Size Selection of Fish by Otter Trawls

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FISHING IS BY NATURE a very selective process. The selection results from the direction of fishing operations and from selective properties of the gear itself. Perhaps the most important of the selective properties of otter trawls is the selection of certain sizes of fish, since it is this property which permits the harvesting of fish stocks at the age which will ensure maximum production. The size selection of fish in otter trawls may be conveniently divided into two categories, extraneous and inherent.

Extraneous size selection is caused by factors other than those associated with the gear itself. The two major sources of extraneous selection are (1) non-representative distribution of the fishing fleet over the total size distribution of the fish and (2) differential availability of different size groups within the fishing region. Selection from the first process will vary in response to seasonal or sporadic changes in either the distribution of the fishing fleet or distribution of the fish stock. Selection by the second process will be affected by changes in fish habits and behavior among areas, seasons and years. Little control can be exercised over either of these factors in management programs, but both are important in the application of biological sampling to the understanding of the structures of fish populations.

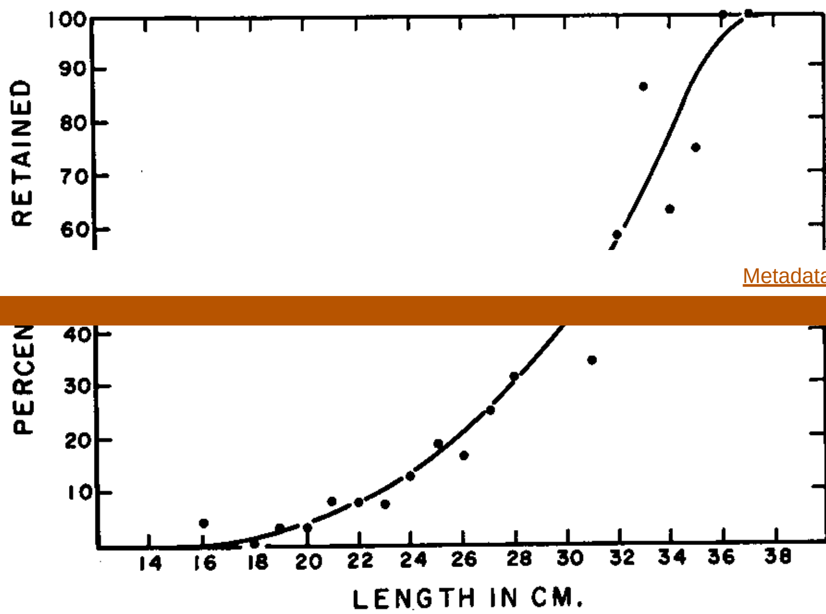

FIGURE 1.—Percentage of various sizes of ocean perch *(Sebastes marinus)* retained by a manila cod end of 132 mm mesh size. Based on experiments conducted by North Atlantic Fishery Investigations.

Inherent size selection comes about through the action of the trawl upon the fish entering the net and, being the most easily controlled, is the type of selection most important in management considerations. Of all the alterable properties of a trawl net the most easily controlled is the size of the mesh. An extensive series of experiments, mostly for the cod end of the net alone, has shown that meshes of trawls do release fish. Moreover, the escapement from a given mesh size has been shown to be inversely related to fish size, with proportionately more small than large fish escaping. The type of size selection occurring in otter trawls is illustrated in Figure 1 by a typical sigmoid selection curve. The size selectivity of a trawl is most commonly defined in terms of its 50 per cent point. This is the fish length which corresponds to the point on the curve at which half the fish entering the cod end are retained and half escape. The 50 per cent point usually increases in direct proportion to mesh size. This relationship is commonly defined by the SELECTION FACTOR, which is the quotient of 50 per cent point (cm.)/mesh size (cm.). Thus, the selection factor is an expression of the fish's capacity to escape. The selection factor varies from species to species and for a particular species varies with the conditions associated with its capture.

Some general knowledge of the type mentioned above was at one time sufficient to provide a basis for management programs. Precise definition of selection was not required because little was known of optimum rates of exploitation. The application of modern statistical methods to studies of fish populations has made precise estimation of optimum size at harvest possible. A demand for similarly precise determinations of gear selectivity has arisen therewith. This need for precision has required the expansion and elaboration of gear selection research in the North Atlantic. This paper will be concerned with the status of otter trawl selection research in the North Atlantic as it has been affected by recent developments.

