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Mesh Selection of Silver Hake (*Merluccius bilinearis*) in Otter Trawls on the Scotian Shelf with Reference to Selection of Squid (*Illex illecebrosus*)

by

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Introduction

Selection experiments to design "savings gear" were begun nearly a century ago (Fulton, 1893). Many original studies were attempts to design nets to reduce the destruction of immature fish and although some of these were effective modifications (Ridderstad, 1915; Pettersson, 1925; Buchanan-Wallaston, 1929) they were generally too cumbersome for commercial use because of their rigid frames. Cassie (1955) pointed out that "it is now generally agreed that an ordinary trawl with no further modifications than an increased mesh size in the codend can act as an effective savings gear." For this reason the current studies concentrated on comparing the selection characteristic of various mesh sizes of kapron* codends. (Some commonly used expressions are defined in Appendix II.)

Selection studies are important for two reasons. First and foremost they can be used as management tools to reduce the destruction of undersized fish. Secondly, such studies allow biologists, who can rarely study a fish population directly, to use catch statistics more accurately to evaluate actual population numbers; this should lead to more accurate assessment techniques and a better understanding of the population dynamics of a species.

Studies of the life history of silver hake (*Merluccius bilinearis*) show that it grows rapidly during the first year of life (Hunt, MS 1977;

* Kapron is a polyamide synthetic material used extensively in the Soviet and Cuban fishing fleets.

Anon., MS 1976a). Spawning occurs between April/May and October/November with the peak occurring in June/July (Sauskan, MS 1964; Sarnitts and Sauskan, MS 1966). The larvae hatch from pelagic eggs and do not move to the bottom until they are approximately 4 cm in length (Nichy, MS 1967). Approximately 10% of the male population is mature in the first year (20 cm) and 98% in the second year while the females are 3% and 80% mature in their first and second years respectively (Doubleday and Halliday, 1976).

During the period March to October a large silver hake fishery, made up primarily of Soviet stern trawlers (1800+ tons), fishes the Scotian Shelf in the Northwest Atlantic. In the last few years other countries, most notably Cuba, have also entered the commercial hake fishery. In addition to this, some exploratory fishing by Canadian companies has been carried out. Historically, the Soviet fishing fleet used 40 mm mesh codends often with 40 mm liners (Anon., MS 1976c). The modal length of the commercial catch of silver hake, according to Soviet statistics taken from the ICNAF sampling Yearbooks, is 28 to 30 cm (ICNAF, 1962-1972). This modal length group represents fish of approximately 2 to 3 years of age. The small mesh nets and liners (40 mm) used prior to 1977 would have retained most fish over 15 cm (1+ years). Because the numbers of 2 and 3 year olds in the catch are greater than the numbers of 1 year olds (Doubleday and Hunt, MS 1977) there must be some selection in the fishery as a result of availability of juveniles.

Legislation agreed upon in December 1976 (Anon, MS 1976b) was a conservation measure to limit fishing inside (on the Shelf) the line shown in Fig. 1, to midwater trawls of a minimum of 60 mm mesh and to bottom trawls of a minimum of 130 mm mesh. The aims of the regulation were to increase the maximum sustainable yield of the silver hake fishery, and, if possible, reduce any undesirable bycatch of juveniles of other commercially important species. The regulation was based upon selectivity data from ICNAF Subarea 5 (Halliday, personal communication) where materials used in the codends differed from those currently used in Subarea 4. The purpose of the two joint mesh selection studies undertaken in 1977 between Canada and Cuba, and Canada and the USSR, was to quantify the effects of this new legislation upon the fishery.

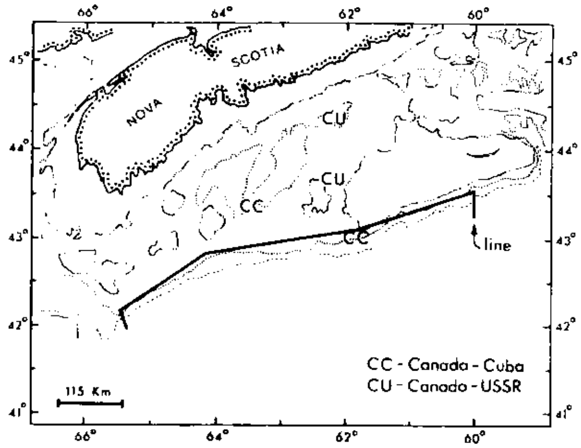

Fig. 1. **Map showing the "small mesh gear line" and the approximate locations of the joint Canada-Cuba and Canada-USSR mesh selection studies in 1977.**

Methods

A summary of the vessels and gears used is presented in Tables 1 and 2. Table 3 gives a comparison of the theoretical (commercial) mesh size and the average measured mesh sizes for both the cover and codends used in the studies. Throughout this report the measurements used in the text will be the commercial size measurements. Figure 1 indicates the locations of the two study areas in relation to the legislated small mesh gear line.

On the Soviet vessel, R/V *Foxton,* the topside cover was fitted to the codend in a manner similar to ICES specifications (ICES, 1964). The general construction and dimensions of this gear are shown in Fig. 2. On the Cuban vessel, R/V *Isla de la Juventud,* exact details of the attachment of the cover are not available in the cruise reports (Anon, 1977; Hare, 1977) althouth Hare (pers. comm.) has recalled the cover was attached close to the codend. This problem of cover attachment may have affected the selectivity (see below).

The sizes of the codend meshes were measured with an ICNAF gauge at 4 kg pressure. During the Canada-USSR study three series of measurements were taken on 10 random meshes for each mesh size. During the Canada-Cuba study fewer measurements were taken. All of these data are presented in Table 3.

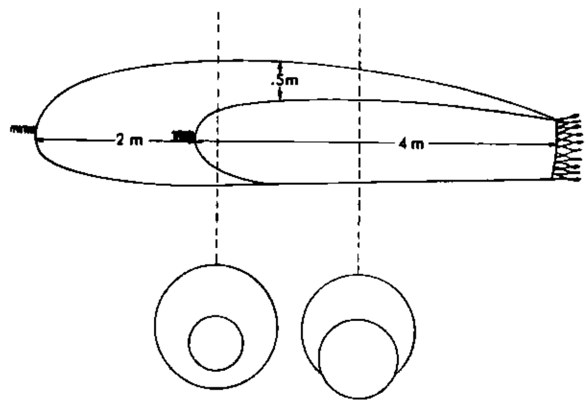

Fig. 2. **Schematic diagram and dimensions of the topside covered codend used by the USSR R/V *Foton* during the joint Canada-USSR mesh selection study in 1977.**

TABLE 1. Research vessel specifications for mesh selection studies.

Technical Data - RV *Isla de la Juventud* (Cuba)

Length over all:		70.3 m
Beam:		12.5 m
Displacement:	Net	1556 tons
	Gross	2200 tons
Power:		2400 hp
Speed:		14.5 knots
Type of Ship:		Stern Trawler/Freezer

Technical Data - RV *Foton* (USSR)

Length over all:		54.6 m
Beam:		
Displacement:	Net	660 tons
	Gross	987 tons
Power:		800 hp
Speed:		10 knots
Type of Ship:		Side Trawler

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TABLE 2. Gear specification for the bottom trawl nets used on the Cuban RV *Isla de la Juventud*

		1	2	3
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 of Bridles		113 m	...	...
Type of Doors		oval	...	...
Door Weight		1500 kg	...	...
Door Area		5.3 m^2	...	...
Mesh Size (Wings)		204 mm	...	...
Mesh Size (Body) -	square	200 mm	...	...
	middle	150 mm	...	...
	end	123 mm	...	...
Mesh Size (Codend)	dry	40.1	66.1	90.0
	wet	40.1	66.1	90.0
Liner in Codend		yes (covering the codend knot)		...
Cover on Codend		yes	...	...
Mesh Size (Cover)	dry	20 mm	...	...
	wet	20.1 mm	...	...
Chafing Gear Fitted		yes	...	...
Rollers on Foot Rope		no	...	...
Codend Material		kapron	...	...
Codend Twine		unknown	...	...
Cover Material		kapron	...	...
Cover Twine		unknown	...	...

Gear Specification for the bottom trawl nets used on the USSR RV *Foton* (Fishing Licence #214-197).

	1	2	3	4
Type of Trawl	Bottom trawl	...	...	...
Foot Rope Length	31.4 m	...	...	...
Head Rope Length	28.0 m	...	...	...
Head Rope Height	5.0 m	...	...	...
Wing Spread	11.0 m	...	...	...
Length of Bridles	50.0 m	...	...	...
Type of Doors	oval steel	...	...	...
Door Weight	650 kg	...	...	...
Door Dimension	(2.75x1.80) m	...	...	...
Mesh Size (Wings)	200 mm	...	...	...
Mesh Size (Body)	160 mm	...	...	...
Mesh Size (Codend)	39.6 mm	59.6 mm	70.8 mm	124.1 mm
Liner in Codend	no	...	...	...
Cover on Codend	yes	...	...	...
Mesh Size (Cover)	34.5	...	...	...
Chafing Gear Fitted	no	...	...	...
Rollers on Foot Rope	yes*	...	...	...
Codend Material	kapron	...	...	...
Codend Twine	93.5 tex x 18	...	...	93.5 tex x 12†
Cover Material	kapron	...	...	...
Cover Twine	93.5 tex x 12	...	...	...

* Rollers were 145 mm diameter steel weights connected through the centre to a heavy rope. The entire apparatus was connected by 18 cm chains to the foot rope.

† Assumed although not checked.

TABLE 3. Results of measurements of codend and cover mesh sizes of kapron codends from the RV *Isla de la Juventud*.

'Size'* mm	50	60	90	20†
Dry	40.1	66.1	90.0	20.0
Wet	40.1	66.1	90.0	20.1
		66.2	90.2	
		66.1	90.2	
		66.1	90.2	
Mean Dry	40.1	66.1	90.0	
Mean Wet	40.1	66.1	90.2	

* Commercially rated size (used throughout the study to denote the different gear types).

† Cover.

Results of measurements of codend and cover mesh sizes of kapron codends from the RV *Foton.*

Set Number	2	7	8	13	29	50	59	71	96	103	Before Fishing				
'Size'* (mm)	40	60	30†	70	120	120	60	70	70	60	40	60	70	120	30†
Measurements	(wet)	(wet)	(wet)	(wet)	(wet)	(wet)	(wet)	(wet)	(wet)	(wet)	(dry)	(dry)	(dry)	(dry)	(dry)
1	40	59	34	72	127	124	59	69	69	61	33	58	67		33
2	38	60	33	72	128	126	63	70	68	59	30	55	65		31
3	41	61	37	70	216	120	62	68	72	59	33	56	70		33
4	40	60	34	70	128	121	60	68	68	60	34	57	64		32
5	39	60	34	70	125	120	60	67	72	56	34	56	65		33
6	39	59	35	72	127	120	58	70	69	60	33	56	64		30
7	39	59	32	71	127	120	61	72	70	60	36	57	64		33
8	37	7	35	71	123	125	59	70	71	62	34	54	67		34
9	42	61	36	70	125	122	60	68	67	59	34	57	64		34
10	41	60	35	70	129	120	59	66	70	61	33	58	63		33
Mean	39.6	59.6	34.5	70.8	126.5	121.8	60.1	68.8	69.6	59.7	33.4	56.4	65.8	nil	32.6
± S.D.	±1.5	±1.2	±1.4	±0.9	±1.8	±2.4	±1.5	±1.8	±1.7	±1.6	±1.5	±1.3	±2.1		±1.3

* Commercially rated size (used throughout study to denote different gear types).

