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Lee Trent

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U. S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL MARINE FISHERIES SERVICE
PANAMA CITY LABORATORY
3500 DELWOOD BEACH ROAD
PANAMA CITY, FLORIDA 32407-7499

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John V. Byrne, Administrator
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William G. Gordon, Assistant Administrator for Fisheries

ABSTRACT

Information from experimental settings of gill nets reported in the literature and data taken from commercial fishermen in Florida from 1973 to 1981 were used to analyze gill net selection on Spanish mackerel, *Scomberomorus maculatus*, king mackerel, *S. cavalla*, and bluefish, *Pomatomus saltatrix* from Florida and Serra Spanish mackerel, *S. braziliensis*, from Brazil.

The information on Spanish mackerel and bluefish obtained from the commercial gill-net fisheries did not further our understanding of selectivity over that produced by experimental nettings except in defining girth-length relations. The commercial fisheries data appeared to reflect mostly the sizes of fish that were abundant at the time of capture rather than the effects of selectivity. We did use commercial fisheries data for describing selectivity of king mackerel, however, because we had other estimates of the size compositions of the populations to adjust the gill-net distributions for unequal numbers of fish in the length intervals.

Selectivity was evaluated under the assumptions that: (1) the selectivity curve would take the form of a normal frequency distribution; (2) the efficiencies of two nets with different mesh sizes would be similar for fish of their respective lengths; and (3) the standard deviations of the distributions for two different mesh sizes would be equal. Under these assumptions the computed mean selection lengths in relation to mesh size and species were:

Spanish mackerel - 6.3 cm stretched mesh, 30.8 cm fork length; 7.0 cm SM, 33.9 cm FL; 7.6 cm SM, 37.0 cm FL; 8.2 cm SM, 40.1 cm FL; 8.9 cm SM, 43.2 cm FL; and 9.5 cm SM, 46.3 cm FL.

Bluefish - 6.3 cm SM, 28.5 cm FL; 7.0 cm SM, 31.4 cm FL; 7.6 cm SM, 34.2 cm FL; 8.2 cm SM, 37.1 cm FL; and 8.9 cm SM, 40.0 cm FL.

King mackerel - 12.1 cm SM, 92.1 cm FL.

Serra Spanish mackerel - 6.0 cm SM, 42.1 cm FL; 8.0 cm SM, 43.6 cm FL; and 10 cm SM, 55.2 cm FL.

INTRODUCTION

Rarely will a particular type of fishing gear capture all sizes of a species of fish with equal probability. Gill nets are selective in that, for a particular species and mesh size, fish are retained with high probability at certain lengths and with decreasing probability for larger and smaller individuals. Most streamlined fishes--such as the herrings--without projecting spines, teeth, or opercular bones are caught in gill nets by becoming tightly wedged or enmeshed in the webbing. To describe selectivity for these streamlined fishes, a smooth unimodal curve with capture probabilities descending to zero is suggested by several workers (Regier and Robson 1966, Hamley and Regier 1973).

An understanding of the selection properties of gill nets is necessary to evaluate catch statistics, alter catch per unit effort, and regulate the sizes of captured fish. Most methods of estimating recruitment, growth, sex ratio, and survival of a fish species require samples that are representative of the population in respect to size of individuals. Only if size selectivity of the fishing gear is known can the catch statistics be adjusted and used to provide correct estimates of the parameters of interest (Cucin and Regier 1966). Alternatively, an understanding of how selectivity depends on the characteristics of the gear may be used to design a series of gear to yield samples of known characteristics over a specified size range (Regier and Robson 1966). A knowledge of the size selective properties of the gear permits recommendations of mesh sizes to maximize (increase capture efficiency) or minimize (protect from harvest) the catch on certain sizes and species.

Information on the selection properties of gill nets on members of the genus Scomberomorus is limited. Fonteles-Filho and Alcantara-Filho (1977) and Trent and Pristas (1977) reported selectivity information on a species that, at the time, was named Spanish mackerel (Scomberomorus maculatus). Later, Collette, Russo, and Zavala-Camin (1978) studied Atlantic species of Scomberomorus. The species reported by Fonteles-Filho and Alcantara-Filho was defined as a new species, S. braziliensis, a species that grows much larger than S. maculatus. Throughout this paper Spanish mackerel will refer to S. maculatus and Serra Spanish mackerel to S. braziliensis.

To evaluate selectivity on S. braziliensis from northeastern Brazil, Fonteles-Filho and Alcantara-Filho (1977) used empirical data from three mesh sizes. Mean fork lengths (FL) of Serra Spanish mackerel, by stretched mesh size, were: 6 cm (36.2 cm FL), 8 cm (42.6 cm FL), 10 cm (48.1 cm FL). The selectivity curves, using the method by McCombie and Fry (1960), were bimodal.

To evaluate selectivity on S. maculatus and bluefish (Pomatomus saltatrix) much of the information provided by Trent and Pristas (1977) was re-analyzed in this paper. This information was then compared with the data from Brazil and also used to form hypotheses concerning selectivity of gill nets on king mackerel, S. cavalla.

The objectives of this study were to show (1) relations between mesh sizes and sizes of netted Spanish mackerel, bluefish, and king mackerel and (2) girth-length relations for each species.

STUDY AREA, GEAR, AND METHODS

Samples were obtained from commercial fishermen in south and northwest Florida, from recreational fishermen on the west coast of Florida, and experimentally in northwest Florida. The mesh sizes were measured and recorded for the samples taken from commercial fishermen. Locations of the study area and net positions for the experimental netting are shown in Figure 1. King mackerel were not caught in the experimental nets. The numbers of fish and mesh sizes used to evaluate or determine selectivity relations are shown in Table 1.

Gill nets are the dominant gear in the commercial mackerel fisheries in south Florida. The methods used to fish for Spanish mackerel were provided in detail by Trent and Anthony (1979) and for king mackerel by Manooch (1979). Bluefish are caught with the same gear and essentially the same methods as those used to catch Spanish mackerel. Mesh sizes of gill nets most frequently used to capture various species of fish in the commercial gill-net fishery in Florida were reported by Siebenaler (1955). Stretched-mesh sizes used to capture each species generally ranged as follows: Spanish mackerel and bluefish, 8.2 to 10.2 cm; king mackerel, 12.1 to 13.0 cm.

Experimental Gill Nets

Eleven experimental gill nets (Figure 1), each of a different mesh size, were fished for 126 days from 4 April to 29 December 1973 (Trent and Pristas 1977). Nets were anchored about 50 m apart parallel to each other, perpendicular to shore, and in water depths of 2.2 to 2.6 m (mean low tide). Nets were randomized among net locations each time the nets were set. Damage to each net was maintained below 10% of the total surface area of the net. Increments of mesh sizes in the series of fished nets were small, so that widely overlapping ranges of fish lengths would result. Stretched-mesh sizes ranged from 6.35 cm (2.5 inches) to 12.70 cm (5.0 inches) in 0.63 cm (0.25 inch) increments. The nets were 33.3 m long and 3.3 m deep. They were made of #208 clear monofilament (0.33 mm diameter, filament break strength about 26.4 kg) nylon webbing. The webbing was hung to the float and leadlines on the half basis (two lengths of stretched webbing to one length of float or leadline, i.e., a hanging coefficient of 0.5).

The total numbers of each netted species, including the damaged specimens, were counted. Fork lengths (tip of snout to fork of tail) of the undamaged specimens were measured to the nearest 0.5 cm.

Length-frequency distributions of the catch by species and mesh size, based on the number of fish that were measured, were adjusted to represent the number of fish that were caught (those measured plus those damaged), so that the number making up each distribution represented catch per unit effort for each net. For selectivity analyses, lengths were grouped into 2.5-cm intervals for bluefish and Spanish mackerel and 5-cm intervals for king mackerel.

Commercial Gill Nets

Samples were obtained from commercial gill-net fishermen during the following periods: for Spanish mackerel, 1972-73 and 1979-81; for king mackerel, 1979-80; for bluefish, 1972-73 and 1979-80. Fork lengths and girths were measured to the nearest millimeter, or 0.1 inch and converted to millimeters. Girth measurements were taken just anterior to the origin of the second dorsal fin.

Recreational and Commercial Hook and Line

King mackerel were caught by commercial and recreational hook-and-line fishermen using methods described by Manooch (1979). King mackerel data were obtained from commercial fishermen during the winter of 1979-80 and from recreational fishermen during the spring of 1980.

MODELS FOR DETERMINING SELECTIVITY

A method proposed by Holt (1963) was used to evaluate selectivity on Spanish mackerel and bluefish caught in the experimental nets. Holt assumed that: (1) the selectivity curve would take the form of a normal frequency distribution; (2) the efficiencies of two nets with different mesh sizes would be similar for fish of their respective mean lengths; and (3) the standard deviations of the distributions for two different mesh sizes would be equal. The equations for evaluating the above assumptions and for describing selectivity have been given by Holt (1963), Regier and Robson (1966), and Hamley (1975).

If Holt's three assumptions are analyzed and deemed acceptable, points of the selectivity curve for mesh size m_i can be computed by

$$s_{ij} = \exp\left[-\frac{1}{2s_i^2}(l_j - \bar{l}_i)^2\right]$$

where l_j = length of fish in length stratum j

$\bar{l}_i$ = mean selection length

s_i = standard deviation of the selectivity curve

n_{ij} = number of fish of length l_j caught in net m_i.

The n_{ij}/s_{ij} can be used to estimate abundance of fish for each l_j and, therefore, the length-frequency distribution in the fished population can be estimated from the length-frequency distribution obtained from fishing a particular mesh size on the population.

Selectivity on king mackerel was evaluated by a method presented by Holt (1957) and used by Trent and Hassler (1968). With this method length-frequency distributions of catches of fish in gill nets are adjusted so that unbiased estimates of selection characters can be made if accurate estimates of the length-frequency distribution of the population can be obtained. We used king mackerel caught by commercial hook and line and by recreational hook and line to estimate the length-frequency distribution of the population and to adjust the length-frequency distribution obtained with gill nets. Sufficient numbers of netted fish were available only for the 12.1-cm stretched-mesh nets (Table 1).

