

# MESH RETENTION OF LARVAE OF *SARDINOPS CAERULEA* AND *ENGRAULIS MORDAX* BY PLANKTON NETS

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## ABSTRACT

Mesh retention of the standard plankton sampling gear used by the California Cooperative Oceanic Fisheries Investigations between 1949 and 1968 for larvae of the Pacific sardine (*Sardinops caerulea*) and northern anchovy (*Engraulis mordax*) was estimated by comparing catches made by the standard gear with a gear that retains larvae of all sizes. The results indicate that 67% of sardine larvae and 60% of anchovy larvae are retained by the meshes of the standard gear. The standard gear was replaced by a similar gear in 1969. Apparently all anchovy larvae are retained by the new gear. The new gear is the same as the old gear except for the netting. The netting of the new gear is constructed from 0.505-mm mesh width nylon while the netting of the standard gear was constructed from 0.55-mm mesh width silk. Catch curves of anchovy and sardine larvae corrected for escape through meshes revealed no evidence of a critical period.

Although fisheries literature contains numerous examples of estimates of mesh retention of fish by commercial fishing gear, there is little quantitative work on mesh retention of fish larvae by plankton gear. A review of such studies by Vannucci (1968) revealed only three papers containing quantitative estimates of mesh retention by plankton gear. The lack of knowledge on this subject can cause serious errors when comparing the estimates of abundance of fish larvae made from samples taken by different sampling gears or of two or more species of fish larvae by the same gear.

This paper presents estimates of mesh retention of larvae of the Pacific sardine (*Sardinops caerulea*) and northern anchovy (*Engraulis mordax*) by plankton nets that have been used by the CalCOFI (California Cooperative Oceanic Fisheries Investigations). Estimates are made of the errors that result because mesh retention is ignored when the relative abundance of the two species is calculated and when abundance of the anchovy is computed using data from two quite similar types of sampling gear. Finally the catch curves of the two species are examined for evidence of the critical period proposed by Hjort (1926).

Several authors have noted that small larvae of the Pacific sardine and northern anchovy are not completely retained by the meshes of the plankton nets used by the CalCOFI, but did not have the necessary data to make quantitative estimates of the retention rates. Ahlstrom (1954) noted that small sardine larvae were not fully retained by the meshes of the net in use at that time. Ahlstrom (personal communication) attempted to obtain a measure of the retention rates with a series of paired plankton samples made with a regular CalCOFI net and a net with a finer mesh, but failed to capture an adequate number of sardine larvae. Isaacs (1965) concluded that anchovies up to 7.75 mm were not fully retained by the meshes. He attributed differences in the form of catch curves of anchovy larvae in different years to changes in the minimum size of complete retention. Murphy (1966) stated that anchovy larvae are undersampled ". . . by a factor of about 2, relative to sardines, i.e., they tend to pass through the mesh of the net to a marked extent." He did not describe his method of obtaining the estimate but later informed me (Murphy, personal communication) that he based his conclusion on comparison of catch curves with hypothetical curves based on the assumption of exponential mortality. Lenarz (in press) estimated that

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northern anchovy larvae were undersampled by a factor of 3.4 relative to sardine larvae because of differences in retention rate and rate of decline in catch with increase in size. His estimates of retention rates also were based on differences between observed catch curves and hypothetical curves based on a constant rate of decline.

## METHODS

The data for this study on fish larvae were taken from CalCOFI plankton tows. From 1949 to 1968, CalCOFI used a single silk net (type 1) of 0.55-mm mesh with a 1-m diameter mouth opening. During 1966-68 this net was paired with one of nylon of 0.333-mm mesh (type 2) with a 1/2-m diameter mouth opening. In 1969 the netting of the larger net was replaced with monofilament nylon netting of 0.505-mm (type 3). The variance of mesh width of the type 3 net is considerably less than that of the type 1 net. Other details of the net characteristics are available from Smith<sup>2</sup>. The nets were lowered and raised obliquely at a rate of 1.5 knots to a depth of 140 m in 1966-1968 and to 210 m during 1969. Since very few anchovy or sardine larvae occur below a depth of 140 m, the change in depth should make no difference in the results of this study. Other details of sampling are described by Ahlstrom (1966).

