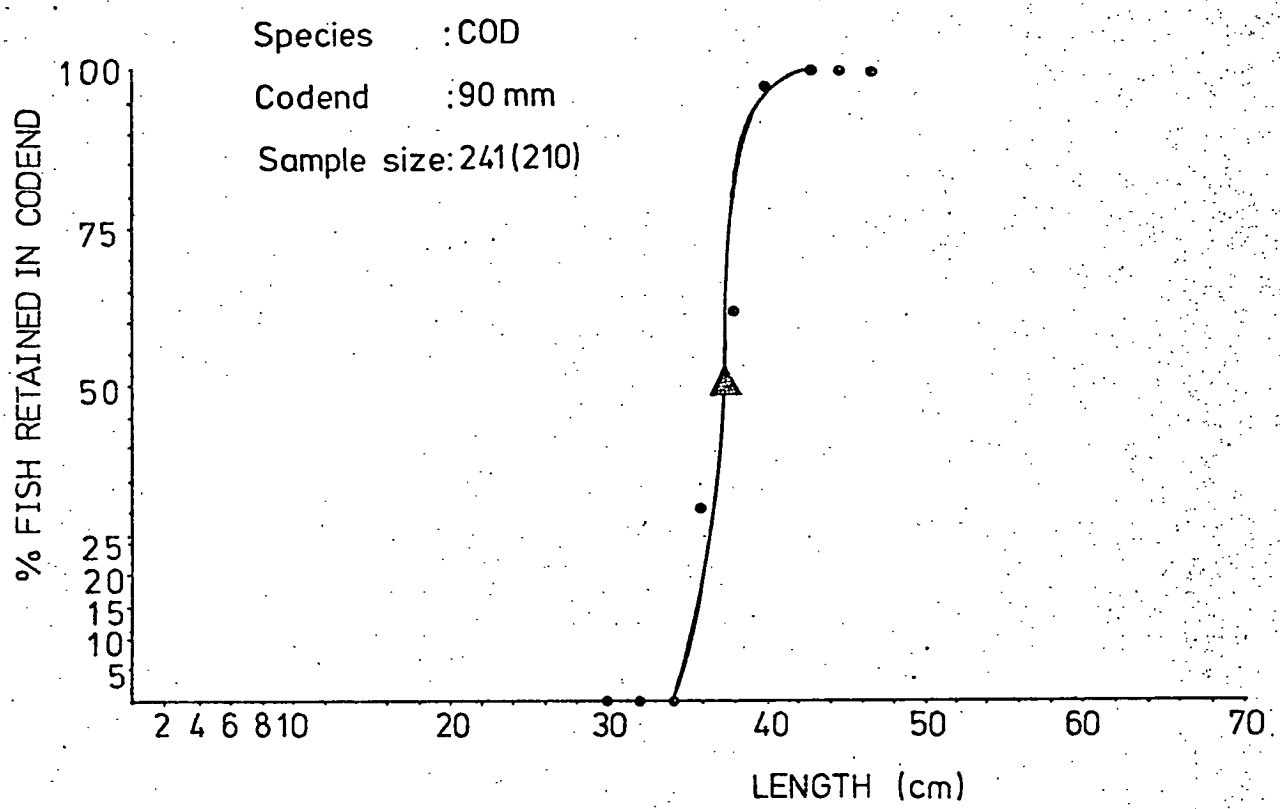

Species :HADDOCK
Codend :90 mm
Sample size : 1393(418)
% FISH RETAINED IN CODEND
100
75
50
25
20
15
10
5
2 4 6 8 10
20
30
40
50
60
70
LENGTH (cm)

Figure 3


Species :COD
Codend :90 mm
Sample size: 241(210)
% FISH RETAINED IN CODEND
100
75
50
25
20
15
10
5
2 4 6 8 10
20
30
40
50
60
70
LENGTH (cm)

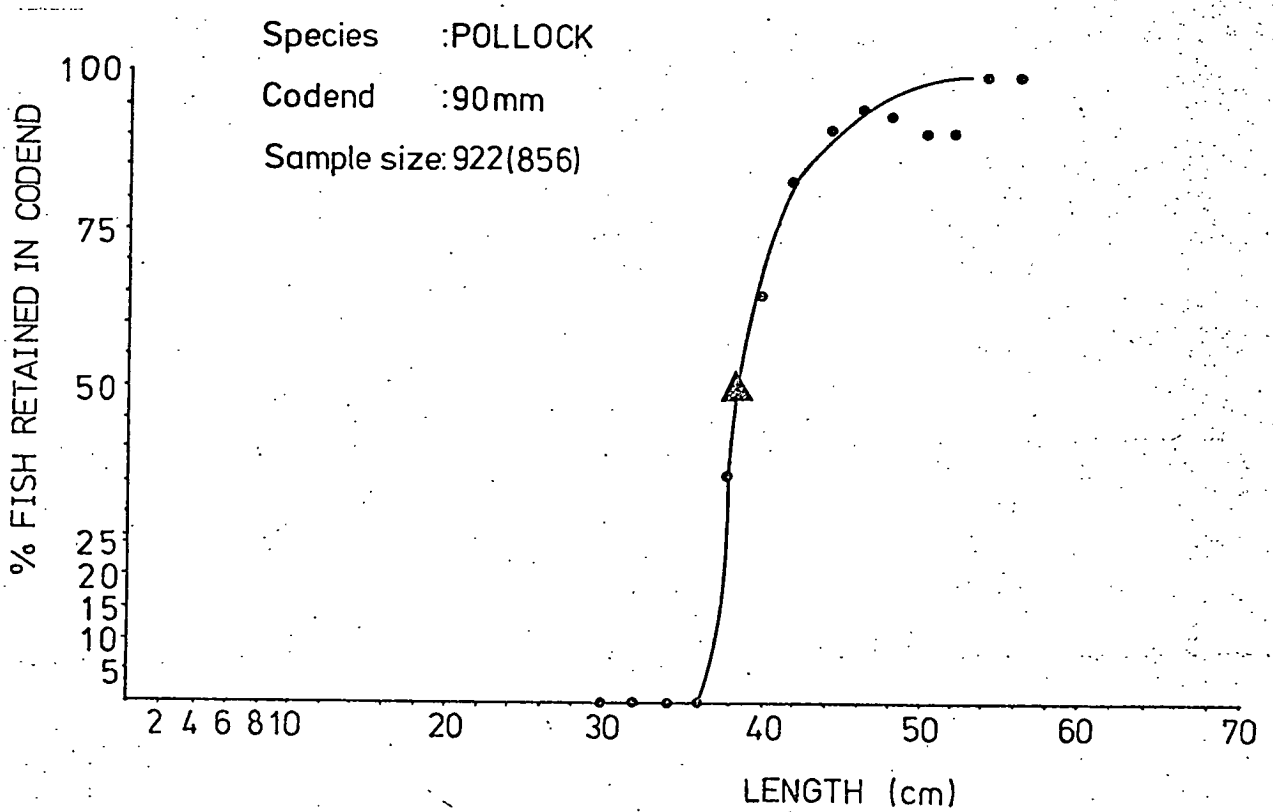
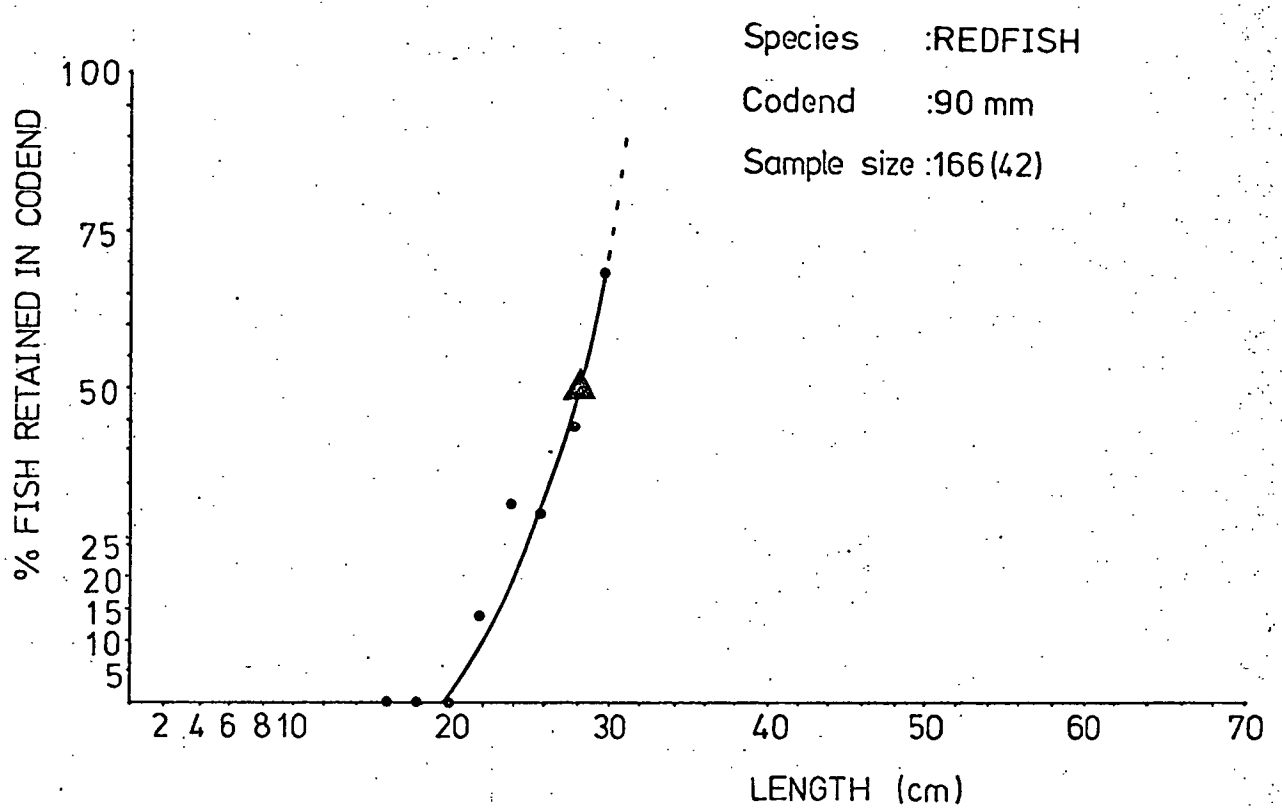

Species :POLLOCK
Codend :90mm
Sample size: 922(856)
% FISH RETAINED IN CODEND
100
75
50
25
20
15
10
5
2 4 6 8 10
20
30
40
50
60
70
LENGTH (cm)

Figure 4


Species :REDFISH
Codend :90 mm
Sample size :166(42)
% FISH RETAINED IN CODEND
100
75
50
25
20
15
10
5
2 4 6 8 10
20
30
40
50
60
70
LENGTH (cm)

Length frequency of all species of fish for which adequate data are available

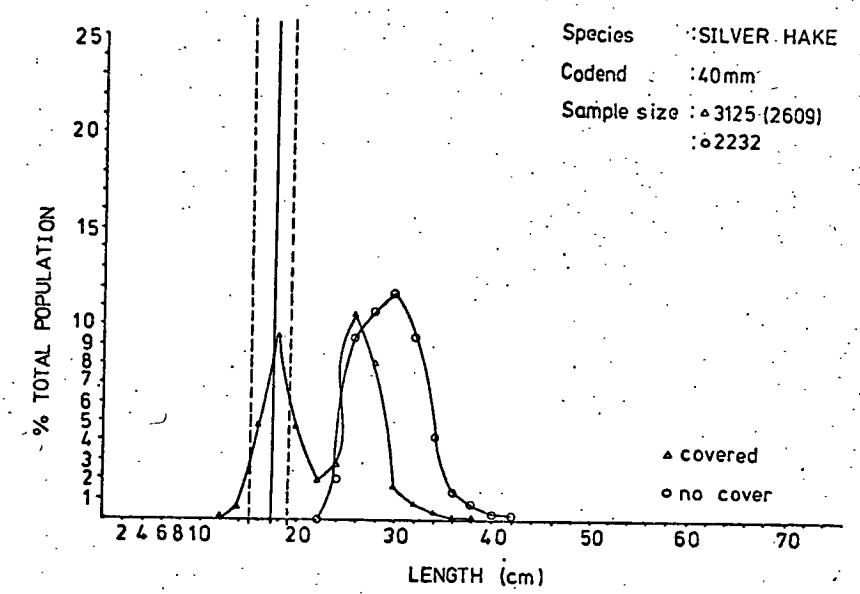
Figure 1. silver hake 40-60-90 mm
Figure 2. haddock 60-90 mm
Figure 3. cod 60-90 mm
Figure 4. redhake 60mm; pollock 90 mm
Figure 5. redfish 90 mm
Figure 6. yellowtail 60-90 mm
Figure 7. witch 60-90 mm
Figure 8 plaice 60 mm

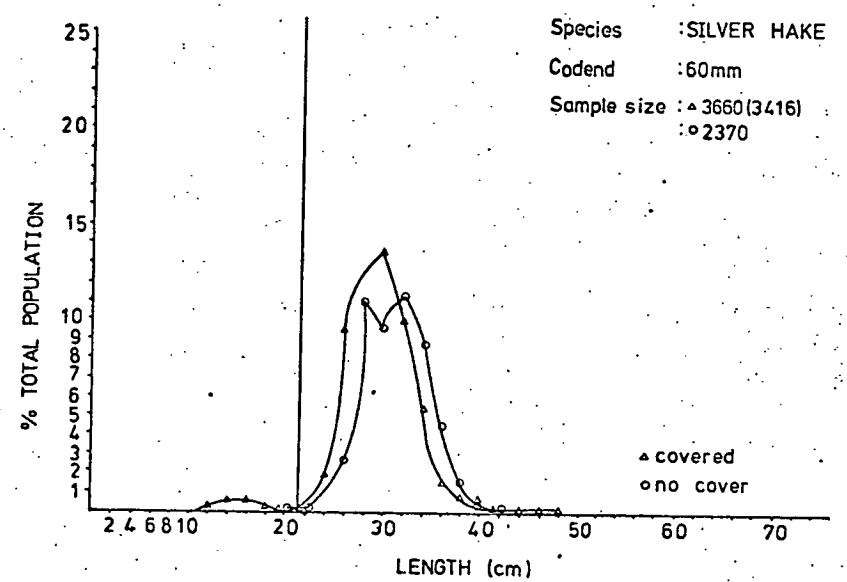
Note: 1) The vertical solid lines indicate the 50% retention level and the broken lines indicate the 25-75% levels (selection range) when the data were available. If the selection range is knife edged the broken lines are omitted.

2) The sample size is the total number of fish measured for the distribution, the number in brackets is the number of fish in the codend, the difference is the fish from the cover.