Information derived from a selectivity study has various uses depending upon the validity of the mathematical model used to describe selectivity and upon the required accuracy and precision. The model can be useful for some purposes even if all the assumptions are not met or even if the model is not the most accurate and precise one for describing the empirical data. We applied a single mathematical model and either accepted or rejected the model in relation to each assumption. By accepting the model we did not infer that it was the most accurate or precise model and conversely, by rejecting the model we did not infer that it was not useful; it often provided an approximation that was sufficiently close and accurate to the data.

MEAN LENGTHS AND LENGTH-FREQUENCY DISTRIBUTIONS BY MESH SIZE

The assumption that mean lengths of fish that are caught in gill nets increase with an increase in mesh size was strongly supported by the experimental data but not strongly supported by the data obtained from the commercial fisheries (Figure 2). For the experimental data an increase in mean length with an increase in mesh size held throughout the mesh-size range (where numbers of fish used were $\geq$10; Table 1) for S. maculatus from Florida and S. braziliensis from Brazil and for most of the mesh-size range for bluefish from Florida. The primary reason for low catches in some experimental mesh sizes and for length not increasing progressively with increasing mesh size was that the length ranges in the fished populations were not great enough to provide the sizes of fish that many of the mesh sizes would efficiently capture. We caught only 13 Spanish mackerel and 15 bluefish in combined mesh sizes of 12.1 and 12.7 cm; Fonteles-Filho and Alcantara-Filho (1977) caught only 2 Serra Spanish mackerel in their 12 and 14 cm stretched-mesh nets.

Apparently the experimental nets were much less limited in respect to fishing over a wide range of lengths of fish in the population when compared to the commercial nets. This is logical in that the commercial fisheries almost always catch most of their fish from the most abundant age classes regardless of what mesh size (within a narrow range) their net happens to be. The distributions generated from the commercial data probably represent mostly the chance combinations of available fish sizes and used mesh sizes.

Mean lengths were greater for the Serra Spanish mackerel than Spanish mackerel at comparative mesh sizes in the experimental gear; the distributions of the lengths of the fish caught were distinctly bimodal in 4 of 6 mesh sizes (6.3, 7.0, 8.2, and 8.9 cm) from Florida (Figure 3) and 1 of 3 mesh sizes from Brazil (Figure 4). Mean lengths did not increase with an increase in mesh size in the commercial data and the length-frequency distributions (Figure 5) were unimodal for most mesh sizes.

For bluefish, mean lengths increased in a linear fashion, more or less, for mesh sizes from 6.3 to 10.2 cm for the experimental data (Figure 2). Length frequency distributions were mostly unimodal with positive skews in the smaller mesh sizes and negative skews in the larger mesh sizes (Figure 6). Mean lengths generally increased with an increase in mesh size for the commercial data but with high variability (Figures 2 and 7).

Data from experimental nets were not obtained for king mackerel and only limited amounts of data were obtained from commercial nets except for nets with a mesh size of 4.75 cm (Table 1, Figures 2, 8). King mackerel data were considered insufficient to evaluate mean-length mesh size relations but we assumed that the pattern would be similar to that for Spanish mackerel.

GIRTH-LENGTH RELATIONS

Relations between girth and length are often used to define gill-net selectivity. Girth-length relations of fish are usually linear (Holt 1957, McCombie and Fry 1960). Fonteles-Filho and Alcantara-Filho (1977) computed and used girth-length relations for S. braziliensis in their selectivity study (Figure 9), and we computed similar relations for all three species in our study (Table 2 and Figure 9). Serra Spanish mackerel were slightly longer per unit girth than Spanish mackerel from Florida and, over the range of comparison, the king mackerel were much longer per unit girth than were the Spanish mackerels.

ESTIMATING SELECTIVITY

Based on the data requirements of Holt's method, only Spanish mackerel and bluefish were selected to evaluate one or more of the three assumptions--normality of selection curve, linearity of mean length-mesh size relation, and constancy of standard deviation between mesh sizes. For these species, length-frequency distributions for those mesh sizes where $n_i > 50$ are shown in Table 3. These distributions are provided as the basis for our evaluation of selectivity and for applying other mathematical models to the data if other investigators so desire.

Normality of Selection Curves

Natural logarithms of the ratios ($\ln R_{i+1,i,j,}$) of numbers of fish of length l_j caught in meshes m_{i+1} and m_i were plotted against lengths of fishes to test normality of the selection curves (Figure 10). Least squares regression equations were computed, and the intercepts (a) and slopes (b) of these equations are shown in Table 4.

The normal curve provided acceptable approximations to the data for bluefish but not for Spanish mackerel. Refinements in data collection procedures, indicating how each fish was caught, are needed to evaluate more accurately the model for each species. Bluefish are frequently enmeshed or entangled by their teeth, maxillaries, preopercles, and opercles. The girth of a Spanish mackerel increases gradually from its snout to the anterior insertion of its second dorsal fin; most individuals are wedged in the mesh at any point between just behind the opercle and point of maximum girth. The point of retention, therefore, is dependent upon the mesh size within a small range of mesh sizes. Also, many are entangled by the teeth, maxillaries, and occasionally by the tail.

Attempts to suggest models which might better define selectivity for bluefish and Spanish mackerel were not made in this study, because the position at which each fish was wedged in the net and, for those fish not wedged in the net, the position in which each fish was entangled was not recorded. Holt (1963) suggested that, for species that are caught at two or more distinct positions along their body, selectivity could be defined by regarding the selection curve as the algebraic sum of two or more normal selection curves, or by fitting an empirical curve such as the cubic exponential. Hamley and Regier (1973) found that the selectivity curve for walleyes (Stizostedian v. vitreum) was bimodal; they resolved this curve into two unimodal components representing fish that were caught by wedging and by entangling. The gill-net selectivity curves obtained by Fonteles-Filho and Alcantara-Filho (1977) were bimodal but were treated as if they were unimodal in arriving at modal lengths.

Mean-length-Mesh-size Relation

The second assumption of Holt's method is that mean length of captured fish is proportional to mesh size. To test this assumption, -2a/b was plotted against the sum of mesh sizes ($m_{i+1} + m_i$) (Figure 11) for each mesh-size pair (data from Table 4). Mean selection length (a/b or $\bar{l}_i$) in relation to mesh size can also be determined from Figure 11 using the bottom and right-hand scales. Data for Spanish mackerel were plotted even though the assumption of normality (previous section) for this species was rejected. The straight lines in Figure 11 were fitted through the origin by the least squares method and the slopes (k) of these lines are given in Table 4. With k determined, the mean selection length ($\bar{l}_i$) for any mesh size is determined by $\bar{l}_i = m_i k$.

More data are required to determine the degree of fit for bluefish and Spanish mackerel. Although the degree of fit cannot be evaluated, information presented in Figure 11 and Table 4 can be used to provide rough estimates of mean selection length in relation to mesh size. Much of the deviation about the regression for bluefish probably resulted from fitting the line through the origin (Figure 11). Apparently the mean-length-mesh-size relation is not linear throughout a range of mesh sizes between 0 and 8.6 cm for bluefish. A more reasonable approximation of the mean-length-mesh-size relation for bluefish might result by fitting a regular linear regression equation ($Y = a + bX$ rather than $Y = bX$) to the points in Figure 11. Variability about regression was great for Spanish mackerel but this information was the best available to estimate the mean-length-mesh-size relation.

Standard-deviation-Mesh-size Relation

The third assumption of Holt's method is that the standard deviations of length between mesh sizes estimate a common standard deviation. Standard deviations for the selectivity curves are shown in Table 4 by species and mesh-size pair. Standard deviations tended to increase with an increase in mesh size for Spanish mackerel and decrease with an increase in mesh size for bluefish.

Standard deviations for bluefish and Spanish mackerel were large, because individuals of these species were frequently caught entangled in the meshes or caught at different girths along the body. Lengths of fishes that are caught usually wedged in the meshes at one gilling point usually vary much less than do those of bluefish and Spanish mackerel.

Direct Estimation for King Mackerel

Length-frequency data obtained from the commercial and from the recreational hook-and-line fisheries for king mackerel were used to adjust the length-frequency distribution obtained from 12.1-cm stretched-mesh gill nets (Table 5). That one or both types of data were not representative of the fished population was apparent (Figure 12); the commercial hook-and-line data yielded a bimodal curve, whereas the recreational hook-and-line data yielded a unimodal curve. Although the adjusted distributions varied greatly, the mean lengths of the two distributions were similar. We assumed, therefore, that the adjusted lengths of between 900 and 950 better represents the modal or mean selection length for king mackerel caught in a 12.1-cm stretched-mesh net than does the unadjusted estimates of $\bar{x} = 81.1$ and modal length = 825 shown in Figure 8. The probable reason that commercial fishermen appear to be using a mesh size larger than one most efficient for capturing the dominant size groups of king mackerel is that a minimum mesh size of 12.1 cm is in force in the State of Florida. Data from other mesh sizes are required to evaluate selectivity for king mackerel.

CONCLUSIONS AND DISCUSSION

The information on Spanish mackerel and bluefish obtained from the commercial gill-net fisheries did not further our understanding of selectivity over that produced by the experimental netting by Trent and Pristas (1977) except in defining girth-length relations. The commercial fisheries data appeared to reflect mostly the sizes of fish that were abundant at the time of capture rather than the effects of selectivity (see Hamley 1975 for further discussion). We did not, as with king mackerel, have other estimates of size composition of the populations to adjust the gill-net distributions for unequal numbers of fish in the length intervals.

Estimates of selectivity of gill nets varied considerably between the experimental studies done on Spanish mackerel and the Serra Spanish mackerel. Mean fork lengths of unadjusted distributions by area and mesh size were: Spanish mackerel - 6.3 cm (33.4 cm FL), 7.0 cm (34.5 cm FL), 7.6 cm (36.0 cm FL), 8.3 cm (38.1 cm FL), 8.9 cm (39.7 cm FL), and 9.5 cm (42.2 cm FL); Serra Spanish mackerel - 6.0 cm (36.2 cm FL), 8.0 cm (42.6 cm FL), and 10.0 cm (48.1 cm FL). Mean lengths of Serra Spanish mackerel caught in gill nets, therefore, were all larger than Spanish mackerel when adjusted for mesh size. Further, values of K (K = bar measure of mesh in centimeters/mean length of fish caught--McCombie and Fry 1960) were smaller for mackerel from Brazil (K = 0.08) than for those from Florida (K = 0.10). These K values clearly indicated that longer Serra Spanish mackerel, on the average, were caught in a particular mesh size than were Spanish mackerel.