All sardine and anchovy larvae in each sample were identified and measured to the nearest 0.5 mm, standard length. The data revealed evidence of varying degrees of personal bias towards favoring measurements of whole millimeter rather than half millimeter. Sette (1950) was aware of the potential for this type of bias in measuring adult fish and stated: "... to avoid personal bias in favor of whole or half centimeter marks, the measuring scale had uniform graduation marks and they were serially numbered. In addition to avoiding bias, this had the advantage of giving two digit numbers for all listings and computations, the data being divided by two for conversion to centimeters at the final stage of work." Perhaps it would be

prudent to follow the advice of Sette, if 0.5 mm accuracy is desired. Evidence of personal bias in measuring the smallest sizes of larvae was also noted. Since the smallest larvae are often distorted, it is difficult to make objective measurements. Because of the above described biases, measurements of the larvae are grouped into the intervals shown in Tables 1 and 2. Larvae captured by the type 2 net were multiplied by the ratio of volume of water sampled by the type 1 net to the volume of water sampled by the type 2 net to adjust for the smaller size of the type 2 net. The samples were chosen on the basis of the presence of sardine larvae or moderate numbers of anchovy larvae.

The following equations, using the notation of Regier and Robson (1966), were used to estimate mesh retention of the type 1 net

$$n_{ijk} = S_{ij}n_{2jk} + e_{jk} \quad (1)$$

where  $n_{ijk}$  = number of larvae of size  $L_j$  caught by type  $i$  net in  $k$ th sample.

$$s_{ij} = \text{mesh retention of type } i \text{ net to larvae of size } L_j, \text{ i.e.,} \\ s_{ij} = n_{ij}/N_j$$

where  $N_j$  = either absolute or relative number of larvae of size  $L_j$  in the population.

$$e_{jk} = \text{error term that is assumed to be normally distributed and independent of } n_{2jk}.$$

The use of equation (1) to estimate mesh retention of the type 1 net implies the assumption that  $s_{2j}$  is 1 for all  $j$ , i.e.,  $N_j \approx n_{2j}$ . Preliminary analysis of data obtained from a series of paired samples of the type 2 net and a finer meshed net indicates that this assumption is valid for northern anchovy and Pacific sardine (P. E. Smith, personal communication). This method of estimating  $S_{1j}$  from a known or estimated  $N_j$  is noted as the "direct approach" in the terminology of Regier and Robson (1966).

The least squares estimate of  $s_{1j}$  is given by Cochran (1963) as

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TABLE 1.—Catches of northern anchovy larvae by type 1 (0.55-mm mesh) and type 2 (0.333-mm mesh) nets for each sample.

