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Summary of Gear Selection Information for the Commission Area

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INTRODUCTION

At the Joint Scientific Meeting of ICNAF, ICES and FAO in 1957 working groups considered many aspects of our knowledge of gear selection. They reviewed the current status of knowledge and suggested further important research for each of these aspects. At the final session of this Joint Meeting it was concluded that many gear selection problems should be related to specific geographical areas. The recommendation of this final plenary was that the status of gear selection knowledge in the ICNAF area should be examined in order to establish priorities for necessary gear research.

Two of the authors, Clark and McCracken, were asked at that time to carry out this review and to report their results to the Research and Statistics Committee of ICNAF at the Eighth Annual Meeting. Templeman was subsequently asked for his assistance in preparing the redfish review.

We have taken as our basic terms of reference the species caught in the ICNAF area and the gears used to catch them. A limited amount of published data are available, but our sources of information are chiefly the papers presented at the Lisbon meeting (to be published in the coming year). We have used primarily the results of gear selection experiments from the ICNAF area, but Northeastern Atlantic results were included where necessary.

We have considered only "inherent" (or intrinsic) selection by gear; that is, selective properties which can be modified by changing certain properties of the gear. We have not considered non-inherent (or extrinsic) selection, which results from such factors as non-representative distribution of fishing effort over the whole range of sizes of the stock of fish.

SUMMARY OF SELECTION KNOWLEDGE

The following summaries of selection knowledge for various gears and species are presented in a brief form. The derivation of specific selection estimates is presented in more detail in Appendices I - IV. General background material is included in Appendix V to provide a basis for understanding the importance of various aspects of selection processes.

Hook Selection

Only a limited amount of information is available with which to judge the selective effect of various sizes and shapes of hooks. Little is known about the possible selective effect of various kinds and sizes of bait. Hook fishing can be considered in handline and longline categories.

It seems established that hooks fished on longlines select fish from the stock in relation to size; for instance, large hooks catch fewer small cod than small hooks. Preliminary attempts to relate hook dimensions to sizes of cod caught appear promising, but as yet there is no well-defined relationship such as the 50 percent escapement length/

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mesh size ratio for otter trawls. The results available suggest probable selectivity values for some hooks currently in use.

Data for handlines are inadequate for positive conclusions but generally indicate that their selective action may not be so directly related to hook size as in longlines. For both hook methods the catch of cod and haddock within the selection range of a 4½ inch mesh codend is low in the ICNAF area.

<u>Cod</u>. Some results for hooks fished on longlines are available for the ICNAF area (McCracken) and off Norway (Saetersdal). The estimates of selection provided by these experiments are given in Table 1.

For handlines we can only say 1) that results of experiments off the Norwegian coast (Saetersdal) suggest similar selectivity for handlines and longlines, and 2) that size composition of cod catches off the Newfoundland east coast suggests that large handline hooks catch the same size cod as smaller longline hooks.

Table 1. Cod selection estimates for hooks fished on longline.

Hook Type	50% Escapement Length	25-75% Selection Span
No. 17 Mustad	ca. 35-40 cm.	?
No. 14 Mustad	48	12-14 cm.
No. 7 (Norwegian)	55	14 cm.
No. 11 Mustad	65	15-18 cm.

<u>Haddock</u>. Limited results obtained by McCracken for longlines provide the only information available for haddock. These results indicate that hooks select sizes of haddock in a manner similar to otter trawls. McCracken's data are too limited to predict a 50 percent point and only indicate that the smallest hook used by Canadian liners (#17) appears to release as many haddock as a 4½ inch mesh otter trawl codend. Nothing is known about handline selection.

Pair Trawls

There are no data on selection by pair trawls. It is known that the trawls are of natural fibres (manila or sisal); that the twine is usually light and flexible; that codends are unprotected on top; and that mesh size is large. It is believed that they may fish higher in the water than the conventional otter trawl. Length composition of catches by pair trawls has not, to our knowledge, been compared with that of otter trawls.

Gill Nets

No data are available on the selection by gill nets in the ICNAF area.

Traps

No experimental evidence is available with which to make estimates of the selection by traps. Some general knowledge of the use of traps and their catches is presented in Table 2.

......../3

Table 2. Information regarding catches and selectivity of traps.

Species	Where traps used	Sizes caught	Selection
Cod	Extensively for inshore fisheries of Subareas 2 and 3 and Subdivisions 4R and 4S. Also used in Subarea 1.	For example, off Nfld. east coast 1950-53, 14% by number under 45 cm.; 54% by number under 55 cm.	About 15-20% by number within selection range of 4½" mesh; more than 50% within selection range of 5½" mesh. However, since traps take the smallest fish in the area, there is no quantitative evidence re possible escapement.
Haddock	Small catches in Subarea 4.	Varies with season; in 1928 less than 2% under 45 cm., 30% under 55 cm. in 1955 - none of scrod size (under 50 cm.)	Catches mainly large haddock. General knowledge of the area suggests that only large fish present, thus scarcity of small fish in the catch not a result of escapement.

Danish Seines

European experiments have shown that seine net escapement is usually higher than otter trawl escapement for equivalent mesh sizes and material. Since Danish seining is of little importance in the ICNAF area and species caught differ from those caught in European waters, no estimates have been attempted from the European information.

Otter Trawls

An extensive series of experiments with otter trawls has been carried out in the ICNAF area. The majority of the work has been concentrated on haddock, with lesser amounts of work on cod, redfish, plaice, and silver hake. Most of these results are available in the papers of the Lisbon meetings. Results from a considerable amount of European work are also available in publication and in the Lisbon papers.

Escapement through forward parts of the trawl. Replicate haul experiments with haddock in Subarea 5 have indicated generally that escapement through the lower wings and belly was relatively unimportant. The total numbers escaping from forward parts of a trawl are lower, however, than for a codend of the same mesh size; the estimated 50% retention point for the whole No. 41 trawl, of 4¾ inch mesh (internal size), excluding the codend, occurred 5 to 12 cm. lower than for a codend of equivalent mesh size. In addition, escapement through the forward parts of the net may be of even lower practical importance, as fish which are prevented from escaping through forward parts of the trawl will probably escape afterwards through the codend.

Replicate haul experiments with a 3½ inch mesh trawl have shown that the forward parts are important for the escapement of silver hake. Most of the fish of less than 16 cm. escaped; about half the fish of 16-36 cm. escaped, with little selection action shown; and most of the fish above 36 cm. escaped. The forward parts were thus permitting substantial escapement of sizes of fish which would have been retained if they had entered into the codend. Controlling mesh size in the forward parts of the trawl thus appears more important for silver hake than for

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haddock.