† Cover.

All lengths taken during both the Canada-Cuba study and the Canada-USSR study were total lengths measured to the closest 1 cm. All weights are expressed in kilograms to the nearest 0.1 kg. The data collected during these series of covered codend mesh selection trials were analyzed according to Pope *et al.* (1964). More recent reviews of analysis of selection data by Pope *et al.* (1975) and Holden (1971) have also been consulted. The above reports conclude that fitting the selection ogive by the maximum likelihood method is the most accurate method of deriving the curve. The tedious calculations associated with this method are not often warranted, and 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, *ibid.*). Another problem with using the maximum likelihood method is that the "entire curve" must be fit (Pope *et al.*, *ibid.*) and in the case of the Canada-Cuba data where this was not possible (Mari, pers. comm.) biased results can be achieved (Mari, MS 1978). The 50% retention level was calculated for this study by a moving average of 3 points and compared to the curve fitted by eye. Although this gives unbiased estimates of the 50% point, it should not be used for other points (Pope *et al.*, 1964). As a check of technique, the 50% retention point was also found by a linear regression (by the method of least squares) carried out on data between the 25% and 75% retention levels.

In order to obtain a "commercial average" the satisfactory* hauls from one area and one codend mesh size were combined to produce a single selection ogive. To estimate the variability of the data, the 50% retention point of each satisfactory haul was calculated and the mean and standard deviation of these hauls were calculated (ICES, 1964).

To act as a check on the calculated selection factor, a series of 93 length-girth measurements were taken. These were collected from a stratified sample of fish between the lengths of 15 and 57 cm. The unconstricted maximum girth was measured by a loop of synthetic twine.

The areas of study for the Canada-Cuba survey were determined by a searching program which attempted to find commercial sized silver hake

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* In this case a satisfactory haul is one that was completed according to plan and did not have a tear-up.

concentrations. In this study the percent of the catch make-up of silver hake ranged from 9% in the first two parts of the study to 67% in the third part (only 15 complete covered codend tows were made). In order to avoid the problem of extensive searching and enable more fishing time for the Canada-USSR study, the author chose three likely areas of silver hake concentrations in waters of less than 150 m depth. It was agreed fishing would continue at each location, whatever the species make-up, in order to provide as large a number of individual hauls as possible. The percent make-up of silver hake using this method ranged from over 60% to 30% (103 covered codend tows were made). Soviet scientists wished to carry out a feeding survey on Sable Island Bank and thus one additional area was studied. Although the percentage of hake was very low (9%), the number of tows and thus time was very low.

Results and Discussion

The major purpose of these two cruises was to obtain selectivity data on the silver hake. Therefore, length and girth measurements were collected from a stratified sample of fish between the lengths 15 and 57 cm. The resulting relationship (Fig. 3) was:

$$\text{Girth (cm)} = 0.48\ (\text{TLcm}) - 1.99,\ (r^2 = 0.97,\ n = 93)$$

where TL is the total length in cm. This is nearly identical to the one calculated by Hennemuth (MS 1964) for silver hake in ICNAF Subarea 5. Margetts (1954 and 1957) showed how girth measurements can provide a preliminary estimate of selectivity and a means of validating the selectivity results found in such studies.

Canada-Cuba study

The fitted selection ogives for the three studied mesh sizes indicate 50% retention points of 17.5, 21.6, and 26.0 cm for mesh sizes of 40, 60, and 90 mm respectively (Fig. 4, Table 4). Figure 5 shows the length frequency of the population sampled and the location of the 50% retention point.

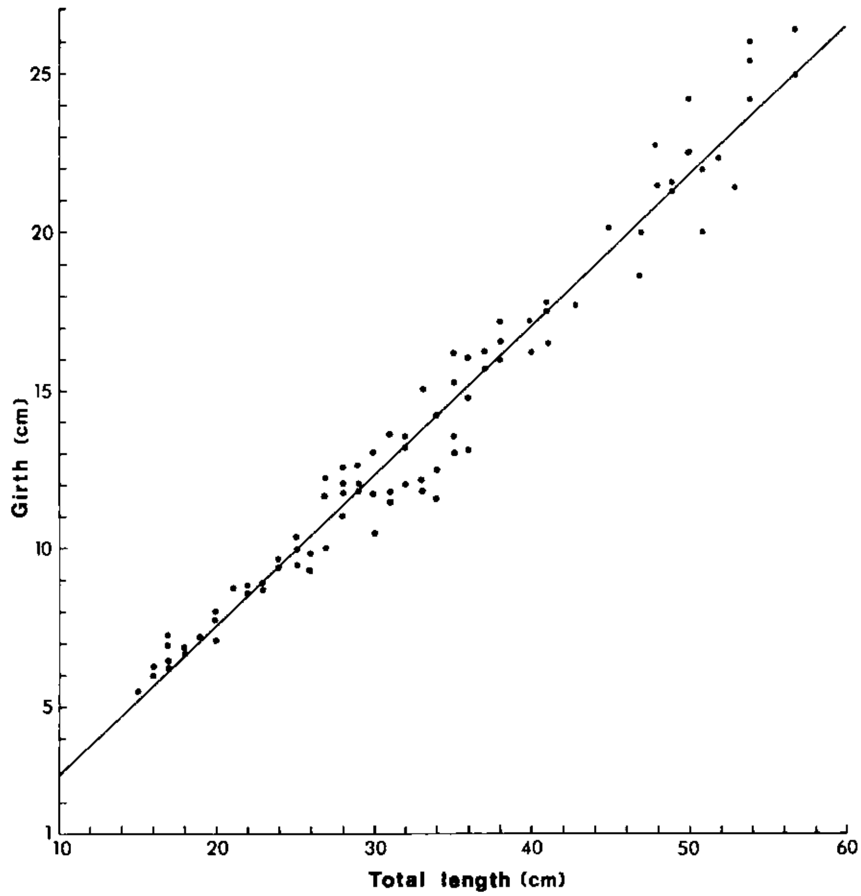

Fig. 3. Total length-girth relationship for silver hake in ICNAF Div. 4W in October 1977. Girth (cm) = 0.48(TLcm) - 1.99, (r^2 = 0.97, n = 93).

Due to an acute lack of data from this study, no attempt was made to calculate variations in the data or any effect on the 50% retention point caused by different sizes of catch. Although both cruise reports calculated a masking effect of the cover, the author felt the data inadequate to attempt any such estimate (only 15 usable covered codend tows for 3-gear types). Pope *et al.* (1975) reported that between haul variation was normally very large and it was thus advisable to make as many hauls as possible in the experimental area. In a detailed study of such variation, Gulland (1964) found the variation mainly due to "a real difference between sets of hauls," caused either by the fish (e.g. feeding) or by the gear (e.g. towing speed).

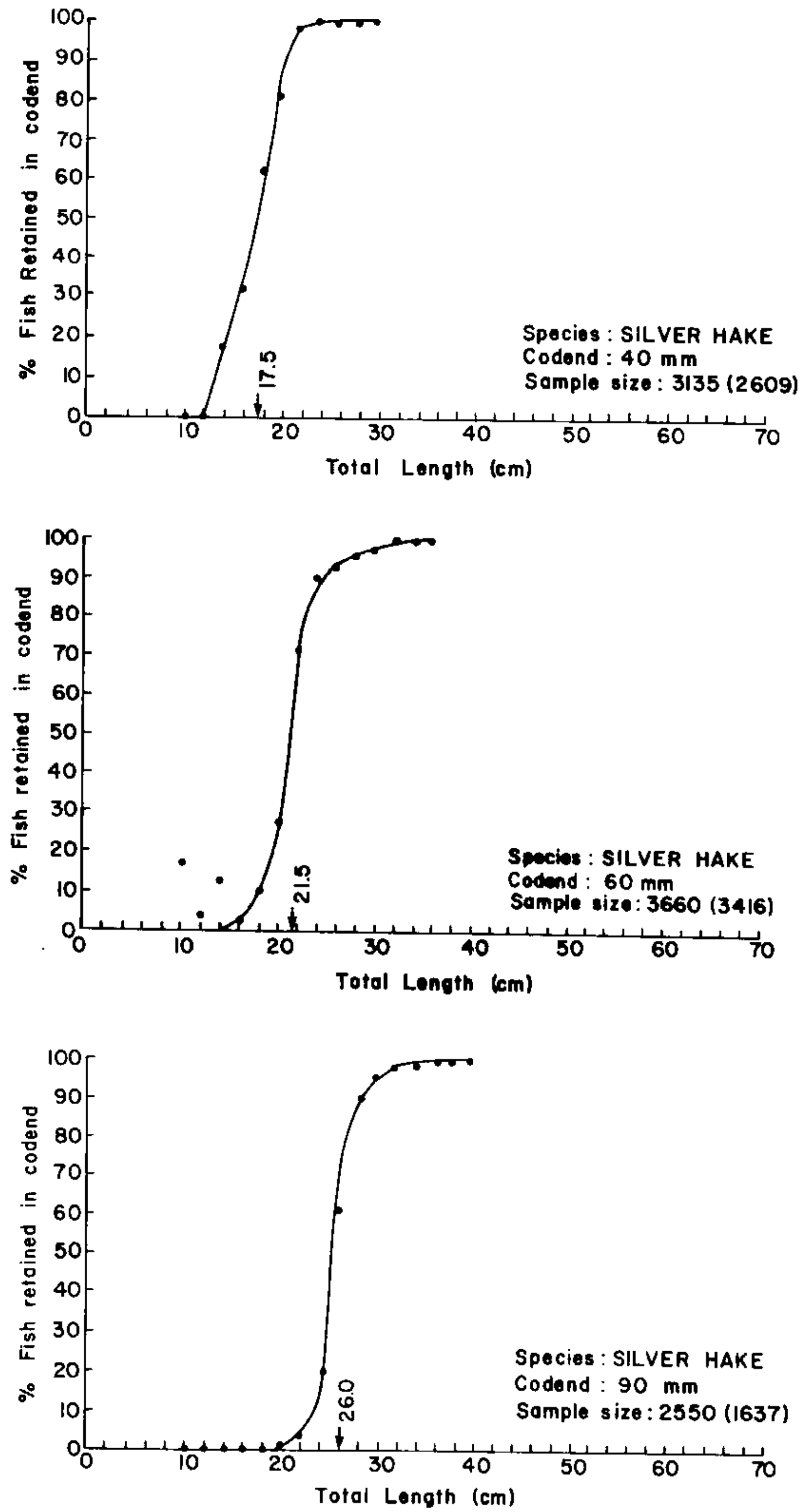

Fig. 4. Selection ogives for silver hake from ICNAF Div. 4W in the fall of 1977. The sample size has the number of fish in the codend shown in brackets. The arrow on the X-axis indicates the 50% retention point. Data from Canada-Cuba study, August 1977.

TABLE 4. The selection factor, selection range and 50% retention point for kapron codends for silver hake from the Scotian Shelf.

Mesh Size* (mm)	50% Retention Point (mm)	Selection Range (25-75%)	Selection Factor
CC 40	175† 177	6.3 cm	4.4
60 CR	225† 229	13.2 cm	3.8
CC 60	216† 216	1.7 cm	3.6
70 CR	205† 219	15.4 cm	2.9
CC 90	260† 259	1.9 cm	2.9
120 CR	411† 402	17.9 cm	3.4

* CC = Canada-Cuba study; CR = Canada-USSR study.