Cruise	Station	Net type	Standard length							
			2.5	3.75	4.75	5.75	6.75	7.75	8.75	9.75
6601	93.35	1	141	175	38	18	17	14	4	0
		2	994.950	55.275	22.110	25.795	14.740	0.000	0.000	0.000
6601	103.29	1	95	121	291	145	45	23	10	5
		2	164.250	141.255	351.495	128.115	42.705	22.995	13.140	3.285
6601	120.24	1	22	51	66	62	30	21	15	4
		2	32.330	54.961	109.922	42.029	42.029	32.330	22.631	12.932
6601	120.35	1	25	59	37	17	11	0	0	0
		2	36.113	68.943	36.113	16.415	0.000	0.000	0.000	0.000
6607	113.50	1	3	1	1	1	0	0	1	0
		2	9.716	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6607	117.45	1	0	11	23	22	13	6	6	5
		2	4.448	84.512	44.480	26.688	12.344	4.448	8.896	0.000
6607	118.39	1	17	64	22	9	8	10	14	0
		2	208.518	117.858	13.599	13.599	9.066	4.533	4.533	4.533
6607	119.33	1	96	72	109	126	90	56	33	9
		2	32.508	102.168	130.032	130.032	116.100	55.728	32.508	9.288
6607	120.25	1	8	11	2	2	0	0	0	0
		2	97.196	128.122	26.508	8.836	4.418	0.000	0.000	0.000
6607	133.23	1	1	0	0	0	1	0	0	0
		2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6607	137.22	1	3	58	217	133	91	45	25	3
		2	8.212	143.710	316.162	176.558	90.332	86.226	36.954	16.424
6607	137.23	1	6	29	41	80	45	27	13	2
		2	66.195	61.782	105.912	52.956	26.478	30.891	8.826	13.239
6608	87.35	1	360	11	13	6	6	8	2	0
		2	877.150	162.190	122.470	33.100	39.720	26.480	6.620	3.310
6608	130.28	1	23	43	21	10	1	1	1	0
		2	29.552	51.716	18.470	0.000	0.000	0.000	0.000	0.000
6608	130.30	1	13	29	29	15	7	1	0	0
		2	47.879	66.294	22.098	11.049	11.049	7.366	0.000	0.000
6608	133.25	1	32	19	7	8	0	0	1	0
		2	151.578	79.398	21.654	25.263	7.218	0.000	0.000	0.000
6610	120.40	1	0	0	0	0	0	0	0	0
		2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6610	130.28	1	0	5	6	9	2	3	0	1
		2	0.000	7.128	10.692	0.000	0.000	0.000	0.000	0.000
6611	120.25	1	0	0	0	0	0	0	0	0
		2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6611	137.23	1	32	1	1	0	0	0	0	0
		2	127.575	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6706	83.55	1	9	17	36	53	35	33	23	25
		2	41.808	62.712	70.551	39.195	44.421	23.517	15.678	33.969
6706	110.40	1	21	6	30	57	56	52	48	58
		2	3.074	3.074	24.592	18.444	36.888	12.296	15.370	3.074
6706	120.24	1	1	0	0	4	4	1	0	0
		2	6.278	0.000	0.000	0.000	3.139	0.000	0.000	0.000
6706	120.40	1	2	4	14	31	19	26	12	7
		2	0.000	0.000	17.550	14.625	14.625	20.475	5.850	5.850
6712	107.45	1	123	106	18	10	13	1	5	0
		2	287.586	114.297	11.061	14.748	14.748	0.000	0.000	0.000
6712	120.50	1	333	23	9	11	7	6	1	0
		2	496.110	14.380	0.000	7.190	17.975	0.000	3.595	3.595

$$\tilde{s}_{ij} = \frac{\sum_{k=1}^m n_{1jk} n_{2jk}}{\sum_{k=1}^m n_{2jk}} \quad (2)$$

where  $m$  = number of samples.

However, if the assumption of independence of  $e_{jk}$  is violated, (2) is not the least squares estimate of  $s_{ij}$ . A form of violation of the assumption which is common in plankton sampling is that the error term is proportional to  $\sqrt{n_{2jk}}$ . In this case the least squares estimate of  $s_{ij}$  is given by Cochran (1963) as

TABLE 2.—Catch of Pacific sardine larvae by type 1 (0.55-mm mesh) and type 2 (0.333-mm mesh) nets for each sample.