3) The silver hake 40-60 mm samples show a comparison between the catch in the covered tows to that of the uncovered tows.

Figure 1


Species :SILVER HAKE
Codend :40mm
Sample size : ▲3125 (2609)
: ○2232
▲ covered
○ no cover
% TOTAL POPULATION
LENGTH (cm)


Species :SILVER HAKE
Codend :60mm
Sample size : ▲3660 (3416)
: ○2370
▲ covered
○ no cover
% TOTAL POPULATION
LENGTH (cm)

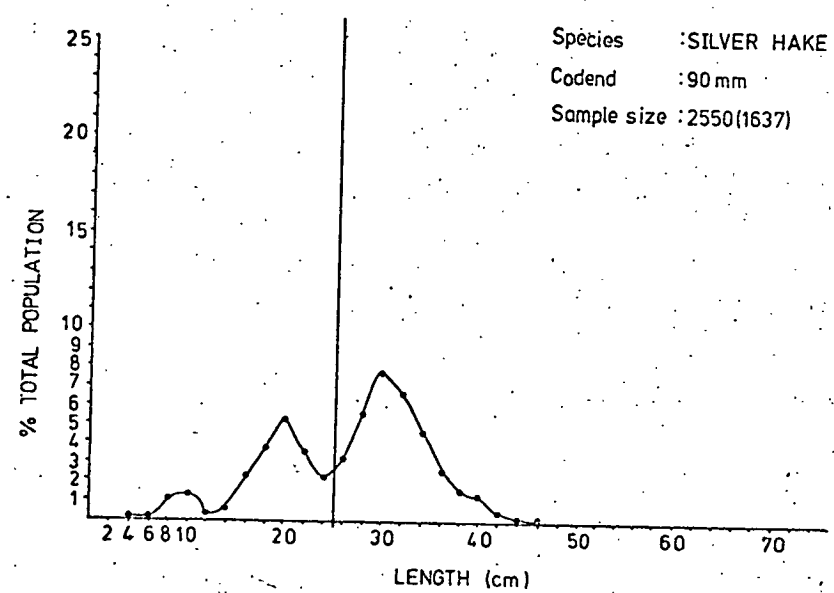
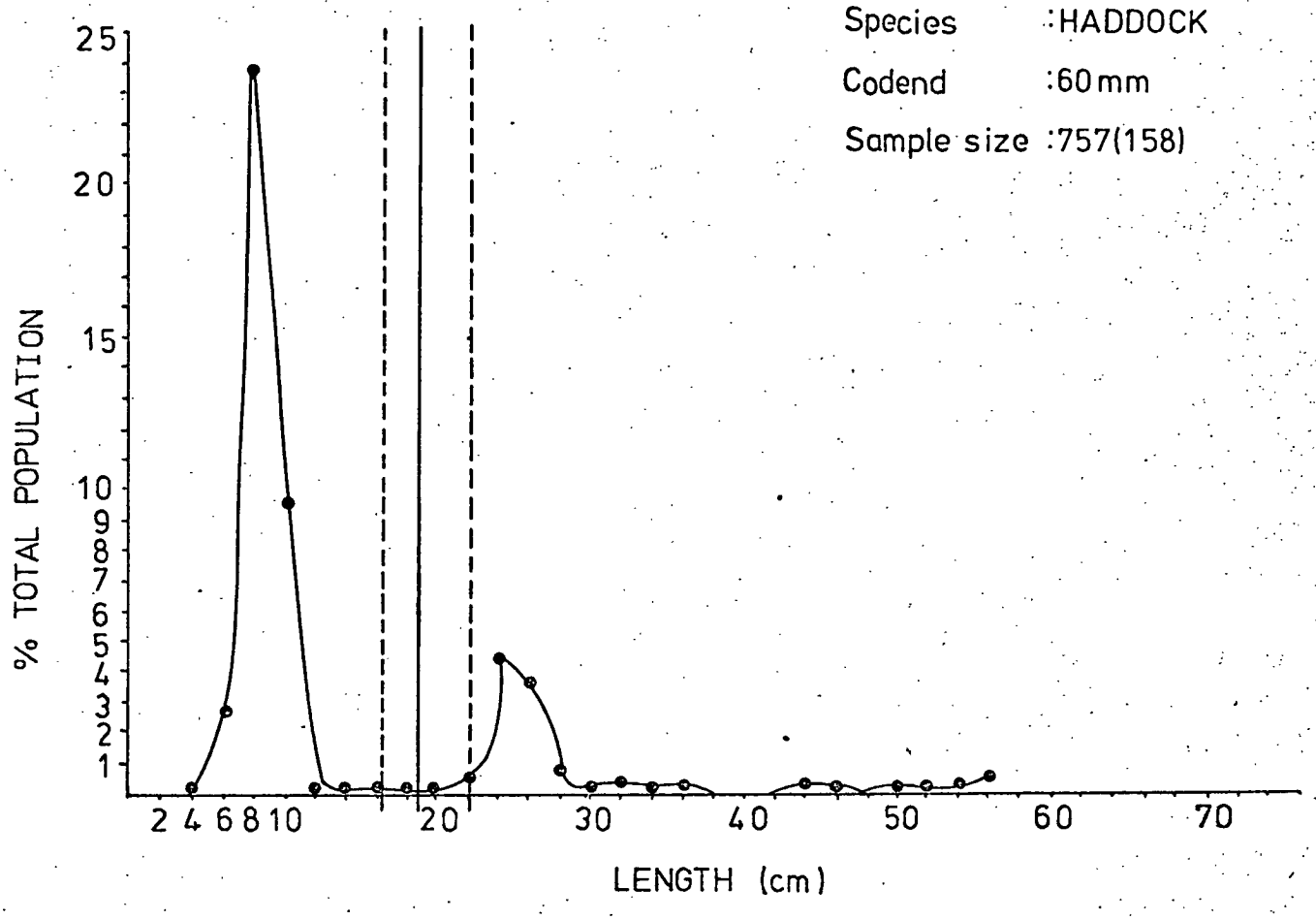

Species :SILVER HAKE
Codend :90mm
Sample size : 2550 (1637)
% TOTAL POPULATION
LENGTH (cm)

Figure 2


Species :HADDOCK
Codend :60 mm
Sample size :757(158)
% TOTAL POPULATION
25
20
15
10
9
8
7
6
5
4
3
2
1
2 4 6 8 10
20
30
40
50
60
70
LENGTH (cm)

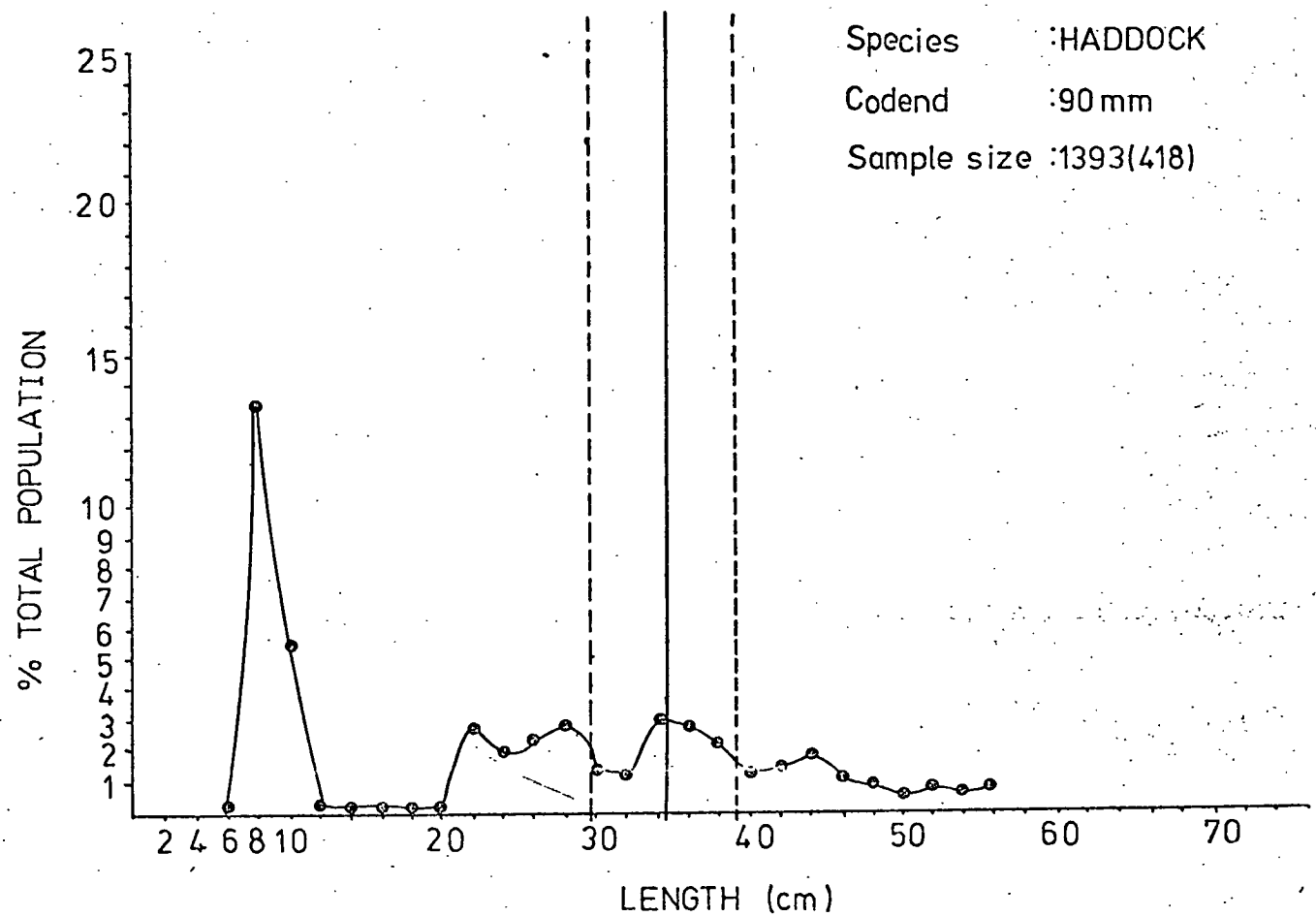
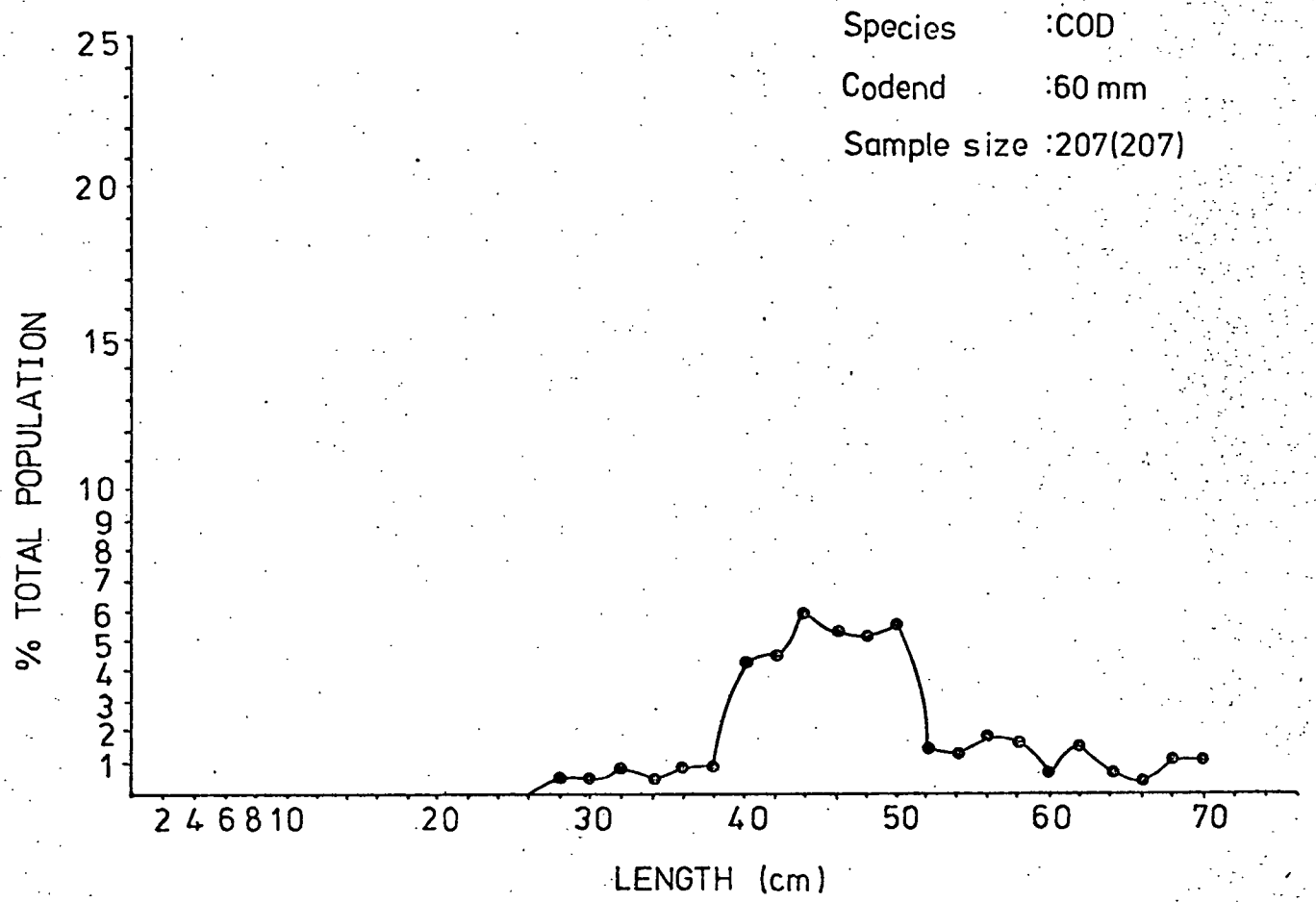

Species :HADDOCK
Codend :90 mm
Sample size :1393(418)
% TOTAL POPULATION
25
20
15
10
9
8
7
6
5
4
3
2
1
2 4 6 8 10
20
30
40
50
60
70
LENGTH (cm)

Figure 3


Species :COD
Codend :60 mm
Sample size :207(207)
% TOTAL POPULATION
25
20
15
10
9
8
7
6
5
4
3
2
1
2 4 6 8 10
20
30
40
50
60
70
LENGTH (cm)

