THE SALMON GILLNET MESH SELECTIVITY CURVE

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CONTENTS

INTRODUCTION

In 1959, the International North Pacific Fisheries Commission established a working group to prepare a report on the offshore distribution of salmon for inclusion in the Commission's comprehensive report on North Pacific salmon. During the course of preparing this report, the members of the group repeatedly noted and discussed the need for a standardized catch per unit of effort of salmon gillnets, the gear most commonly used in the high seas salmon fisheries and fished by both commercial and research vessels. Through these discussions it became clear that a mesh selectivity curve should be obtained for the standardization of catch per unit of effort data. Fortunately, after a series of analyses based on available data, such curves were obtained for the major salmon species (Ishida, 1962 ; Manzer *et al.*, 1965).

Apart from these analyses, gear selectivity was taken up at a conference held in Lisbon in 1957 and sponsored by ICNAF, ICES and FAO (FAO, 1960). At this conference, results of an initial study on the mesh selectivity of gillnets were presented and distributed in mimeograph form (Holt, 1957). This report was published subsequently (Holt, 1963). Since then, mesh selectivity curves of gillnets have been estimated by many scientists for various species by various methods (Olsen, 1959 ; McCombie and Fry, 1960 ; Berst, 1961 ; Garrod, 1961 ; Gulland and Harding, 1961 ; Ishida, 1964a ; Ishida, 1964b ; and others). The analysis of the INPFC working group was made coincidentally with these various works.

Although the basic methodology for assessing gillnet mesh selectivity curves is now well established, the author considers that it is worthwhile to prepare an overall review of this problem. Most studies on the salmon gillnet selectivity curve have been published only fragmentarily in the Japanese language. Dr. F. Nagasaki of the International North Pacific Fisheries Commission suggested that the author prepare this review for publication in the INPFC Bulletin.

The author is deeply indebted to Mr. J. I. Manzer of the Biological Station, Nanaimo, B. C., of the Fisheries Research Board of Canada and to Mr. A. E. Peterson of the Biological Laboratory, Seattle, Washington, of the U. S. Bureau of Commercial Fisheries, for the discussions concerning this problem which were held in the working group mentioned above. Guidance from Dr. Shoichi Tanaka, professor at the Marine Research Institute of Tokyo University, also is gratefully acknowledged.

CATCH BY GILLNET AND MESH SELECTIVITY

There are two components in the mechanics of a gillnet catching fish, namely " gilling " and " tangling ". These two components can work independently or in combination, e.g., when fish which are initially gilled are retained in the net only by tangling at the opercle. The relative effectiveness of either of the two components depends on the shape of fish, thread material of net, and net construction (particularly the way the net is hung and the type of knot used).

In catching spiny, long-legged animals such as king crab or flat, widened fish like flounders, the larger portion of the catch is retained by tangling (Ishida, 1964c). In catching spindle-shaped fish, without spines, such as salmon and mackerel, gilling is of primary importance. In some species of fish, however, fishermen have learned that a larger portion of the catch is retained by tangling in nets of fine, elastic thread and with nets " hung in " considerably, i.e., with more netting hung on the cork line and lead line.

From the viewpoint of mesh selectivity, " gilling " works to select fish and " tangling " works to counteract selection. Because of the difficulty in separating catches quantitatively according to the two components, mesh selectivity is considered in practice

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within a certain size range). However, full consideration has not been given in these studies to size ranges where this assumption is no longer applicable, and the data alone are insufficient to estimate the selectivity curve.

One way to handle this defect may be to introduce $g(k)kl$ for length instead of kl where $g(k)$ is an adjusting factor. The approximate value for $g(k)$ can be obtained from the discrepancies between deduced (as $g(k)=1$) and actual values of the optimum lengths for each mesh size, estimation of which is easier than that of the selectivity curve itself, or deduced and actual values of the intersecting points among each mesh's selectivity curve (intersecting point locates at a body length class in which both catch numbers of the two mesh size nets are equivalent).

According to this idea, amendment is possible graphically. In the first place, selectivity curves for different mesh sizes should be figured out using the curve estimated within the size range at which the assumption holds good. Then, relative catch efficiencies of various meshes for each body length class of fish are plotted on the graph for all size ranges under consideration. In order to make visual identification easier, principal values for a given mesh size should be plotted in such a manner that they fall on the curve previously drawn for that mesh size. If the author's assumption is applicable throughout the whole length range, points plotted for each mesh size must distribute evenly below and above the curves. Amendment is unnecessary at this time. If the points show some inclination to distribute unevenly, either below or above the curves, it should be considered that the assumption no longer holds for that part of the length range. Amendment must be made by using the positions of intersecting points among each mesh, and the plotted points of relative catch efficiencies.

Figures 1, 3, 4, 6, and 9 described later are thus depicted. In Figure 1, for example, four curves are estimated from length values between 41 cm and 61 cm. A definite discrepancy is observed below 40 cm between the curve and the plotted points in both the $2\frac{1}{2}''$ and $3\frac{1}{4}''$ meshes.[1] The curve for $3\frac{1}{4}''$ mesh, therefore, should be adjusted to make a steeper slope in its left limb. This reflects the fact that younger fish are less fat (i.e., smaller girth per given length) than older fish. However, no proper adjustment can be made around the intersection of the curves for $2\frac{1}{2}''$ and $3\frac{1}{4}''$ meshes, unless data are available for a mesh size for which the optimum length is located at that point, because the right limb of the $2\frac{1}{2}''$ mesh curve is most likely shifted towards larger lengths.