Cruise	Station	Net type	Standard length							
			2.5	3.75	4.75	5.75	6.75	7.75	8.75	9.75
6601	93.35	1	0	0	0	0	0	0	0	0
		2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6601	103.29	1	0	0	0	2	1	0	0	0
		2	0.000	3.285	3.285	0.000	0.000	0.000	3.285	0.000
6601	120.24	1	1	2	7	8	4	3	0	1
		2	0.000	3.233	16.165	6.466	12.932	0.000	0.000	0.000
6601	120.35	1	0	1	38	4	0	0	0	0
		2	0.000	3.283	42.679	0.000	0.000	0.000	0.000	0.000
6607	113.50	1	0	0	2	8	0	0	0	0
		2	0.000	0.000	4.858	4.858	0.000	0.000	0.000	0.000
6607	117.45	1	0	0	0	2	8	5	5	3
		2	0.000	0.000	0.000	13.344	8.896	8.896	17.792	13.344
6607	118.39	1	0	3	16	17	4	2	0	0
		2	0.000	0.000	31.731	18.132	0.000	0.000	0.000	0.000
6607	119.33	1	0	0	0	0	2	1	0	0
		2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6607	120.25	1	4	3	4	0	0	0	0	0
		2	13.254	8.836	17.672	0.000	0.000	0.000	0.000	0.000
6607	133.23	1	10	28	8	6	2	0	0	0
		2	43.030	51.636	12.909	21.515	8.606	0.000	4.303	4.303
6607	137.22	1	60	15	8	11	14	6	3	3
		2	147.816	24.636	24.636	32.848	12.318	4.106	8.212	8.212
6607	137.23	1	5	0	1	0	1	1	0	1
		2	0.000	4.413	0.000	0.000	0.000	0.000	0.000	0.000
6608	130.28	1	8	33	29	27	9	5	1	1
		2	36.940	70.186	33.246	33.246	3.694	7.388	3.694	0.000
6608	130.30	1	83	56	15	8	1	0	2	1
		2	99.441	77.343	7.366	11.049	7.366	0.000	3.683	0.000
6608	133.25	1	11	63	13	3	6	0	1	0
		2	43.308	198.495	14.436	10.827	3.609	0.000	0.000	0.000
6610	120.40	1	2	14	9	4	5	8	6	8
		2	0.000	10.761	7.174	3.587	14.348	17.935	10.761	3.587
6610	130.28	1	2	32	2	0	0	0	0	0
		2	7.128	46.332	0.000	0.000	0.000	0.000	0.000	0.000
6611	120.25	1	1	13	263	294	111	75	40	33
		2	3.621	28.968	318.648	152.082	83.283	83.283	65.178	32.589
6611	137.23	1	1	23	2	1	0	0	0	0
		2	10.935	54.675	0.000	0.000	0.000	0.000	0.000	0.000
6706	110.40	1	0	1	9	0	0	0	0	0
		2	0.000	0.000	3.074	0.000	0.000	0.000	0.000	0.000
6706	120.24	1	5	30	57	13	4	1	0	0
		2	113.004	194.618	116.143	12.556	0.000	0.000	0.000	0.000
6706	120.40	1	4	118	175	65	25	11	5	2
		2	32.175	216.450	187.200	35.100	8.775	5.850	2.925	0.000

$$\tilde{s}_{1j} = \frac{\sum_{k=1}^m n_{1jk}}{\sum_{k=1}^m n_{2jk}} \quad (3)$$

Plots of  $n_{1jk}$  and  $n_{2jk}$  did not clearly indicate the relation between  $e_{jk}$  and  $n_{2jk}$ . Thus both methods of estimating  $s_{1j}$  were used.

Examination of the data revealed that a linear equation is appropriate to describe the relation between  $s_{1j}$  and  $L_j$  when  $L_j \leq 5.75$  mm.

$$\tilde{s}_{1j} = a + bL_j \quad (4)$$

Linear regression techniques were used to estimate the parameters,  $a$  and  $b$ , of the equation.

## RESULTS

Table 1 presents catches of anchovy larvae by the type 1 and type 2 nets for each sample. The first two digits of the cruise refer to year and the second two by month. Station notation is explained by Ahlstrom (1966). Larvae greater than 9.75 mm were captured, but the numbers involved were too small to be useful for the study. Estimates by (2) and (3) of  $s_{1j}$  are as follows:

$L_j$ (mm)	$\tilde{s}_{1j}(2)$	$\tilde{s}_{1j}(3)$
2.50	0.312	0.367
3.75	0.512	0.603
4.75	0.711	0.699
5.75	0.946	1.057
6.75	0.875	0.916
7.75	0.753	1.021
8.75	1.007	1.226
9.75	0.664	1.087

Plots, Figure 1, of the estimates show that there is a very good linear relation between the estimates and  $L_j$  when  $2.50 \text{ mm} \leq L_j \leq 5.75 \text{ mm}$ .