NOTE: 50% retention point or 50% escapement point calculated by eye (†) and by moving average of three points. The 50% retention points were also calculated by linear regression for the Canada-USSR study and they were found to be closer to the results of the curve fitted by eye than the values found by the moving average method (60 mm net = 224 mm; 70 mm net = 200 mm; 120 mm net = 417 mm).

The mean selection factor found in this experiment was 3.6, this is between the 3.1 average recorded by Clarke (1963a) and the 4.1 obtained by Gulland (1956) for past studies on hakes using codends made of cotton, manila, and nylon. The selection range generally tends to increase as the mesh size increases (Clarke, MS 1954; Jensen and Hennemuth, 1966). In this study the reverse was found to hold, i.e. the selection range decreased as mesh size increased. Clay (1977) suggested in an earlier analysis of this topic that this could be due to variation in netting material. Boerema (1956) has shown differences in selection between various materials and kapron is known to have an elongation factor almost 50% greater than nylon (Holden, 1971). More recent information on the current study has indicated some possible problems with the attachment of the cover. If the cover was too closely attached it is conceivable that the escape of large fish (i.e. fish at or over the 50% retention length) would be inhibited. This would depress the 50% retention point and such an effect would become progressively greater as the mesh size and thus the size of escaping fish increases.

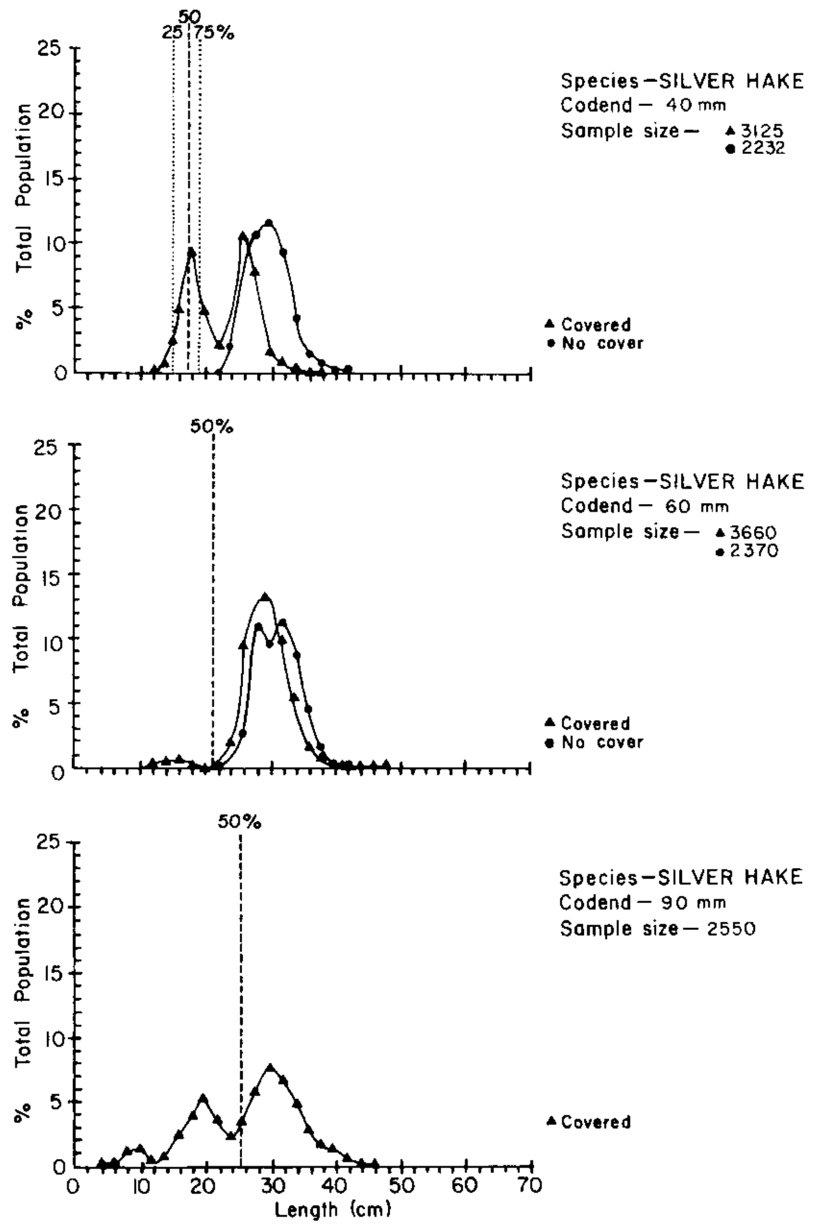

Fig. 5. Length frequency of the catch during the Canada-Cuba study for the covered and uncovered tows. The vertical lines indicate the 50% retention point and the selection range of the selection ogives (Fig. 4).

Figure 6 shows a plot of both the length of fish at the 50% retention point, and the length of fish whose girth equals the circumference of the mesh size, against the stretched mesh size. For most fish this latter plot (i.e. girth) can be taken as a crude approximation of the 50% point. This figure indicates that the 50% retention points found for the 60 mm and especially the 90 mm codends during the Canada-Cuba study were depressed by some factor. Therefore the most probable factor depressing the 50% retention point and the selection range was the incorrect attachment of the cover to the codend.

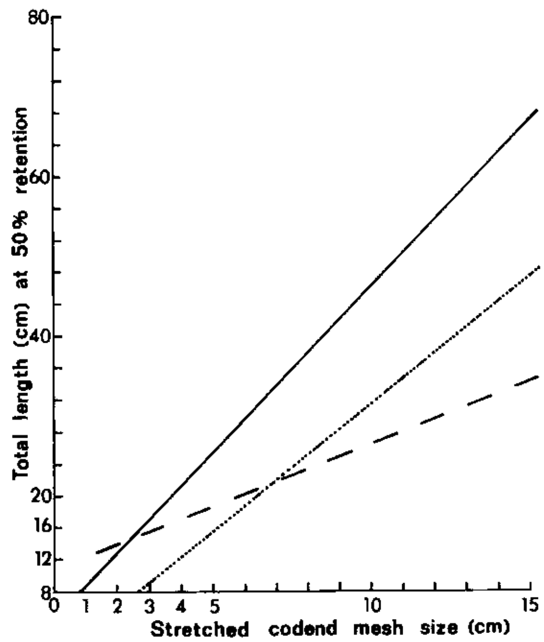

Fig. 6. The 50% retention point and the length at which the girth equals the circumference of the mesh plotted against the mesh size. The solid line represents the girth relationship while the broken line represents the 50% retention points for the Canada-Cuba mesh selection study. The dotted line represents the Canada-USSR 50% retention points.

Canada-USSR study

During the Canada-USSR study, greater amounts of data were collected than on the earlier Canada-Cuba cruise, and these data should provide more realistic commercial averages for mesh selection estimates. The first analysis on these data was to find the 50% retention point, selection range, and selection factor for each mesh size (Table 4). The mean selection factor of 3.3 is within the historical bounds for hake (Gulland, 1956; Clarke, 1963). The selection ogives (Fig. 7) give 50% retention points of 22.6, 21.0, and 41.0 cm for 60, 70, and 120 mm respectively. Figure 8 shows the length frequency of the sampled populations and the location of the 50% retention point. Appendix I gives numerical selection ogives for the hake (expressed as percentage retention for total length) and the 1977

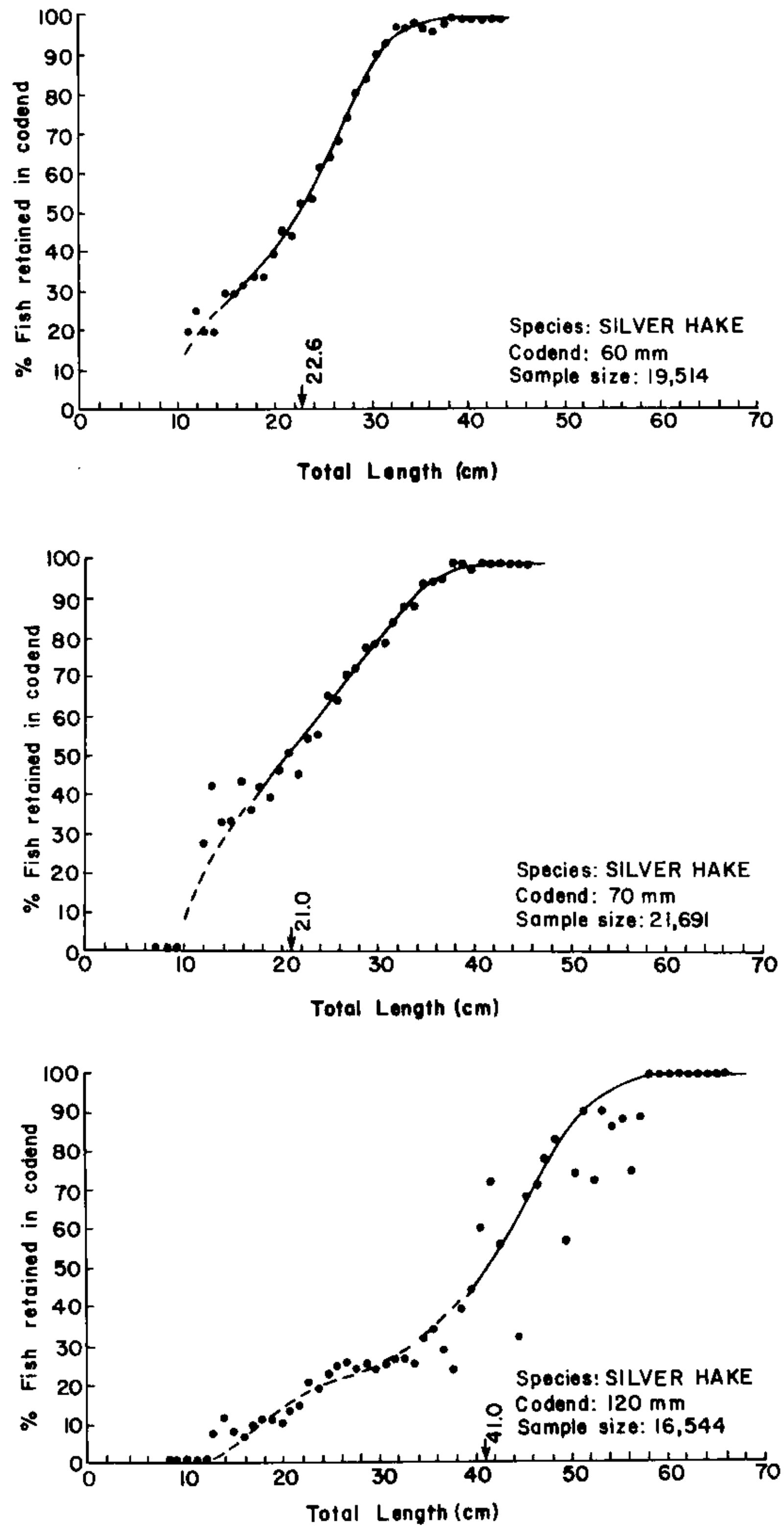

Fig. 7. Selection ogives for silver hake from ICNAF Div. 4W in the fall of 1977. The arrow on the X-axis indicates the 50% retention point. Data from Canada-USSR study October/ November 1977.

selection at age values. Three methods were used to calculate the selection at age (Appendix I) and some differences were found. It is felt that the method of 'fishing' a population at each length interval and summing the results is the best technique.