Curves were fitted to points of the selectivity curves derived from the data from Florida and Brazil (Figure 13). Note that smaller fish, on the average, comprised the Florida data and that the curve is more spread out (higher variance) than that derived from the Brazilian data. Part of the size differences are possibly explained by the fish from Brazil being slightly longer per unit girth than the fish from Florida (Figure 9).

Data from both studies on selectivity of mackerel indicated that the selectivity curve, when accurately defined, will probably be multimodal. Sufficient information is still not available, however, to define the selectivity curve to our satisfaction. Trent and Pristas (1977) did not have the necessary information to separate the data in respect to where the fish were gilled. Fonteles-Filho and Alcantara-Filho (1977) recorded the gilling points by body zone but did not record the fish that were caught by the teeth or tail. Further, both studies were weak in terms of the numbers of fish caught in the experimental nets.

The use of Holt's (1963) normal probability model appeared adequate in defining selectivity for bluefish. Equations were provided for estimating mean selection length by mesh size, and methods were suggested for possibly improving the estimates. The selectivity curve for a 8.2-cm stretched-mesh net is shown in Figure 13.

For king mackerel a direct method was used to determine an adjusted length-frequency distribution for a single mesh size. For this adjusted distribution a mean selection length of 92.1 cm and standard deviation of 8.55 were computed. These values were then used to compute the selectivity curve shown in Figure 13.

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Table 1. Number of fish caught (n_i), number measured (nm_i), mean length in centimeters ($\overline{Sl}_i$), and standard deviation of length (Ss_i) by type of fishing, species, and mesh size.

Type of fishing	Species	Statistic	6.3 (2.5)	7.0 (2.75)	7.6 (3.0)	8.2 (3.25)	8.9 (3.50)	9.5 (3.75)	10.2 (4.0)	10.8 (4.25)	11.4 (4.50)	12.1 (4.75)	12.7 (5.0)
			Mesh size in centimeters and (inches)										
Experimental	Spanish mackerel	n_i	146	109	145	133	101	81	41	27	17	8	5
		nm_i	126	91	130	108	81	76	38	26	15	5	5
		Sl_i	33.4	34.5	36.0	38.1	39.7	42.2	44.5	45.7	47.4	44.6	49.1
		Ss_i	4.9	4.7	4.8	4.9	5.0	4.9	4.2	4.3	7.9	9.1	7.4
	Bluefish	n_i	148	247	287	164	69	95	46	25	8	11	4
		nm_i	138	236	279	148	67	91	46	22	7	11	4
		Sl_i	30.1	31.9	33.4	36.3	38.7	39.1	41.4	38.9	40.6	35.6	31.0
		Ss_i	3.8	3.8	3.5	3.9	3.4	4.0	3.7	7.1	5.9	11.0	4.4
Commercial	Spanish mackerel	nm_i	0	0	5,905	1,487	163	518	63	120	24	150	0
		Sl_i	-	-	40.4	40.9	52.1	50.5	46.6	39.6	50.8	51.4	-
		Ss_i	-	-	5.1	5.7	6.3	7.2	6.0	4.7	7.3	5.2	-
	Bluefish	nm_i	200	0	0	182	189	461	126	72	29	0	0
		Sl_i	33.3	-	-	34.4	33.4	41.3	38.7	42.4	37.8	-	-
		Ss_i	1.8	-	-	3.9	1.9	3.2	6.0	5.2	6.7	-	-
	King mackerel	nm_i	0	0	0	17	131	1	0	30	30	1,618	0
		Sl_i	-	-	-	498.5	414.7	575	-	922	80.8	81.1	-
		Ss_i	-	-	-	118.7	51.8	-	-	69.4	54.7	101.6	-

Table 2. Coefficients of least squares regression equations of length on girth, error estimates, and correlation coefficients by area and species.

Area	Species	No. of fish	Length intercept (a)	Slope (b)	Standard error of estimate ($s_{y.x}$)	Correlation coefficient (r)
Florida	Spanish mackerel	1,054	-1.2	0.21	2.9	.96
Brazil	Serra Spanish mackerel	269	-0.4	0.25	-	.97
Florida	Bluefish	936	11.9	0.12	2.3	.87
Florida	King mackerel	1,200	34.0	0.15	5.6	.80

Table 3. Length-frequency distribution by mesh size for bluefish and Spanish mackerel.

Length midpoint (cm)	Stretched mesh size in centimeters and (inches)					
	6.3 (2.5)	7.0 (2.75)	7.6 (3.0)	8.2 (3.25)	8.9 (3.5)	9.5 (3.75)
	n_{ij}					
			Bluefish			
24.0	12.8	1.0				
26.5	23.5	24.1	3.0			1.0
29.0	51.5	75.4	68.0	15.4	1.0	3.0
31.5	31.0	61.7	53.4	15.4	3.0	4.0
34.0	10.8	36.6	78.3	26.6	7.2	4.1
36.5	10.7	30.2	52.4	45.5	10.3	13.8
39.0	6.5	6.2	21.6	41.0	24.8	32.8
41.5	1.1	10.4	9.0	12.1	17.5	21.1
44.0		1.0	1.0	6.6	4.1	11.6
46.5				1.1	1.0	4.0
			Spanish mackerel			
26.5	4.6	3.6			1.2	
29.0	42.9	21.6	12.2	2.4		
31.5	37.1	21.6	22.3	13.6	2.4	1.1
34.0	12.7	16.8	39.0	21.0	15.0	2.2
36.5	20.7	13.2	30.2	38.2	18.9	7.5
39.0	13.8	20.4	16.6	14.8	25.2	21.4
41.5	7.0	7.2	12.2	22.2	11.2	17.1
44.0	2.4	3.6	2.2	13.6	13.8	13.9
46.5	3.6	1.2	6.6	3.6	7.5	9.7
49.0	1.2		2.2	1.2	2.4	4.3
51.5					2.4	1.1
54.0			1.1	1.2	1.2	1.1
56.5						1.1
59.0				1.2		1.1

Table 4. Coefficients of, and estimates from, least-squares-regression equations of $\ln R_{i+1,i,j}$ on length by species and mesh-size pair, and k values by species.

Species	Stretched-mesh size (cm) (m_i)	a	b	$s_{y.x}$	Calculated mean selection length ($\bar{l}_i$ in cm)	Standard deviation of selection curve (s_i)
Spanish mackerel	6.3				30.84	
	7.0/6.3	-3.25	0.09	0.404		5.54
	7.0				33.92	
	7.6/7.0	-1.89	0.06	0.673		7.60
	7.6				37.00	
	8.2/7.6	-4.01	0.11	0.316		5.45
	8.2				40.09	
	8.9/8.2	-1.36	0.03	0.586		9.71
	8.9				43.17	
	9.5/8.9	-5.61	0.13	0.436		4.96
	9.5				46.26	
		Mean $s_{y.x}$ = 0.483			k = 4.856	
Bluefish	6.3				28.54	
	7.0/6.3	-2.94	0.11	0.198		5.39
	7.0				31.39	
	7.6/7.0	-7.27	0.22	0.582		3.59
	7.6				34.25	
	8.2/7.6	-7.94	0.21	0.312		3.58
	8.2				37.10	
	8.9/8.2	-9.81	0.24	0.422		3.35
	8.9				39.96	
		Mean $s_{y.x}$ = 0.378			k = 4.495	

Table 5. Gill-net length-frequency distribution (12.1-cm stretched mesh) adjusted for unequal numbers of king mackerel of various lengths in the population fished.

Length midpoint (cm)	Gill nets No. (fi)	Gill nets % (fi)	Commercial hook and line No. (hi)	Commercial hook and line % (hi)	Commercial hook and line ri 1/	Commercial hook and line Adj. fi 2/	Recreational hook and line No. (fi)	Recreational hook and line % (hi)	Recreational hook and line ri	Recreational hook and line Adj. fi
475			8	0.3						
525			11	0.4						
575	7	0.4	100	3.7	0.108	10.7	37	1.6	0.24	7.7
625	86	5.3	398	14.7	0.360	35.5	719	32.1	0.16	5.1
675	122	7.5	452	16.7	0.449	44.3	625	27.9	0.27	8.7
725	208	12.9	390	14.4	0.896	88.3	364	16.3	0.79	25.4
775	334	20.6	376	13.9	1.482	146.2	320	14.3	1.44	46.2
825	340	21.0	337	12.4	1.693	167.0	100	4.5	4.69	150.6
875	264	16.3	312	11.5	1.417	139.8	50	2.2	7.31	234.7
925	115	7.1	193	7.1	1.000	98.6	7	0.3	23.67	759.9
975	76	4.7	69	2.5	1.880	185.4	14	0.6	7.83	251.4
1,025	30	1.8	38	1.4	1.286	126.8	0			
1,075	26	1.6	10	0.4	4.000	394.5	0			
1,125	6	0.4	8	0.3	1.333	131.5	2	0.1	4.0	128.4
1,175	1	0.1	5	0.2	0.500	49.3	0			
1,225	3	0.2					0			
1,275			1	0.1						
Sum	1,618	99.9	2,708	100.0	16.405	1,617.98	2,238	100.0	50.4	1,617.99
										92.07
										8.55
										0.21