When  $L_j > 5.75 \text{ mm}$   $\tilde{s}_{1j}(2)$  decreases while  $\tilde{s}_{1j}(3)$  fluctuates about 1. Thus it appears that a linear relation (4) provides an adequate de-

scription of the relation between  $\tilde{s}_{1j}$  and  $L_j$  when  $2.50 \text{ mm} \leq L_j \leq 5.75 \text{ mm}$ . When  $L_j > 5.75 \text{ mm}$

it is assumed that  $\tilde{s}_{1j} = 1$ . Vannucci (1968) reviewed papers that used the logistic and normal distribution functions which have  $s_{ij}$  approaching 1 as an asymptote rather than the discontinuous equation used in this study. The data used in this study are not accurate enough when  $L_j > 5.75 \text{ mm}$  to warrant use of an asymptotic relation. The very good linear relation between  $L_j$  and  $\tilde{s}_{1j}$  when  $L_j \leq 5.75 \text{ mm}$  and the high values of  $\tilde{s}_{1j}$  when  $L_j = 5.75 \text{ mm}$  indicate that any deviation from the equation used in this study would cause minor errors when  $\tilde{s}_{1j}$  are used to correct catches of anchovy larvae for loss through meshes.

The estimate of  $a$  from (2) and (4) is  $-0.1942$ ,  $b$  is  $0.1945$ , and the correlation coefficient,  $r$ , is  $0.9961$ . When (3) was used  $a$  is  $-0.1075$ ,  $b$  is  $0.1850$ , and  $r$  is  $0.9814$ .

Table 2 contains catches of sardine larvae used in the study. Estimates by (2) and (3) of  $s_{1j}$  are as follows:

$L_j$ (mm)	$\tilde{s}_{1j}(2)$	$\tilde{s}_{1j}(3)$
2.50	0.375	0.358
3.75	0.385	0.436
4.75	0.817	0.782
5.75	1.754	1.330
6.75	1.275	1.203
7.75	0.881	0.926
8.75	0.584	0.526
9.75	0.873	0.854

The estimates of  $s_{1j}$  for sardine larvae are similar to those for anchovy larvae. Thus the same discontinuous function is assumed. The estimate of  $a$  from (2) and (4) is  $-0.2382$ ,  $b$  is  $0.2107$ , and  $r$  is  $0.9320$ . Estimates obtained when (3) was used are  $a$ ,  $-0.2286$ ,  $b$ ,  $0.2084$ , and  $r$ ,  $0.9639$ . The resulting curves for both anchovy and sardine larvae are shown in Figure 2. The curves differ little either within or between species. Since the highest value of  $r$ ,  $0.9961$ , was estimated for anchovy larvae using equation (2), the somewhat arbitrary decision was made to use the results obtained from equation (2).

#### ESTIMATION OF PORTION OF LARVAE PASSED THROUGH MESHES OF TYPE 1 (0.55-MM MESH) NET

The type 1 net has been the major plankton sampler of the CalCOFI. Estimates of spawning biomass of the northern anchovy population have been based on the ratio of total catches of sardine larvae to total catches of anchovy larvae (Ahlstrom, 1968). If there are major differences in the percentages of sardine and anchovy larvae retained by the net, then the estimates of anchovy spawning biomass may be seriously in error. Ahlstrom (personal communication) believed that his assumption that the two species were sampled equally well was valid because of the similar forms of larvae of the two species and his interpretations of catch curves of larvae of the two species.