As mentioned earlier, historical selection experiments (Clarke, MS 1954 and 1963; Gulland, 1956; Bohl *et al.*, 1971) have tended to find an increasing selection range with greater codend mesh size. This was not found for the Canada-Cuba study but was observed for the Canada-USSR data (Table 4).

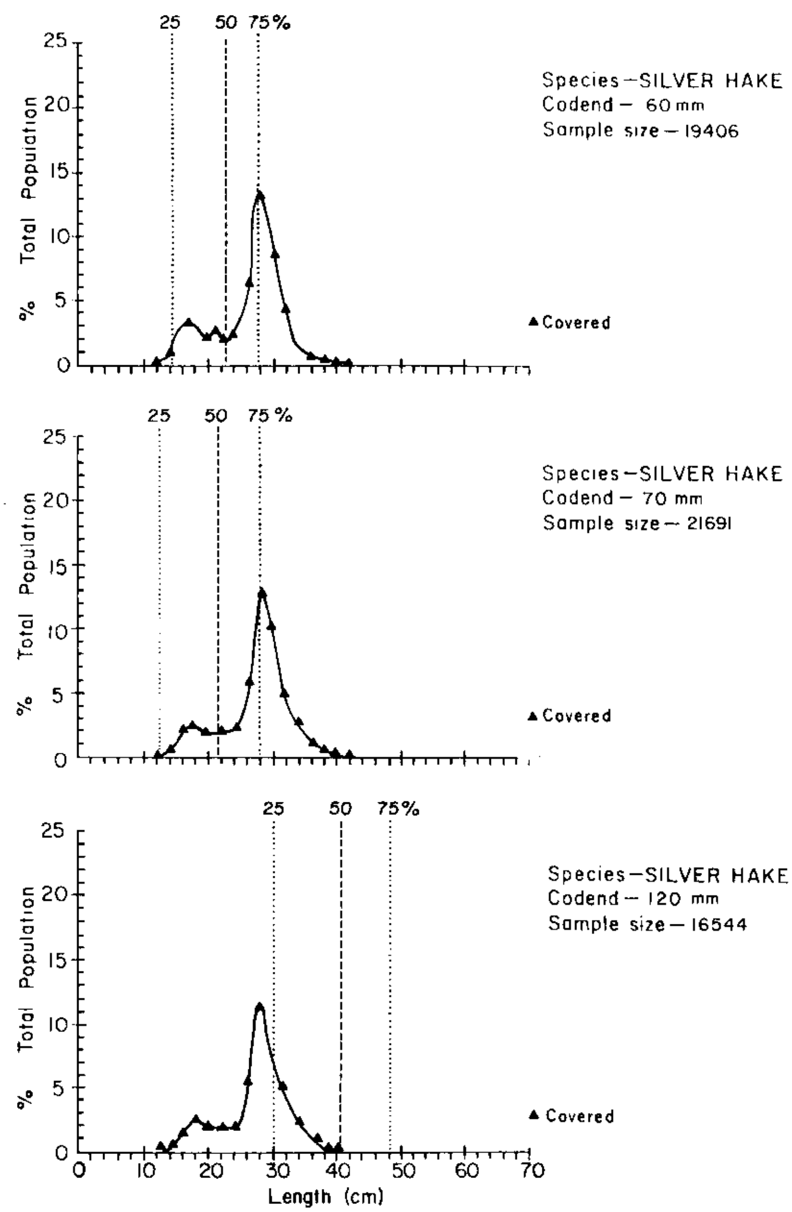

Fig. 8. Length frequency of the catch during the Canada-USSR study with covered codends. The vertical lines indicate the 50% retention point and the selection range of the selection ogives (Fig. 7).

Where reliable data were collected, the selection factor has been plotted against the weight of the total catch of individual 60 mm and 70 mm hauls. Individual 50% retention lengths and selection factors are shown in Table 5 and the plot of catch weight and selection factor in Fig. 9. The scatter on this plot is very wide and has a slight positive correlation. This is not as expected because such species as haddock, cod (Beverton, 1964; Clarke, 1963b; Hodder and May, 1964) and the cape hake (Bohl *et al.*, 1971) show much better correlations that are all negative. The variation (scatter) although great is comparable to that found by Bohl *et al.* *(ibid.)* although his range of catch size was much greater than that found in this study. The effect of an increase in the weight of the catch on the selection factor of the Cape hake (Bohl *et al.*, *ibid.*) was a decrease of 0.18 per metric tonne. In the present study the selection factor increased by over 10 per metric tonne increase in the catch. The decrease in selection factor for other species is reported to range from 0.05 per metric tonne in the haddock to 0.3 for a change in catch from 10 to 15 kg in the dab and plaice (Bohl, 1964). There is no simple explanation for the above discrepancy, although probable reasons for this anomaly are the small range in size of catch due to the small research trawl used in the study and the large variation in the data. As the increase in selection factor with increase in size of catch is not feasible, no attempt was made to extrapolate to commercial sized catches.

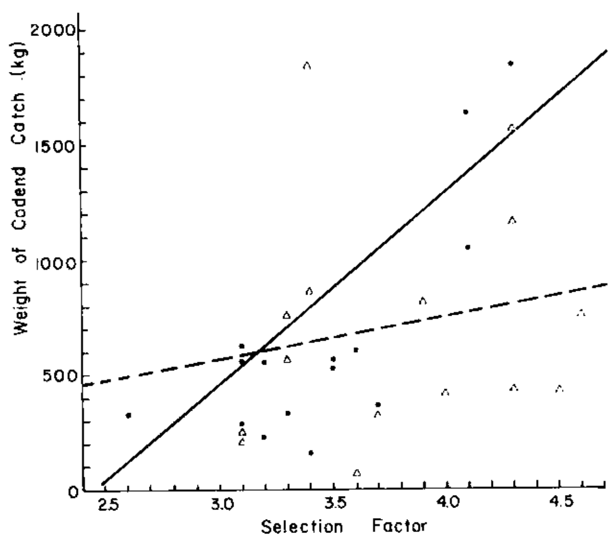

Fig. 9. The selection factor of individual tows with the 60 mm codends (broken line, circles) $y = 164.76x + 72.53$, ($r^2 = .30$, $n = 15$), and 70 mm codends (solid line, triangles) $y = 818.38x - 2012.44$ ($r^2 = .36$, $n = 16$) against the weight of the codend catch. One point over 2000 kg is omitted from the plot. Data from Table 5.

TABLE 5. The 50% retention length (cm) and selection factor for sets where codend mesh size was 60 or 70 mm and data from catch were adequate to provide a unique result.

Set Number	Codend Catch (kg)	Mesh Size 60 mm	70 mm
		50% retention length/selection factor	
5	1839	20.16/3.4	
8	762	19.62/3.3	
9	872	20.27/3.4	
10	1047		28.43/4.1
11	1610		29.93/4.1
13	1833		30.31/4.3
23	3083		27.26/3.9
24	329		18.26/2.6
26	248	18.42/3.1	
27	93	21.75/3.6	
32	200	18.51/3.1	
34	805	23.57/3.9	
37	590	19.73/3.3	
38	306	22.85/3.8	
42	394		14.95/2.1
43	215		22.18/3.2
44	183		23.47/3.4
45	244		21.61/3.1
47	623		21.77/3.1
48	580		21.94/3.1
88	421	25.76/4.3	
89	409	23.84/4.0	
90	1161	25.55/4.3	
91	1577	26.04/4.3	
93	574		22.59/3.2
94	569		24.33/3.5
95	305		23.40/3.3
96	364		25.61/3.7
97	605		25.10/3.6
98	533		24.75/3.5
101	419	27.07/4.5	
102	761	27.70/4.6	
mean 50% retention length		22.72 ±3.19	23.82 ±3.82
mean selection factor		3.79 ±0.52	3.40 ±0.55

General

An initial overview of the selection factor for silver hake from the current studies would indicate that selection of silver hake is different from the European or Cape hakes. However, two problems that may alter such as assumption involved the type of cover material and cover mesh size. ICES (1964) suggested that the cover material should be made of a buoyant material such as polyethylene (e.g. Courlene). In both of the studies under investigation, nonfloating kapron covers were used. ICES *(ibid.)* also recommended the cover mesh be no smaller than one-third to one-half of the codend mesh size. As the Canada-Cuba study used 20 mm mesh covers and the Canada-USSR study used 30 mm mesh covers through all phases of the investigations, the 90 mm and 120 mm mesh nets of the two studies will have definite masking effects, perhaps serious ones. Masking is an effect described by Davis (1934) as an "elusive factor" of the "flow" effect of the cover. Masking tends to reduce the flow of water through the meshes and thus reduces the 50% retention point which results in a decrease in the selection factor. The selection factor in both studies (Table 4) decreases as the codend mesh size increases (e.g. 4.4 to 2.9 and 3.8 to 3.4). Thus if we take the selection factor of the codend with the least effect of masking by the cover (i.e. 40 mm mesh net for the Canada-Cuba study, and 60 mm mesh net for the Canada-USSR study) the mean selection factor is 4.1, a value that allows us to consider the possibility that silver hake will have essentially the same selection characteristics as the European and Cape hakes. Such an assumption is further borne out by the length-girth relationships for the three hakes (Table 6). It can be seen from this table that the general shape (fatness) of these fish is very similar (less than 5% difference) and is probably the same within the bounds of variation caused by feeding and sexual maturity. The 50% retention points calculated from the Canada-USSR mesh selection study bear a reasonably close relationship to the points calculated from the length-girth measurements as described earlier (Fig. 6).

TABLE 6. Comparison of girth/length relationship for silver hake, European hake, and Cape hake (modified after Bohl *et al.*, 1971).

Species and Author	Relationship	Relative Girth as % of Girth of Silver Hake	
Silver hake			
present study	G = 0.48 (TLcm)-1.99	30 cm = 100.00	50 cm = 100.0
(Hennemuth, 1964)	G = 0.44 (FLcm)-0.31	= 105.5	= 100.5
European hake			
(Gulland, 1956)	G = 0.47 (TLcm)-1.10	= 104.8	= 101.7
Cape hake			
Cape Grounds	G = 0.49 (TLcm)-2.44	= 98.7	= 100.2
Luderitz Grounds	G = 0.46 (TLcm)-1.45	= 99.5	= 97.9
(Bohl *et al.*, 1971)			

G = girth TL = total length (cm) FL = fork length (cm)

A selection factor of 4.0 has been accepted as a provisional working figure for the European hake *(M. merluccius)* for cotton and hemp trawls (ICES, 1957). Bohl *et al. (ibid.)* found similar selection factors for the Cape hake and assumed that "as the selectivities of cotton/hemp and polyamide are known to be the same" that there was no difference in escapement for Cape hake and European hake; we can now further add that the silver hake also appears to have the same selection characteristics as these other members of the genus *Merluccius*. Because of this, Clay (1978) calculated a "general selection pattern" for the hake family as: 50% Retention Point = $-26.12 + 4.04 \times M$; where the 50% retention point is expressed in mm and M is the codend mesh size in mm.

Application of the data

To the hake fishery. The first application of selection data to a fishery is the investigation of the immediate effect of various mesh sizes on catches. Two scenarios are possible, the first assuming that fishing effort remains constant and the mesh size changes, and the second assuming that fishing effort is altered to generate some "optimal" value of fishing mortality (e.g. $F_{0.1}$) as the mesh size changes. Using the first of the previous assumptions we can take the measured length frequency of fish (n = 16,544) that were caught as part of the Canada-USSR study as representative of the commercial population (includes catch in cover and in codend). We can then 'fish' this population with various gears and study the effects. Using the selection ogive for the 60 mm mesh net we find that 72% of the fish (numbers) are caught while 82% of the available weight is caught. The weight of the average fish caught will increase from 146 g (the average weight of a fish in the population) to 168 g. Using the 120 mm selection ogive, only 23% of the fish (numbers) are retained and 30% by weight are held, the average weight of fish would increase to 188 g. Absolute values for comparison are given in Table 7. A slightly different population from another area (n = 19,406) is also presented. Figure 10 shows the population before and after fishing with 60 and 120 mm codends (note: the y-axis is logarithmic).