No quantative data are available with which to determine the importance of escapement from the forward parts of trawls for redfish, cod or plaice.

Similarity of the selection curves for haddock and cod suggest that for the latter species the forward parts of the trawl may be relatively unimportant also. European results suggest the same conclusions for flatfish.

Escapement through the codend. Most fish of sizes within the selection range of the mesh escape from the codend of the trawl. Moreover, the greater proportion of codend escapement occurs in the after 6 or 8 feet. The precise area of escapement will depend upon the amount of catch accumulating in the codend, of course. Most codend mesh sizes reported for selection experiments, however, represent averages for the whole codend and these are the figures which we have used.

The estimates of 50 percent retention lengths shown in Tables 3 to 6 are based primarily upon experiments in the ICNAF area. When necessary (such as in the case of the variable haddock results for synthetics), the European data have been drawn upon. Estimates are presented for simplicity in the form of 50 percent retention lengths only.

The range over which the selection operates is extremely variable. The reasons for such variations are not well known and could not be investigated in a work of such restricted scope. Average figures have been determined and are provided along with the estimates of 50 percent points as selection span adjustments, which may be added to the 50 percent point to obtain the 75 percent point and subtracted to obtain the 25 percent point. The total range of codend selection can be taken as roughly twice the 25 to 75 percent span.

The derivation of our estimates is detailed in the appendices, where appropriate. The mesh sizes are, unless otherwise specified, in terms of ICNAF gauge measurements (i.e. internal size, used,wet, with the vertical pressure gauge under 10 - 15 pounds pressure).

The relation between mesh size and 50 percent retention length is linear but does not appear to have a zero intercept for redfish, haddock and silver hake. Investigation as to whether the intercept values are significant or not is beyond the scope of this study; the 50 percent points for redfish and haddock have been read from the regression lines shown in the appendix. Average selection factors have been estimated for the range of mesh sizes considered and are included with the tables.

The 50 percent length/mesh size relation for silver hake is described better by a curve than by a straight line. The escapement lengths have been estimated from the curve, and as average selection factors were not considered appropriate, none have been provided.

Selection experiments for cod cover a relatively wide range of mesh sizes, but in many cases cod have been taken as an incidental species. These data indicate that the selection factor is not constant but rather varies with mesh size. The data are not sufficiently extensive to evaluate properly these variations, and the 50 percent retention length estimates in Table 6 have been based on what is considered to be the most appropriate selection factor for ICNAF purposes.

Results for American plaice and witch flounder suggest that selection factors for these species are similar to those for some of the flatfishes of European waters. The 50 percent retention lengths for these species, given in Table 7, have similarly been determined from selection factors considered most appropriate for the ICNAF area.

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Table 3. . Estimates of 50 percent retention lengths for haddock. Selection span adjustment = 4 cm.

Mesh size		50 percent retention length (cm.)		
		Double Manila	Single Cotton	Synthetics
mm.	in.	Av. Selection Factor = 3.2	Av. Selection Factor =.3.6	Av. Selection Factor = 3.5
102	4	32	35	35
108	4¼	34	38	37
114	4½	36	41	40
121	4¾	39	44	42
127	5	41	46	44
133	5¼	43	48	46
140	5½	46	52	48

Table 4. Estimate of 50 percent retention lengths for redfish with double manila codends. Selection span adjustment = 2 cm.

Mesh size mm.	in.	50 percent retention length Av. Selection Factor = 2.5
70	2¾	16
76	3	18
83	3¼	20
89	3½	22
95	3¾	23
102	4	25
108	4¼	27
114	4½	29

Table 5. Estimates of 50 percent retention lengths for silver hake. Selection span adjustment = 4 cm.

Mesh size mm.	in.	Manila Single or double	Cotton 72-84th	Nylon 400/3 Single
76	3	21	23	25
83	3¼	24	26	28
89	3½	26	29	31
95	3¾	29	32	34
102	4	32	35	38
108	4¼	36	39	41
114	4½	39	-	-

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Table 6. Estimates of 50 percent retention lengths for cod. Selection span adjustment = 5 cm.

Mesh size mm.	in.	50 percent retention length (cm.) Manila Av. Selection Factor = 3.5	Single Cotton Av. Selection Factor = (3.7)	Synthetics Av. Selection Factor = 3.8
102	4	36	38	39
114	4½	40	42	43
127	5	44	47	48
140	5½	49	52	53
162	6	53	-	61

( ) less adequate data

Table 7. Estimates of 50 percent retention lengths for American plaice and witch[1]. Selection span adjustment = 3 cm.

Mesh size mm.	in.	50 percent retention length (cm.) Manila Av. Selection Factor = 2.0	Synthetics Av. Selection Factor = 2.2
102	4	20	22
114	4½	23	25
127	5	25	28
140	5½	28	31

1) Selection factors for witch probably slightly higher than for American plaice; data not really adequate.

The Problem of Chafing Gear

The codend results presented for all species assume a single-layered codend which is uncovered on its upper surface. Various protective devices (chafing gear), such as secondary codends fitted over the primary codend or various covering materials over the codend, are commonly used in the ICNAF area. We have very little experimental evidence on the effect of such chafing gears. It shows that these protective devices may cause a substantial reduction in fish escapement with certain methods of application. The considered opinion of ICNAF workers is that a covering piece of netting, if affixed loosely and left open at its rearward edge, should not markedly reduce escapement. Whether this opinion is justified and whether other types of chafing gears could be used without reduction of escapement must await the results of further experiments.

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FURTHER RESEARCH REQUIREMENTS

Evaluation of the adequacy of our current information on gear selection must be related to the importance of species and gears. To this end we have listed in Table 8 a summary of landings from the ICNAF area for 1955. The most important species is seen to be cod, followed by haddock, redfish, flounders (American plaice). Relative importance of the species varies somewhat from subarea to subarea.

Summaries of the catches by various gears are given in Tables 9 and 10. For cod, otter trawls are of the greatest overall importance, particularly those over 500 tons. However, hooks and traps are also of great importance, especially in the inshore fishery. For the remaining species otter trawls, primarily those under 500 tons, are most important.