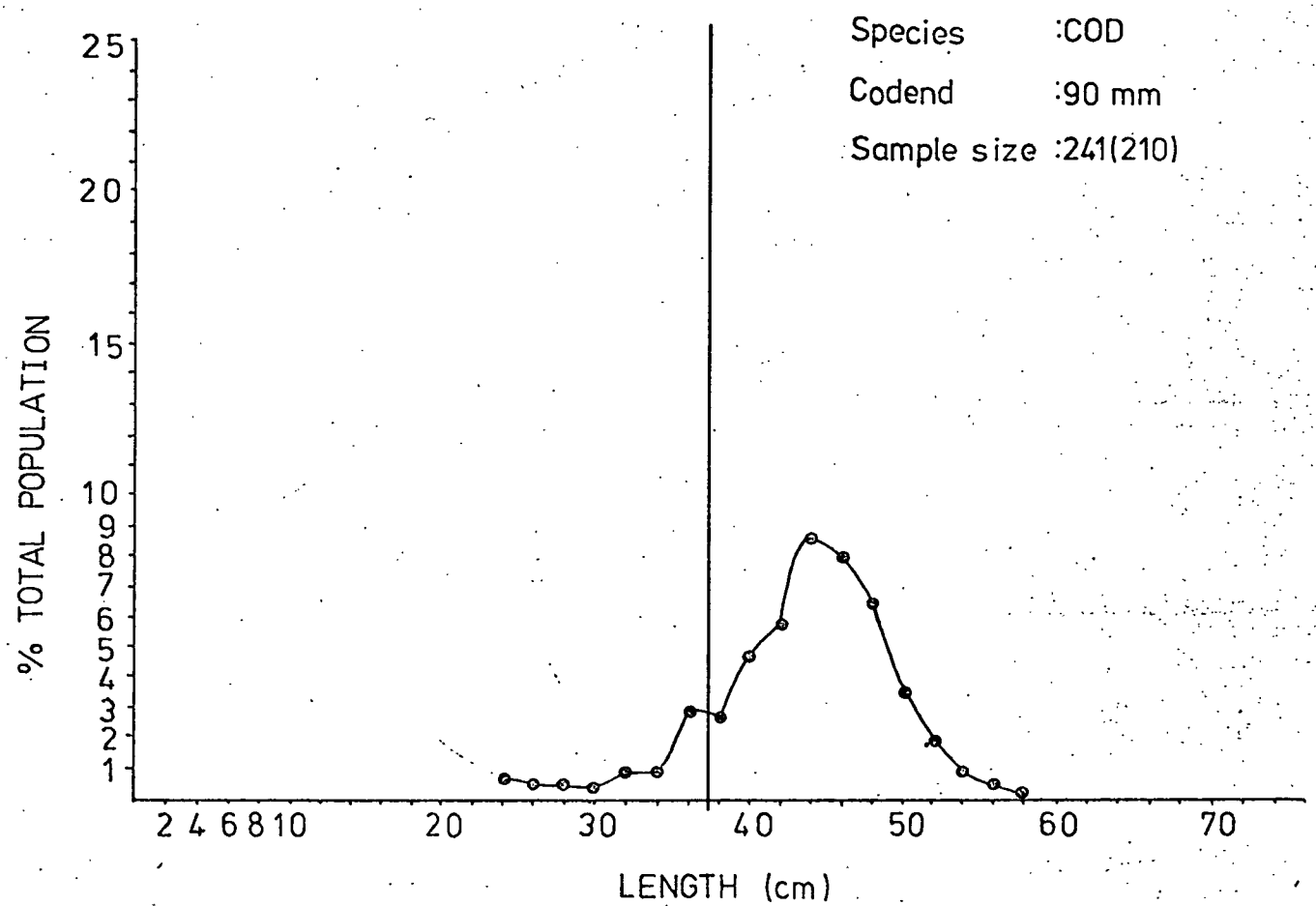
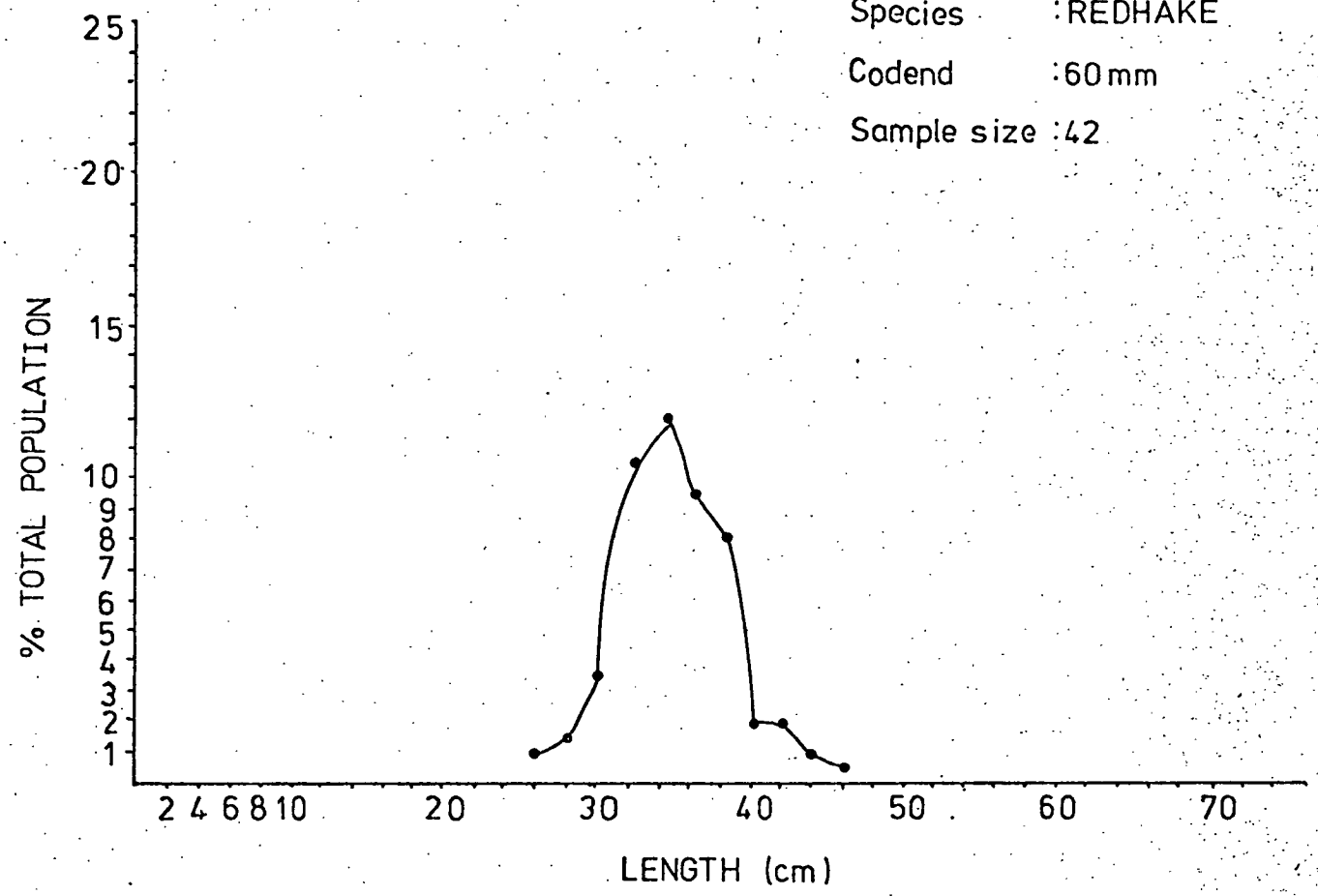

Species :COD
Codend :90 mm
Sample size :241(210)
% TOTAL POPULATION
25
20
15
10
9
8
7
6
5
4
3
2
1
2 4 6 8 10
20
30
40
50
60
70
LENGTH (cm)

Figure 4


Species :REDHAKE
Codend :60 mm
Sample size :42
% TOTAL POPULATION
25
20
15
10
9
8
7
6
5
4
3
2
1
2 4 6 8 10
20
30
40
50
60
70
LENGTH (cm)

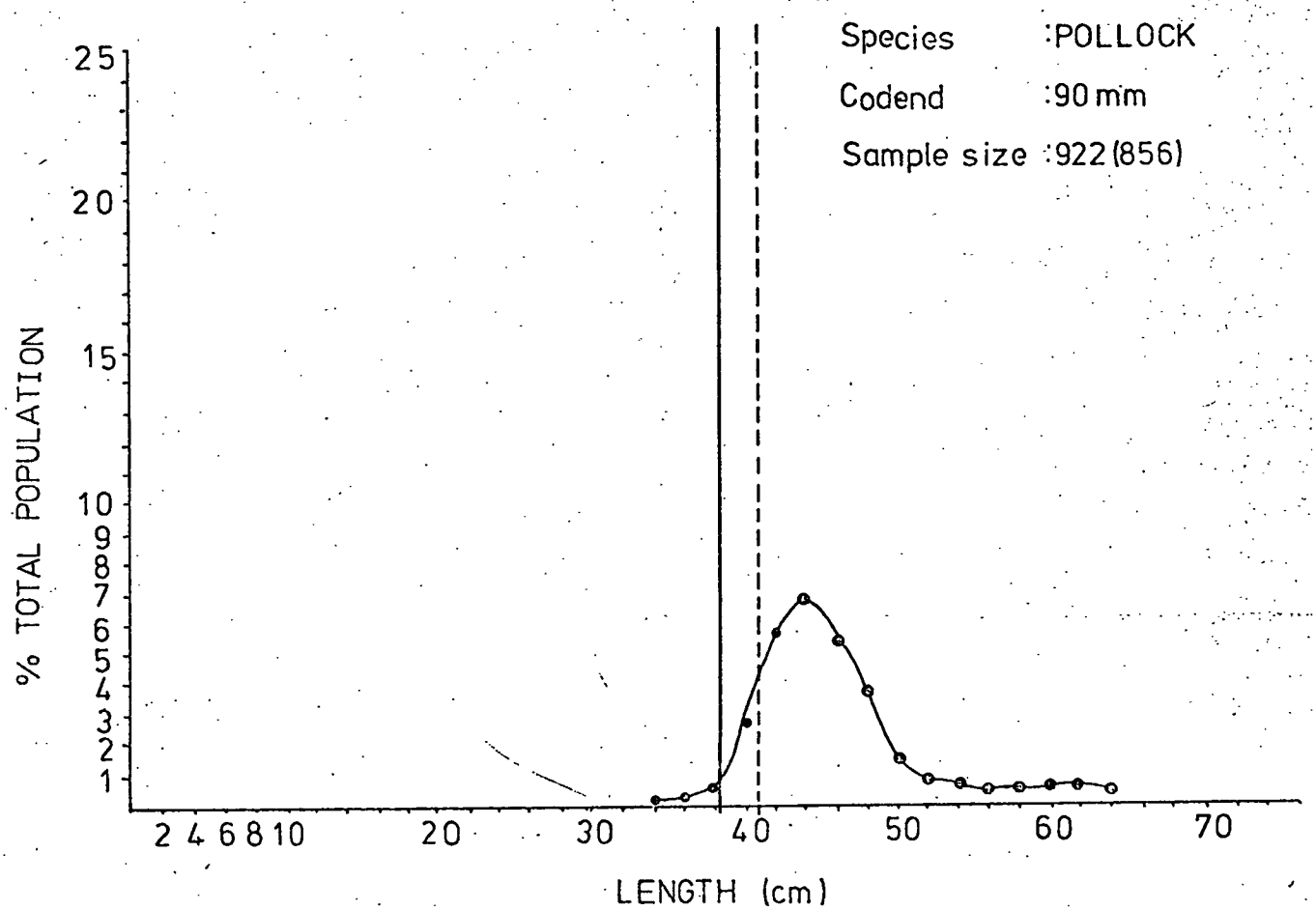

Species :POLLOCK
Codend :90 mm
Sample size :922 (856)
% TOTAL POPULATION
25
20
15
10
9
8
7
6
5
4
3
2
1
2 4 6 8 10
20
30
40
50
60
70
LENGTH (cm)