Since it is generally believed that the fatness of fish is reflected by the girth at the abdomen rather than at the head, it is more appropriate to consider that changes in fatness usually give more effect to the left limb of the curve than to the right limb. However, in some instances, such as the case of pink salmon described later, the curve for thinner fish is sometimes shifted towards the right as a whole in comparison with that for fatter fish. Therefore, the abovementioned concept is not always correct.

[1] Equivalents of mesh sizes in inches and millimeters are given on page 10 for convenience of readers.

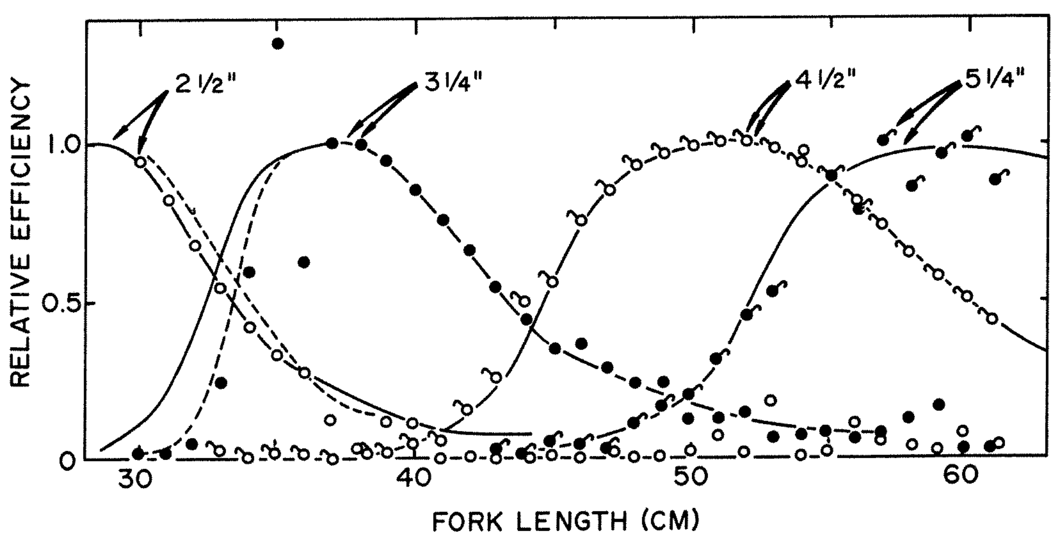

FIGURE 1. Selectivity curves (solid lines) of $2\frac{1}{2}''$, $3\frac{1}{4}''$, $4\frac{1}{2}''$, and $5\frac{1}{4}''$ mesh gillnets for sockeye salmon obtained by Manzer *et al.* (1965). Plotted symbols represent relative catch by mesh size. Adjusted curve (see text) is shown by broken line.

on the basis of catches involving both components.

Mesh selectivity for a given species caught by gillnets of given construction and mesh size is generally represented in terms of a mesh selectivity curve. This curve can be drawn on a graph, with relative catch efficiency on the ordinate and size of fish caught (usually body length) on the abscissa. This relationship, however, generally cannot be estimated directly because of difficulty in obtaining the real length composition of the total population. Even if the real length composition of a fished population were obtained by some independent means, the movement and behaviour of different sized fish in encountering nets could vary, affecting their catchability. Direction of movement of fish may differ according to size of fish. Thus, accuracy in estimating the size composition of the total population from the catch by use of an estimated mesh selectivity curve is questionable.

We can, however, deduce the relative catch efficiency of a given mesh size for different sized fish from the relative catch efficiency of various mesh sizes for fish of a given size, if we make certain assumptions. Minimum assumptions necessary are that relative catch efficiency for fish of optimum size is the same regardless of the mesh size of net, and that mesh selectivity curves of various mesh sizes have either identical distribution patterns or some systematic modification of the distribution pattern. Experiments indicate that the parameters of the various curves are proportionate to mesh size within certain ranges of body length and that the curves for spindle-shaped fish are either of normal distribution or of skewed logarithmic normal. These experimental findings simplify mathematical treatment.

On the assumptions and conditions mentioned above, the mesh selectivity curve can be estimated from catch data according to length and mesh size obtained by gillnets of more than two different mesh sizes used simultaneously and in equal number (or converted to equal number).

Since methods for determining mesh selectivity curves, including the author's, are reviewed and examined by Regier and Robson (1966), these reviews are not repeated in the present paper.[1] Regier and Robson refer to five methods previously described and introduce four more, each slightly different but related. Regier and Robson outline the various methods under three headings, (1) the direct method, (2) indirect methods, and (3) iterative methods. The direct method, used in the rare instance where size frequencies of the population vulnerable to gillnets are either known or reliably estimated independently, is not considered further here. Indirect methods, developed by Holt (1957, 1963), Olsen (1959), McCombie and Fry (1960), and others, assume, *a priori*, a type of curve with some unknown parameters. These parameters are determined by solving equations and giving the relationship between these parameters and observed values, and by fitting observed values. Iterative methods, used by Gulland and Harding (1961) and Ishida (1962, 1964a, 1964b), transpose (on the basis of assumptions mentioned previously) the relative catch efficiency of various mesh sizes for a given fish length into relative catch efficiency of a given mesh size for various fish lengths. A selectivity curve can be drawn freehand to the scatter of points plotted according to length. The iterative method is simpler than the indirect method for estimating this curve because all processes can be done quickly using graph paper and a slide rule. Even where the indirect method is to be applied, the type of curve should be determined first by the iterative method.

A mesh selectivity curve thus obtained, however, is only applicable to the sizes of fish subjected to the fishing operations, and the curve may be modified if extrapolated to other sizes of fish outside the range of catchability. Also, the curve may change according to the type of thread material in the net and to the way the net is hung.