TABLE 7. Values resulting after two populations are fished with various selection ogives (Appendix I). These results are based on a constant effort and are therefore very different from the results of catch projections (Table 8) where the effort is altered to maintain the $F_{0.1}$ level.

Population	Number of Fish a	Number of Fish b	Weight of fish (kg) a	Weight of fish (kg) b	Average Weight (g)
Total population	19406	16544	255.628	2411.18	146
Catch (60 mm)	13265	11883	2062.07	2000.61	168
Catch (90 mm)	9549	8122	1493.75	1396.14	172
Catch (120 mm)	4262	3810	730.69	715.68	188
Change* to (90 mm)	-28%	-32%	-28%	-30%	+2%
Change* to (120 mm)	-68%	-68%	-65%	-64%	+12%

* Change from the present fishery (1977) where 60 mm codends are the standard mesh size to the larger mesh nets.

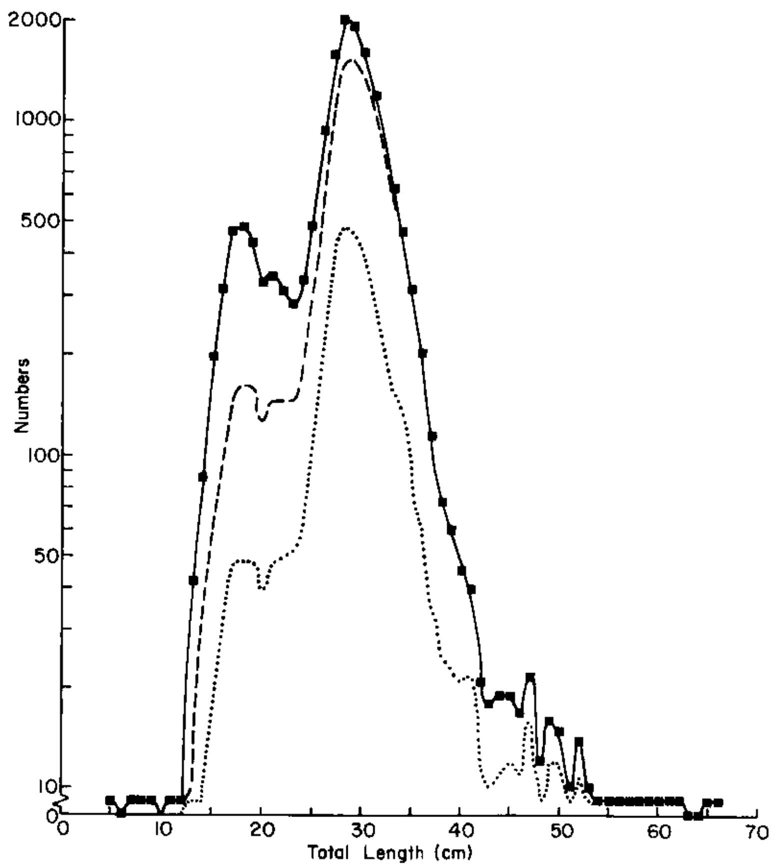

Fig. 10. Length frequency of population (assumed equal to catch of codend and cover). The solid line (squares) represents the population. The broken line represents the immediate loss by length of fishing with a 60 mm mesh codend and the dotted line the immediate loss using a 120 mm mesh codend.

The second scenario, a more realistic way of studying the change in yield, assumes the effort will be regulated to the $F_{0.1}$ level. The partial recruitments (PR) for the 40 mm codend mesh were averaged and then smoothed from the fishing mortality tables of Doubleday and Hunt (1977) and Doubleday and Halliday (1976). They are 0.08, 1.00, 0.97, 0.54, 0.63, 0.27 for ages 1 to 6+ respectively. These PR are estimated from data collected from the historical fishery before area and gear restrictions were imposed. Initially the technique to estimate change in yield as proposed by Allen (1967) was tried. This method assumes a knife-edge selection at the 50% retention point and is therefore unsuitable for partial recruitments such as those of the silver hake. The yield per recruit (to the fishery) method of Thompson and Bell (Ricker, 1975) was chosen in an attempt to predict an equilibrium yield. The inputs for this method are the weights at age as taken from the latest assessment by Halliday *et al.* (MS 1978) and the partial recruitments for each different mesh size. The partial recruitments listed above for the 40 mm mesh codend contain factors for both the selectivity of the net and the general availability (or distribution) of the fish at each age group. This follows the relationship:

PR = (AVAILABILITY) X (SELECTION)

and thus the partial recruitments for the 60, 90, and 120 mm codends are calculated, assuming no alteration of fishing patterns, by multiplying the selection at age for each mesh size (Appendix I) by the availability calculated from the 40 mm PR and selectivity. These data are presented in Table 4 of Appendix I. When calculating the fishing mortalities for each age group, the $F_{0.1}$ is usually multiplied by the normalized (to 1) partial recruitments. In order to make the fishing mortalities (and thus fishing effort) comparable for all mesh sizes, the partial recruitments for this exercise are based on the 40 mm net where age 2 is normalized to 1.0. As an example of this, the fishing mortalities (from Fig. 11) by age have been calculated for a natural mortality (M) of 0.4 (Table 5, Appendix I). Figure 11 gives the yield per recruit (YPR) for natural mortalities from 0.2 to 0.5. The YPR for the fishery at age 1 decreases for M = 0.5 but for all other cases there is an increase with larger increases occurring at lower natural mortalities.

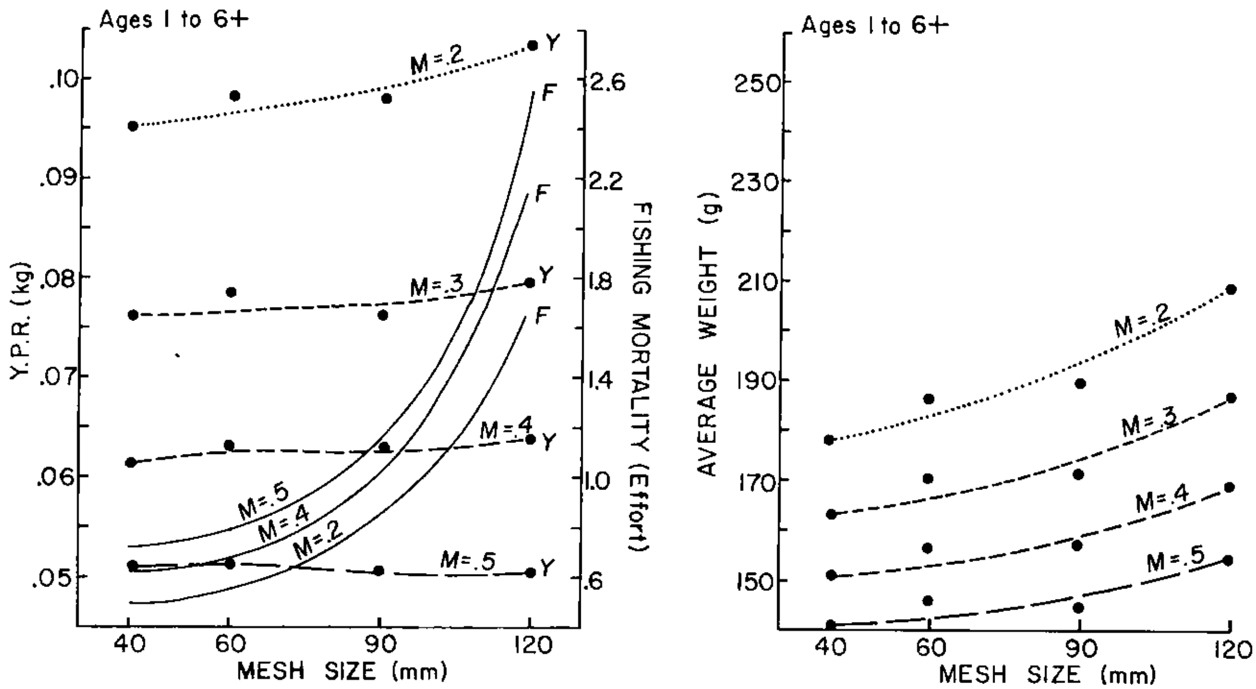

Fig. 11. Yield per recruit (YPR) for ages 1-6 plotted against mesh size for four different values of natural mortality (M). The fishing mortality (F), proportional to effort, is plotted against mesh size for the same values of M. The F's on this plot are $F_{0.1}$ calculated for the partial recruitments (Tables 4 and 5, Appendix I) normalized for the 40 mm mesh size to 1. This makes the F or effort comparable within the graph for each mesh size but not comparable to the F values on Figures 12 and 13. Thus the F values can be considered an index of effort. The second graph is the mean weight of fish in the catch plotted against mesh size for the same levels of M.

The amount of increase shown in Figure 11 is the minimum that could be expected. This is due to two factors, first, using our premise of M = 0.4, data have historically been worked up only to age 6+, thus fish over age 6 have not been fully considered. This is particularly important with an M = 0.2. For all values of M <0.4 the increase in yield would be greater than that shown on Figure 11 due to older fish living longer. The second factor which depresses the projected yields is the partial recruitment which decreases with age. With small mesh gear we can assume fishermen are concentrating their effort on the largest commercial concentrations of saleable fish - at the present time this is the 2 and 3 year olds. As these fish become less available due to larger mesh trawls and as in time the 4, 5 and older year classes become more abundant, it will be more economic to fish for the larger fish. This will cause a change in the availability pattern. We have no way of knowing how much this pattern will change although we can assume some upward change for the older age groups.

To investigate the extreme limits of the change in yield two additional series of yield per recruit calculations were carried out. The first series used partial recruitments of 0.08, 1, 1, 1, 1 and 1 for ages 1 to 6+ respectively (Fig. 12). The increase in yield is much greater in this case than in the first and the average weight of captured fish increases by about 30%. As a final estimate of the maximum yield, weights at age and other data have been estimated for fish aged 6 to 12 years. The weights chosen were 600, 730, 890, 1000, 1120, 1280 and 1370 g for ages 6 to 12 respectively - these weights were estimated from lengths calculated from a Von Bertlanaffy growth equation (L_∞ = 74.65, K = 0.116, T_0 = -1.976; r^2 = 0.78, n = 2080) using the length-weight relationship:

$$WT\ (g) = 2.06\times10^{-3}\ [TL\ (cm)]^{3.317}$$ (Halliday *et al.*, MS 1978)

Redoing the yield per recruit (Fig. 13) with a maximum age of 12 years the increases in yield are again up over the initial estimates for low values of M <0.4. However at M = 0.4 the yield drops off between 90 and 120 mm mesh size - an indication that growth cannot compensate for natural mortality at this size of net. The loss of weight of the 6+ age group to the 6 year olds and older is not compensated for due to the high natural mortality.