Catch (average) curves of anchovy and sardine larvae were calculated from a series of CalCOFI samples taken during the months of January through July during the decade 1951-1960. More than 10,000 samples are involved. Catch curves were calculated for day and night samples separately because of marked differences between the two. The curves were then corrected for nonretention of larvae as follows:

$$n'_{1jko} = n_{1jko} (1/s_{1j}) \quad (5)$$

where  $n'_{1jko}$  = the corrected catch of larvae of size  $L_j$  by net type 1 in the  $k$ th time of day, and oth species.

$$k = \begin{cases} 1 & \text{for night samples} \\ 2 & \text{for day samples} \end{cases}$$

$$o = \begin{cases} 1 & \text{for anchovy} \\ 2 & \text{for sardine} \end{cases}$$

The corrected and uncorrected curves plotted on a semilogarithmic scale are shown with  $n_{1jko}$  and  $n'_{1jko}$  expressed in percent of total in Figures 3-6. The corrected curve for anchovy larvae caught at night shows a slight increase in the rate of decline with size. The corrected curve for anchovy caught during the day is essentially linear as is the corrected catch curve for sardine larvae caught during the night. The corrected catch curve for sardine larvae caught during the day shows a decreasing rate of decline with size. In all cases the corrected curves show little indication of undersampling of small larvae.

The following equation was used to estimate the portion of larvae not collected by the type 1 net because of passage through the mesh:

$$P_{1o} = \frac{\sum_{jk} \sum_{jk} n_{1jko}}{\sum_{jk} \sum_{jk} n'_{1jko}} \quad (6)$$

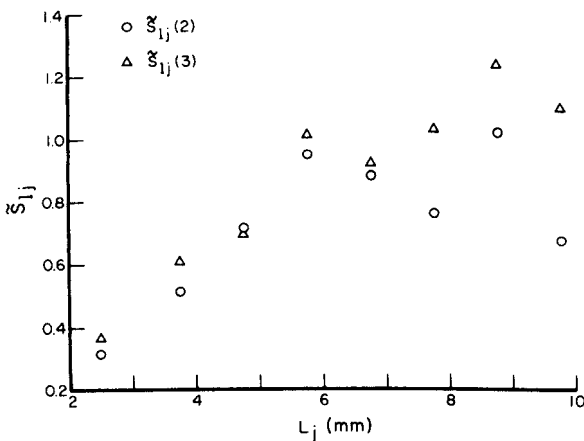


FIGURE 1.—Scatter diagram of estimates of mesh retention by type 1 (0.55-mm mesh) net using equation (2) ( $S_{1j}(2)$ ), mesh retention using equation (3) ( $s_{1j}(3)$ ), and standard length ( $L_j$ ) for northern anchovy larvae.

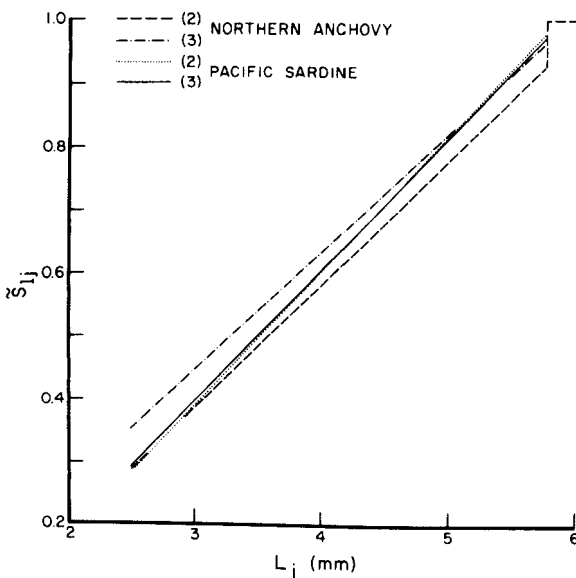


FIGURE 2.—Estimates of mesh retention by type 1 (0.55-mm mesh) net ( $s_{1j}$ ) against standard length ( $L_j$ ) for larvae of northern anchovy and Pacific sardine using equations (2) and (3).

where  $1 - P_{io}$  = portion of larvae of species  $o$  not sampled by type  $i$  net because of passage through meshes.