We are lacking information on many important "gear-species" categories. Perhaps the best summary of our research needs in gear selection is given in the "Outline of Present Research and Long-Range Needs in the Convention Area" prepared by the Research and Statistics Committee in 1956. The following is excerpted from the section on gear selection:

> Determination of the size selectivity of different kinds and sizes of fishing gear.
>
> <u>Present Status</u>: Selectivity of the catching gear is unknown for about 80% of the cod taken in the area. More adequate knowledge is available for about 75% of the present haddock catch.
>
> a. Otter trawl selectivity - Much research has been carried out with single, large mesh codends by several countries. Selection experiments with multiple codends have not been attempted.
> b. Pair trawls selectivity - Inactive.
> c. Hook selectivity - Canada has compared the selectivity of various sizes of hooks. Norway has compared the sizes of fish caught by hooks with the sizes of fish caught by other gears.
> d. Trap selectivity - Inactive.
>
> <u>Additional Resources Required</u>:
>
> a. Mesh experiments with traps should be carried out by countries using these gears to determine what effect mesh size has on the size of the fish caught.
> b. Selective properties of otter trawls with multiple codends should be obtained by the countries using these gears. Covered net experiments and comparative fishing experiments are recommended.
> c. Present knowledge about hook selection should be assembled and considered in relation to mesh selection. This would provide a basis for planning further hook selection experiments.
> d. Length composition samples of cod and haddock taken by different gears should be compared to help assess the general problem of selectivity. For each sample a complete description of the catching gear must be included.

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Table 8. Statistics of landings from ICNAF area, 1955, in thousands metric tons.

Species	Subareas 1	2	3	4	5	Total
Cod	265	26	429	159	12	892
Haddock	-	-	105	43	51	198
Redfish	32	-	18	60	14	123
Flounders						
Am. plaice	-	-	15	12	2	
Witch	-	-	3	7	1	60
Other	1	-	1	2	16	
Halibut	1.4	-	1	1.8	-	4
Pollock	-	-	7	19	10	36
Silver Hake	-	-	-	-	46	46
Other	4	-	2	17	107[1]	130

[1] Includes menhaden, herring, alewives, etc.

Table 9. Landings of major species by different gears in 1955, in thousands metric tons

Gear	Cod	Haddock	Redfish	Flounders
Otter Trawls				
over 500 tons	345	56	32	
151-500 tons	28	77	91	56
under 151 tons	30	48		
Pair Trawls	33	4	-	-
Traps	ca. 100+	Some	-	-
Hooks Longlines / Handlines	ca. 300+	ca. 12	-	0.3
Seine Nets	Negligible	Very few	Very few	1.3
Gill Nets	Negligible	Few	-	-

Table 10. Landings of minor species by different gears in 1955 in thousands metric tons

Gear	Halibut	Pollock	Silver Hake
Otter Trawls	0.8	Some pollock caught by most gears in Subareas 3, 4 and 5.	46
Hooks	1.7		-
Miscellaneous	1.7[1]		-

[1] Mainly hooks

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Reviewing the present status of gear selection for the ICNAF area we find that it has changed very little from its condition in 1956. Our recommendation for further research must remain the same.

Encouragement is provided, however, by the fact that progress has been made in implementing the following recommendations, also excerpted from the 1956 report; this implementation was directly a result of the Lisbon Joint Meeting:

> Determine which parts of the trawl and which sections of the codend contribute most significantly to the release of fish. Determine what factors cause variation in mesh selectivity, such as effect of catch size, towing time, towing speed, differences between material, etc.
>
> Present Status:
>
> In the ICNAF area a number of mesh selection experiments have been carried out by Canada and the U.S. Experiments are continuing on the differences in selection for different materials. Many of the experiments carried on by other countries outside the ICNAF area are applicable.
>
> Additional Resources Required:
>
> Most of the mesh selection experiments carried out in the ICNAF area have been only summarily analyzed. All extant mesh selection data should be analyzed with emphasis given to determining the causes for variation in selection results and amount of escapement in forward parts of the trawl. Results of the analysis should be presented as a basis for determining what further mesh selection experiments are needed. Because future planning is so dependent on the consideration of these past experiments, this should be carried out as soon as possible. Publication of the results by ICNAF should be considered.

A more detailed evaluation of the effects of these factors for the ICNAF area than could be considered for our present brief report would be desirable.

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APPENDIX I

Redfish Selection

Figure 1 indicates that the selection factor decreases with mesh size, ranging from 2.56 at a mesh size of 140 mm. to 2.30 at a mesh size of 70 mm. The factor for 75% retention also decreases with mesh size, from 2.75 at 140 mm. to 2.54 at 70 mm. (Figure 2).

In Figure 3 it is shown that the escapement for 45-50/4 manila, mostly at the large mesh sizes, is usually below that for 90-100/3 manila. It is thus possible that if heavier twine had also been used at smaller mesh sizes the selection factor would have declined even more rapidly.

The data of Clark and Templeman have been further analysed to show that in the covered codend experiments, summarised in Figure 1, the selection factor is lower with larger catches and higher with smaller catches.

Most of the selection points in Figures 1 to 3 were obtained from experiments in which there were small to moderate catches. Selection factors are needed for larger hauls, preferably from the paired tow method or if this is not possible from alternate hauls of commercial vessels operating in areas where large catches are obtained.

The above data have been taken mainly from manuscript papers by Clark, McCracken, Saetersdal, and Templeman. All the data except that of Saetersdal is for the American form of redfish tentatively referred to as Sebastes marinus mentella, Travin. We do not at present know the depth in which Saetersdal's redfish hauls were taken, and thus these redfish may be either Sebastes marinus marinus (L.) or mentella. Saetersdal's mesh sizes were measured under 8 lb. pressure, while the remainder of the mesh size data is for 12 lb. pressure. We also do not know for Saetersdal's data whether the mesh in the codend was double or single. All the measurements on the North American data were from the chin, with the mouth closed, to the end of the median ray of the caudal fin. Saetersdal's fish may have been measured to the tip of the caudal fin. If so, his fish length should be reduced by about a centimeter.

All the alternate haul data have been adjusted by assuming that large redfish beyond the size of 100% retention by the codend meshes were equal in both large and small selectivity nets and adjusting the remaining part of the frequency accordingly.

In the alternate hauls the large mesh nets had codend, lengthening piece and after belly meshes of the same size mesh, while the remaining forward parts of the nets were the same as in forward parts of the small mesh nets (mainly 6" mesh overall, apart from the usual gradation of mesh sizes from the forward belly to the size used in the after part of the belly).