Looking at all these cases it would appear that 90 mm mesh nets generally promise at least the same - or a slight increase in - long term yield over 60 mm nets with an increase in average size of fish. Looking at the economics, best indicated by the fishing mortality - which is directly related to fishing effort, there is an exponential rise in effort required as net size increases (Fig. 11, 12 and 13). This exponential rise indicates the increased effort when changing from 60 to 90 mm nets is in the order of 10 to 30% while the increased effort to change from 90 to 120 mm nets is in the order of 30 to 100%. Such dramatic increases in effort required to move up to 120 mm mesh codends could not be justified until better quantitative estimates of yield are available. Thus based on effort projections it would appear 90 mm mesh codends would be a most suitable temporary mesh size while studying the change in fishing pattern caused by the shift in population age structure.

The historical (40 mm) availability (distribution) which gives a partial recruitment of age 1 fish of 0.08 indicates that shifting from the 40 mm to the 60 mm mesh codends is going to make little if any difference

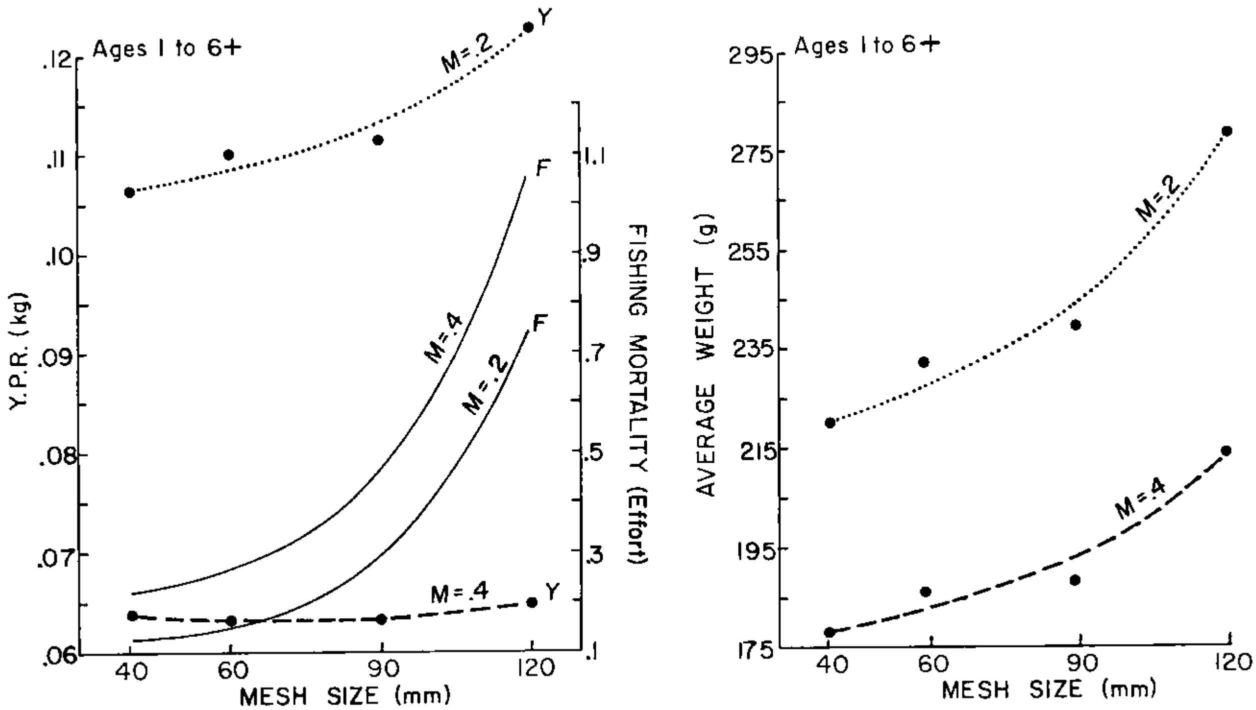

Fig. 12. Similar to Figure 11 except the partial recruitment has been altered to assume full recruitment after age 2 (see text for values).

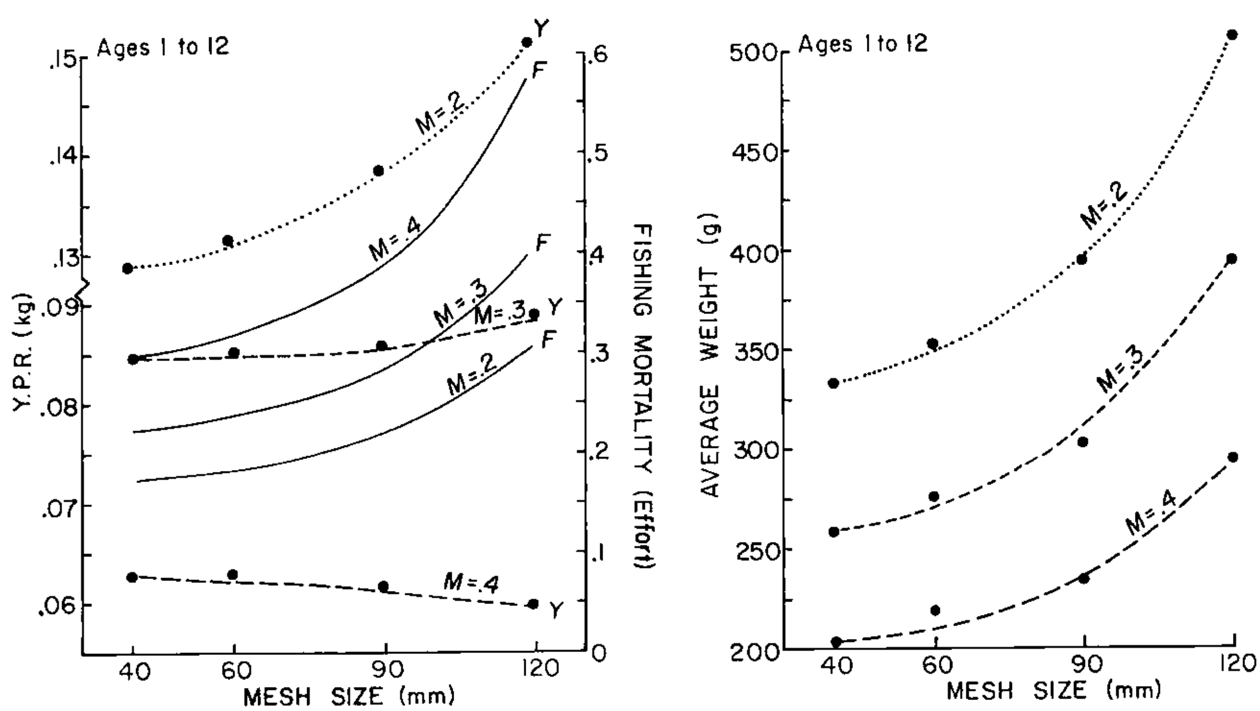

Fig. 13. Similar to Figure 12 except the age structure has been altered from 1-6 to 1-12 (see text for values).

to the catch. This is because both mesh sizes would catch 1 year olds if they were available and by inference if the 1 year olds are not available neither net will catch them. Therefore to force a shift in population structure it is necessary to change from the 60 mm mesh size to a 90 mm mesh which will permit escape of at least some 2+ fish.

Doubleday and Halliday (1976) suggested the greatest yield-per-recruit would come if the length of recruitment was raised to 25.5 cm. These authors studied the sexual maturity of hake from Canadian research vessel data and found that male hake were mostly mature by their second year while all females were mature by their third year. Past conservation philosophy which is generally accepted until more detailed information is available permits that each fish in a population should be allowed to spawn at least once. It therefore follows that we should not start cropping the hake until their third year (i.e. 30 to 32 cm). From these hypotheses a 90 mm mesh codend would seem the most likely choice of an interim mesh size while detailed monitoring is being carried out to investigate the effects on the population.

<u>To the squid fishery.</u> Both the Canada-Cuba study and the Canada-USSR study had large percentages of squid in the catches; this was similar to current (1977) commercial catches. Thus the masking that may be caused by squid in large commercial catches will be at least partially accounted for in the present studies. The larger commercial catches will tend to depress the selection factor (reduce the percent escapement) although from the current study no estimate of this can be made. However, we can use the results from Bohl *et al.* (1971) to indicate that the selection factor may drop by as much as 0.2 per metric tonne increase in catch. Thus mesh size estimates to release specific sized fish that are based on the current experimental study data will be on the low side - and possibly considerably so. One factor which could depress the selection ogive even further is any 'strengthening' that may be carried out on commercial sized codends (i.e. double twine, etc.); such alterations are common although not necessarily uniform throughout a fishing fleet.

As much of the current silver hake fishery by the USSR and Cuba is a joint hake-squid fishery, and as the biomass of squid appears to be increasing (Scott, MS 1977) it would be advisable to consider the effects of a 90 mm mesh net on squid catches. Squid, due to their morphology and small range of size, cannot be studied for mesh selection as easily as can most fin fish species. The tentacles on squid can cause variation in selection data which makes the 50% retention point difficult to measure - in much the same way as teeth and spines complicate selection ogives of gill nets for many species of fish. Fitted selection ogives which give 50% retention points of approximately 14.0, 18.0, and 24.0 cm for mesh sizes of 60, 70, and 120 mm respectively (Fig. 14). Because of the problems of morphology and small range of length of squid at any one time on the Scotian Shelf (Fig. 15), it was decided to study the percent of the population, during different seasons, which pass through each codend mesh size rather than trying to utilize the 50% retention length. Figure 16 and Table 8 show the percent by weight of squid passing through codends of different mesh sizes. Twenty five to 30% of the squid encountered by the gear in late summer and early fall will escape a 90 mm research type trawl. These escapees will tend to be smaller squid which may increase the yield per recruit, but more importantly the 90 mm mesh codends will allow

TABLE 8. Percentage by weight of squid passing through the codend of various mesh sizes of kapron codends.

Mesh Size† (mm)	% by Weight of Squid in the Catch	% by Weight of Squid Released from Codend
CC 40 mm	29.5*	0.0
60 mm CR	28.0	0.5
CC 60 mm	83.0*	1.8
70 mm CR	21.0	0.5
CC 90 mm	66.0*	28.0
120 mm CR	26.0	59.8

† CC = Canada-Cuba study; CR = Canada-USSR study.

NOTE: The Canada-Cuba cruise (*) covered very different locations (a range of 450 km) and therefore the variation in percent squid by weight of the catch cannot be linked to mesh size. The mode of the length frequency of these populations in August-September is less than those in October-November (Fig. 12). The modal size of the population would probably be the determining factor for mesh selection of squid.