Figure 5

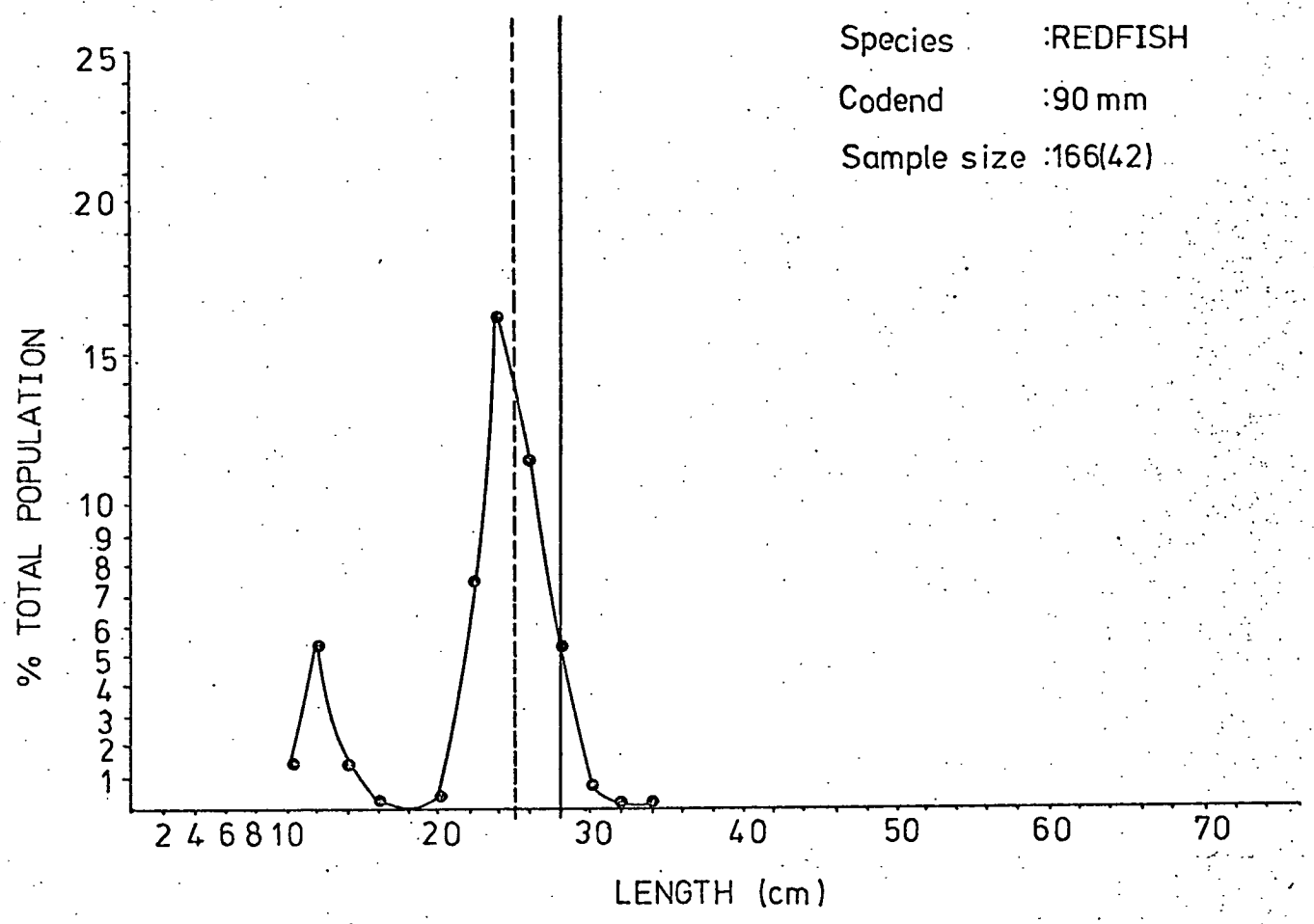
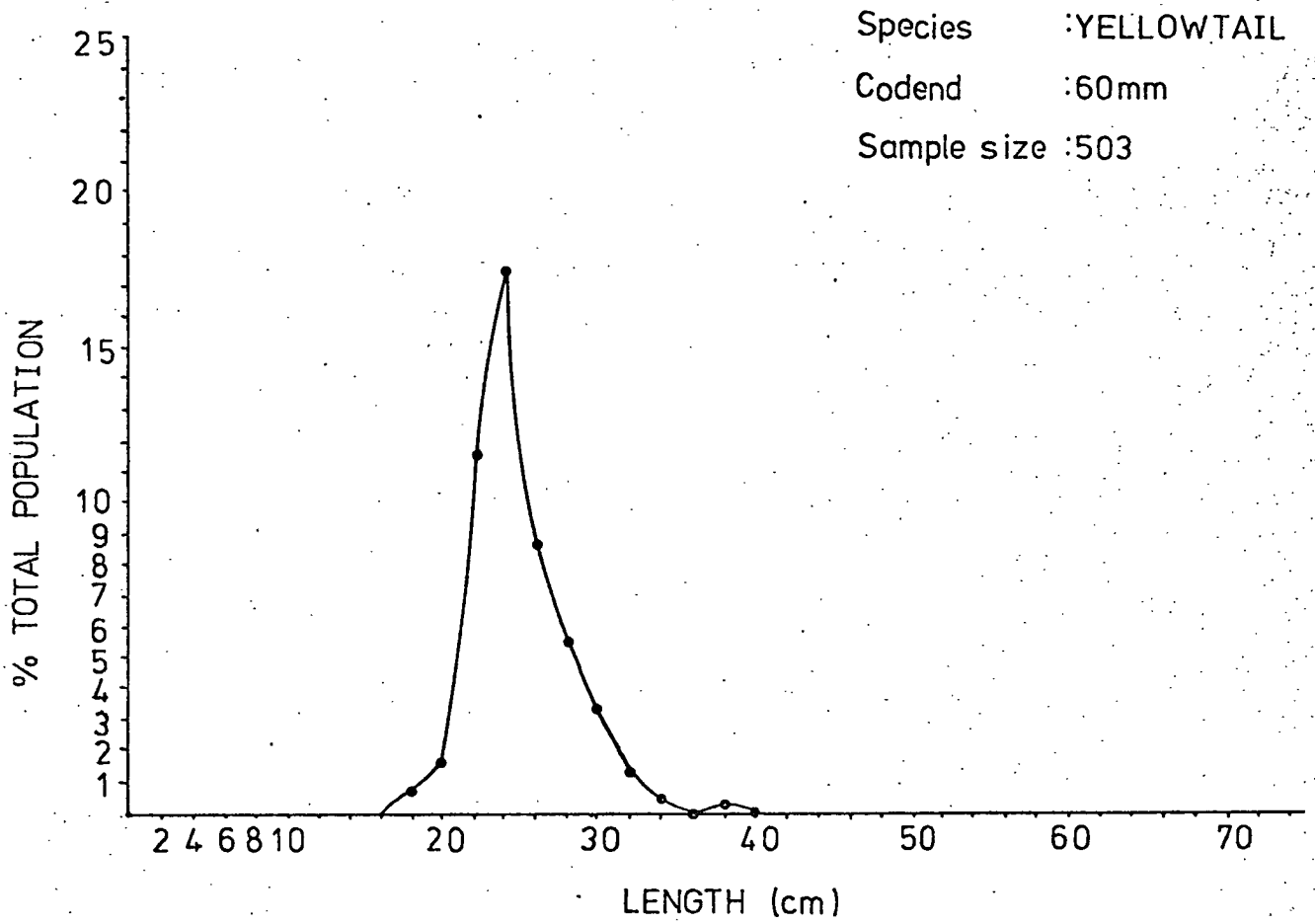

Species :REDFISH
Codend :90 mm
Sample size :166(42)
% TOTAL POPULATION
25
20
15
10
9
8
7
6
5
4
3
2
1
2 4 6 8 10
20
30
40
50
60
70
LENGTH (cm)

Figure 6


Species :YELLOWTAIL
Codend :60mm
Sample size :503
% TOTAL POPULATION
25
20
15
10
9
8
7
6
5
4
3
2
1
2 4 6 8 10
20
30
40
50
60
70
LENGTH (cm)

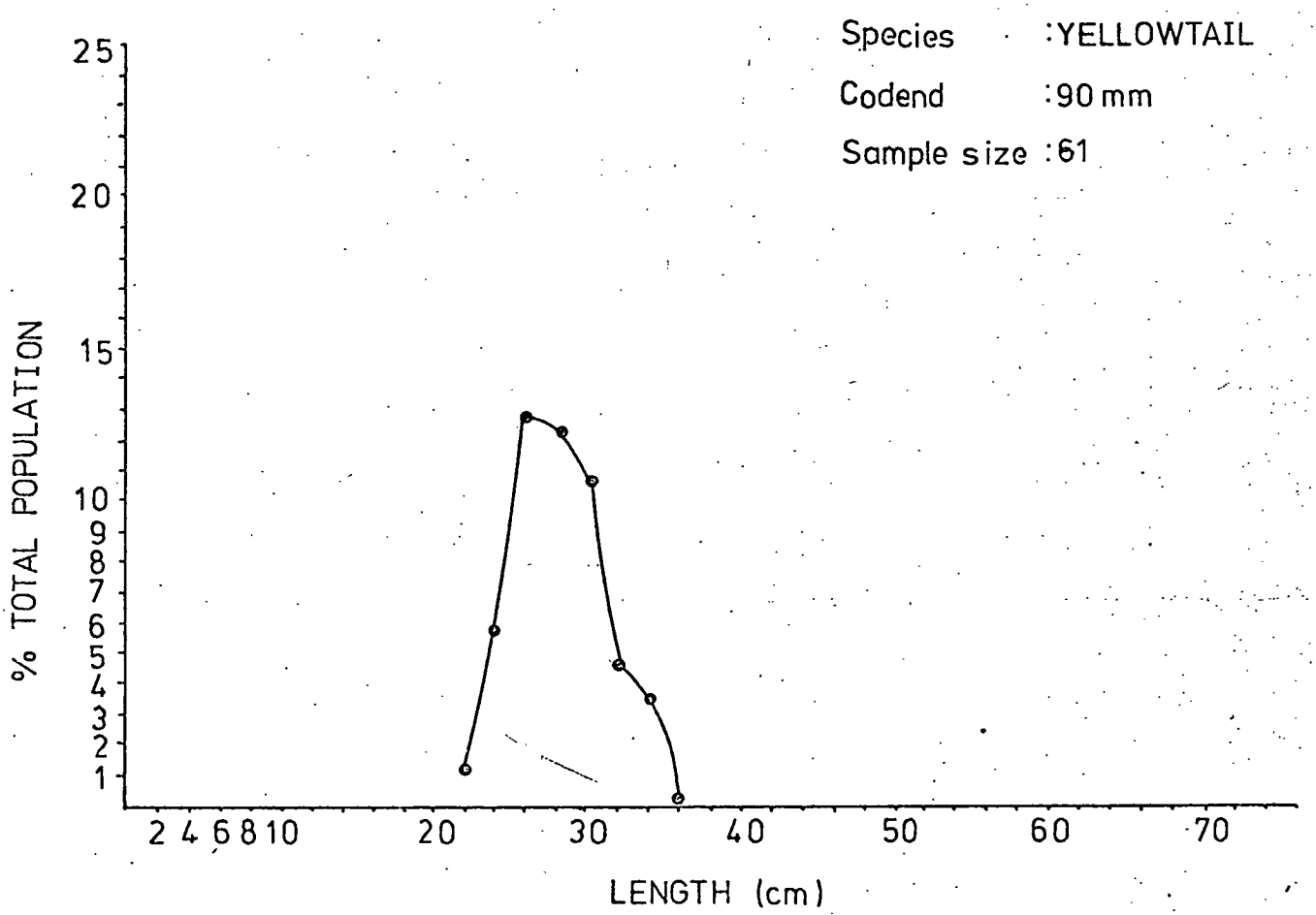
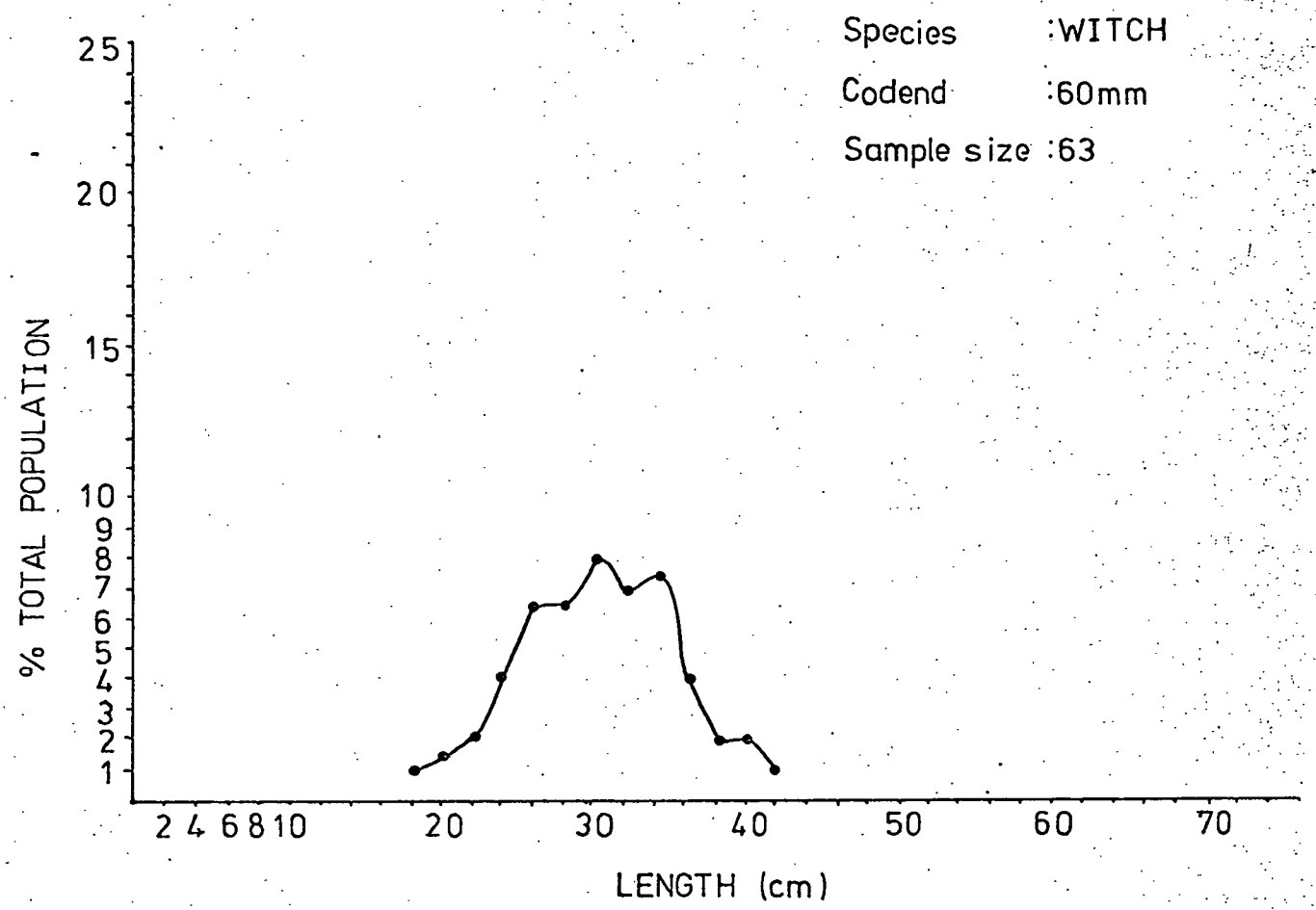

Species :YELLOWTAIL
Codend :90 mm
Sample size :61
% TOTAL POPULATION
25
20
15
10
9
8
7
6
5
4
3
2
1
2 4 6 8 10
20
30
40
50
60
70
LENGTH (cm)

Figure 7


Species :WITCH
Codend :60mm
Sample size :63
% TOTAL POPULATION
25
20
15
10
9
8
7
6
5
4
3
2
1
2 4 6 8 10
20
30
40
50
60
70
LENGTH (cm)