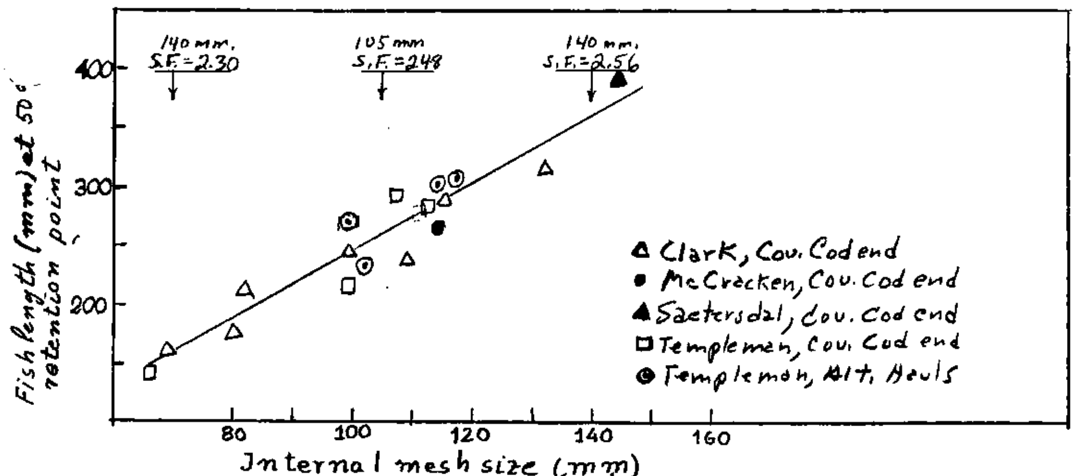


Figure 1. Redfish 50% selection sizes with double manila codends, 45/4-125/3.

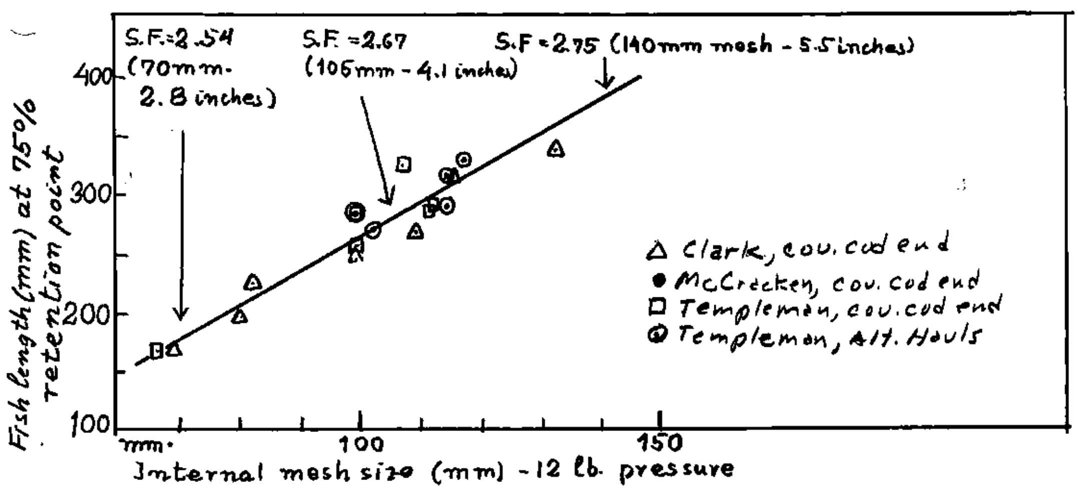


Figure 2. Redfish 75% retention sizes with double manila codends, 45/4-125/3.

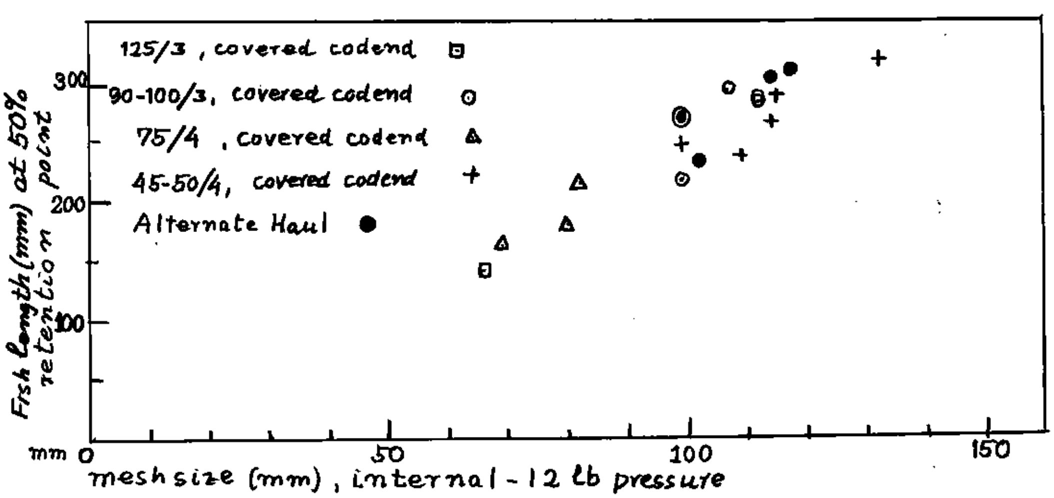


Figure 3. Redfish 50% selection sizes with double manila codends of different twine sizes.

APPENDIX II

Haddock

Such a great quantity of data from codend selection trials with haddock are available that an exhaustive analysis of the causes of variations was not possible. The lines of best fit plotted in Figures 4-7 were calculated by the least squares method from the 50 per cent escapement length/mesh size data.

The line for manila (Figure 4) was fitted to the results of 30 separate trials. Only those results for 45/4 and 50/4 twine were used in the least squares calculation as these are the common sizes in use in the ICNAF area. Inclusion of results for 75 and 125 yard twines would affect the line very slightly, however. The European and early U.S. experiments are included in Figure 5 for comparison. The European experiments vary considerably but in general confirm the line. The early U.S. experiments, based on alternate hauls and "trouser" codends, are now considered to be in error.

The line, when extrapolated, does not pass through the zero point. For this reason the selection factor is not constant and theoretically not appropriate. An average factor of 3.2 is roughly applicable to the middle range of values and will suffice for most purposes.

Nor does the line of best fit for single cotton (Figure 5) pass near the intercept. The one European point (which was not included) would have the effect of drawing the intercept somewhat nearer to zero.

The data for synthetics are much more variable. All data for synthetics were included together as so few data were available for the individual types of twine. Final consideration of differences in various kinds of twine must await more detailed analysis. One factor of considerable importance is that synthetic codends often have much larger meshes at their after ends, past the splitting strap, due to the stretching effect of the weight of fish being hauled aboard. This will produce an effect of higher 50 per cent lengths for given average mesh size of the whole codend since it is the area past the splitting straps that most fish escape from. If the 50 per cent length is plotted against the mesh size in the after quarter only for the U.S. experiments a somewhat better fit is obtained.

We have merely used the line fitted to all data (on the basis of average mesh size for the whole codend) for the purpose of our estimates.