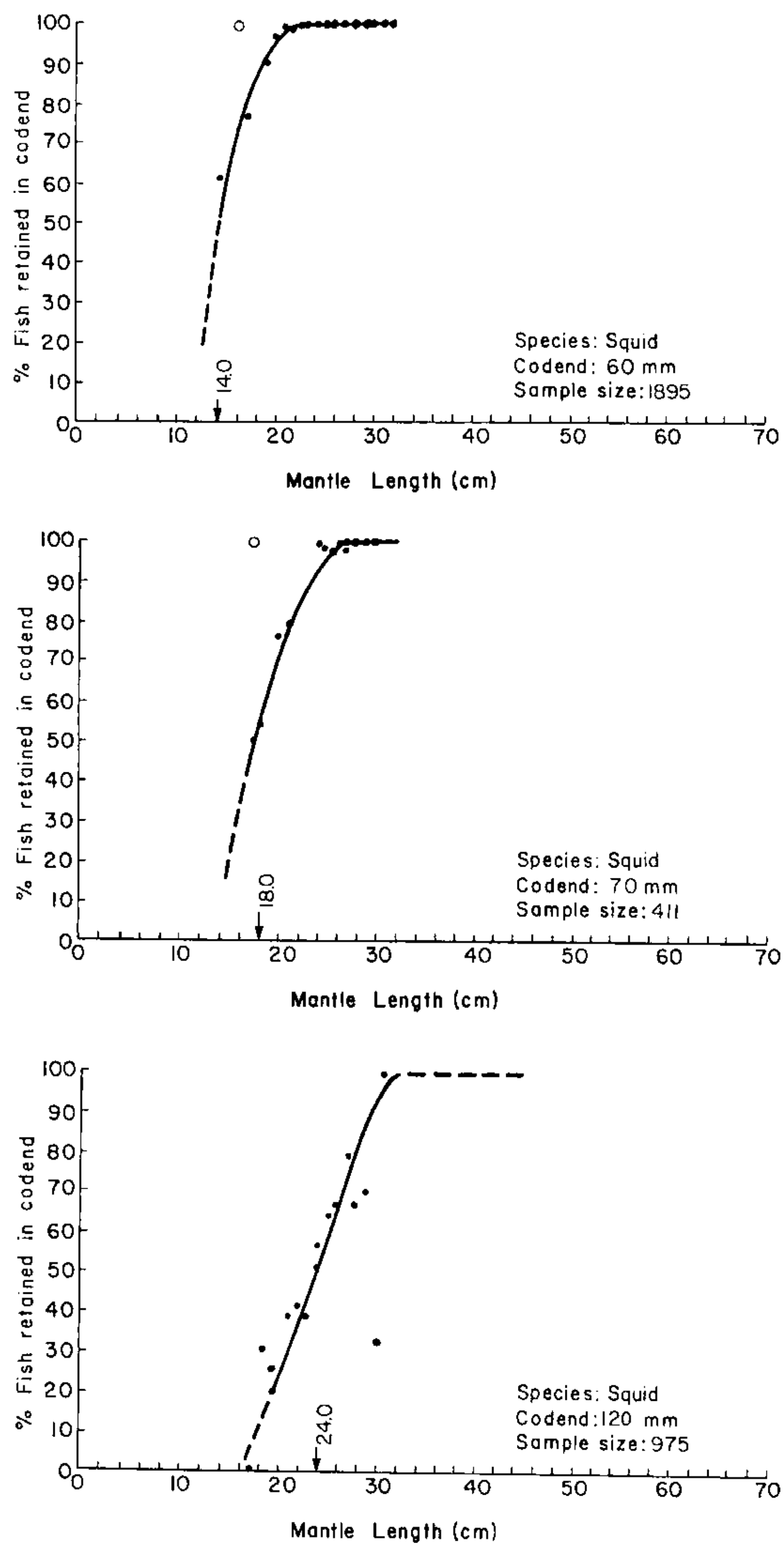

Fig. 14. Selection ogives for squid from ICNAF Div. 4W in October 1977. The arrow on the X-axis indicates the 50% retention point. Data from Canada-USSR study.

otherwise discarded juvenile fin fish the chance to escape. The research studies were conducted in August and October/ November, times when the squid population had a mode or peak at 20 to 22 cm (Fig. 15 and 17). The percent squid released by the 90 mm net (Fig. 16) decreases from the August study to the October/November study, due to the growth of individual squid in the population. Growth of the population is greatest from April to June, from June to September growth levels off (Fig. 17). A 90 mm mesh net would allow cropping of larger squid in June with the majority of the population growing to catchable size by August. These data suggest that a 90 mm mesh regulation applied to squid would not prevent catch allocations from being taken although it would substantially reduce the catch rates in June and July. There would be little effect from August onwards (according to 1977 sample data). Precise calculations on the affect on YPR and on fishing effort of increasing mesh size to 90 mm requires more data than is presently available.

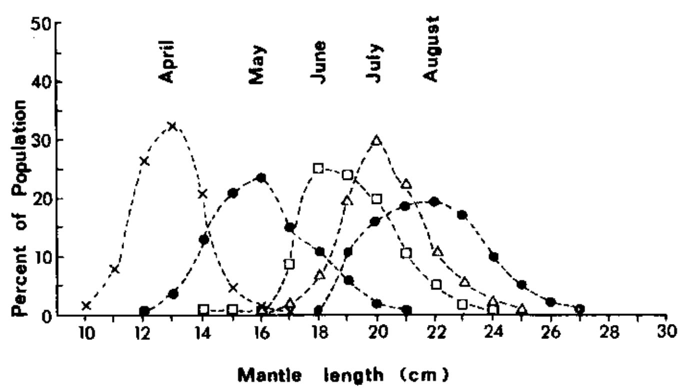

Fig. 15. Monthly length composition of the commercial squid catch from 1977. Data from the 1977 International Observer Program.

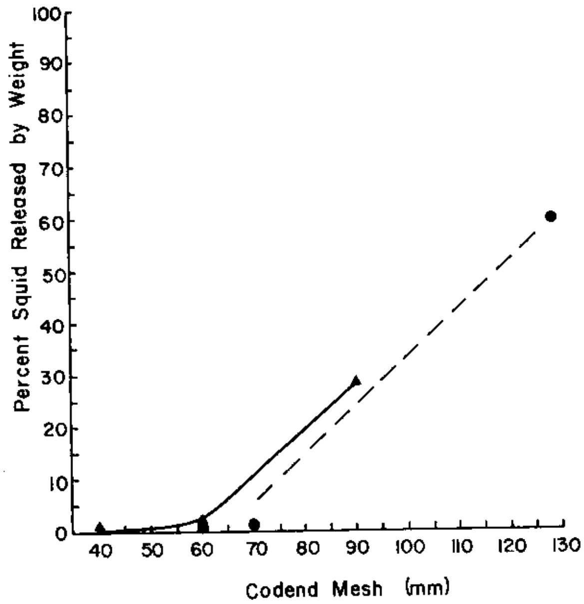

Fig. 16. Codend mesh size and the percent of squid released by each mesh size. The solid line represents the Canada-Cuba study while the broken line represents the Canada-USSR study. The difference between the two lines is presumed due to the growth of the squid population between August and October/November (Figure 15). Data from 1977 International Observer Program.

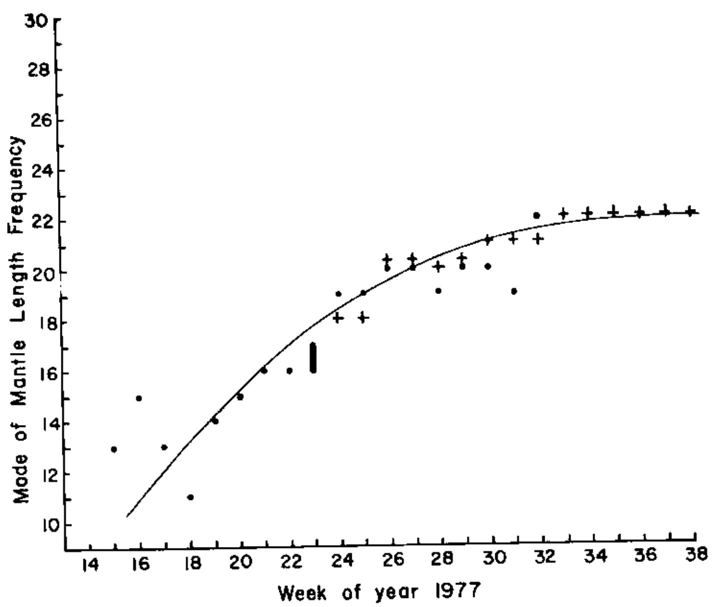

Fig. 17. Growth of squid measured by movement of modal peak on a weekly basis. Circles are samples from Cuban commercial catches while crosses are samples from Russian commercial catches. The vertical bar represents one week with mode spread over two centimeter groups. Data from 1977 International Observer Program.

Conclusions

A 90 mm mesh codend regulation would appear suitable for silver hake as an experimental level to test population response and changes in the fishery due to changes in mesh size. While the long term benefits cannot be firmly established, it has been shown that long term loses will not occur over the wide range of parameters considered here. It appears that this regulation would not have a severe adverse affect on the squid fishery. There is the additional factor of bycatches to be considered when setting such mesh regulations. These bycatch species are in part juveniles of species whose fisheries are regulated by 130 mm minimum mesh sizes (Waldron, MS 1978) and reduction of these bycatches would result in an increase in yield of these other fisheries.

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References

ANON. MS 1976a. Report of the Silver Hake Ageing Workshop, Dartmouth, Canada, 1-3 April 1976. Ann. Meeting June 1976. ICNAF Summ. Doc. 76/VI/21, 6 p. (Mimeo).

ANON. MS 1976b. Ninth Special Commission Meeting - December 1976: Proc. No. 6. ICNAF Serial No. 4076 (B.E. 76) Appendix I, 2 p. (Mimeo).

ANON. MS 1976c. Canadian proposal for the regulation of fishing gear used in the directed silver hake fishery in ICNAF Subarea 4. ICNAF Comm. Doc. 76/VI/25, 1 p. (Mimeo).

ANON. 1977. [B/I Isla de la Juventud. Informe de Crucero No. 3. Projecto FAO/PNUD/cip CUB 73/007.] Desarrolo de las Investigaciones Pesqueras - Cuba, 33 p. (Mimeo). (In Spanish).

BEVERTON, R.J.H. 1964. The selectivity of a flap-type topside chafter. Int. Comm. Northw. Atlant. Fish. Redbook 1964 (III): 132-139.

BOEREMA, L.K. 1956. Some experiments on factors influencing mesh selection in trawls. *J. Cons., Cons. Int. Explor. Mer XXI* (5): 175-191.

BOHL, M. 1964. [Selektionsdaten fur Kliesche und Scholle aus Schleppnetz experimenten in Seegebiet von Helgoland.] Protok. Fisch. Tech., 8: 304-356 (not seen in original).

BOHL, M., L. Botha, and T.M. van Eck. 1971. Selection of the Cape Hake *(Merluccius merluccius capensis Castelnan* and *Merluccius merluccius paradoxus Franca)* by bottom trawl cod-ends. *J. Cons., Cons. Int. Explor. Mer. 33* (3): 438-471.

BUCHANAN-WOLLASTON, H.J. 1929. The selective action of the Gelder-cod-end and that of other cod-ends compared. *J. Cons., Cons. int. Explor. Mer* (4): 300-308.

CASSIE, R.M. 1955. The escapement of small fish from trawl nets and its application to the management of the New Zealand snapper fisheries. New Zealand Mar. Dept. Fish. Bull. No. 11, 99 p.

CLARKE, J.R. MS 1954. Preliminary report on the escape of Silver Hake through trawl meshes. Int. Comm. Northw. Atlant. Fish. Res. Doc. Serial No. 343 (Appendix No. 3), 10 p. (Mimeo).

CLARKE, J.R. 1963a. Size selection of fish by otter trawls. Results of recent experiments in the Northwest Atlantic. Int. Comm. Northw. Atlant. Fish. Spec. Pub. No. 5: 24-96.

CLARKE, J.R. 1963b. Escapement of Haddock through cod-ends meshes. Int. Comm. Northw. Atlant. Fish. Spec. Pub. No. 5: 63-80.

CLAY, D. MS 1977. Selection of Silver Hake *(Merluccius bilinearis)* in kapron codends (a preliminary report). CAFSAC Res. Doc. 77/20, 45 p. (Mimeo). (Includes - Addendum, 10 p.).