The establishment of international commissions for management of certain North Atlantic fisheries during the past decade has encouraged an increase in size selection experiments with otter trawls. The resulting accumulation of information has increased our knowledge tremendously, but because of the precision required, disagreements among the results of many experiments have caused great concern. The seriousness of the differences moved the Permanent Commission, dealing with management problems in the Northeast Atlantic, to establish an *Ad Hoc* Committee to consider variations in results. The committee analyzed all available data in order to recommend certain selective standards for otter trawls. For a few species it was possible to choose a single selection factor. For many of the important species, however, the selection factor could be defined only in general terms. These results have been published by the Permanent Commission (1956).

The International Commission for Northwest Atlantic Fisheries (ICNAF), meanwhile, was meeting with similar problems. A summary of haddock selectivity data is shown in Figure 2 (from Graham, 1952) to illustrate the variations in results obtained for a single species of concern to ICNAF. The extent of differences is well demonstrated at a mesh size of approximately 3-3/4 inches where the 50 per cent point varies from 25 cm. to 43 cm. and the resulting selection factor varies from 2.6 to 4.5. Variations such as these render selection data difficult to apply to management programs.

The increasing concern over size selection problems on both sides of the Atlantic resulted in a meeting of gear selection experts from ICNAF, the Inter-

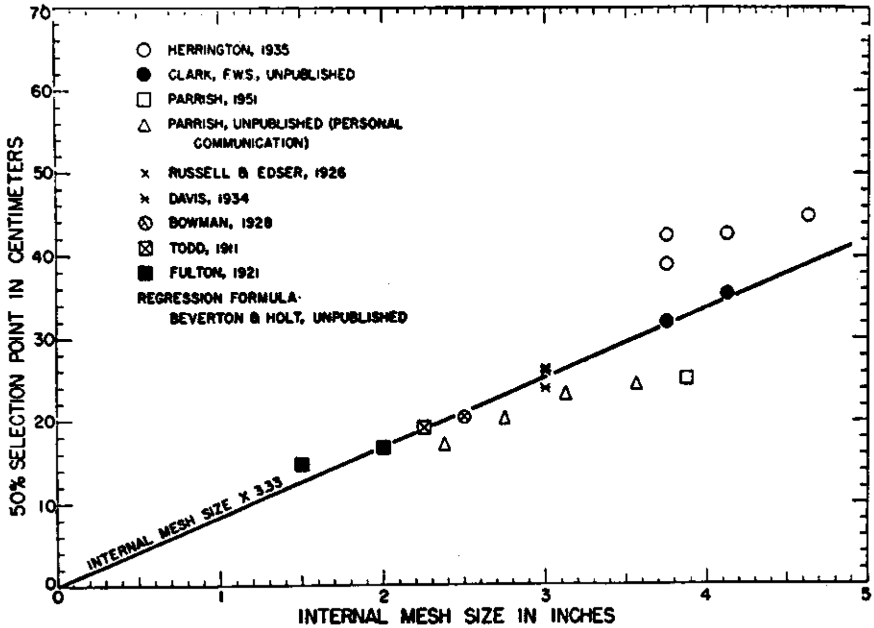

FIGURE 2.—Relation of size of mesh to 50 per cent retention size of haddock.

national Commission for the Exploration of the Sea (ICES), and the Food and Agriculture Organization of the United Nations (FAO) at Lisbon, May 27 to June 3, 1957. At the Joint Meeting, working parties were established to consider, among other matters, the factors of importance in the variations among gear selection results. The deliberations of the working parties demonstrated the complexity of the situation and indicated fruitful avenues of research that could be followed to provide a better understanding of gear selection processes. The results of this Joint Meeting[1] are used as a basis for the following discussion. The working parties were primarily concerned with results of otter trawl selection studies, the majority of which dealt with selection in the cod end.

It was brought out at the meeting that the variations in results can be attributed to either experimental causes or substantive causes. The experimental variations are those deriving from the manner of conducting the experiments and do not arise from real differences in the selective action of the trawls.