Since many kinds of synthetic fibers have been used for nets in recent years, selectivity cannot be properly discussed without a consideration of materials used (Ueno *et al.*, 1965). When the legal mesh size is larger than the optimum for fishing, fishermen sometimes use a less elastic polyester thread in order to produce the same effect as a smaller mesh. On the other hand, they sometimes used a more elastic thread to catch fish of wider range in length. It is difficult, therefore, to anticipate the future development of net materials. However, this problem is not taken up in the present paper ; only limited information has been published and almost no study has been made on this problem by a public research agency.

MESH SELECTIVITY CURVES FOR SALMON

Curves Obtained and Their Examination

Mesh selectivity curves for salmon have been obtained either by the author's method (Manzer *et al.*, 1965 ; Ishida, 1962 ; 1967) or by Holt's method (Peterson, 1966), for sockeye, chum, and pink salmon. The former method stands on the assumption that the relative catch efficiency of a gillnet with mesh size m for fish of length l is equal to that of mesh size km for length kl (k is a constant factor applicable

[1] The author's method is appended to this paper (see Appendix).

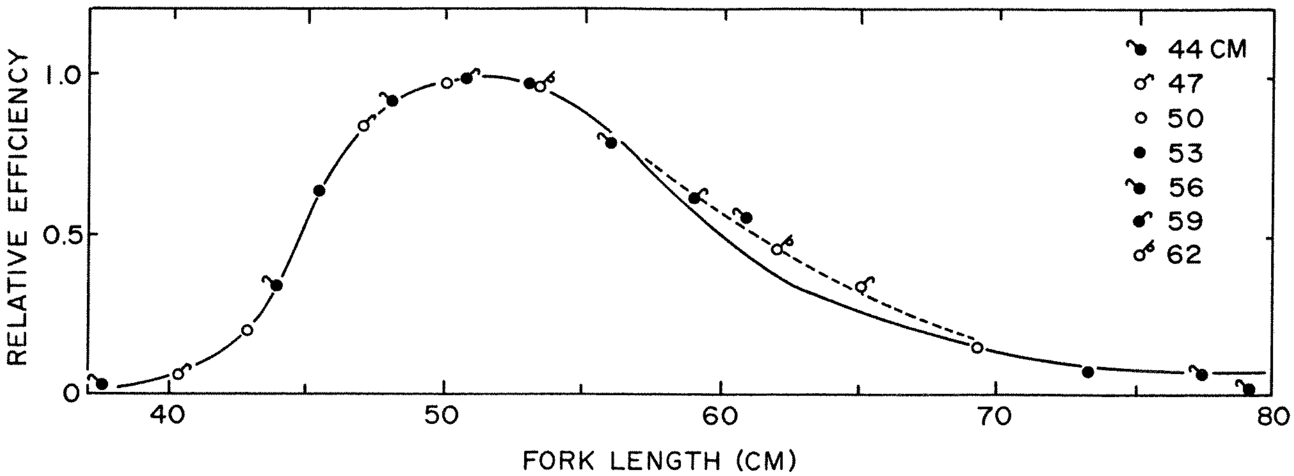

FIGURE 2. Comparison of selectivity curve of 4½″ mesh gillnet for sockeye salmon obtained by Manzer *et al.* (1965) with that obtained by applying the author's method to Peterson's (1966) data. Plotted symbols and broken line are from Peterson's data; solid line is curve of Manzer *et al.* (1965).

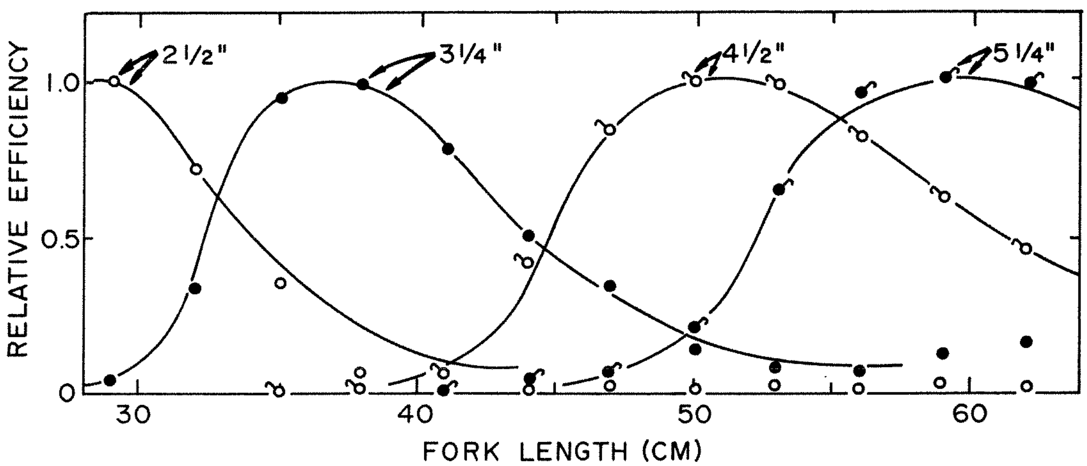

FIGURE 3. Selectivity curves of 2½″, 3¼″, and 5¼″ mesh gillnets for sockeye salmon deduced from curve for 4½″ mesh based on Peterson's data (Figure 2). Plotted symbols represent relative catch by mesh size at each length.

The selectivity curves of normal distribution estimated by Peterson (1966) involve a defect because they were obtained by Holt's method which assumes that selectivity curves of neighbouring mesh sizes have the same standard deviation. The author applied his own method to Peterson's data and recalculated the curves. The recalculated curves for sockeye and chum salmon are in good agreement with those of Manzer *et al.* (1965), because the two calculations are based largely on the same data.