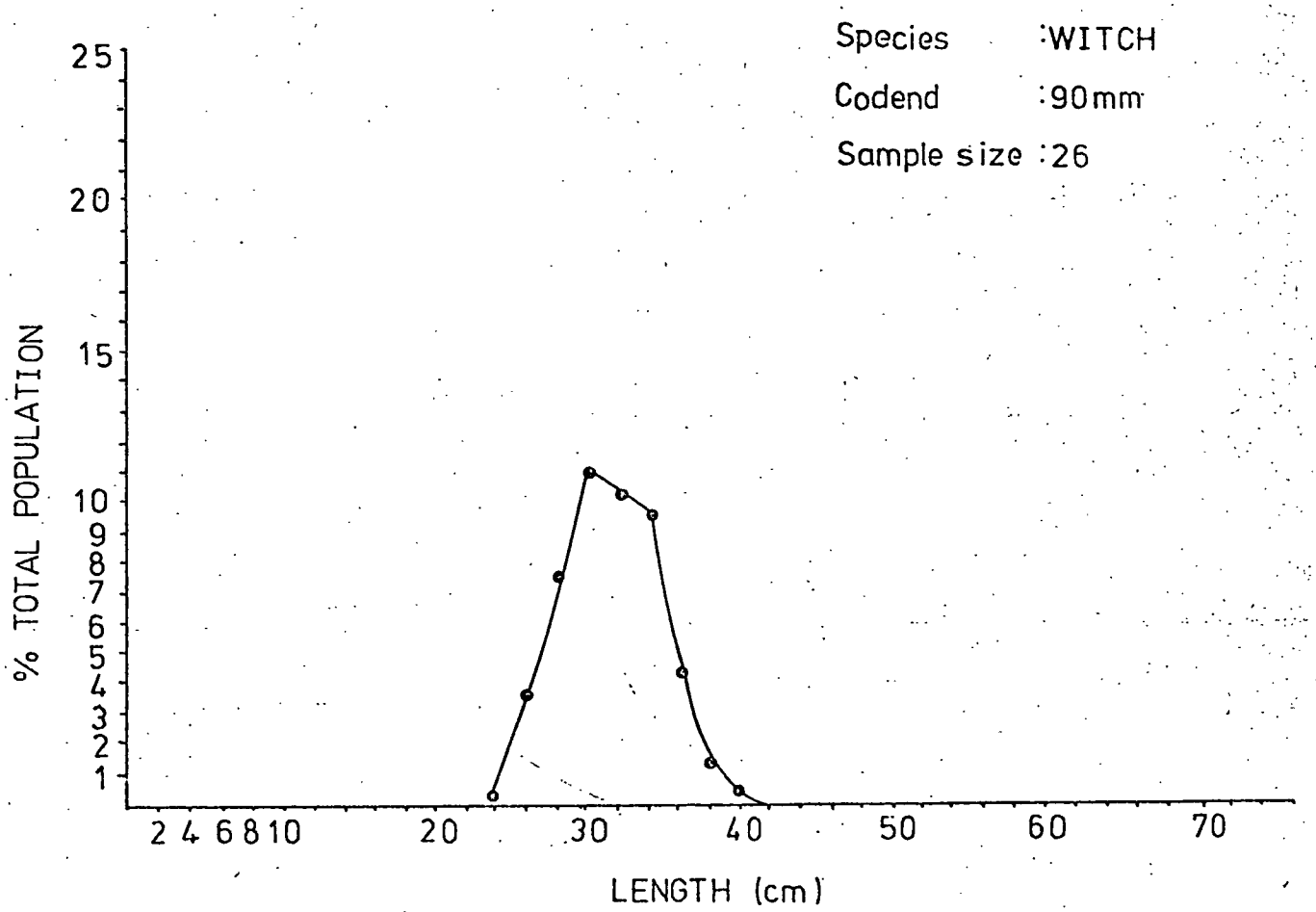
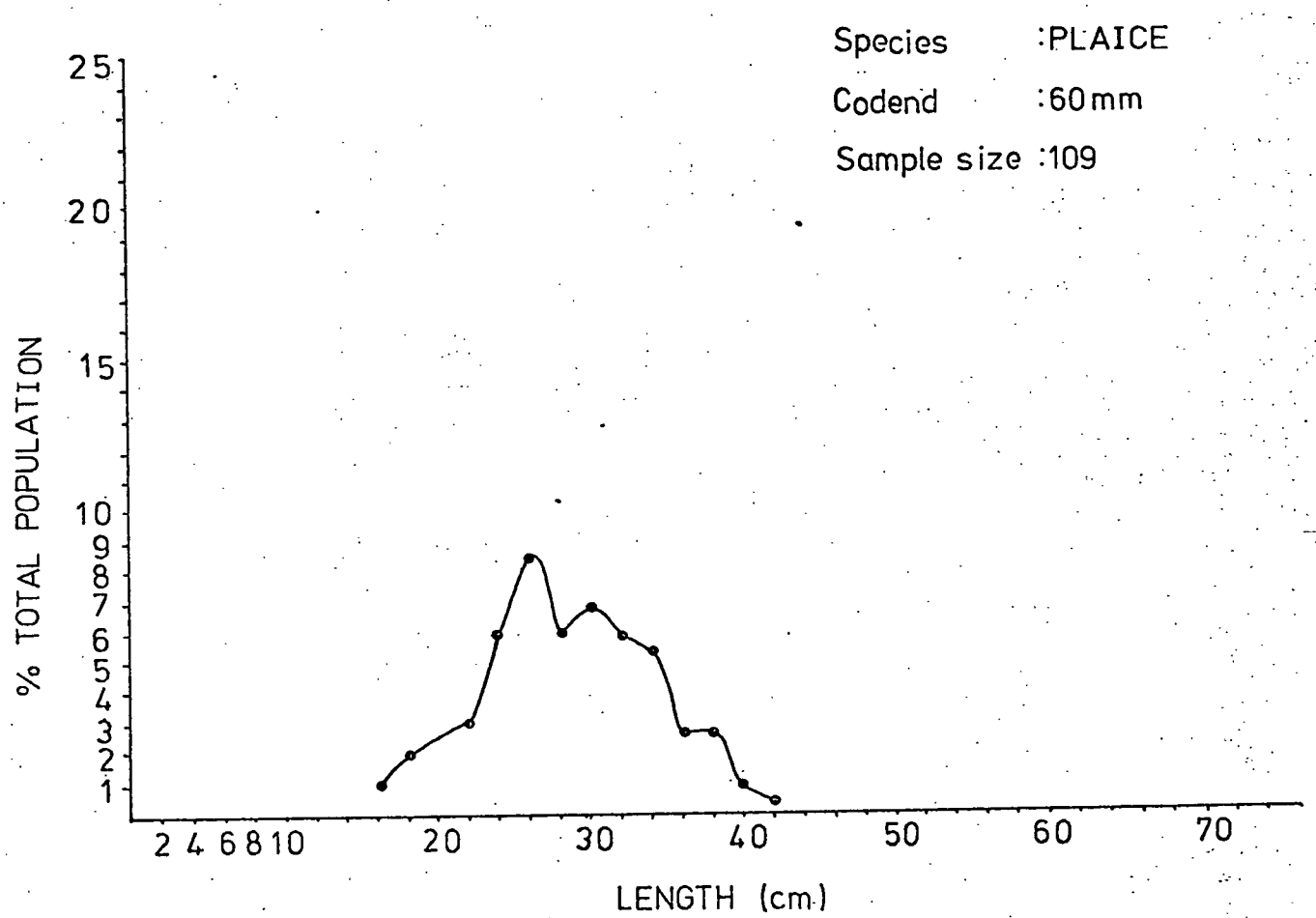

Species :WITCH
Codend :90mm
Sample size :26
% TOTAL POPULATION
25
20
15
10
9
8
7
6
5
4
3
2
1
2 4 6 8 10
20
30
40
50
60
70
LENGTH (cm)

Figure 8-


Species :PLAICE
Codend :60mm
Sample size :109
% TOTAL POPULATION
25
20
15
10
9
8
7
6
5
4
3
2
1
2 4 6 8 10
20
30
40
50
60
70
LENGTH (cm)

Historical selectivity ogives for silver hake (*Merluccius bilinearis*).

Figure 1. nylon codend (1966)

Figure 2. nylon codend (1954)

Figure 3. manila codend

Figure 4. cotton codend

Figure 5. kapron codend

Figure 1.

Selectivity ogives for nylon codends (Jensen & Hennemuth,1966)

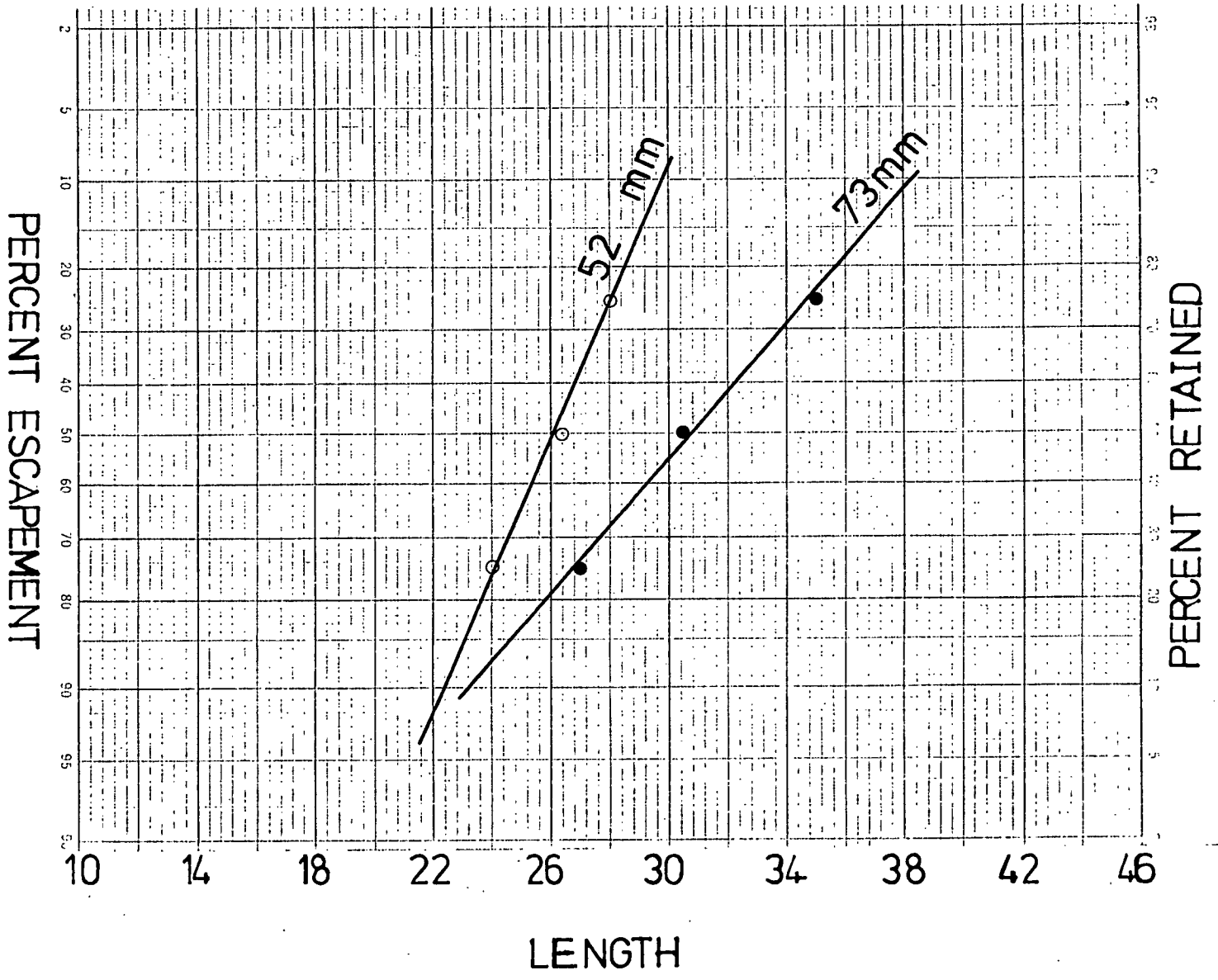


Figure 2.

Selectivity ogives for nylon codends (Clarke,]954)

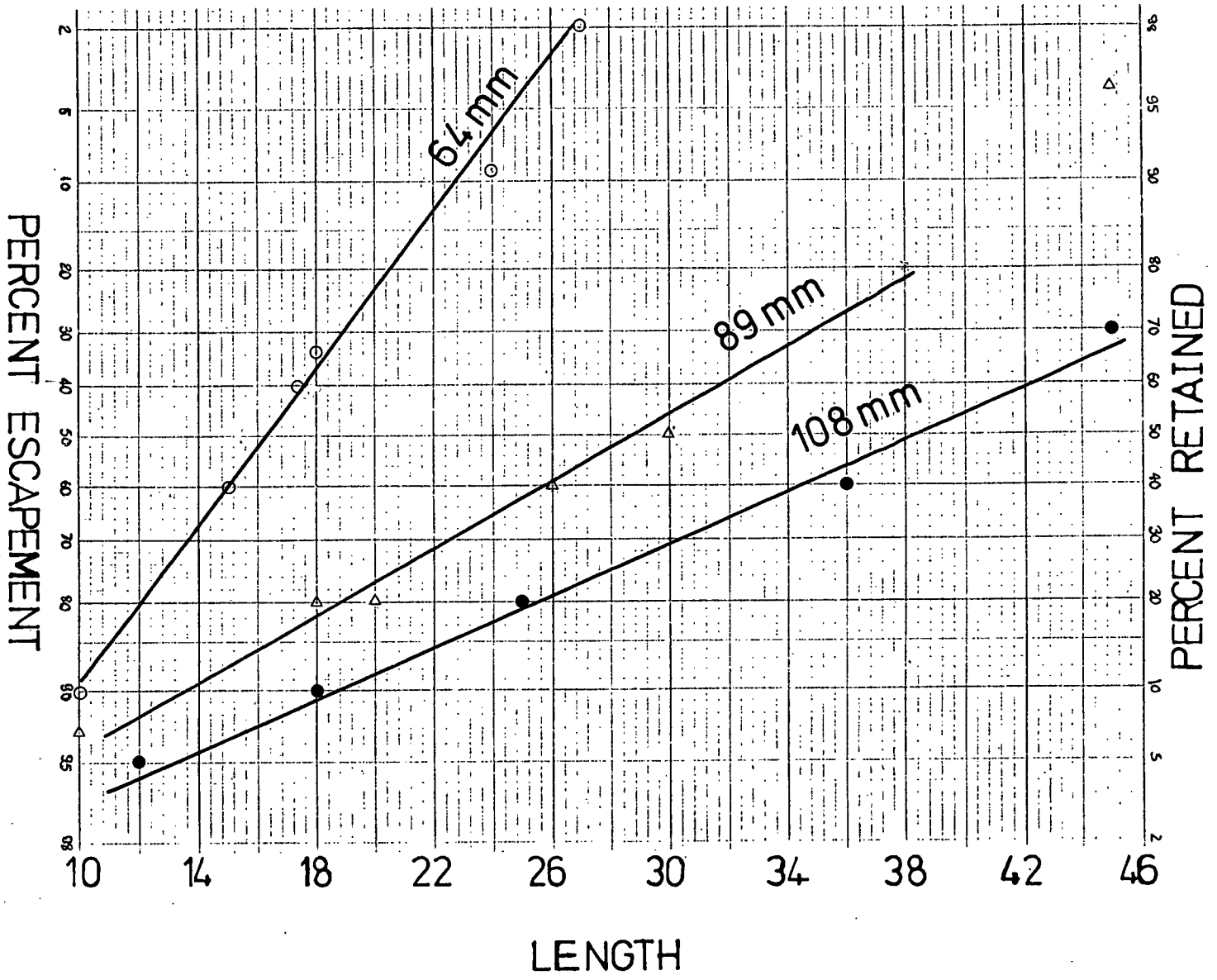


Figure 3.