1/ ri = percent fi/percent hi

2/ adjusted fi = sum fi x ri/sum ri

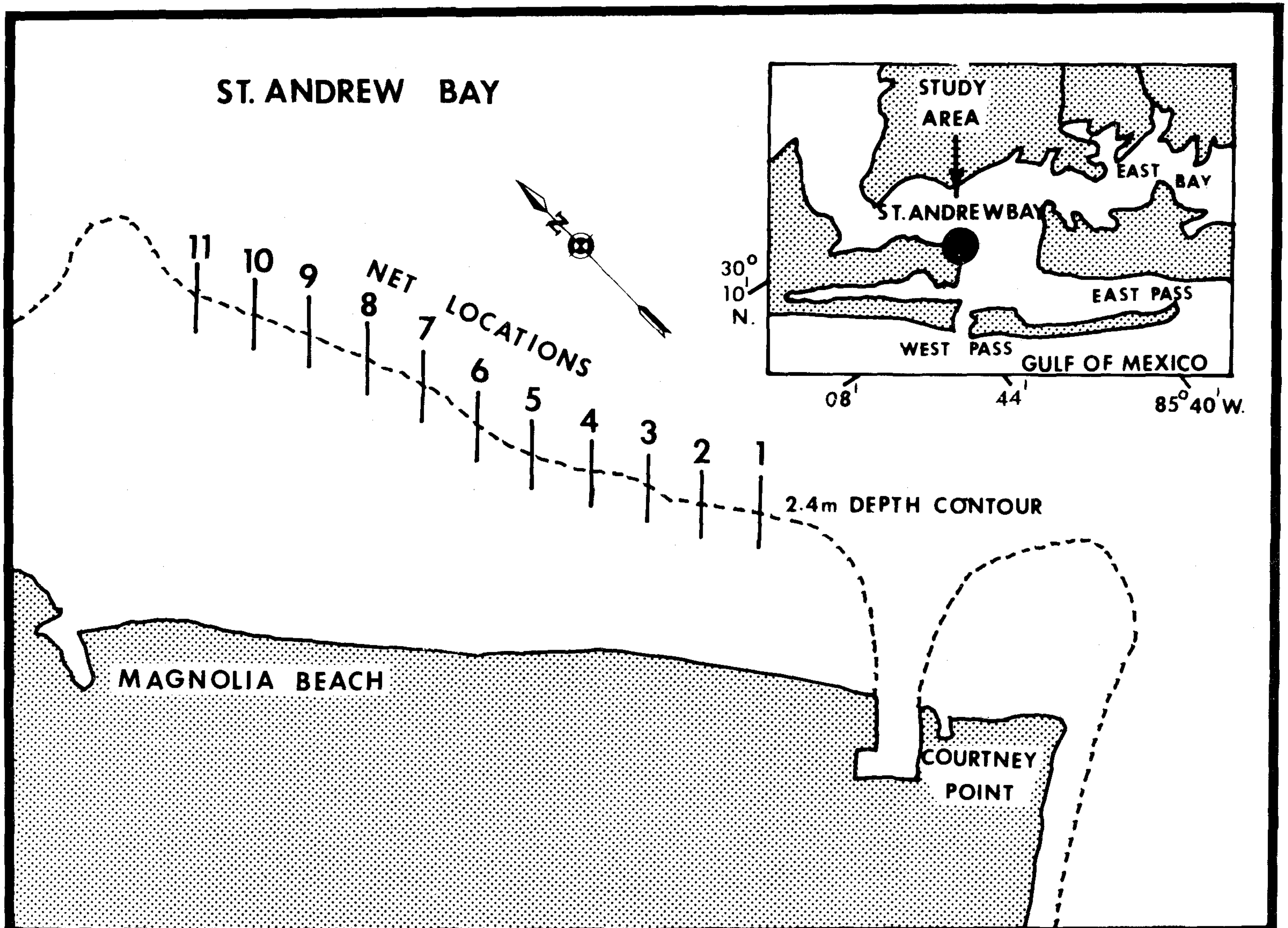

Figure 1. Study area and net locations for experimental netting in St. Andrew Bay, Florida.

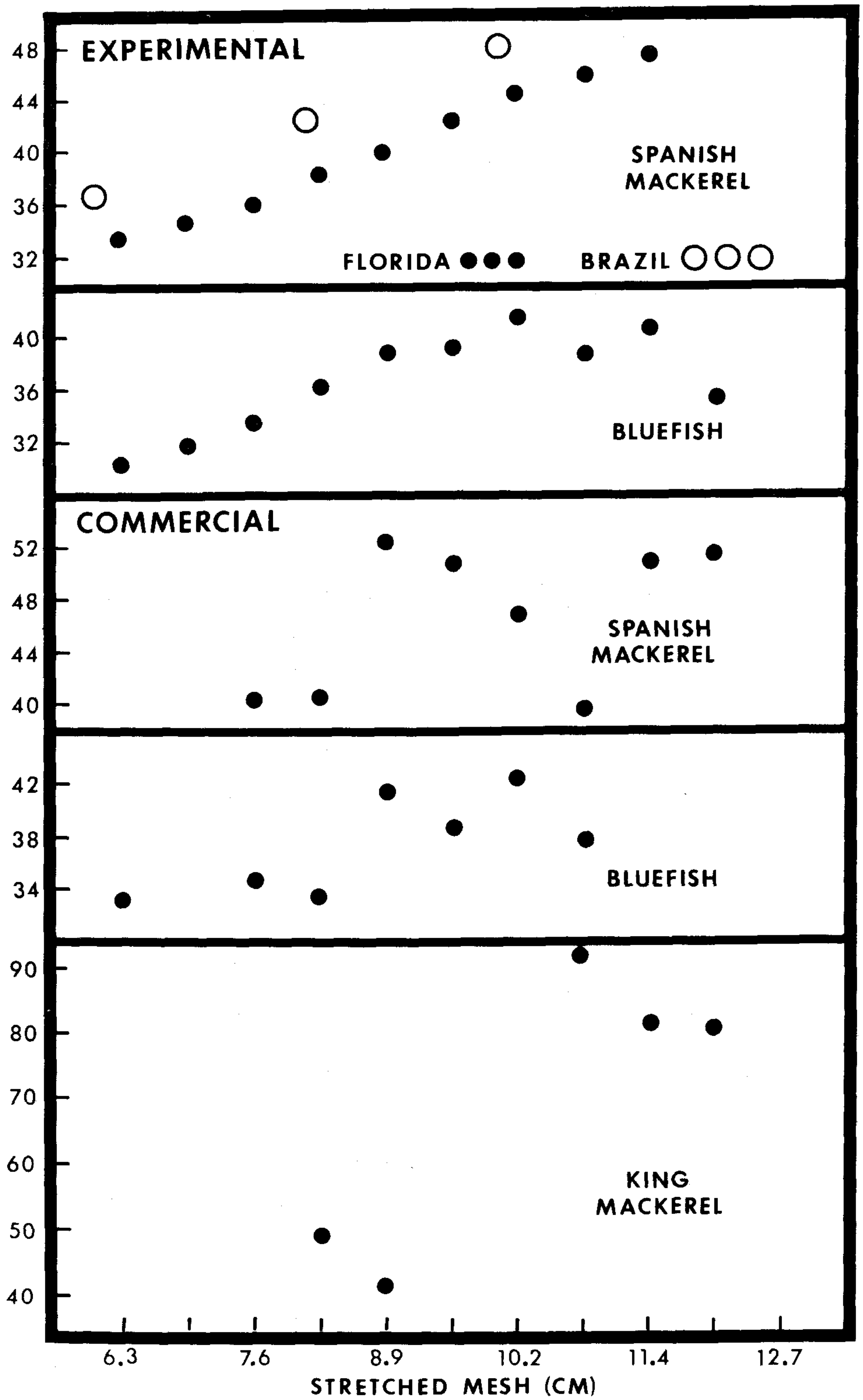

Figure 2. Mean lengths of fishes caught in experimental and commercial gill nets of various mesh sizes.

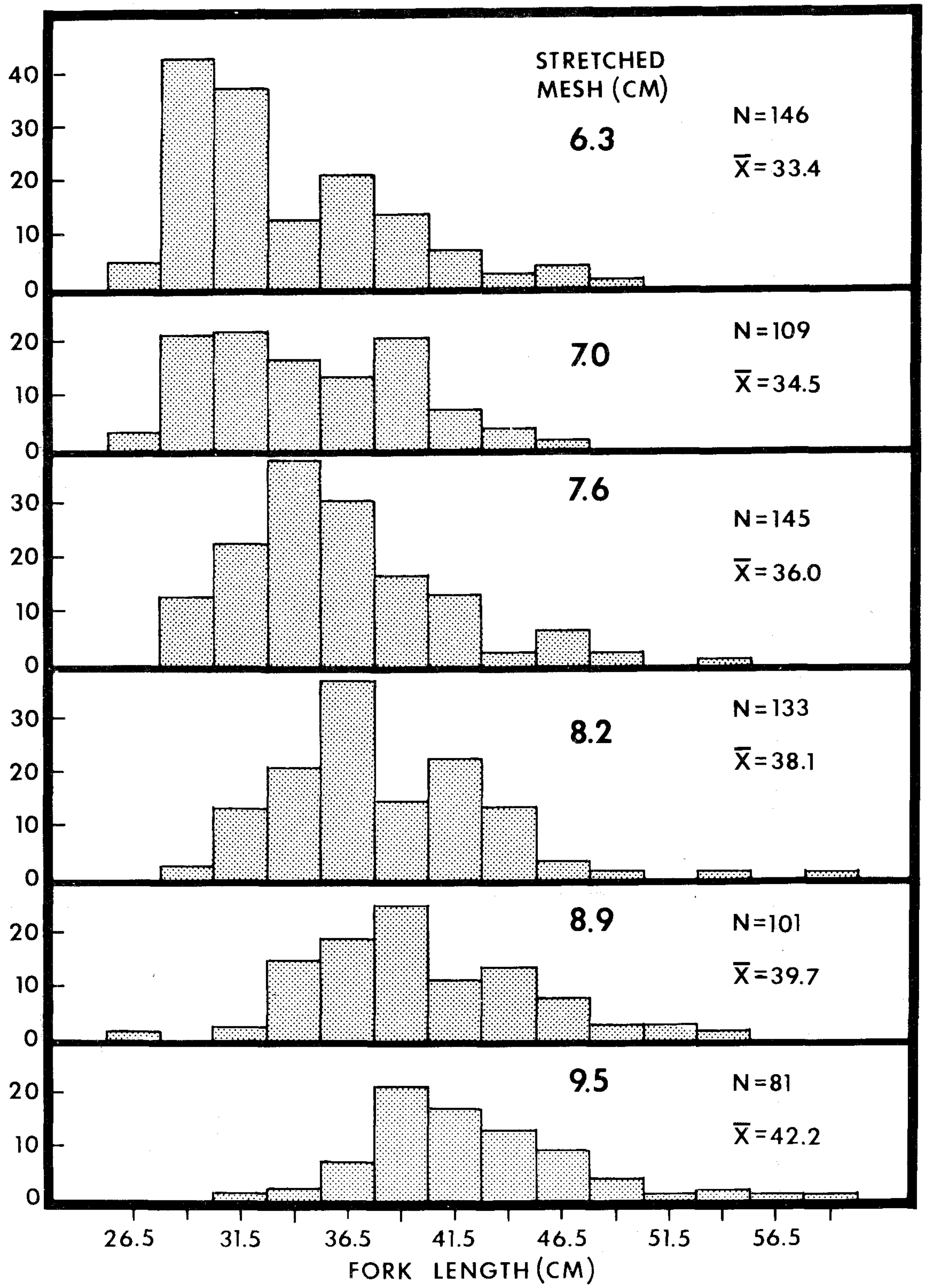

Figure 3. Length-frequency distributions by mesh size of Spanish mackerel caught in experimental gill nets.