Curves for Sockeye

Figure 1 shows curves for 2½″, 3¼″, 4½″, and 5¼″ mesh sizes obtained by Manzer *et al.* (1965). The portion for fish lengths less than 40 cm has been adjusted by the method mentioned previously.

Figure 2 compares a curve for 4½″ mesh obtained by applying the author's method to Peterson's data for lengths of 44–62 cm with the curve for 4½″ mesh from Figure 1. Little difference is observed between these two curves, because they are based largely on common data.

Curves for 2½″, 3¼″, and 5¼″ mesh sizes were deduced from the curve for 4½″ mesh (based on Peterson's data), and an examination was made to determine if the assumption held for the entire size range (Figure 3). As Figure 3 clearly shows, the assumption holds throughout a wide range of fish lengths extending from 30 cm to 60 cm. In this case, no adjustments in the curves at lengths below 40 cm

TABLE 1. Relative catch efficiency at each length of the 121 mm (4.8″) mesh nylon multifilament gillnet for sockeye, chum, and pink salmon (from Manzer *et al.*, 1965, and Ishida, 1967).

Fork length (cm)	Sockeye[1]	Chum[1]	Pink 1957	Pink 1961
40	—	—	—	5
41	3	—	2	10
42	4	—	3	18
43	6	—	5	26
44	10	—	11	39
45	16	—	25	53
46	23	14	40	74
47	38	23	57	89
48	57	35	73	96
49	73	50	89	99
50	84	67	98	100
51	91	84	100	98
52	95	93	100	96
53	98	98	100	92
54	99	99	100	85
55	100	100	99	77
56	99	99	94	69
57	96	96	82	60
58	92	92	71	53
59	87	87	63	45
60	79	79	55	38
61	72	72	48	32
62	65	65	42	25
63	58	58	—	—
64	51	51	—	—
65	44	44	—	—
66	38	38	—	—
67	34	34	—	—
68	31	31	—	—
69	29	29	—	—
70	25	25	—	—

[1] Original values are not readily readable because the maximum value for relative catch efficiency was set at 115. The figures in this table were converted to a maximum value of 100.

were necessary.

At the present stage of the study, it may be concluded that relative values given by Manzer *et al.* (1965) represent adequately a mesh selectivity curve for nylon multifilament gillnets for sockeye over 40 cm in length in offshore waters (Table 1). The results of applying the author's method to Peterson's data lead to the same conclusion.

It is noted here that unexpectedly high proportions of mature fish are sometimes caught in the smaller mesh gillnets by tangling or snagging at the snout (probably more so towards the end of the spawning migration, at which time considerable changes have taken place in the shape of the salmon's head) (Ishida and Kakitani, unpublished). For example, sockeye

TABLE 2. Numbers of sockeye and chum salmon, by length, caught by five different mesh sizes of gillnet operated simultaneously and in equal number by the research vessel *Wakashio-maru* west of the tip of the Kamchatka Peninsula from July 20 to August 4, 1966 (unpublished material of Ishida and Kakitani).

Fork length (mid-point of length group)	Sockeye Mesh size (mm) 72	93	105	121	157	Chum Mesh size (mm) 72	93	105	121	157
51 cm	6	13	22	8	0	2	11	38	23	0
54 cm	4	15	28	26	3	1	8	31	55	1
57 cm	9	17	19	29	11	1	6	23	53	7
60 cm	18	31	26	53	33	4	4	14	44	34
63 cm	22	23	19	18	42	5	7	9	24	52
66 cm	11	7	6	10	28	3	2	2	8	21

and chum catches off the west coast of Kamchatka from late July to early August in 1966 by gillnets of five different mesh sizes (72, 93, 105, 121, and 157 mm) are shown according to length in Table 2. A tendency is clearly demonstrated for sockeye over 60 cm to be caught more abundantly by the 72 mm or 93 mm mesh than by the intermediate 105 mm mesh. Selectivity curves for the 72 mm and 93 mm mesh sizes tended to show a bimodal length frequency distribution. The 105 mm mesh caught lesser numbers of sockeye over 60 cm probably because fish do not become entangled at the snout so readily in the larger mesh size.

According to the author's direct observation, almost all sockeye salmon found in fine mesh nets were entangled at the snout, and were still alive. Far fewer chum than sockeye salmon were caught in this way, possibly because of morphological differences between the two species and because of differences in their movements and viability after being netted. Chum salmon in more advanced stages of secondary sexual development (hooked snout with well-developed teeth) might be more liable to capture by tangling. This subject will be studied in the future.

CURVES FOR CHUM SALMON

Figure 4 shows selectivity curves for chum salmon obtained by Manzer *et al.* (1965). Since the fatness of chum salmon changes somewhere in the 40–50 cm length range, the adjustment required is larger for chum salmon than for sockeye. However, a conclusive result cannot be expected because of limited mesh sizes used.

Figure 5 compares a curve for $4\frac{1}{2}''$ mesh obtained by applying the author's method to Peterson's data for lengths of 44–62 cm with the curve for $4\frac{1}{2}''$ mesh from Figure 4. As in the case of sockeye, the former curve is located slightly above the latter in the middle part of