Selection ogives for manila codends (Clarke,]954)

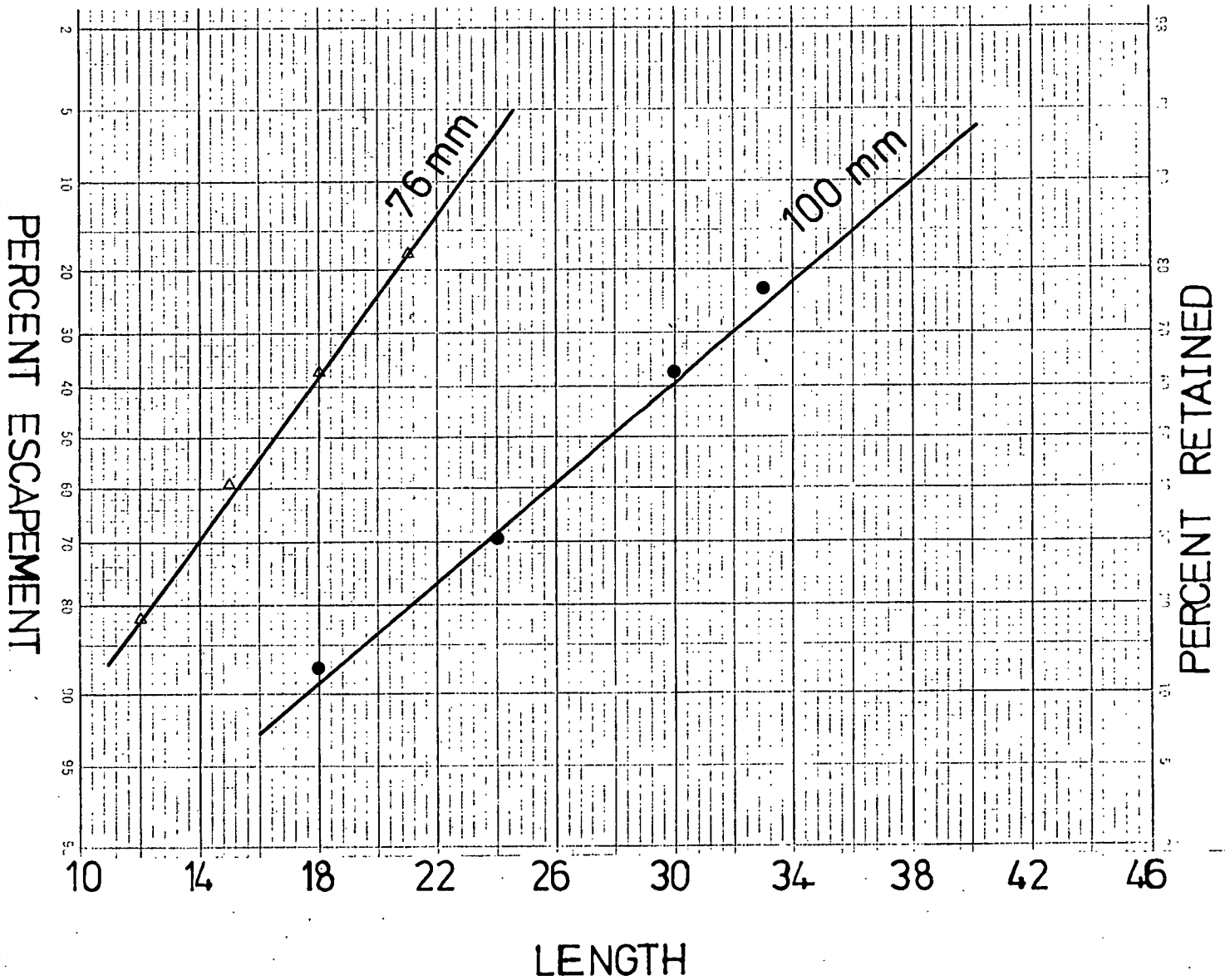


Figure 4

Selection ogives for cotton codends (Clarke, 1954)

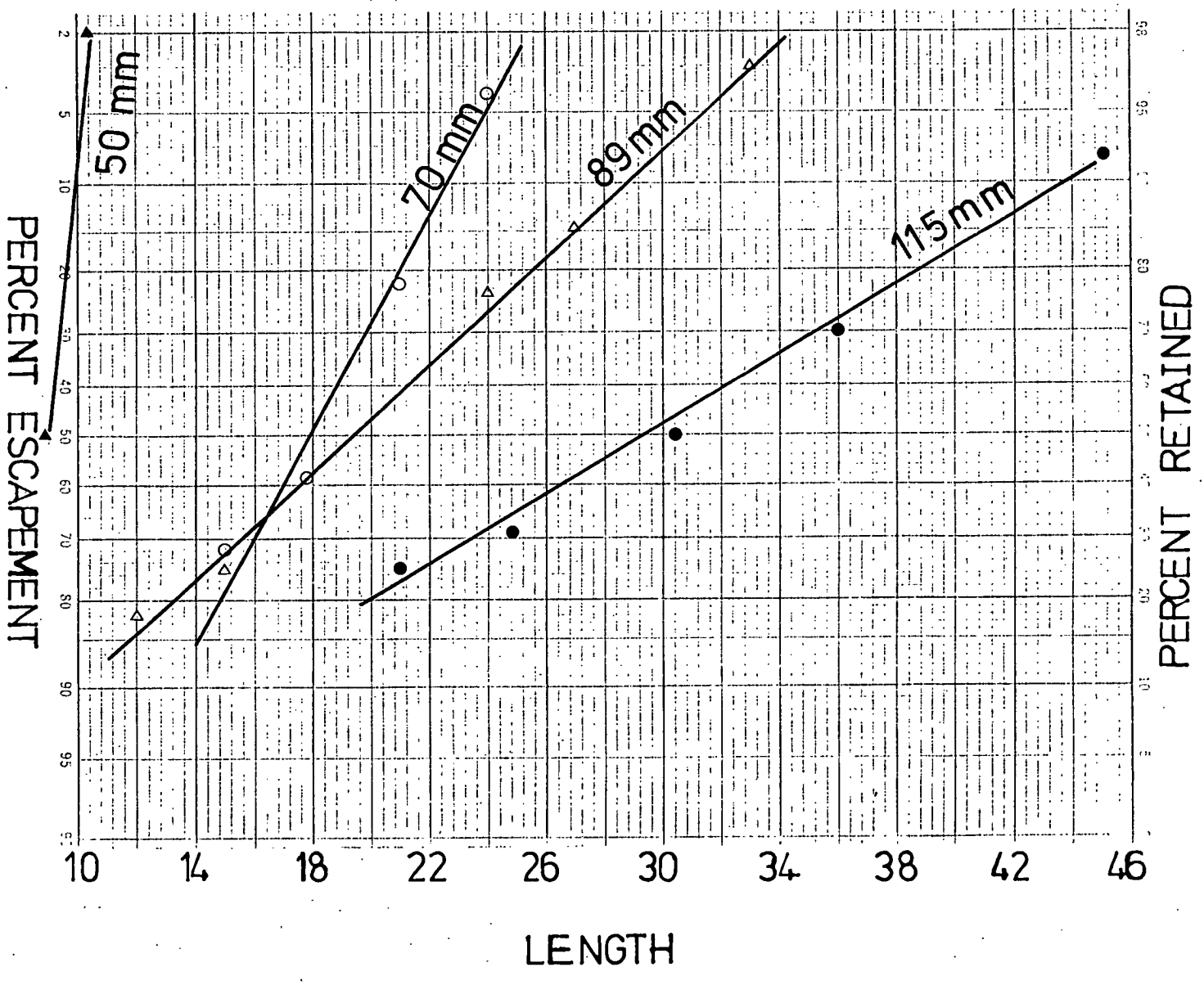
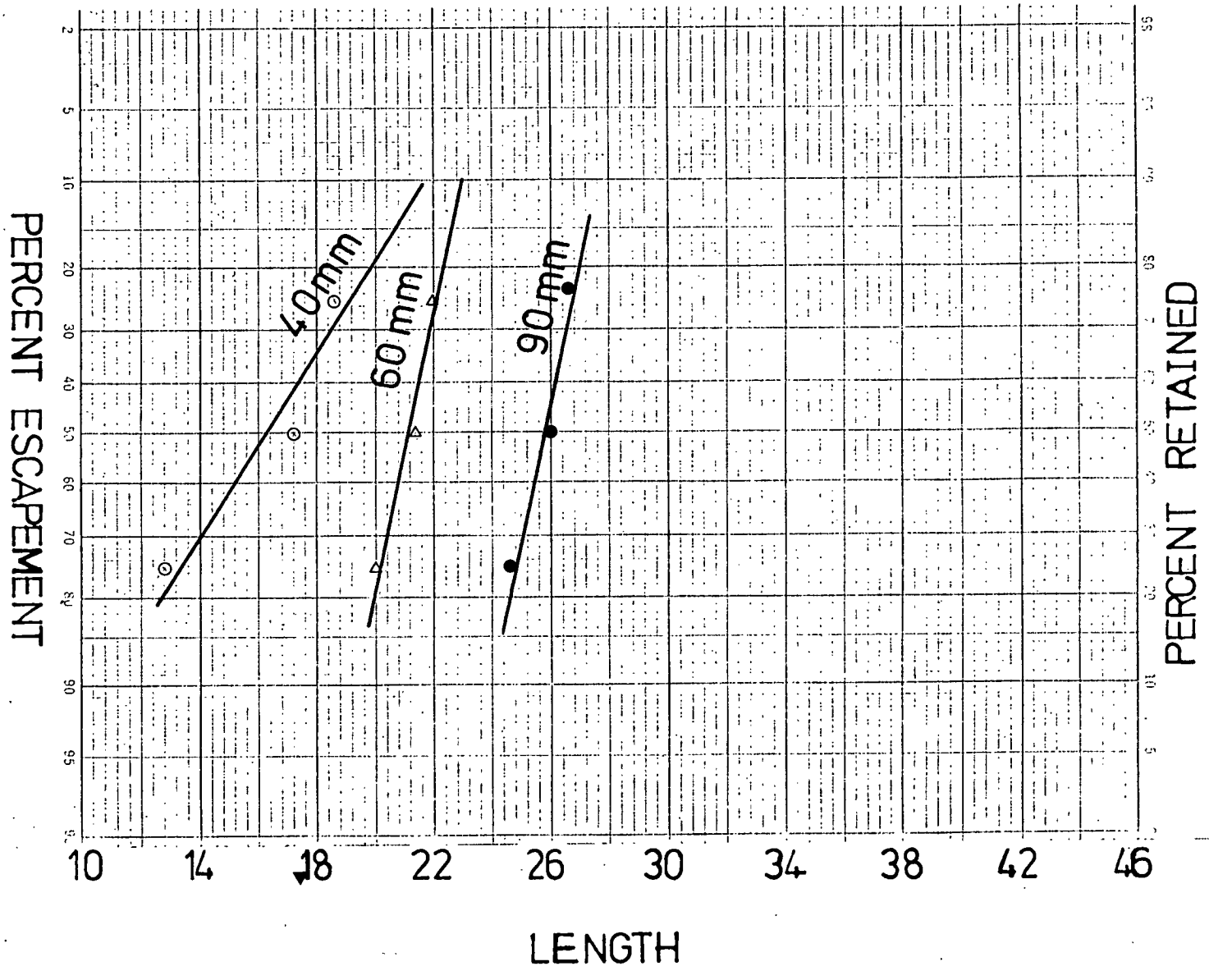


Figure 5

Selection ogives for kapron codends (this study,1977)



Appendix IV

Estimation of changes in silver hake (*Merluccius bilinearis*) catches by different codend mesh sizes.

Table 1. comparative catches 1976-1985

Table 2. selectivity by age

Figure1. yield per recruit figure

Estimation of changes in silver hake catches by different codend mesh sizes.

Total catch or yield of a fishery can be altered by many factors. One of these is selection by the fishing gear which affects the partial recruitment of different age groups into the fishery. The production of the fishery was estimated from the catch projection program used for population assessments. The partial recruitments were calculated for each of the different mesh sizes.

The production estimates from 1976-1985 given in Table 1 are not meant to be absolute values but only comparative. The initial inputs to the program were:- 1) the numbers at age taken from the 1977 assessment by Doubleday and Hunt (1977a), 2) the catch at age from the same source, 3) the recruitment, generated from the geometric mean and standard deviation of the levels from 1966-1975, 4) the weight at age calculated from a 1977 sample of 5000 fish, 5) maturity at age data taken from Doubleday and Hunt (1976), 6) partial recruitment, taken as the selection factor at age (Table 2), 7) the natural mortality which was assumed to be 0.4 from Terre and Mari (1977), and 8) the projected fishing levels which were 70,000 ton quota (as suggested in the 1976 assessment for 1977 and for 1978-1985 a fishing intensity of $F_{0.1}$.

The $F_{0.1}$ or the optimum fishing mortality was calculated by drawing a line at the 10% slope of the yield per recruit curve for each net size (Figure 1). These levels were calculated as 0.56, 0.70, 0.90 for the 40 mm, 60 mm and 90 mm codends respectively. The $F_{0.1}$ for the historical fishery with a selection assumed to be 100% for all age groups was 0.54. The optimum fishing mortality and partial recruitments are very close to that of the 40 mm mesh codend and thus separate calculations were not carried out.

The change in yield to the fishery follows a typical pattern as shown for many fish (Gulland, 1956; Hodder, 1962). Initially a reduction in catch of 6% is observed in 1978 when increasing the net size from 40 mm to 90 mm. It is interesting to note there is a small immediate increase of 5% when increasing the net from 40-60mm. The long term effectof the 40-60mm change is only an increase of about 6%. The long term effect of the 40-90mm change is an increase of about 25%.

Table 1

Comparative estimated catches in metric tons from 1976-1985 for three codend mesh sizes.