CLAY, D. 1978. Mesh Selection of Groundfish by Otter Trawls on the Scotian Shelf. ICNAF Sel. Pap.

DAVIS, F.M. 1934. Mesh experiments with trawls 1928-1933. Fish. Invest. Lond. Series II, XIV (1): 56.

DOUBLEDAY, W.G. and R.G. HALLIDAY. 1976. An analysis of the Silver Hake fishery on the Scotian Shelf. ICNAF Sel. Pap. (1): 51-58.

DOUBLEDAY, W.G. and J. HUNT. MS 1977. An assessment of the Div. 4VWX Silver Hake fishery incorporating 1976 Provisional nominal catch statistics reported to 18 April 1977. ICNAF Res. Doc. 77/VI/44, p. 7 + corrigendum. (Mimeo).

FULTON, T.W. 1893. The capture and destruction of immature sea fish. Part III. The relation between the size of the mesh trawl nets and the fish captured. Rep. Fish. Bd., Scotland 12 (3): 302-312.

GULLAND, J.A. 1956. On the selection of Hake and Whiting by mesh of trawls. *J. Cons., Cons. Int. Explor. Mer* 21 (3): 269-309.

GULLAND, J.A. 1964. Variations in selection factors, and mesh differentials. *J. Cons., Cons. Int. Explor. Mer* 29(2): 158-165.

HALLIDAY, R.G., P.F. LETT and D. CLAY. MS 1978. Silver hake *(Merluccius bilinearis)* in ICNAF Division 4VWX: a stock assessment and estimate of the total allowable catch (TAC) for 1979. ICNAF Res. Doc. 78/VI/62. Serial No. 5230 13 p. (Mimeo).

HARE, G. 1977. Cruise Report Cuban Canadian Co-operative Mesh Selection Study, Mimeo report, 16 p.

HENNEMUTH, R.G. MS 1964. Estimated relationship of length-girth for Red and Silver Hake collected from Subarea 5 in 1963. ICNAF Res. Doc. 47, 2 p. (Mimeo).

HODDER, V.M. and A.W. MAY. 1964. The effect of catch size on the selectivity of otter trawls. Res. Bull. Int. Comm. Northw. Atlant. Fish. (1): 28-35.

HOLDEN, M.J. (ed.) 1971. Report of the ICES/ICNAF Working Groups on Selectivity Analysis. *J. Cons., Int. Cons. Explor Mer* Coop. Res. Rep. Series A, No. 25, 144 p.

HUNT, J. MS 1977. Age, growth and distribution of Silver Hale *(Merluccius bilinearis)* on the Scotian Shelf from modal analysis of length frequencies. ICNAF Res. Doc. 76/XII/164 (Mimeo).

ICES. 1957. International Fisheries Convention 1946: Report of the Ad Hoc Committee established at the 4th meeting of the Permanent Commission, September 1955. *J. Cons., Int. Cons., Explor. Mer* 23: 1-37.

ICES. 1964. Part IV. General considerations on trawl and seine mesh selection and its measurement. In: Cooperative Research Report No. 2, *J. Cons., Int. Cons. Explor. Mer* (May 1964): 138-156.

ICNAF. 1962-1972. ICNAF Sampling Yearbooks Vol. 7 - Vol. 17.

JENSEN, A.C. and R.C. HENNEMUTH. 1966. Size selection and retainment of Silver and Red Hake in nylon codends of trawl nets. Int. Comm. Northw. Atlant. Fish. Res. Bull. 3: 86-102.

MARI, A. MS 1978. Selection of Silver Hake by kapron codends of trawl nets. ICNAF Res. Doc. 78/VI/63, p. 6. (Mimeo).

MARGETTS, A.R. 1954. The length-girth relationships of Haddock and Whiting and their application to mesh selection. *J. Cons., Int. Cons. Explor. Mer* 20 (1): 56-61.

MARGETTS, A.R. 1957. The length-girth relationships of Whiting and Cod and their application to mesh selection. *J. Cons., Int. Cons. Explor. Mer* 23 (1): 64-71.

NICHY, F.E. MS 1967. Growth patterns on otoliths from young Silver Hake, *Merluccius bilinearis*. ICNAF Res. Doc. 67/109, 15 p. (Mimeo).

PETTERSSON, O. 1925. The Swedish savings trawl. Svenska Hydrogr.-bial Komm. Skr. 6: 6.

POPE, J.A., M. ROESSINGH, and A. VON GRANDT. 1964. Part I. The 1958 International Comparative Fishing Experiment. In: Cooperative Research Report No. 2. *J. Cons., Int. Cons. Explor. Mer* (May 1964): 7-29.

POPE, J.A., A.R. MARGETTS, J.M. HAMLEY, and E.F. AKYUZ. 1975. Manual of methods for fish stock assessment. Part III - Selectivity of Fishing Gear. FAO of U.N. Fish. Tech. Pap. No. 41, 65 p.

RIDDERSTAD, G. 1915. A new construction of trawl intended to spare undersized fish. Svenska Hydrogr.-biol. Komm. Skr. 6: 1-21.

SARNITS, A.A., and V.A. SAUSKAN. MS 1966. Hydrographic conditions and distribution of Silver Hake *(Merluccius bilinearis* Mitchill) on Georges Bank and off Nova Scotia in 1964. ICNAF Res. Doc. 66-51, 8 p. (Mimeo).

SAUSKAN, V.A. MS 1964. Results of Soviet observations on the distribution of Silver Hake in the areas of Georges Bank (5X) and Nova Scotia (4W) in 1962-1963. ICNAF Res. Doc. 61, p. 8 (Mimeo).

SCOTT, J. MS 1977. Distribution of squid *(Illex illecebrosus)* on the Scotian Shelf 1970-1976. CAFSAC Res. Doc. 77/19, 5 p. (Mimeo).

WALDRON, D. MS 1978. Implications of Mesh Size on Potential Yield of Squid in ICNAF Subareas 3 and 4. CAFSAC Res. Doc. (In press). (Mimeo).

Table 1

Selection ogives for Silver hake *(Merluccius bilinearis)* calculated from the joint Canada-USSR mesh selection study of Oct/Nov 1977. Values smoothed by a running average of 5.

TOTAL LENGTH	PERCENT RELEASED FROM CODEND MESH SIZE				
	40mm*	60 mm	70 mm	90 mm*	120 mm
15	59	73	62	77	91
16	56	71	62	76	90
17	53	68	61	74	90
18	51	66	58	73	90
19	46	63	57	71	89
20	41	61	55	68	88
21	37	57	53	66	86
22	33	53	49	64	84
23	30	48	45	62	82
24	27	45	42	60	80
25	21	40	38	56	78
26	17	35	34	52	77
27	11	30	30	48	76
28	8	25	27	46	76
29	3	20	22	44	76
30	1	15	18	42	75
31	0	11	17	40	75
32	.	8	14	38	74
33	.	5	14	37	73
34	.	4	11	35	71
35	.	4	9	33	71
36	.	4	8	31	71
37	.	3	5	30	69
38	.	3	3	28	66
39	.	2	3	27	61
40	.	1	2	26	53
41	.	0	2	25	46
42	.	.	2	24	45
43	.	.	1	23	43
44	.	.	1	22	40
45	.	.	1	20	39
46	.	.	1	19	34
47	.	.	0	14	29
48	.	.	.	10	28
49	.	.	.	7	25
50	.	.	.	2	22
51	.	.	.	1	19
52	.	.	.	0	18
53	.	.	.	.	15
54	.	.	.	.	15
55	.	.	.	.	15
56	.	.	.	.	13
57	.	.	.	.	10
58	.	.	.	.	7
59	.	.	.	.	2
60	.	.	.	.	0

* Estimated values using linear interpolation of 60-70-127 mm results and taking values of the Canada-Cuba cruise into consideration for the 40 mm mesh size.

App. I (continued)

TABLE 2

Selection by age for 60 mm mesh codend by 3 methods. The first method uses sample populations and "fishes" each length frequesncy with the selection ogive of Table 1. The other two methods use the selection values of the ogive at specified lengths.

Age	Sex	Sample Numbers ('fishing')	Modal length	Mean length
1	M	0.41	0.37	0.38
	F	0.40	0.39	0.38
2	M	0.72	0.75	0.68
	F	0.78	0.80	0.74
3	M	0.83	0.89	0.87
	F	0.91	0.95	0.94
4	M	0.91	0.95	0.95
	F	0.95	0.96	0.95
5	M	0.91	0.89	0.96
	F	0.97	0.97	0.99
6	M	1.00	0.98	1.00
	F	0.99	1.00	1.00

Table 3

Mesh Selection by age for Silver hake from ICNAF Subarea 4VWX in 1977 with sexes combined. Four commonly considered nets are shown with the results calculated by "fishing" sample populations (see text and Table 2 of Appendix).

Net Size Age	40 mm	60 mm Fraction of Fish Retained	90 mm	120 mm
1	0.59	0.40	0.34	0.11
2	0.93	0.74	0.52	0.21
3	0.99	0.87	0.59	0.25
4	1.00	0.95	0.64	0.27
5	1.00	0.97	0.69	0.34
6	1.00	0.99	0.83	0.64

App. I (continued)

Table 4 - Partial recruitments calculated for 60, 90 and 120 mm mesh nets from the 40 mm net historic fishery using the relationship: PR = AVAILABILITY x SELECTIVITY

AGE	40 mm Partial Recruitment (Historical fishery)		Selection (40 mm)		Availability	PR* 60 mm	PR* 90 mm	PR* 120 mm
1	0.08		0.59		0.14	0.06	0.05	0.02
2	1.00		0.93		1.08	0.80	0.56	0.23
3	0.97		0.99		0.98	0.85	0.58	0.25
4	0.54	=	1.00	x	0.54	0.51	0.35	0.15
5	0.63		1.00		0.63	0.61	0.43	0.21
6+	0.27		1.00		0.27	0.27	0.22	0.17

*Selectivity taken from Table 3 of Appendix 1

Table 5 - Fishing mortalities by age for the 40 and 120 mm mesh nets for M = 0.40. This was calculated by using the partial recruitments (PR) of Table 4 (Appendix I) to distribute the $F_{0.1}$ of Figure 11 across the age groups. The fishing mortalities for each of the mesh sizes would be calculated in a similar manner.

AGE	40 mm Partial Recruitments (Historical fishery)		$F_{0.1}$ (Fig. 11)		Fishing Mortality	120 mm PR (Table 4)		$F_{0.1}$ (Fig. 11)		Fishing Mortality
1	0.08				0.05	0.02				0.04
2	1.00				0.60	0.23				0.51
3	0.97	X	0.6	=	0.58	0.25	X	2.2	=	0.55
4	0.54				0.32	0.15				0.33
5	0.63				0.38	0.21				0.46
6+	0.27				0.16	0.17				0.37
					$\bar{F}$ = 0.35					$\bar{F}$ = 0.38

This sample calculation shows the $F_{0.1}$ level artifically high when compared to what one would expect when the partial recruitments are normalized to one. Therefore as the PR's are raised through normalization the $F_{0.1}$ will drop - although the resulting mean F or weighted F will be the same in either case.

Definitions taken from Pope et al. (1975).

1. Length selection ogive or curve - the proportions of fish at each length interval entering the net which are retained by the codend.
2. 50% retention point - or 50% escapement point - the point on the length selection ogive where 50% of the fish are retained. Selection curves are nearly always symmetrical about the 50% point.
3. Selection range - the length interval between the 25% retention point and the 75% retention point.
4. Selection factor - is the 50% retention point divided by the mesh size (both being in the same units).