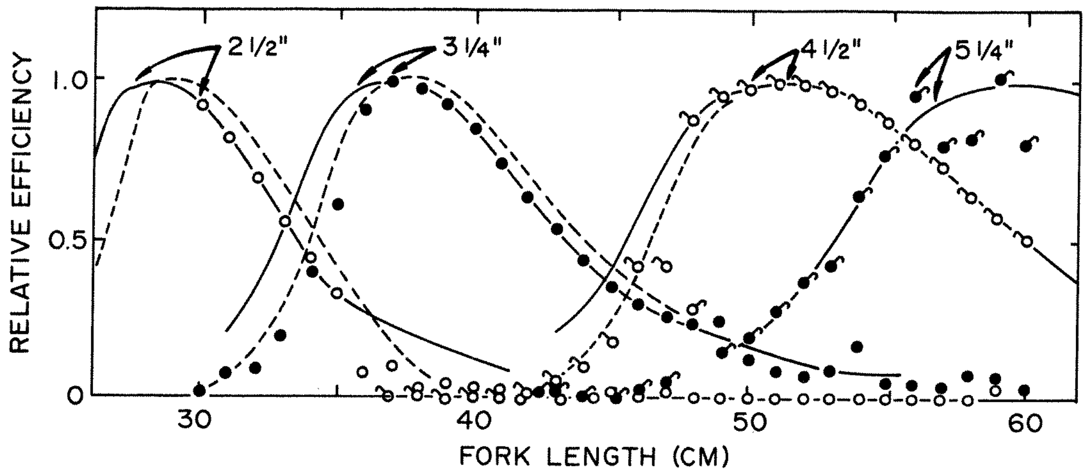

FIGURE 4. Selectivity curves (solid lines) of $2\frac{1}{2}''$, $3\frac{1}{4}''$, $4\frac{1}{2}''$, and $5\frac{1}{4}''$ mesh gillnets for chum salmon obtained by Manzer *et al.* (1965). Plotted symbols represent relative catch by mesh size. Adjusted curve (see text) is shown by broken line.

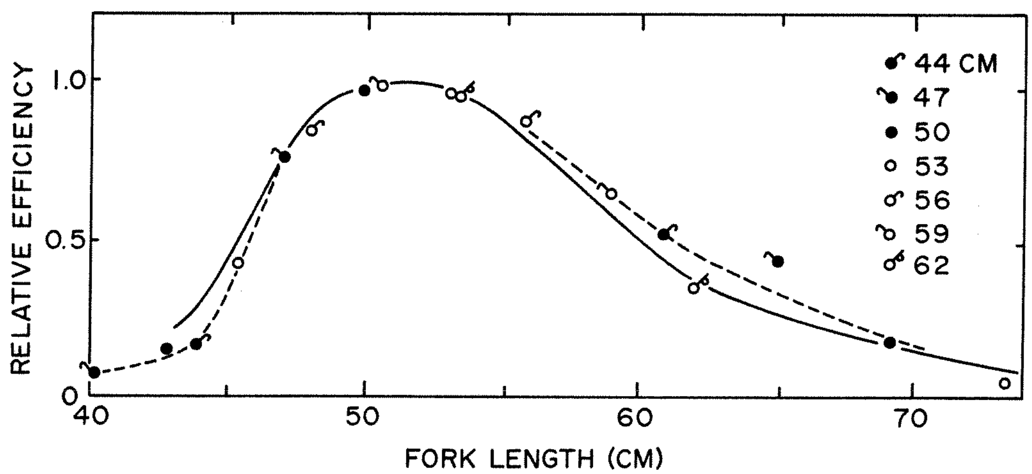

FIGURE 5. Comparison of selectivity curve of $4\frac{1}{2}''$ mesh gillnet for chum salmon obtained by Manzer *et al.* (1965) with that obtained by applying the author's method to Peterson's (1966) data. Plotted symbols and broken line are from Peterson's data; solid line is curve of Manzer *et al.* (1965).

the right limb. For fish of the 30–40 cm length range (Figure 6) the distribution of plotted points should be modified as shown by the broken lines.

Taking the results mentioned above into consideration, the most probable selectivity curve for chum salmon so far obtainable would be that drawn from values given in Table 1. The values for chum salmon are less reliable and less substantiated than those for sockeye or pink salmon. More accurate data must be obtained in the future.

Comparison of Curves for Sockeye and Chum Salmon

Comparison of selectivity curves of the same mesh size for sockeye and chum salmon (Table 1) indicates that the right limb of each curve has good agreement, but that the left limb consists of larger lengths for chum salmon than for sockeye. This difference can be explained by the difference in fatness of the two species. Table 3 gives average weights of sockeye and chum salmon 55 cm in length. Sockeye apparently are heavier than chum at this length. The fatter sockeye are retained in the net, while chum of the same length, thinner than sockeye, may go through the same size mesh. Since sockeye and chum salmon selectivity curves have similar values on the right side of the mode, it is suggested that there is no difference between the two species either in the shape of head and opercle or in the head girth.

Table 1 of Taguchi (1961) suggests the same result.

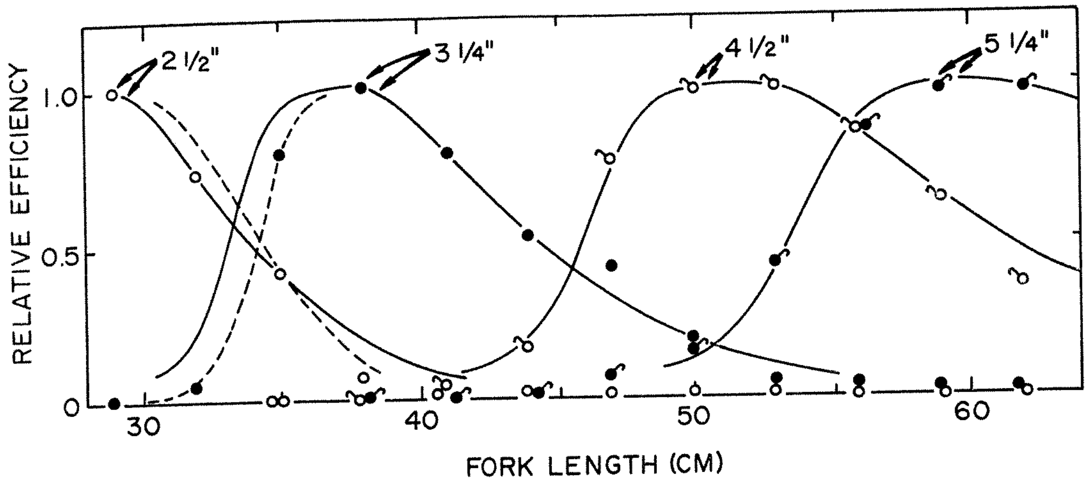

FIGURE 6. Selectivity curves of 2½", 3¼", and 5¼" mesh gillnets for chum salmon deduced from curve of 4½" mesh based on Peterson's data (Figure 5). Plotted symbols represent relative catch by mesh size at each length.