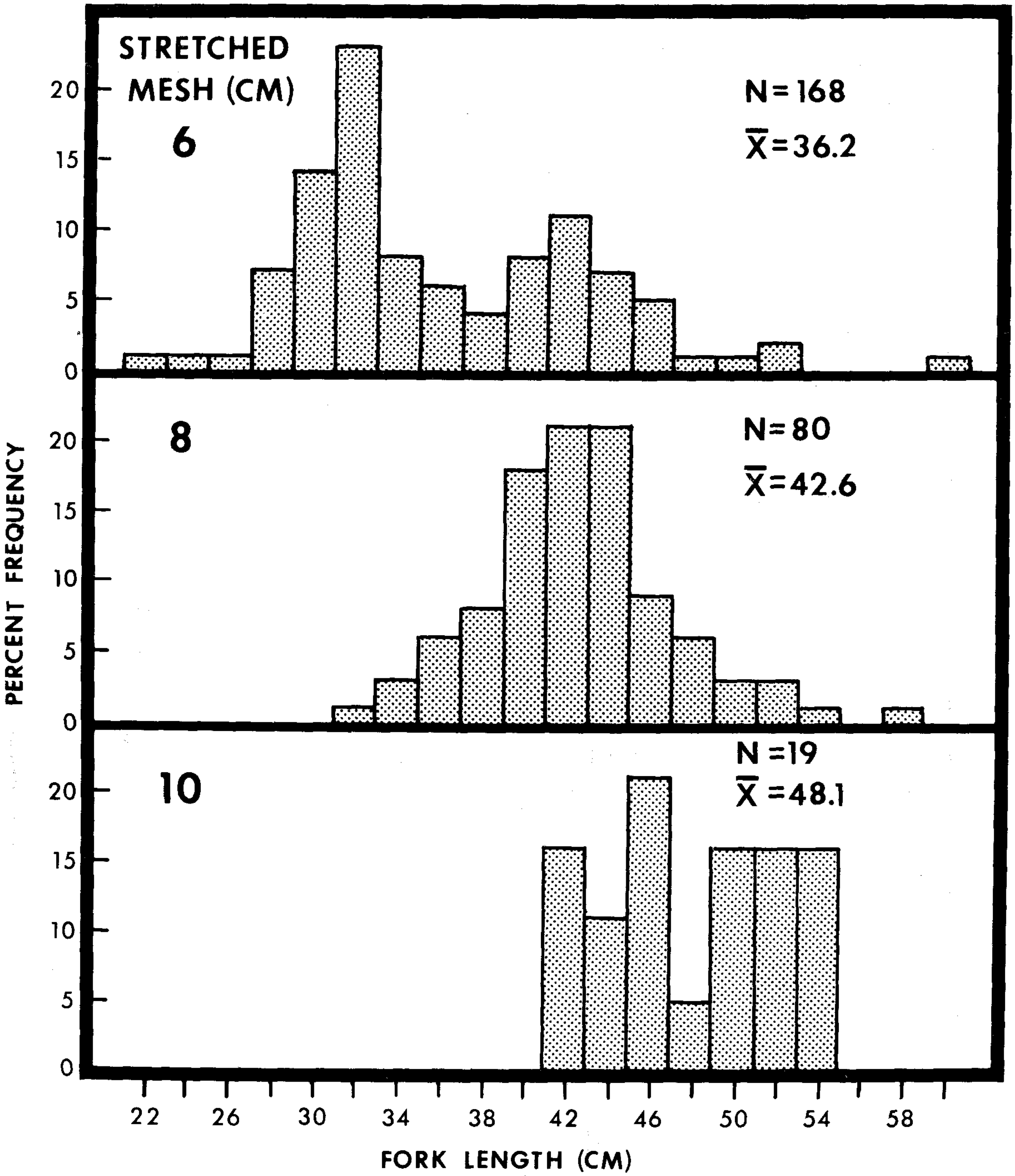

Figure 4. Length-frequency distributions by mesh size of Serra Spanish mackerel caught in gill nets (data from Fonteles-Filho and Alcantara-Filho 1977).

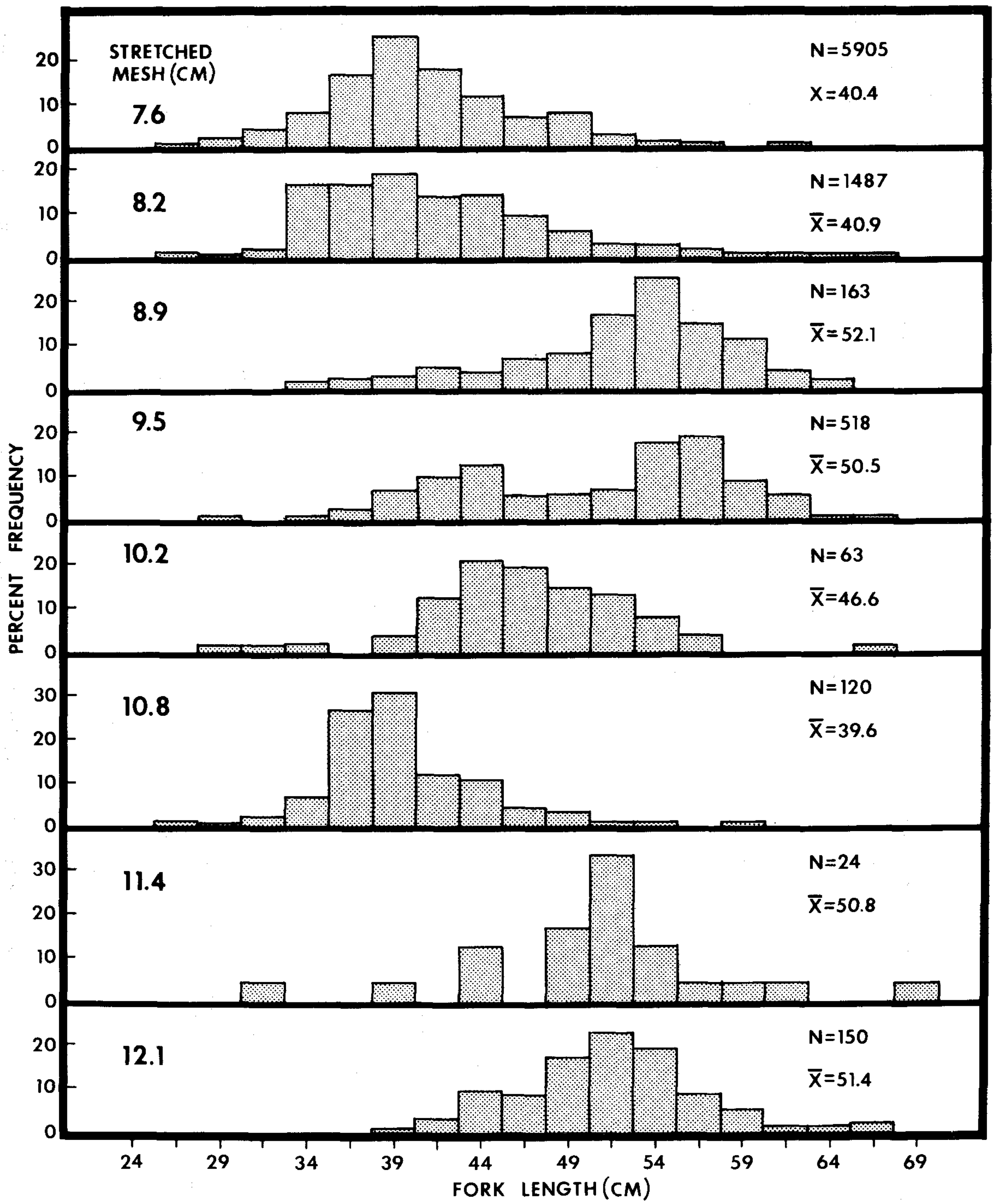

Figure 5. Length-frequency distributions by mesh size of Spanish mackerel caught by commercial gill-net fishermen.