A number of experimental methods for determining the selection of sizes of fish by otter trawls are in use, each with its own peculiar sources of variation. The cover method involves the application of small mesh netting over various parts of the trawl to actually trap the escaping fish. A second method is the trouser trawl method, in which two cod ends of different mesh size are attached to the same net. The selectivity of the larger mesh is estimated by comparing the catches of the two cod ends. A third method, which may be called the replicate-haul method, involves the comparison of catches of two separate nets, towed

[1]The report of the Joint Meeting and the papers presented have not yet been published. The author has drawn freely upon the manuscripts in the following pages.

either in alternate series from one vessel or at the same time by different vessels.

The cover method provides the most precise results. Its use, however, is attended by a considerable amount of danger in that if improperly applied the cover can block the meshes and prevent the escapement of fish, thus giving erroneous results. Other disadvantages are that it may restrict the flow of water through the trawl, thereby altering the selective properties of the net, or may be seen by the fish and thereby discourage their escape, or may allow fish to return to the cod end after having once escaped. This method, although effective for the cod end if properly used, cannot easily be employed on the broad surfaces of the net or on its underside. In any event, the effect of the cover should be tested preliminary to the conduct of the experiment.

The other methods listed involve the comparison of the catch of different nets. The best of these is probably that of towing two nets simultaneously from boats fishing as near together as possible, or towing two trawls from the same vessel, as has been done with shrimp beam trawls and scallop drags. The problems inherent to this type of sampling arise from the non-random manner in which the fish are distributed (see Taylor, 1953). The trouser trawl method (two cod ends of different mesh sizes) is less useful because of the abnormality of its construction and a tendency for the two cod ends to catch different amounts of fish. The lowest of the selection values illustrated in Figure 2 were obtained with the cover method and the highest with the alternate tow and trouser methods; the correct values were found to lie in between.

Even with the experimental error accounted for, considerable variation in results may remain, owing to substantive factors. These are real differences which may be attributed to the type of trawl used and the conditions of its operation. The deliberations at the Joint Meeting brought out many important causes of substantive differences in selection research. These differences were shown to be associated with such things as length of tow, size of catch, type of twine used in the netting, and differences in the distribution of meshes of various sizes within the cod ends.

Varying the length of tow has been shown to alter the selection factor considerably. Experiments conducted to investigate the effect of length of tow on the escapement of haddock, for instance, show the selection factor to vary from 3.0 for 20 minute tows to 3.4 for 80 minute tows. Variations in size of catch of haddock in the cod end have been shown to alter the 50 per cent point by as much as eight cm, the higher 50 per cent point being associated with lower catches.

Comparison of results of many experiments have shown that the type of twine used in cod ends is an important factor. At a cod end mesh size of 60 mm, for example, silver hake *(Merluccius bilinearis)* have been shown to have a selection factor of approximately 2.5 for manila, 2.8 for cotton and 3.2 for nylon twine. The higher selection factors apparently result from more flexible twines.

Non-random distribution of mesh sizes in the cod end have been shown to be an important factor in haddock escapement. Meshes at the aft end of a cod end are stretched by the weight of the catch being hoisted aboard and will gradually increase in size over the meshes at the forward end as the cod end continues in use. Results from experiments with special covers have demonstrated that 70 to 90 per cent of cod end escapement takes place in the terminal five to six feet. Systematic differences in mesh size within the cod end must, therefore, be considered in order to interpret results properly. A demonstration of this effect is provided by one experiment in which a nylon cod end having an average mesh size of approximately 123 mm was tested first in a normal position with the larger mesh aft, and then reversed to put the small mesh aft. In the normal position a selection factor of 3.5 was obtained; with the cod end reversed a selection factor of 3.1 was obtained.

In measuring the meshes of nets certain factors must be given consideration. Of particular importance are the extent to which the mesh is stretched and the particular dimension measured. It is evident that in comparing results of experiments the same dimensions of meshes must be compared. Less evident, but of equal importance, is the problem of stretching the mesh with a standard force. Meshes, of course, must be stretched to some extent in order to measure them accurately. Different instruments and methods may provide different amounts of stretch and, therefore, alter the resulting measurement.