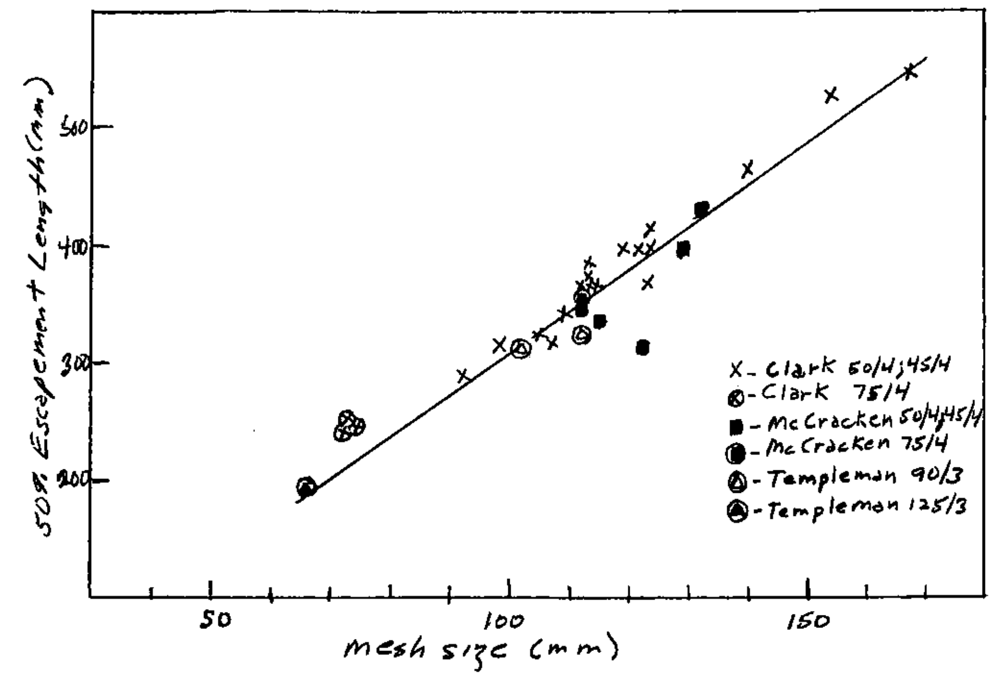


Figure 4. Haddock 50% escapement lengths for double manila for the ICNAF area. Line fitted to the 45/4 and 50/4 data only.

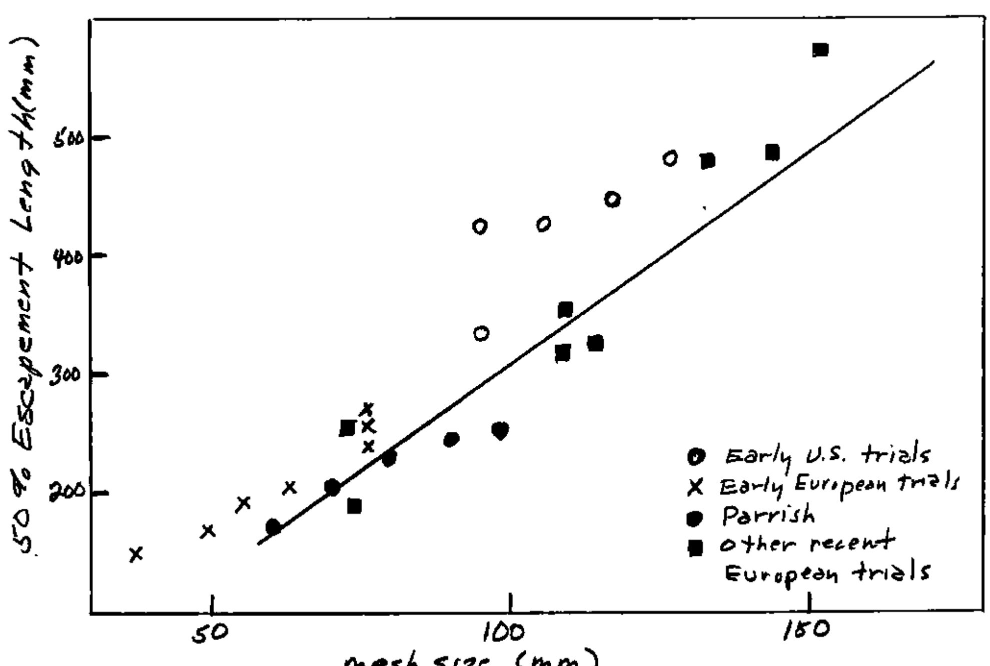


Figure 5. Haddock 50% escape lengths for double manila for the European area with the ICNAF line (from Figure 4) drawn in for comparison.

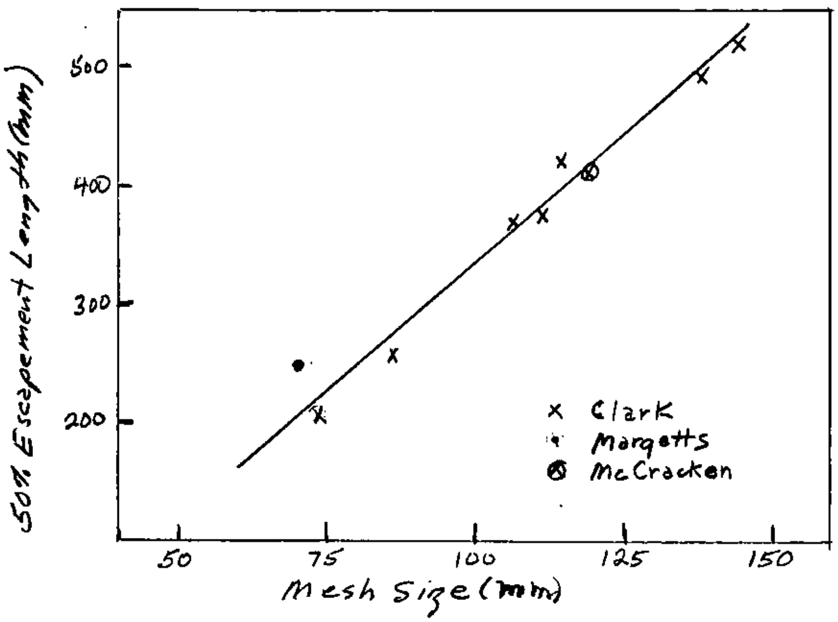


Figure 6. Haddock 50% escape lengths for single cotton.