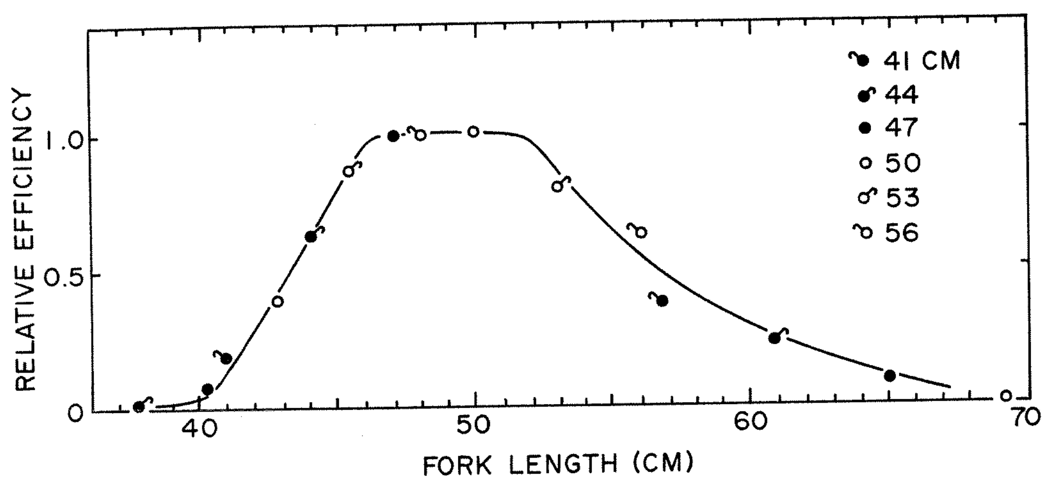

FIGURE 7. Selectivity curve of 115 mm (4½") mesh gillnet for pink salmon obtained by applying the author's method to Peterson's (1966) data. This curve is identical to that of Ishida (1962) and Manzer *et al.* (1965).

TABLE 3. Differences in average weights of sockeye and chum salmon of the same length (55 cm) caught by salmon motherships in 1965. Samples for each month include 122–266 fish.

Month	Sockeye	Chum	Difference
May	2,194 g	1,946 g	248 g
June	2,250 g	1,997 g	253 g
July	2,310 g	2,164 g	146 g

According to Taguchi's table, the average weight of fish gilled at the head is generally larger for sockeye than for chum, while the average weight of fish gilled at the widest part of the abdomen is larger for chum than for sockeye. This can be explained as follows: there is no substantial difference in the length of fish of the two species gilled at the head, and so the chum weigh less because of their smaller girth. In the case of fish gilled at the widest part of the abdomen, chum salmon weigh more than sockeye because of their larger overall size.

CURVES FOR PINK SALMON

The selectivity curve obtained by Manzer *et al.* (1965) is identical to that obtained by the author from Peterson's (1966) data (Figure 7). Data used for estimating the curve of Manzer *et al.* (1965) were obtained by the *Oshoro-maru* of the Hokkaido University during operations from June 9 to July 15, 1957, in waters from off the east coast of Kamchatka to the Aleutian area. In another curve (Ishida, 1967), estimated on the basis of data obtained in fishing

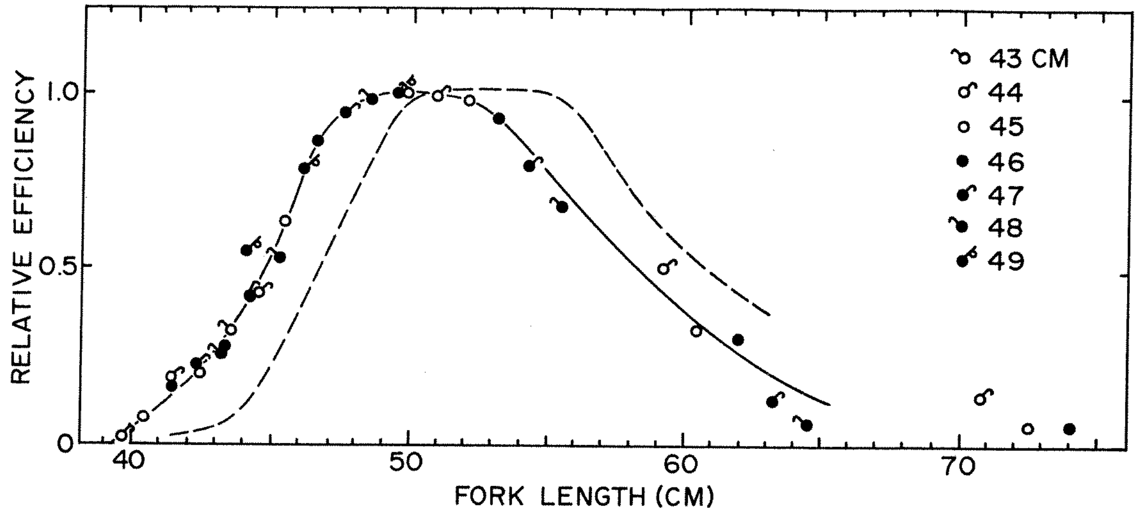

FIGURE 8. Selectivity curves of 121 mm (4.8″) mesh gillnet for pink salmon estimated from results of fishing operations of the *Oshoro-maru* (Hokkaido University) in 1957 (broken line) and 1961 (solid line). From Ishida (1967).