When designing selection experiments the application of the results to the fishery must be thoroughly considered. The following questions are the sort which should be considered in applying results: Are the fish being damaged in escaping through the meshes? Is there an important amount of escapement through the forward parts of the trawl? Have results been obtained for the proper towing speed, twine type, catch size, and so forth? Have proper specifications of the gear been established? What systematic variation is there apt to be within distributions of meshes of given average size?

Another problem of importance involving the application of results is that concerning the type of relationship that exists between mesh size and fish escapement. The establishment of this relationship is necessary in order to predict, from experiments on a few mesh sizes, the size of the fish that will escape from any size of mesh. A simple linear relationship between mesh size and fish size has been accepted as being valid for various species. Certain recent experiments have shown, however, that this relationship cannot be applied to all

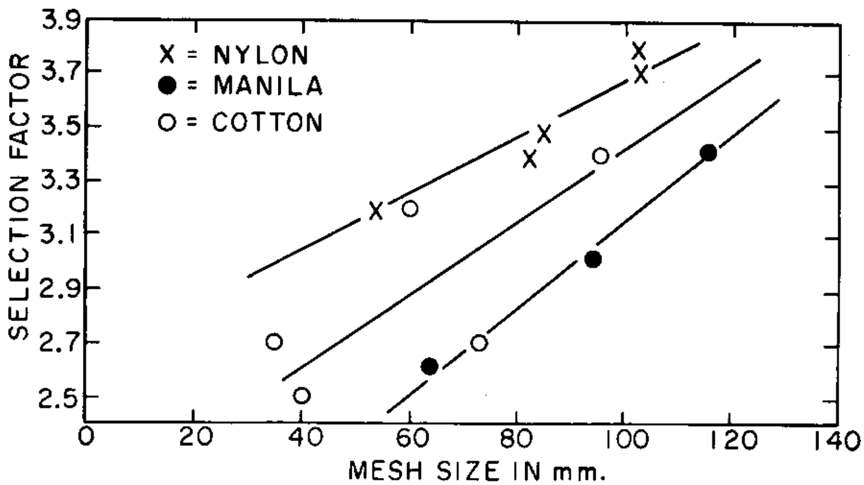

FIGURE 3.—Selection factor—mesh size relation for silver hake with nylon, manila, and cotton cod ends. Based on experiments conducted by North Atlantic Fishery Investigations.

cases. A non-linear relationship between the 50 per cent point and mesh size has been demonstrated for silver hake. This is shown in Figure 3 by the fact that the selection factor is not constant but changes with mesh size. Thus it cannot be accepted that the selection factor is constant over the range of mesh sizes for all species and the relationship must be considered separately for each case.

Research projects were recommended by the working parties of the Joint Meeting to provide solutions to specific problems. Some of this research is already yielding results. Certain studies with underwater television, for instance, which are underway at Woods Hole have provided valuable information on such things as: the action of cod end covers, the behavior of fish in the cod end at various towing speeds, the effect of additional layers of netting on top of the cod end (chafing gear), and the escapement patterns characteristic to various species.

The final test of the validity of selection experiments is, of course, the resulting effect upon the fishermen's catches. ICNAF, realizing the importance of testing the effect of its haddock regulation in this manner, required the maintenance of a licensed study fleet fishing with the small pre-regulation mesh nets as a control. Comparison of catches of this study group with boats using the regulation mesh confirmed the experimental results for haddock—both experimental results and study boat comparisons yielding a selection factor of 3.3.

Complex problems such as those arising from North Atlantic gear selection experiments, which are carried out by many nations, require close liaison between fishery researchers. The Joint Meeting of ICES, ICNAF and FAO by enabling workers from many nations to work together on their mutual problems, has provided a landmark in modern fishery research. Through close cooperation of researchers and the development of modern methods of research, such as underwater television, concepts are emerging to explain the puzzling variations in gear selection results.

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The Use of Radioisotopes as a Tag for Fish

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FOR MANY YEARS fish have been marked or tagged for the purpose of determining rates of movement, migration routes, growth or mortality rates, or other life