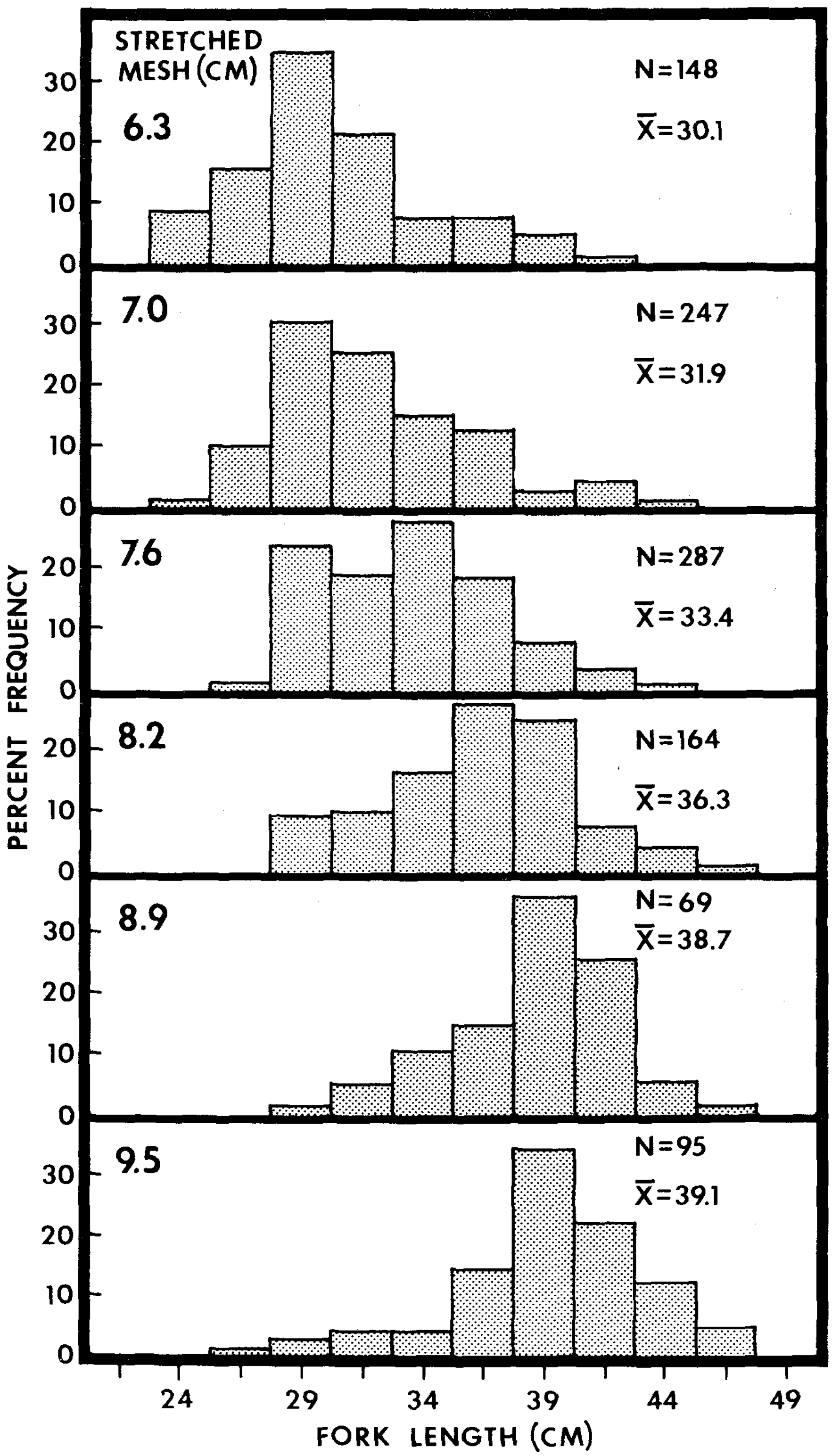

Figure 6. Length-frequency distributions by mesh size of bluefish caught in experimental gill nets.

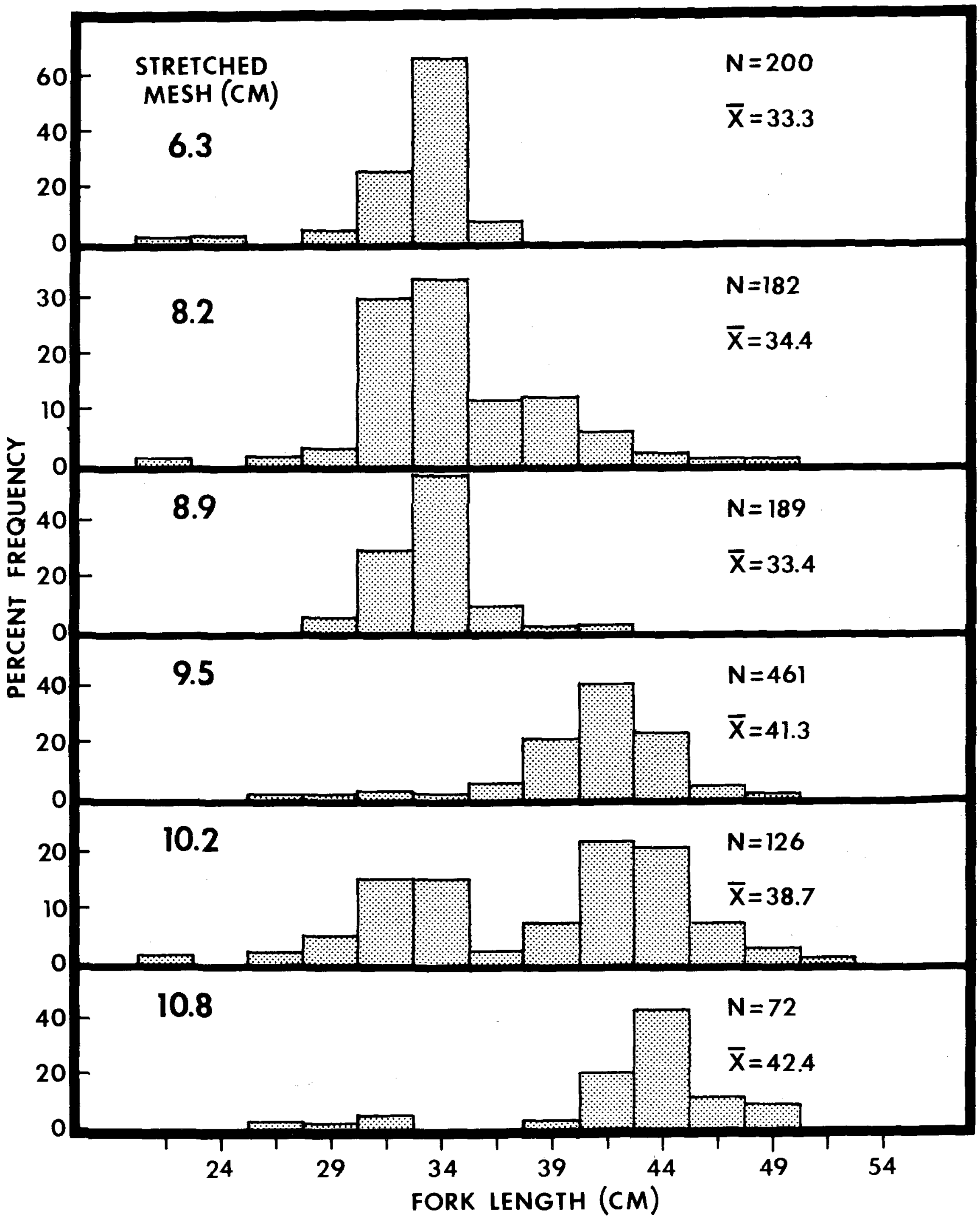

Figure 7. Length-frequency distributions by mesh size of bluefish caught by commercial gill-net fishermen.

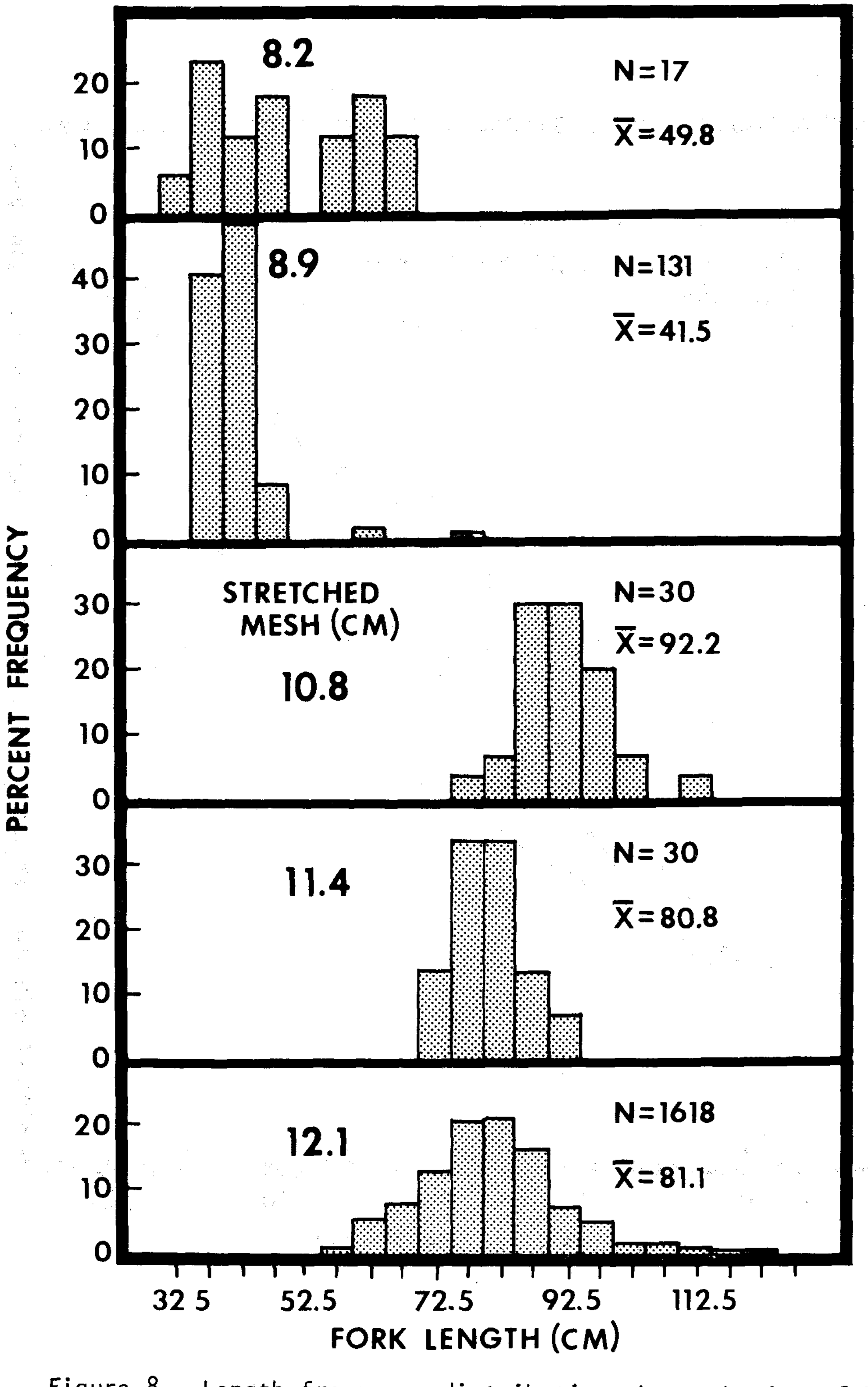

Figure 8. Length-frequency distributions by mesh size of king mackerel caught by commercial gill-net fishermen.