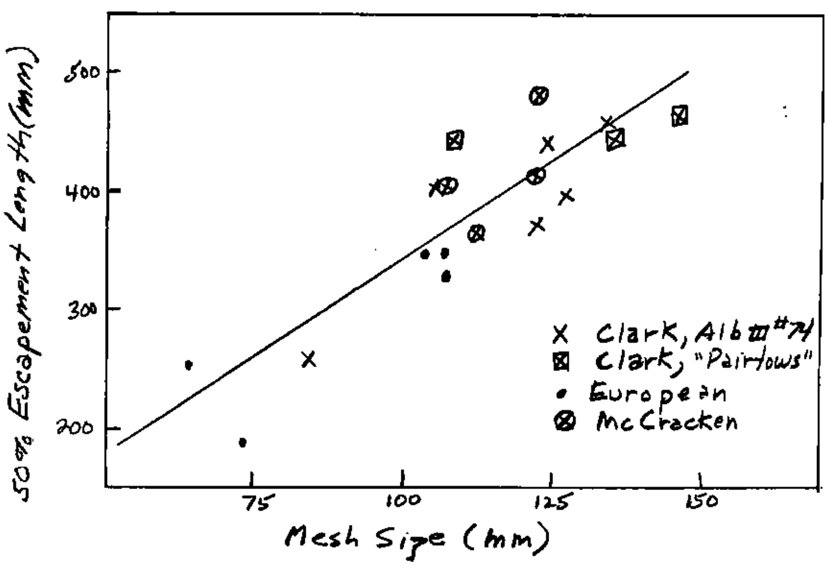


Figure 7. Haddock 50% escape lengths for all synthetics.

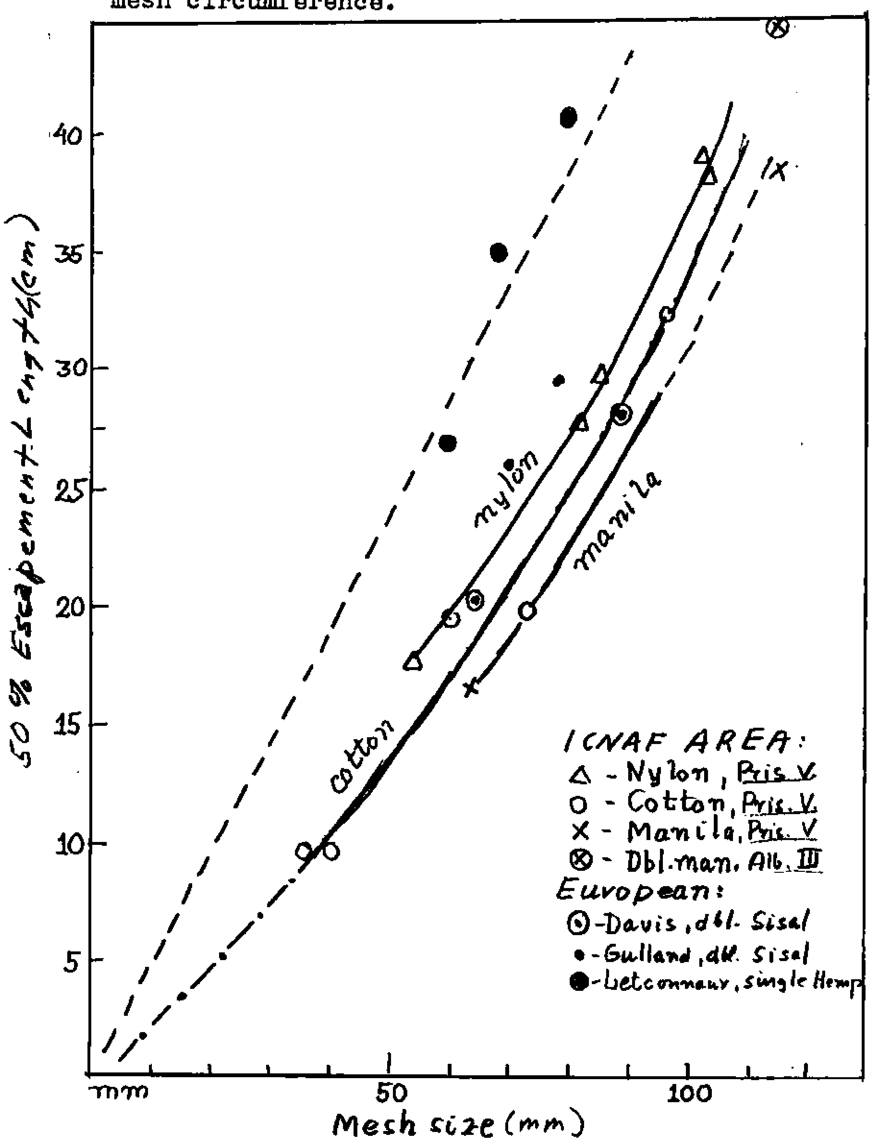
APPENDIX III

Silver Hake

The only extensive codend selection trials from the ICNAF area were conducted aboard a small (47 gross tons) trawler, Priscilla V,* which carries out the major part of the silver hake fishery. The trawler towed a small net slowly (2½ knots) and results are probably not directly applicable to larger trawlers. The results indicated much duller and much lower escapement than would be expected from the girth of silver hake. Much higher escapement is indicated by European experiments.

The results are given in Figure 8. It may be seen that the relation between mesh size and 50 per cent escapement length is fitted better with a curve than a straight line. The curves for the three different materials are of analagous shapes.

Figure 8. Silver hake 50 per cent escapement lengths and mesh size. The dotted line represents the point where fish girth = mesh circumference.



*of the type

The line for cotton may be extrapolated back to the zero point. It is reasonable to assume perhaps that the other two curves should also be fitted to conform to a zero intercept. However, consideration of the significance of intercepts is beyond the scope of this study and the estimates of 50 per cent lengths have been interpolated from the curves shown which have been fitted as closely as possible to the data by eye.

The single point for double manila, Albatross III, is not used in drawing the line as a specific 50 per cent point could not be estimated from the sparse data. These data do, however, indicate a 50 per cent length of a minimum of 450 mm., which is much higher than would be indicated from the Priscilla V work. This would confirm that the Priscilla V data may not be applicable to larger trawlers.

European data as summarized by Gulland also giving much higher selection, are indicated in Figure 8. The data of Davis coincide well with our ICNAF data. Gulland's own data give higher, but not unreasonable estimates. The data of Letaconnoux are so much higher, notwithstanding the fact that they are for single twine of hemp, as to be considered inappropriate for our use. These data are for replicate tows which seem usually to yield artificially high escapement estimates. For example, in two cases his data show half the hake escaping of a size which, on the basis of data for silver hake in the ICNAF area, are larger in girth than the mesh is in circumference and theoretically would be too large to pass the meshes. Moreover, this is only the 50 per cent length, indicating that many even larger fish are escaping. Notwithstanding the fact that the mesh size is only an average and some larger meshes are undoubtedly present, such escapement estimates remain extraordinarily great and more intensive examination of Letaconnoux's data would be required before they could be considered appropriate for our purposes.