YEAR	CODEND MESH SIZE		
	40mm	60mm	90mm
1976	86,377	86,377	86,377
1977(quota)	70,000	70,000	70,000
1978($F_{0.1}$)	184,969	194,941	174,410
1979($F_{0.1}$)	157,162	173,836	213,193
1980($F_{0.1}$)	125,557	133,460	162,961
1981($F_{0.1}$)	82,001	87,664	106,499
1982($F_{0.1}$)	81,011	83,003	83,619
1983($F_{0.1}$)	83,779	91,553	111,767
1984($F_{0.1}$)	96,553	101,000	108,751
1985($F_{0.1}$)	95,316	105,029	133,133

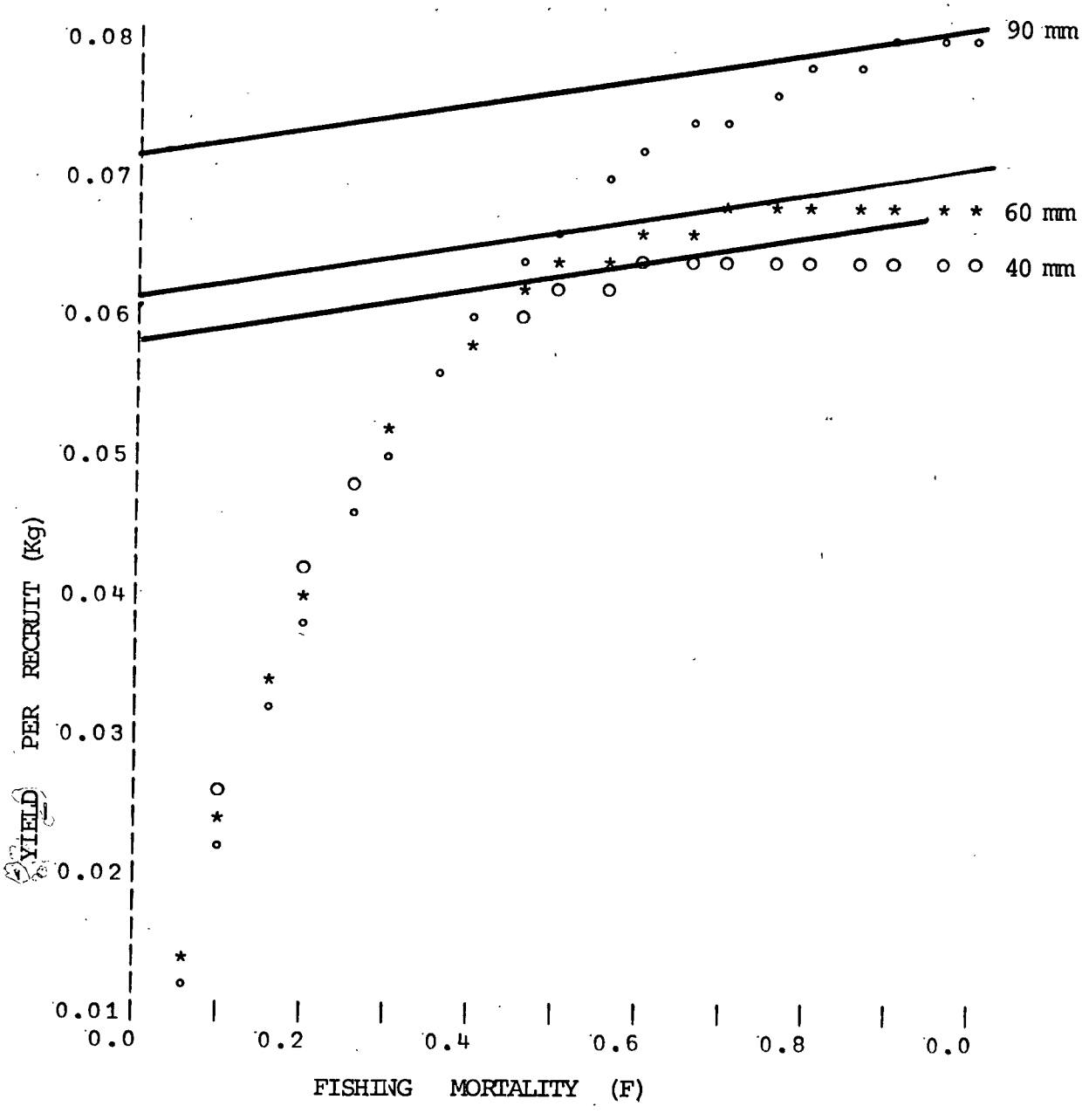
Table 2

Selectivity by age for the three codend mesh sizes (a knife edge selection throughout the entire age group was assumed and only the selectivity of the modal length for each age group was read from the graphs of Appendix I).

MESH SIZE	SELECTIVITY AT AGE			
	1	2	3	4+
40 mm	0.95	1.00	1.00	1.00
60 mm	0.60	0.96	1.00	1.00
90 mm	0.025	0.88	0.97	1.00

FIGURE 1.

The yield per recuit curves for fishing mortalities ranging from 0.0 to 1.0. The straight lines indicate the 10% slope (tangents) which give the optimum fishing mortality ($F_{0.1}$).



Addendum I

Discussion of catch projections with various fishing mortalities and partial recruitments.

Discussion of catch projections with various fishing mortalities and partial recruitments.

The new estimates of these catch figures have used new input data. Figure 6 of the main text shows the catch projection of each of the three net sizes using the $F_{0.1}$ value found in the yield per recruit figures of Appendix IV.

The number of year classes was changed from the 1, 2, 3, and 4 + used throught the original paper to 1, 2, 3, 4, 5, and 6 + as used in past assessments. The weight at age values were changed from .062, .146, .228, .405 kg as calculated from 1977 catch data to values estimated by Doubleday and Hunt (1977). These latter values are .051, .159, .270, .426, .635, and .905 kg.

The initial rise in catches in 1978 in all projections indicates the figures for the population numbers of 1976 are too high. The years 1981 - 1985 give a fair indication of any long term effect that might be expected. The values in this study are only for comparative purposes and are not meant to be any indication of projected catches.

The CAFSAC meeting held at the Bedford Institute of Oceanography on October 3 - 4, 1977 requested the following test runs be made on the input data: - A) projections be run at both the $F_{0.1}$ and at some constant F(in this case F=.6), to enable comparison of the catch when the fishery is under a constant effort, B) projections be run with both the experimentally determined selectivity of the nets and the historically determined partial recruitments from the 40mm (plus liner) codends used in the past.

Initially it was felt that the historically calculated partial recruitments for the fishery multiplied by the experimentally determined selectivity would give reasonable estimates of the availability of different age groups. Unfortunately when this is done all nets end up with the same availability. Because of this it was decided to compare the experimentally determined selectivity to the estimated availability. The figures used for the selectivity at age or the partial recruitment

into the fishery are shown in Table 2. These figures (historical) are in effect the partial recruitment of age 1 and sometimes age 2 fish with the assumption, that older age groups, when fished by larger net sizes will be fully recruited. The 40mm historical partial recruitments are those actually observed in the fishery.

The results of these various assumptions are shown in Figure (s) 1a,b, and c.

The $F_{0.1}$ is calculated from these yield per recruit (YPR) curves and is shown in Table 1. Figure(s) 2a and b show a comparison of the YPR for the 40, 60 and 90 mm codends as determined from the partial recruitments of Table 1. If the historically determined recruitment for the 40mm codend had been altered as the 60 and 90mm had (i.e. if the selection for age groups 4 - 6 had been assumed to be 1.00) the three curves would be nearly identical with $F_{0.1}$ identical as well.

The catch projections for this fishery gives similiar long term end results for all options. The 90mm codend appears to increase the total catch by some 15 - 25% over the 40mm net while the 60 mm net increase the catch by 5 - 10% over the 40mm net. The short term effect is more variable. The 90mm codend often suffers a drop in the first year of 10 - 25%, although, by the second year the catch has risen to at least equal the catch of the other nets in all cases.

Summary

A joint Canada-Cuba mesh selection study was carried out in August 1977. Time limitations and a lack of silver hake concentrations has made the data somewhate unreliable. The data indicates the 50% retention point for 40mm, 60mm, and 90mm kapron codends to be 17.5 cm, 21.5 cm, and 26.0 cm respectively. No masking effect corrections were included.

The CAFSAC meeting of October 3 - 4, 1977 at Bedford Institute accepted a proposal for a minimum mesh size of 90mm. The following reasons were given in support of this:

1. 90mm mesh will increase the yield of silver hake by 15 - 25% after an initial one year drop of from 10 - 25%.
2. 90mm mesh will release 1 year olds and retain most (90%) of the two year olds - the age group the present fishery is based upon.
3. 90mm mesh will release 1 year old haddock as well as the 0 group haddock that are presently released by the 60mm net.
4. 90mm mesh retains 72% of the squid population and will reduce the squid bycatch to some degree.
5. 90mm mesh should reduce the general bycatch of ground fish as the 50% retention point of pollock is 38 cm, of cod is 37 cm, and of redfish is 28cm.

TABLE 1

Values read from Figure(s) 1 indicating the optimum fishing mortalities ($F_{0.1}$) for each codend mesh size from both historical and experimentally determined selections.

NET (mm)	$F_{0.1}$	
	Historical Selection	Experimental Selection
40	.90	.40
60	.70	.47
90	.70	.70

Table 2

Selection on partial recuirtments as determined experimentally by this study and historically by the catch and population numbers of recent assessments (Doubleday and Hunt, 1977).

NET (mm)	SELECTIVITY AT AGE					
	1	2	3	4	5	6+
40 (experimentally)	0.95	1.00	1.00	1.00	1.00	1.00
40 (historically)	0.08	1.00	0.80	0.33	0.33	0.33
60 (experimentally)	0.60	0.96	1.00	1.00	1.00	1.00
60 (historically)	0.03	0.96	1.00	1.00	1.00	1.00
90 (experimentally)	0.025	0.88	0.97	1.00	1.00	1.00
90 (historically)	0.0	0.88	0.80	1.00	1.00	1.00

FIGURE 1.(a)

The yield per recruit curves for fishing mortalities ranging from 0.0 to 1.0 The straight lines indicate the 10% slope (tangents) which give the optimum fishing mortality ($F_{0.1}$).

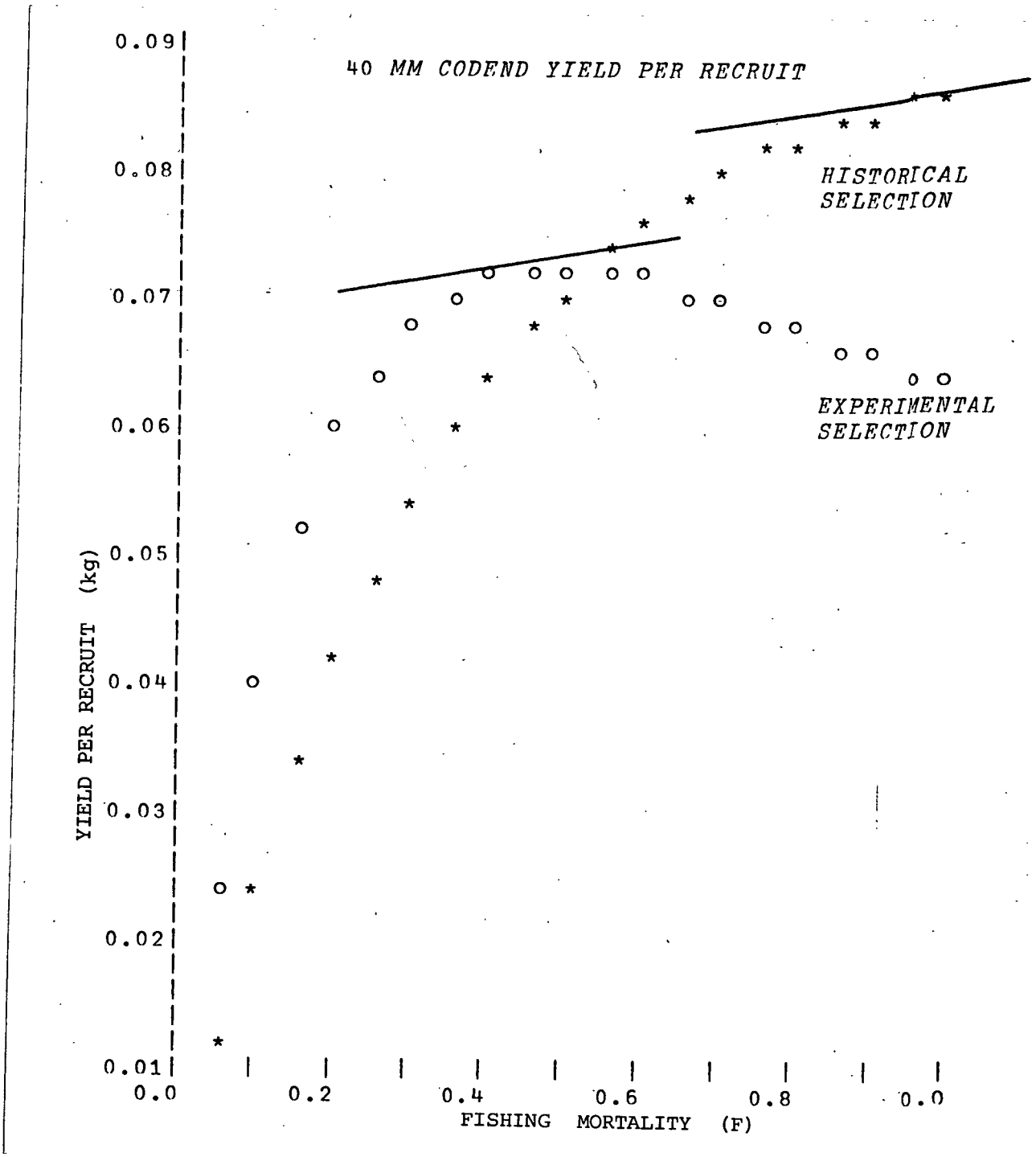


FIGURE 1 (b)

The yield per recruit curves for fishing mortalities ranging from 0.0 to 1.0. The straight lines indicate the 10% (tangents) which give the optimum fishing mortality ($F_{0.1}$).