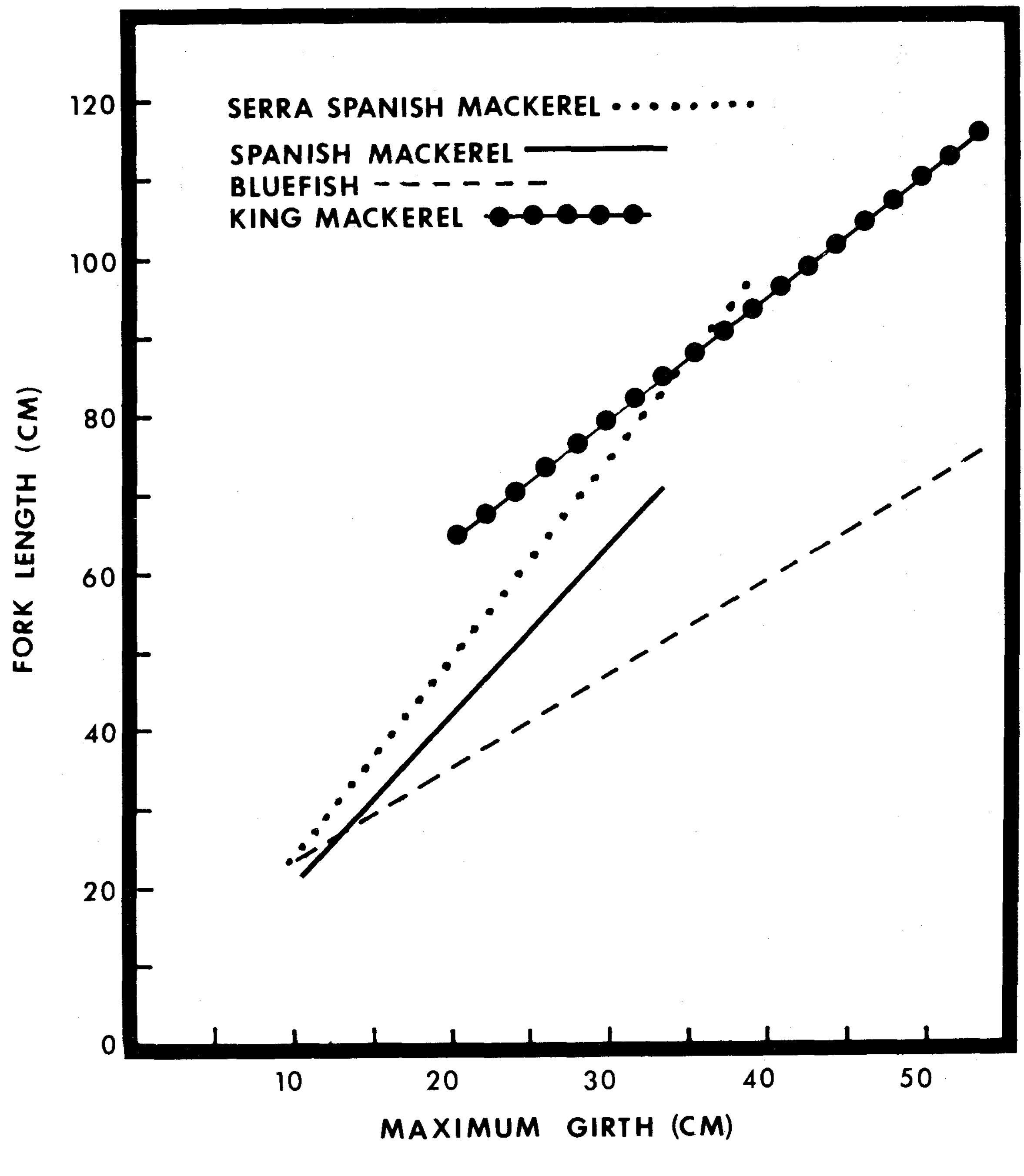

Figure 9. Girth-length relations by species and area (Brazilian data from Fonteles-Filho and Alcantara-Filho, 1977).

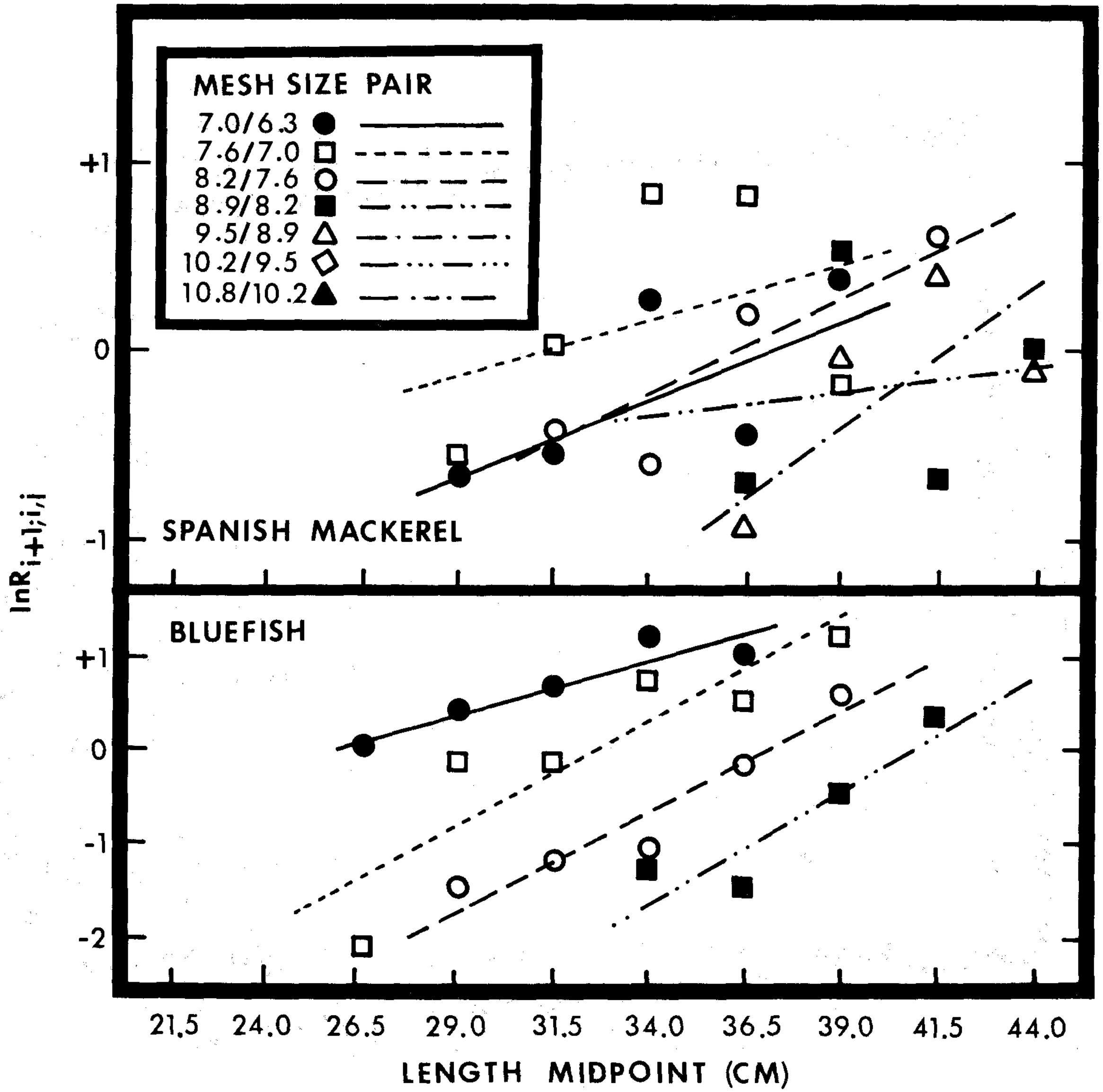

Figure 10. Least squares regression equations of $\ln R_{i+\overline{1},i,j}$ on length by species and mesh size pair.