As such extensive analysis is beyond the scope of this report, the European data have not been utilized for our estimates.

APPENDIX IV

Cod Selection

Within the ICNAF area cod is the species for which the greatest variety of gears makes important contributions to the landings. These gears include traps, hooks, pair trawls, and otter trawls.

The results of selection experiments for hooks have been taken from manuscript papers by McCracken and Saetersdal. Size composition data for cod caught by traps and handlines have been taken from a published paper by Templeman.

Brief documentation re selection factors obtained in various otter trawl selection experiments for cod are shown in Tables I to IV. Comments about the adequacy and variation in the data are noted below each table.

Selection factors for flounders (American plaice and witch) are presented in Table V.

Table I. Cod: Selection factors for manila codends.

	Frequency for covered net experiments							Frequency for parallel hauls & commercial catches	
Sel. Factor	Nfld. SA 3	St. A. SA 4	U.K. North Sea	U.K. Spitzbergen & Bear I.	Germany Spitzbergen	Norway	Total Freq.	Norway Bear I.	SA 4
2.6	(1)						(1)		
3.1		1					1		
3.2	(1)	1	(1)?				1(2)		
3.3	(1)	1(1)					1(2)		
3.4		11(1)			1	(1)	3(2)		1
3.5		1111			1		5		
3.6				1		1	2		
3.7									1
3.8				(1)		(1)	(2)		
3.9									
4.0									
4.1								1	
4.2									
4.3								1	
4.4								1	

( ) Less than 50 fish per tow in the selection range
(1) Comparison of large and small mesh commercial catches in the ICNAF area provide a similar selection factor to those obtained by covered net hauls.
(2) There are some indications that selection factors for Arctic cod may be higher than for more southern stocks.
(3) Increase of selection factor with increased mesh size has not been observed. Other causes of variability in these results are probably more important.

....../18

Table II. Cod: selection factors for cotton, nylon and perlon codends.

Selection Factor	Frequency Covered Net Experiments				
	Cotton	Single Nylon	Double Nylon		Double Perlon
	St. Andrews Subarea 4	St. Andrews Subarea 4	St. Andrews Subarea 4	Germany Spitzbergen	Germany Spitzbergen
3.6	1				
3.7	1				11
3.8		1	11		
3.9		111		1	
4.0					

Table III. Cod: selection range, manila codends.

Mesh size mm.	Distance between 25-75% retention lengths (cm.)										
	3	4	5	6	7	8	9	10	11	12	?
66											x
102	△			x							
109					1	1		O			
112				O			O	Ox		O	
117									O	O	
122											
125					△			1	O		
130								{O+ ++		O	
144						⊕	⊕				⊕
168								O			
Frequency Covered net	-	-	-	2	1	2	2	6	2	3	
Parallel or comm. hauls	1	-	-	-	1	-	-	3	-	-	

△ Subarea 4 commercial catches
O St. Andrews covered net
1 U.K. covered net
x Nfld. covered net
⊕ Norway covered net
+ Norway parallel haul

Table IV. Selection range cotton and nylon codends (covered net experiments).

Mesh size mm.	Distance between 25-75% retention lengths (cm.)						
	Cotton	Nylon Single			Nylon Double		
	8	6	7	8	7	8	9
102	O						
107		O					
112				O	O		
119	O	O					
122		O					O?
Frequency	2	3	-	1			

........./19

Table V. Flounders -- Selection Factors.

Sel. Factor	American Plaice, Covered Net: Manila Nfld. SA 3	American Plaice, Covered Net: Manila St. A. SA 4	Freq.	American Plaice, Covered Net: Nylon St. A. SA 4	American Plaice, Covered Net: Cotton St. A. SA 4	Witch, Covered Net: Manila Nfld. SA 3	Witch, Alternate Haul: Manila Nfld. SA 3
1.8						1?	
1.9							
2.0		11	2				
2.1							
2.2	(1)	(1)	(2)	1		(1)	
2.3	(1)		(1)				
2.4				(1)			1
2.5					(1)		

( ) less than 50 fish per tow in the selection range

......../20

APPENDIX V

GENERAL BACKGROUND MATERIAL

How Gear Selectivity is Measured

The selectivity of gear is determined usually either by capturing the fish which have escaped the gear (covered codend experiments) and comparing their sizes with those retained by the gear, or by comparison of catches for different gear fished at the same time and place. These comparisons usually reveal at first a slow increase in the retention of fish from the smallest size at which some are first retained, followed by a rapid increase in retention, and finally reaching a stage of only gradually increasing retention to the point where full retention is achieved. When such data are plotted they take the form of an extended "S-shaped" curve, which is termed the "selection curve" for the gear.

Variations from the S-shaped pattern are found for certain gears such as gill nets, in which the retention increases to its highest value at a certain fish size and then decreases again past that size, thus describing a bell-shaped or normal curve.

How the Selectivity Process is Defined

Selection of the type that takes place in otter trawls is defined by various properties of the resulting sigmoid curve. These properties are usually the lengths of fish retained at various points along the curve, such as the 25, 50 and 75 percent retention points. Selectivities of different gears and sizes of gears are most often described simply by giving their 50 percent retention length (the length at which 50 percent of the fish are retained by the gear and 50 percent escape). The selection span (length between 25-75 percent retention length) is often included to give a measure of the steepness of the curve. The "regression coefficients" are often used to describe the relation between 50 percent retention length point for various gears and average internal size of mesh. If the form of this relation has an intercept of 0, the "b" value of the regression formula is sufficient to define the relation. This value is called the "selection factor", a higher factor showing greater selection. Selection factors for otter trawls, for example, will vary from 2.0 to 5.0, depending upon the species concerned.

Information Available on the Selection of Fish by Gear Commonly Used in the ICNAF Area

By far the most common type of gear used in the ICNAF area is the otter trawl. A considerable series of experiments has been carried out with trawl nets in the ICNAF area and some little data has been collected on hook selection; other types of selection have not been investigated.

Otter trawl selection work has been concentrated largely on escapement from the codend, as most workers have believed that this part is the important escapement area. Data are available from nearly 100 separate trials with codends of various sizes and types of twine. A few experiments have been carried out to determine the selectivity of parts of the trawl other than the codend.

The Value of Special Trawl Gears (Devised for Improving Escapement)

Various types of special trawls or modification of trawls have been devised with the hope of improving the precision of the selective action of the net. These trawls, incorporating rigid meshes

......../21

of wire, panels of special kinds, or meshes hung in a special fashion to insure their being open, have not shown sufficient superiority over the standard type of netting to be considered for introduction into the fisheries.

Do Fish Escape Undamaged from the Trawl Net Under Tow?