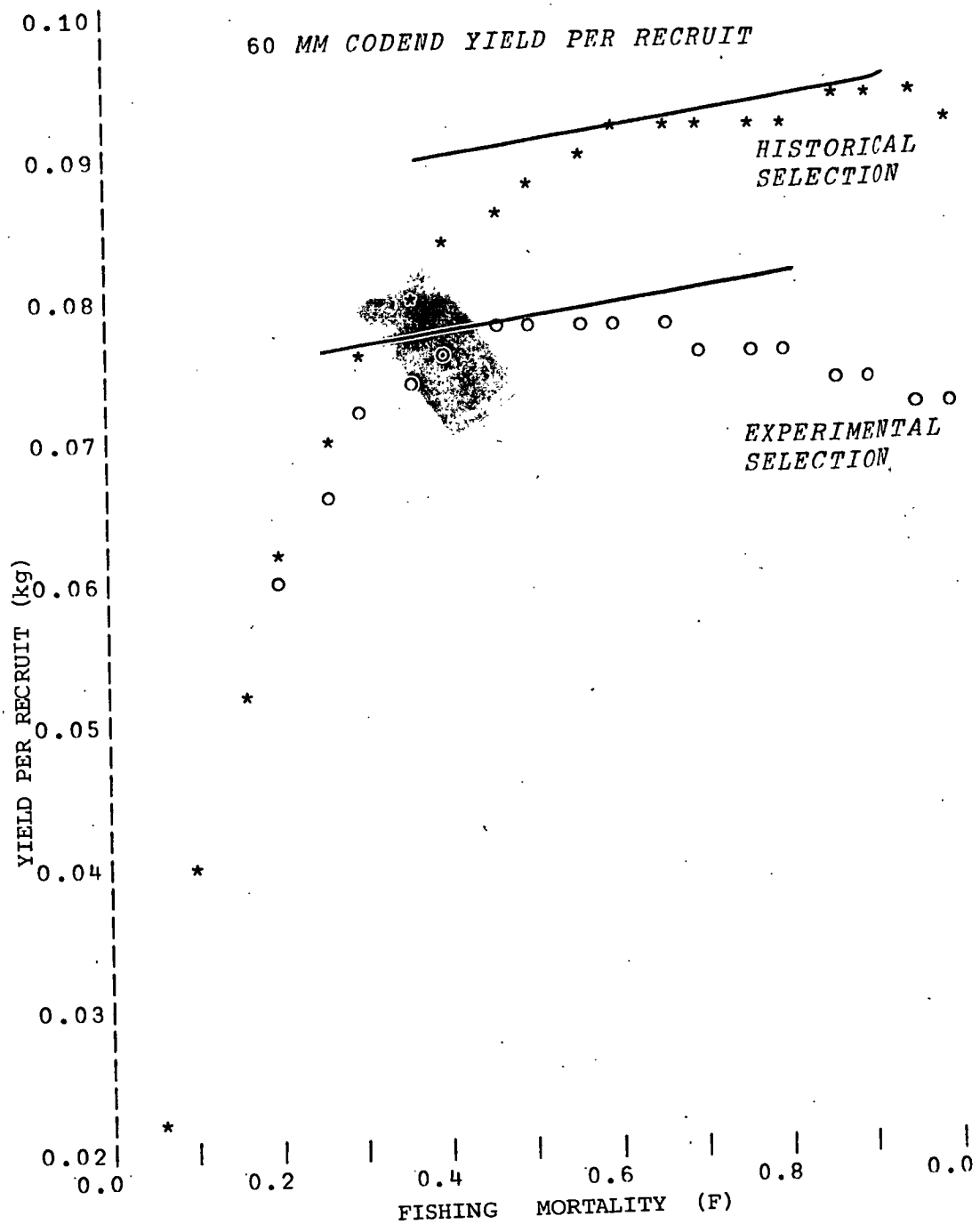


FIGURE 1 (c)

The yield per recruit curves for fishing mortalities ranging from 0.0 to 1.0. The straight lines indicate the 10% (tangents) which give the optimum fishing mortality ($F_{0.1}$).

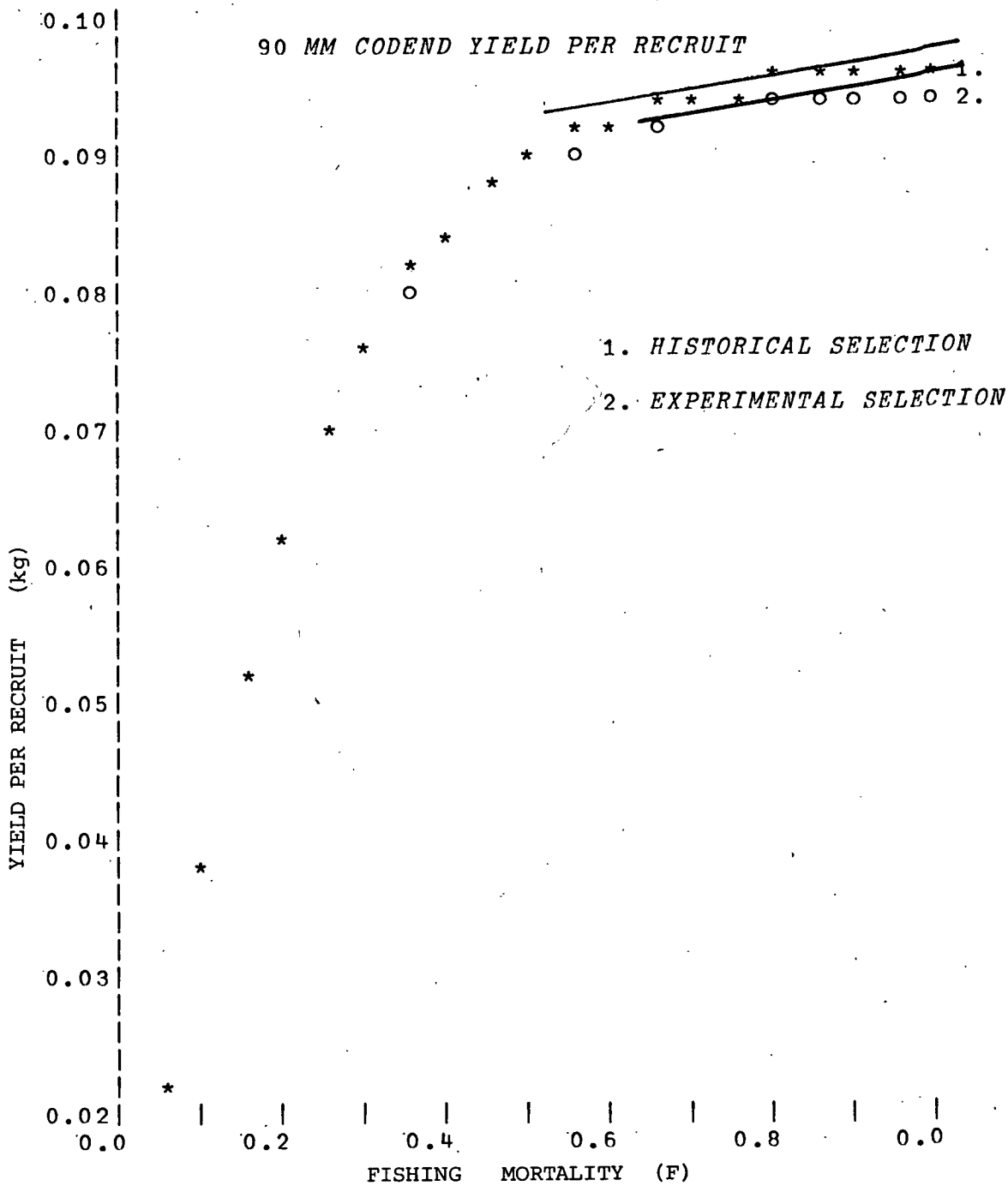


FIGURE 2(a) - 55

The yield per recruit curves as in Figure(s) 1. The three codend sizes are shown with an estimate of slection taken from historical values.

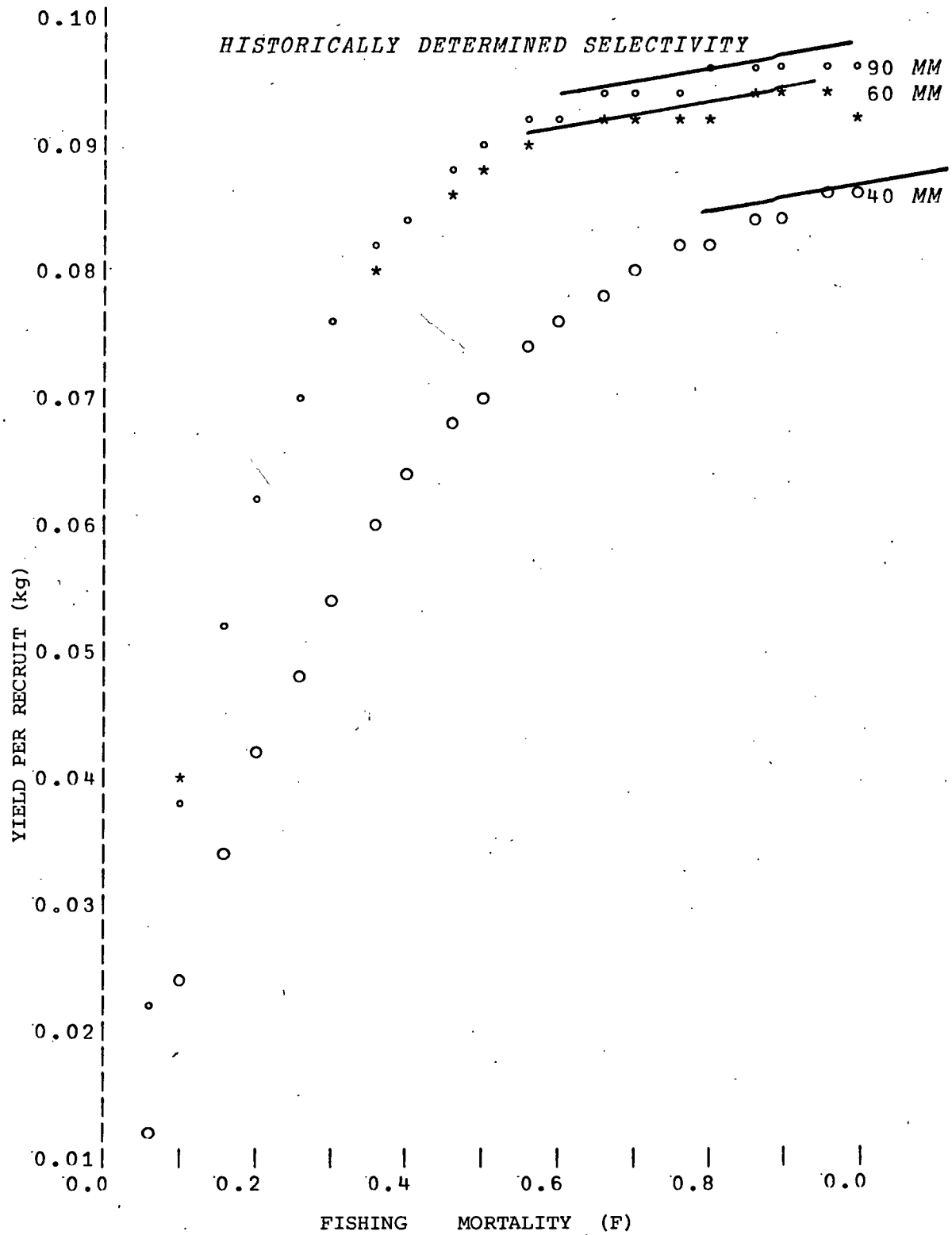


FIGURE 2(b)

The yield per recruit curves as in Figure(s) 1. The three codend sizes are shown with the selection taken from the experimental values of this experiment.

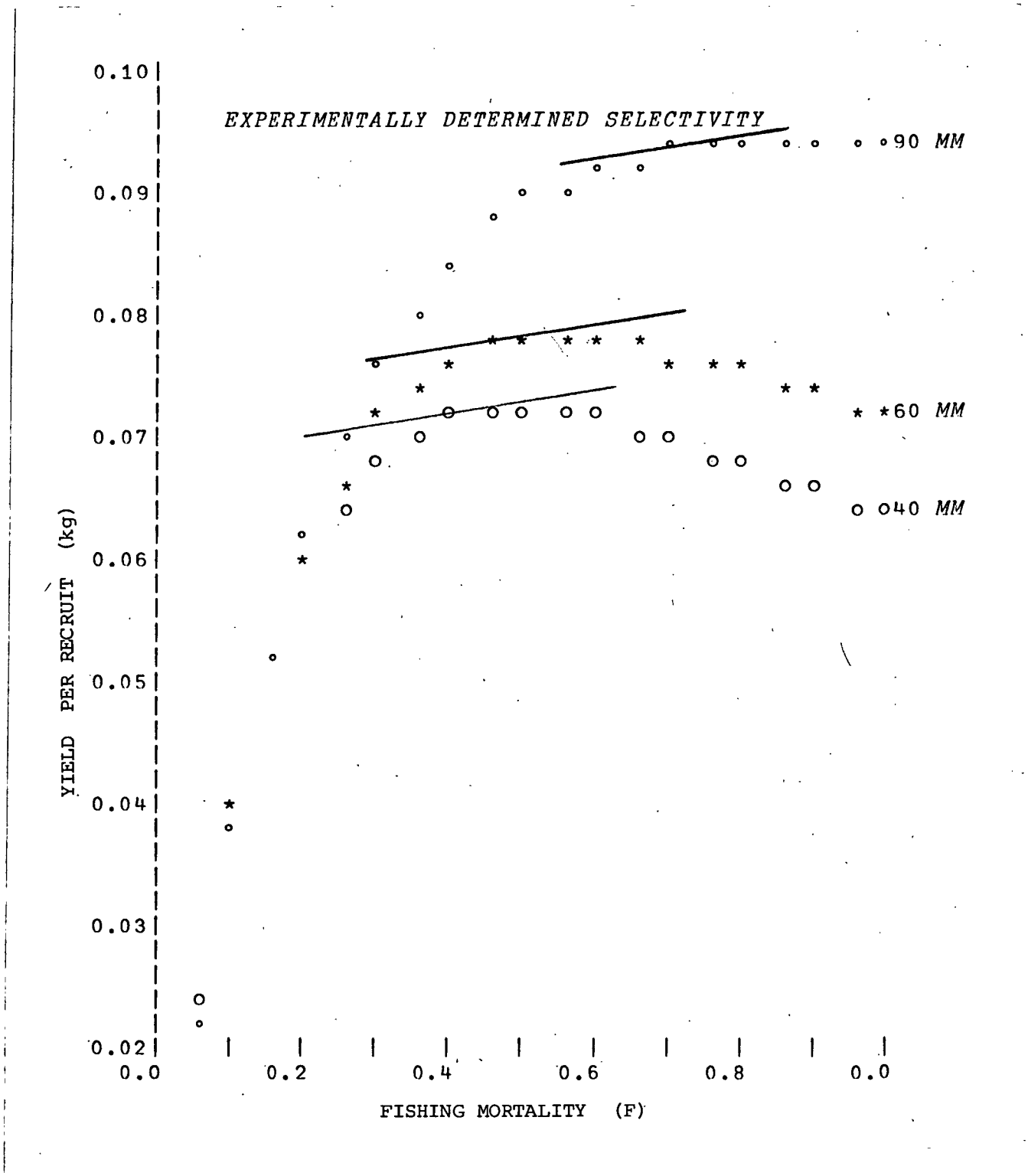


Figure 3

Catch estimates for three codends 40 mm (■) , 60 mm (▲) , 90 mm (○) for the period 1976-1985. The figures A and C are the historical partial recruitments and figures B and D are the experimentally determined partial recruitments. The (F)ishing mortalities are indicated on the figures.