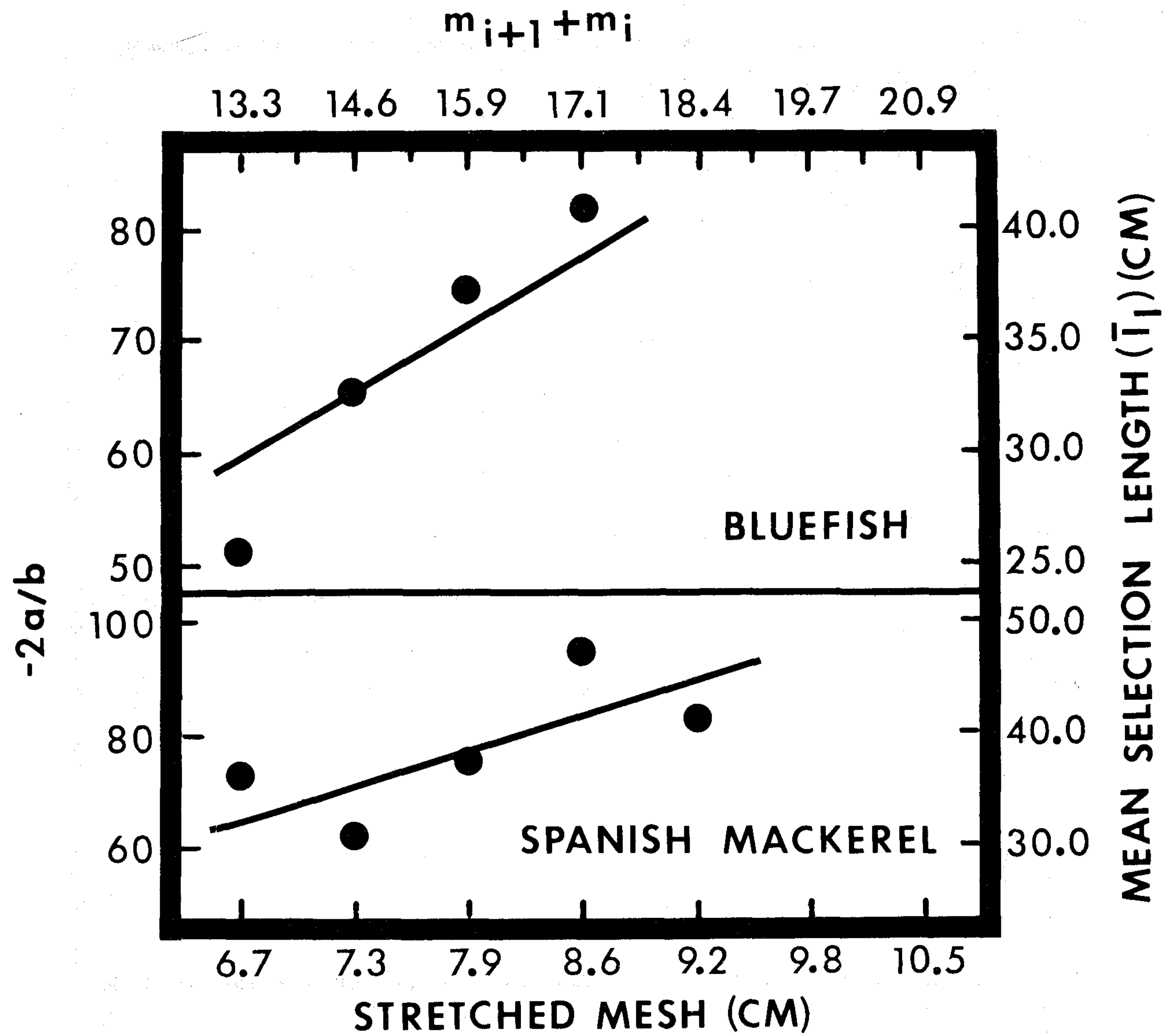

Figure 11. Regression of -2a/b on the sum of mesh sizes ($m_{i+1} + m_i$) and estimates of mean selection length by mesh size.

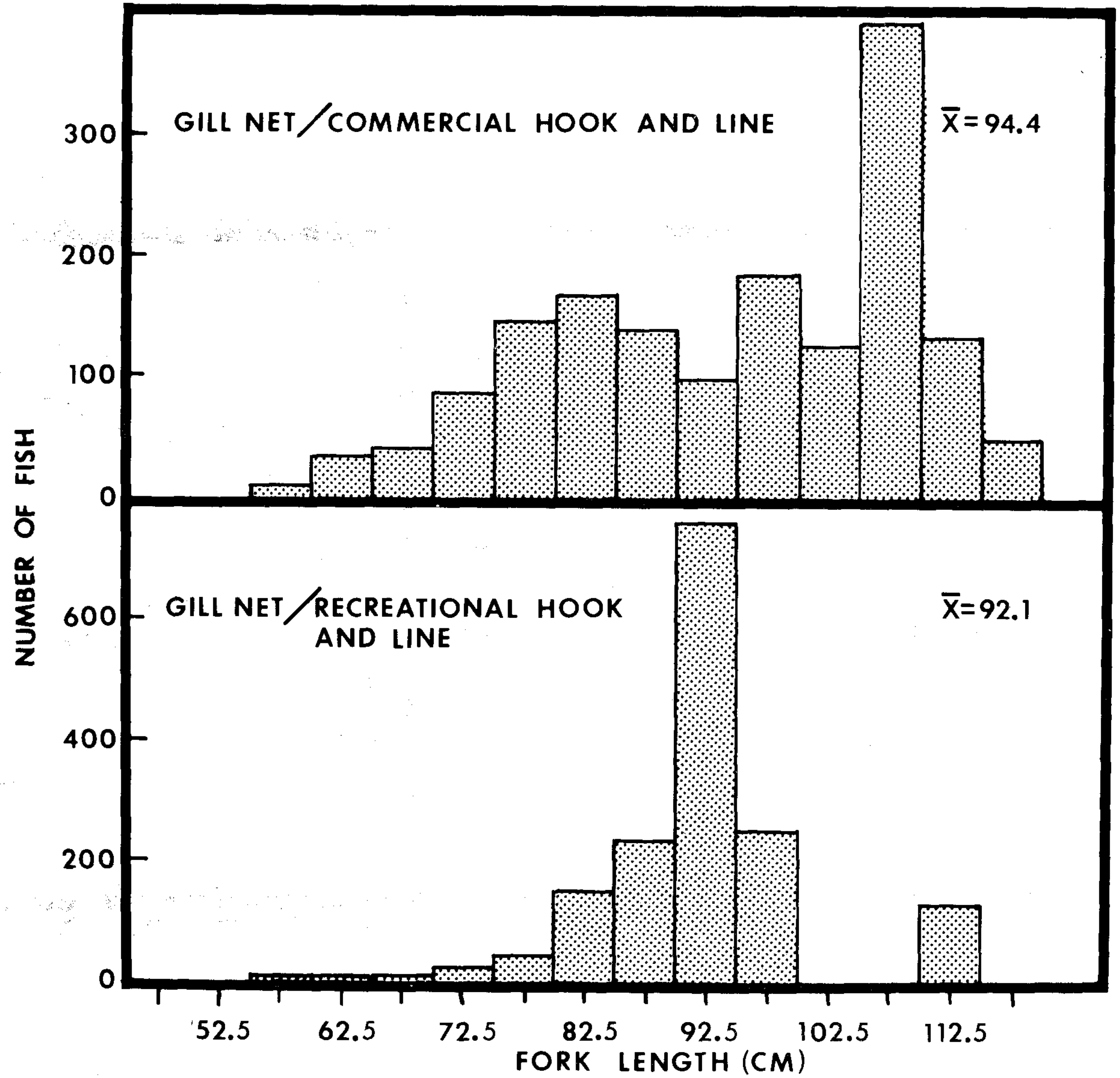

Figure 12. Gill-net length-frequency distributions after adjustment for unequal numbers of king mackerel of various lengths in the population fished.

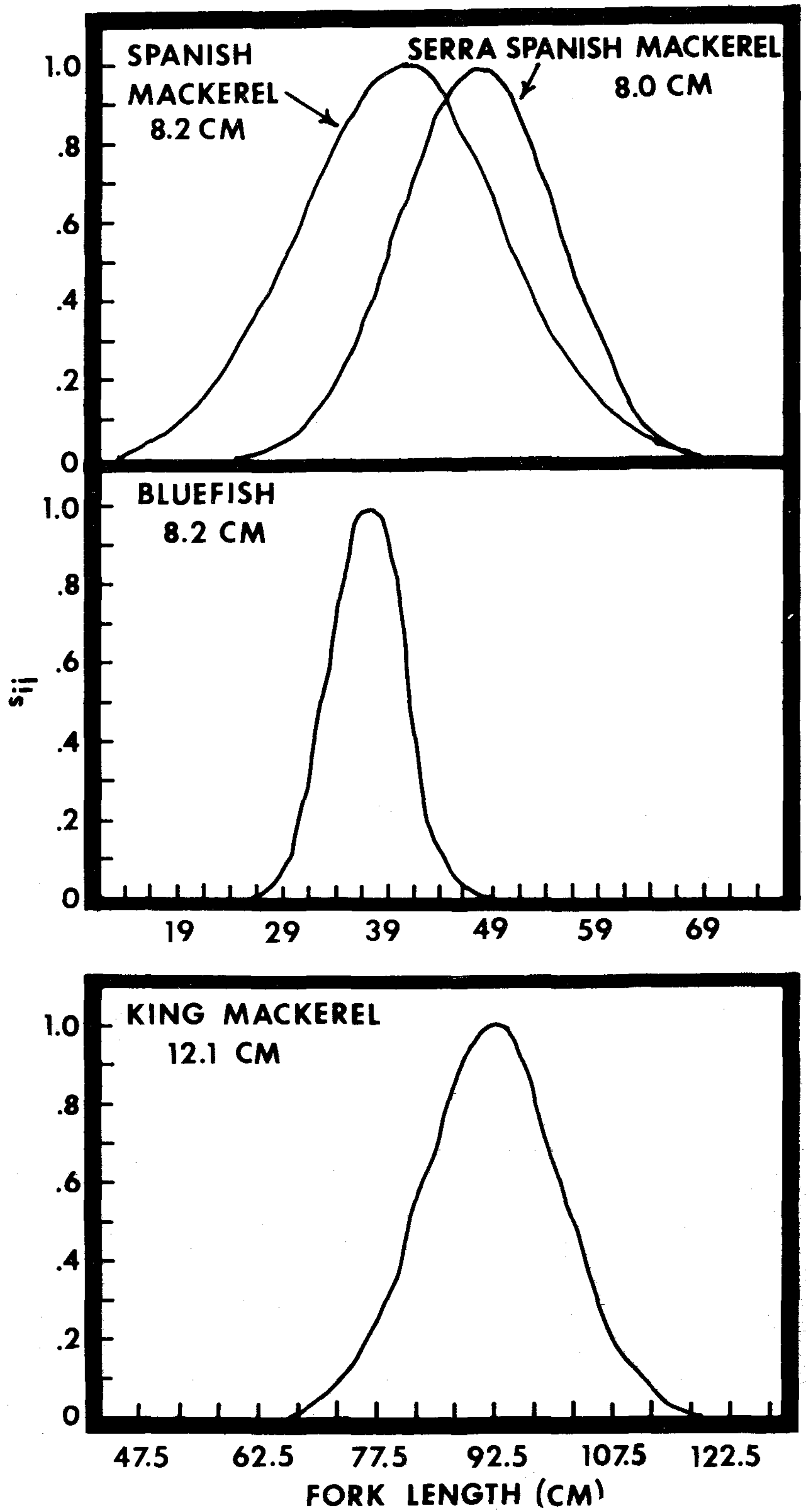

Figure 13. Selectivity curves (s_{ij} plotted against length) by species for indicated stretched-mesh sizes.