It has been amply demonstrated that meshes of the net remain open during towing and that fish escape during this time, not just while the net is being hauled. Early experiments by Davis demonstrated this conclusion indirectly and showed that 90 percent of the fish escaped while the net was under tow. Davis's findings have subsequently been confirmed by observations of SCUBA divers in shallow water and underwater television in deeper water. The other part of this question has not been adequately answered. Examination of limited results from tagging of escapees taken in codends and covers has not indicated any greater mortality for those which passed through the codend meshes into the cover.

Increased Efficiency of Large Mesh Trawls

It is a common result in comparison of catches of large and small mesh gears that larger meshes catch more larger-sized fish. This was first shown by Davis in his North Shields experiment, in which the large mesh caught 11 percent more fish of a size beyond the selection range. Perhaps the best recent demonstration is that for the Georges Bank haddock fishery, in which the regulated (4½ inch mesh) trawlers caught 9 percent more fish of larger sizes than the small mesh (2-7/8 inch) study group vessels. These increases are noticed particularly for sizes of fish just beyond the selection range of the net.

Experimental Results Compared with the Results of Large Mesh in Practice

The North Shields work, in which Davis compared large and small mesh on two commercial trawlers for a period of 3 months, first demonstrated that selection experiments were borne out in practice. A recent study of the regulated (since 1953) Georges Bank fishery has shown the selectivity of the 4½ inch mesh for haddock to be almost exactly that predicted by the experimental evidence.

Escapement of Fish from Forward Parts of the Net

Some information on escapement in the forward parts of the nets shows that it is usually quite limited compared to the amount of escapement that takes place in the codend, which contains only 1 or 2 percent of the total mesh area of the net. Considerable variation is shown from species to species, however, and some fish do escape in large numbers through the forward parts of the net. Data from experiments in the ICNAF area have shown that nearly 100 percent of the very smallest sizes of haddock and silver hake escape through the forward parts of the net.

It has been further demonstrated that fish do not escape equally throughout various parts of the codend, but rather escape through the first few rows of clear meshes ahead of the accumulated catch. This means that in most cases the effective escape area is confined to the last 8 feet or so of the codend. Thus, the most important place in the trawl to control the mesh is probably in the rearmost section of the codend.

Effect of Experimental Error

As an example of the kind of experimental error encountered, the use of a small mesh cover over the codend may easily result in a dampening of the escapement if the cover is not properly fitted. Results from parallel tows with large and small mesh nets tend to give

......../22

artificially high escapement. This comes about through differences in the catching rate of the two gears for different sizes of fish other than that due to the actual selectivity of the mesh. This effect, which may be due to different hydrolynamic properties of large and small mesh nets, is the one responsible for the increased catches of larger fish by regulated Georges Bank trawlers.

Selective Properties of the Trawl for Different Species

Marked differences in escapement values have been shown for various species although the reasons for this are not well understood. The relation between fish shape and mesh shape is undoubtedly important. Wide-bodied flatfish, for example, do not escape nearly so well in respect to length as roundfish. This could be expected because they are so much broader. Redfish, which are a relatively deep fish, also are characterized by low escapement in respect to length. There are also important differences among various species of "roundfish". Cod, for example, escape in somewhat greater numbers at any size than haddock. This means that selection has to be determined for each species.

The Range of Fish Sizes over which a Selection Process Extends

The selective process is not precise, but operates over a more or less extended range of fish sizes. For otter trawlers, about which the most is known concerning gear selection in the ICNAF area, it has been found experimentally that in large mesh nets of over 150 mm. the gear may select sizes of haddock over a range of 35 cm. or more. This range, called the selection range, has been found to be related to the size of the mesh; that is, the range will be very much smaller for smaller sizes of mesh, reduced to about 8 cm. for a mesh of 75 mm., for instance.

Difficulties Arising from the Extended Range over which Selection Operates

Although the gear operates selectively over a large range of sizes, the greatest amount of selection occurs within a much narrower range of sizes. Most investigators consider the important part of the selection as that occurring between the point where 25 percent of the fish are retained and the point where 75 percent of the fish are retained. This is termed the "selection span". The haddock selection span, for instance, may be as low as 4 cm. in 75 mm. meshes and as high as 14 cm. in meshes of 150 mm. or over. This means that to obtain substantial escapement of a certain size of fish one must accept the escapement of a substantial quantity of fish over those sizes. For example, if one is to obtain 75 percent escapement of 34 cm. haddock from a trawl net, one must allow 60 percent escapement of the fish at 36 cm., 40 percent at 38 cm., 25 percent at 41 cm., and smaller percentages of the larger sizes. This factor must be taken into consideration in recommending mesh sizes for fisheries and the proper allowances made.

Kinds of Substantive Variation Encountered

We have come to realize that in addition to the experimental error involved in measuring gear selection, there are also substantive causes of variation; many of these have already been recognized and some have been measured. Those considered to be the most important substantive factors are considered in the following four sections.

Differences in Escapement Associated with Differences in Net Material

Meshes of lighter, more flexible twines usually give higher escapement than heavier and stiffer twines of the same size. For example, the 50 percent point for haddock is about 5 cm. higher for single cotton than double manila at a mesh size of 4½ inches. Similarly, the 50 per-

......../23

cent point for silver hake has been shown to be about 6 cm. higher for light single nylon than for single manila at a mesh size of 4 inches.

Effect upon Escapement of the Speed with which the Net is Towed

Little direct evidence is available on this subject because few controlled experiments on different towing speeds in the ICNAF area have been conducted. However, some of the differences in selection between large boats and small boats (which tow more slowly) are probably due to differences in towing speed. Experimental trawling for selection purposes is usually carried out at a towing speed approximating commercial practice so that results will be directly applicable. However, "commercial practice" varies from fishery to fishery and area to area, making comparison of results of various experiments doubtful.

Effect upon Escapement of the Length of Time over which the Net is Towed

Longer tows appear to afford greater escapement. This has been documented for the ICNAF area in controlled haddock escapement experiments in which the 50 percent point increased by more than 5 cm. in one trial when towing time was increased from 20 to 80 minutes. European work has indicated that 3-hour tows give higher escapement than 1½-hour tows. These differences usually are not so large as to interfere greatly with comparison of experimental results or their application, since tows usually approximate commercial practice, which is 60 to 120 minutes in the ICNAF area. The difference in 50 percent point between these extremes should be only a centimeter or two.

Size of Catch in Relation to Escapement from Codends

That larger catches generally are associated with lower escapement has been shown to be true by many investigators. Work in the ICNAF area has shown that the 50 percent point for haddock, for example, may decrease 5 cm. from light to heavy catches. The expected catch level in a fishery should thus be considered in mesh control programs.