TABLE 4. Average weights by length of pink salmon caught by the research vessel *Oshoro-maru* (Hokkaido University) in 1957 and 1961 (from Ishida, 1967).

Fork length (cm)	1957	1961
41.5	856 g	926 g
42.5	928	1,000
43.5	1,004	1,046
44.5	1,041	1,130
45.5	1,092	1,228
46.5	1,184	1,298
47.5		1,422
48.5		1,518
49.5		1,607
50.5		1,678

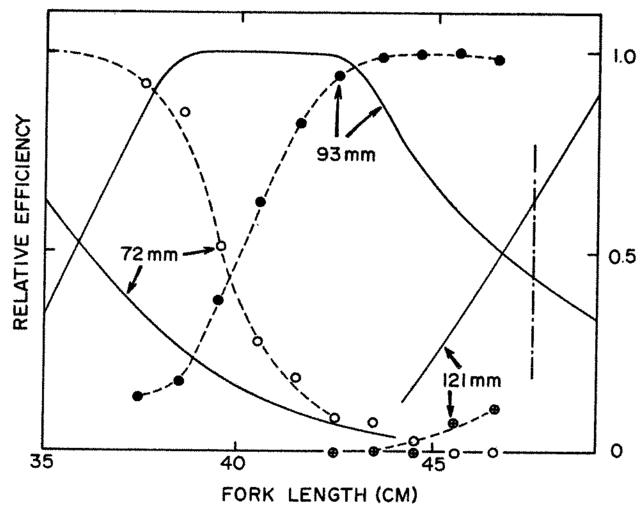

FIGURE 9. Comparison of mesh selectivity curves for pink salmon caught in June-July 1957 (solid line) and April-May 1965 (broken line). Solid curve is from Manzer *et al.* (1965); broken curve (and plotted symbols) are from results of the research vessel *Takuyo-maru* fishing from April 24 to May 22, 1965. The broken vertical line on the right of the drawing shows the position of intersection (47.4 cm) of the 93 mm and 121 mm mesh curves obtained from results of the research vessel *Wakashio-maru* fishing from June 16 to 18, 1965. From Ishida *et al.* (1966).

operations of the *Oshoro-maru* from June 17 to July 18, 1961, in waters off the east coast of Kamchatka, the distribution is shifted towards smaller lengths compared with the curve of Manzer *et al.* (1965). The position of the mode for the 121 mm (4.8″) mesh shifted about 2.5 cm, from 52.5 cm in 1957 to 50.0 cm in 1961 (Figure 8 and Table 1).

This discrepancy was explained by the difference in fatness (or length/weight relationship) among populations fished at different times (Ishida, 1967). Average weights by length are shown in Table 4. Sums of the average weights of fish 41.5 cm to 46.5 cm in length are 6,105 grams in 1957 and 6,628 grams in 1961. Square roots of these values (relative measure of body girth in the first approximation) are in a ratio of 50.4 : 52.5, the reverse of the 52.5 : 50.0 ratio observed in the position of the modes. This relationship suggests some possibility that a selectivity curve for fish of different fatness can be estimated from a known curve for fish of known fatness.

A selectivity curve for pink salmon based on catches made early in the season shows selectivity for larger lengths when compared with a curve based on catches made later in the season. Figure 9 (from Ishida *et al.*,

1966) compares curves (of 72 mm, 93 mm, and 121 mm mesh sizes) based on catches in April-May 1965 with curves based on catches in June-July 1957. The mode of the April-May curve is about 4 cm greater than the mode of the June-July curve. The nets used for the 1965 operations were of nylon monofilament (rather than multifilament), which might partly account for the difference. On the other hand, results from fishing operations off West Kamchatka from June 16 to 18, 1965, show an intersection between the 93 mm and 121 mm curves at 47.4 cm, little different from the 46.7 cm point of intersection observed in the curves based on catches in June-July, 1957 (Figure 9).

Variation of Fatness and Selectivity Curve

The change of fatness by length of fish (i.e., change in weight/length or girth/length relationship) and the effect of average fatness of the fished population on the selectivity curve have been discussed already. It should be noted here that the selectivity curves so far mentioned are determined from fish groups of various fatness. Farran (1936), assuming a selectivity curve in rectangle form as a first approximation, modified both sides of the curve and transformed it into an accumulated normal distribution curve, with reference to the variation in girth due to different fatness. The nature of our selectivity curve is such that it is already modified to that effect. Logically speaking, therefore, if a selectivity curve is obtained from a fish group of invariable fatness, the slope of both sides (particularly of the left side) must be steeper. This kind of curve can be calculated logically by mesh size and length only for selected fish of the same fatness. Unfortunately, no such curve has ever been obtained. As an indirect method, assuming that the left side slope of the curve represents the combined effect of both variation in fatness and of other factors such as different direction of gilled fish and friction coefficient on body surface and that each of these effects shows normal distribution—the slope must follow integral normal distribution—these two effects can be separated easily. This subject will be studied in future.