Equation (6) implies that an equal number of night and day samples are taken. This is approximately correct. The estimate of  $P_{1o}$  for anchovy is 0.60. The estimate of  $P_{1o}$  for sardine is 0.67. Thus anchovy larvae are undersampled by about 12% relative to sardine larvae because of differences in mesh retention and size composition.

### CATCH CURVE OF TYPE 3 (0.505-MM MESH) NET

Figure 7 shows the catch curve plotted on a semilogarithmic scale of anchovy larvae caught by the type 3 net during 1969 by the CalCOFI. This data is preliminary (P. E. Smith, personal communication) and catches have not been separated by day and night. The interesting feature of this curve is that it is essentially linear

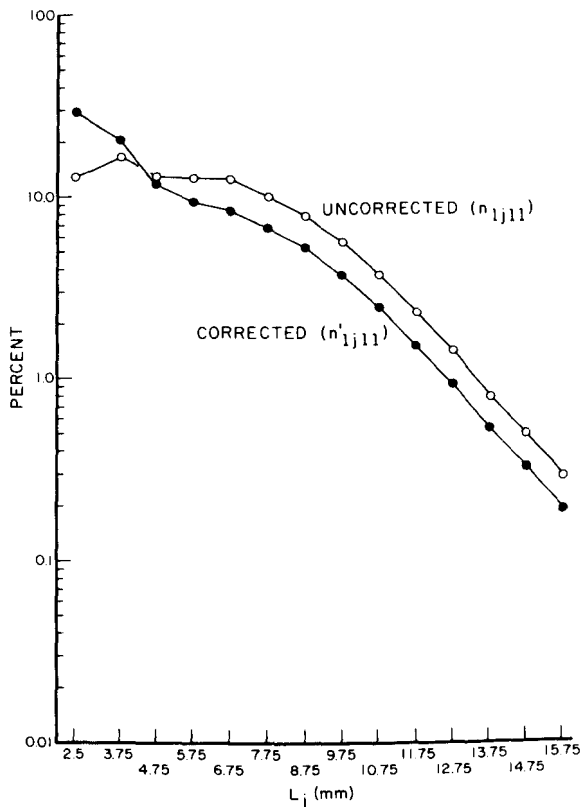


FIGURE 3.—Corrected ( $n'_{1j11}$ ) and uncorrected ( $n_{1j11}$ ) catches by standard length ( $L_j$ ) of northern anchovy taken at night with type 1 (0.55-mm mesh) net. Catches are expressed in percent of total.

with size. This indicates that few if any small anchovy larvae escape capture by passing through the meshes. Thus a 10% decrease in mesh size and a large decrease in the variance of mesh size changed  $P_{ii}$  from 0.60 to about 1. The difference in  $P_{ii}$  between the type 1 and type 3 nets means that total catches of anchovy larvae by the type 1 net should be multiplied by 1.7 to be comparable to catches of anchovy larvae by the type 3 net.

### DISCUSSION

The similarity of the catch curves of anchovy larvae caught by the type 3 net and the corrected catch curve for the type 1 net suggests that the estimates of  $s_{ij}$  are reasonably accurate. It