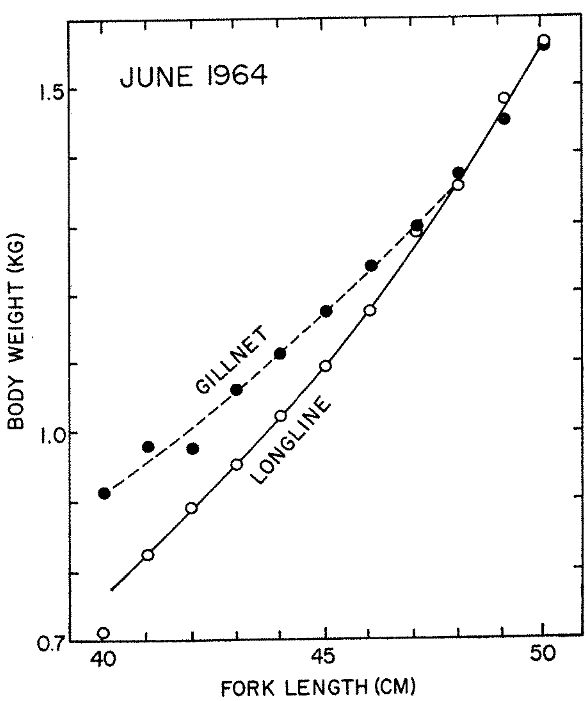

Figure 10. Comparison of average weights by length of pink salmon caught by longlines and 115 mm mesh gillnets.

The problem of variation in fatness also is important in the analysis of catch by gillnet since the selectivity is biased not only by length of fish but also by weight.

Figure 10 shows the length/weight relationship in catches made in the Pacific Ocean off the Kuril Islands in June 1964 by Japanese research vessels using longlines and 115 mm mesh gillnets (Ishida, unpublished). Comparison of these two curves indicates that the smaller the size of fish, the larger the difference between the two gears, and the larger the size of fish, the smaller the difference; no difference exists at 48 cm. The length of 48 cm is located approximately at the highest point of the left limb of the 115 mm mesh selectivity curve (Figure 7). The length of 40–41 cm corresponds with the lower end of the left limb of that curve where only fatter fish of that length are selectively caught.

Application of Selectivity Curve

First, the selectivity curve can be used for adjusting length composition, catch per unit of effort, and sex ratio of the catch of gillnets, which are more or less biased by selectivity of gear (Ishida, 1962; 1963a; 1963b). In order to make these adjustments possible at later stages of data processing, it is required, in measuring the catch by gillnet, to keep a record of the amount of fishing effort expended and of the size composition of catch for each mesh size.

Secondly, after selectivity curves for the various mesh sizes have been obtained, a gillnet with minimum selectivity for research purposes can be made by using various mesh sizes (Ishida *et al.*, 1966). For offshore salmon research use, Ishida *et al.* (1966) recommended five meshes (55, 72, 93, 121, and 157 mm; a ratio of 1 : 1.3 geometrical progression).

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MILLIMETER-INCH MESH SIZE EQUIVALENTS

Inches	*Mm*	*Mm*	*Inches*
$2\frac{1}{2}$	63.5	72	2.8
$3\frac{1}{4}$	82.6	93	3.7
$4\frac{1}{2}$	114.3	105	4.1
$5\frac{1}{4}$	133.4	121	4.8
		157	6.2

APPENDIX

Ishida's Method For Estimating Gillnet Selectivity Curve (Abstracted From Ishida, 1962)

Let RE $(m:l)$ represent the relative catch efficiency resulting from mesh selectivity when gillnets with mesh size m catch fish of length l.

In addition to data on numbers of fish caught by mesh size and by length required for estimating a mesh selectivity curve, the following assumption should apply: namely, that the following relationship should be substantiated within a certain length range:

$$\mathrm{RE}\ (m:l) = \mathrm{RE}\ (km:kl) \tag{1}$$

where k is a constant factor.

The catches of salmon of size class p by a series of mesh sizes $(a, \ldots, i, \ldots)$ are represented by $C_{ap}, \ldots, C_{ip}, \ldots$ These catches are proportional to RE $(a:p), \ldots,$ RE $(i:p), \ldots$ Therefore, under the assumption mentioned above, the following relationship must apply:

$$\begin{array}{ccccc} r_p \cdot \mathrm{RE}\ (a:p) & = & C_{ap} & = & r_p \cdot \mathrm{RE}\ (j:jp/a) \\ \vdots & & \vdots & & \vdots \\ r_p \cdot \mathrm{RE}\ (i:p) & = & C_{ip} & = & r_p \cdot \mathrm{RE}\ (j:jp/i) \\ \vdots & & \vdots & & \vdots \end{array} \tag{2}$$

where r_p is an unknown constant factor relative to the density of size class p fish in the fished population. However, it should be noted that this constant factor involves some variation in liability to catch resulting from different physiological and ecological conditions occurring among different sizes of fish.

So far as the same sizes of fish are under consideration, r_p can be replaced simply by unity, so that the relative efficiency of mesh size j for some lengths can be obtained. Values thus obtained and plotted on a graph form a selectivity curve.

From the above logic, a selectivity curve can be obtained independently from relative catches of adjacent mesh sizes for each size of fish. The number of points plotted are the same as the number of mesh sizes used. The accuracy of a curve is questionable if plotted from only a few points. A more accurate single curve can be estimated by combining the values for various size classes.

An important problem involved in plotting these points on a graph (length of fish on the abscissa and relative catch efficiency on the ordinate) is how to adjust the scale on the ordinate so as to form a combined selectivity curve. The author did this by eye on a trial-and-error basis. The values on the ordinate for a given length (represented by the same symbol for a given length in the figures) show the ratios of catches by two mesh sizes for that length of fish. To form a common curve adjustments are made by moving the positions of points up and down on the graph until they are superimposed.