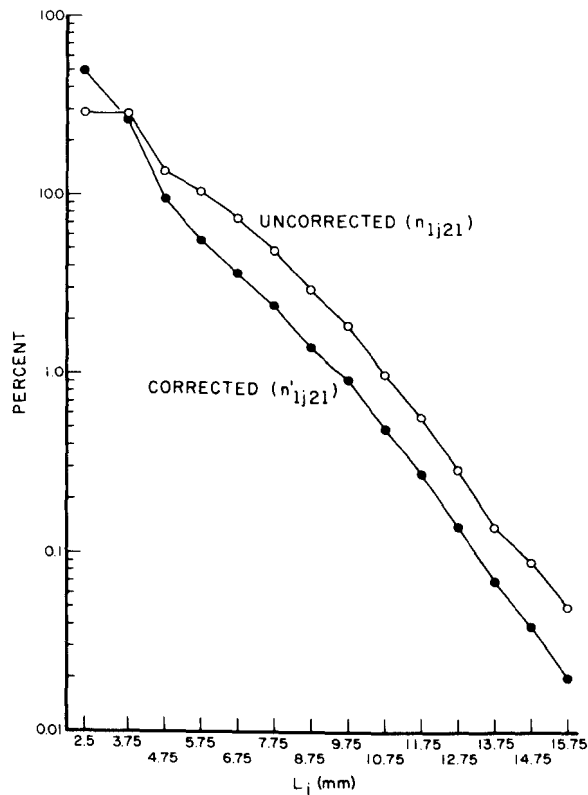


FIGURE 4.—Corrected ( $n'_{1j21}$ ) and uncorrected ( $n_{1j21}$ ) catches by standard length ( $L_j$ ) of northern anchovy taken during day with type 1 (0.55-mm mesh) net. Catches are expressed in percent of total.

would be a remarkable coincidence otherwise as the data are independent.

It is interesting that the type 3 (0.505-mm mesh width) net apparently retains most if not all anchovy larvae, for the body depth at the insertion of the pectoral fin of 3.75-mm anchovy larvae is about 0.35 mm (P. E. Smith, personal communication) which is considerably less than the mesh width. Smith, Counts, and Clutter (1968) summarized the results of Saville (1958) by concluding that an organism must be wider than the mesh diagonal to be completely retained. A conclusion of this study is that the "diagonal rule" is too conservative for slowly towed nylon nets. Heron (1968) concluded that mesh variability is a very important factor in-

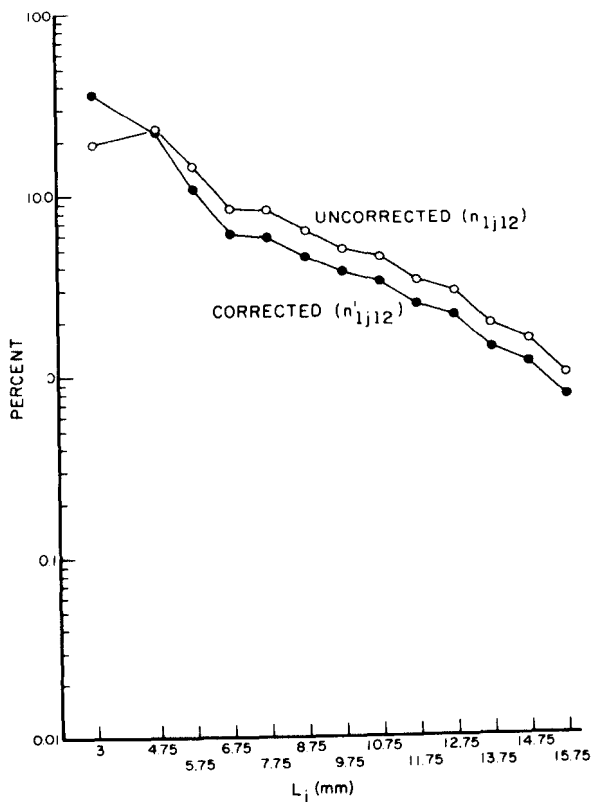


FIGURE 5.—Corrected ( $n'_{1j12}$ ) and uncorrected ( $n_{1j12}$ ) catches by standard length ( $L_j$ ) of Pacific sardine taken at night with type 1 (0.55-mm mesh) net. Catches are expressed in percent of total.

fluencing escapement and implied that the coefficient of variation of mesh width is greater for silk than nylon nets. The results of this study agree with Heron's conclusions.

The results indicate that two similar types of sampling gear have greatly different mesh retention properties for anchovy larvae. This implies that considerable care should be taken in the selection of sampling gear if quantitative estimates of the abundance of fish larvae are desired. The similarity in mesh retention shown for anchovy and sardine larvae may be due to the fact that the larval forms are very similar. However the diversity of forms found in fish larvae is tremendous. Mesh retention should be estimated before quantitative estimates of the relative

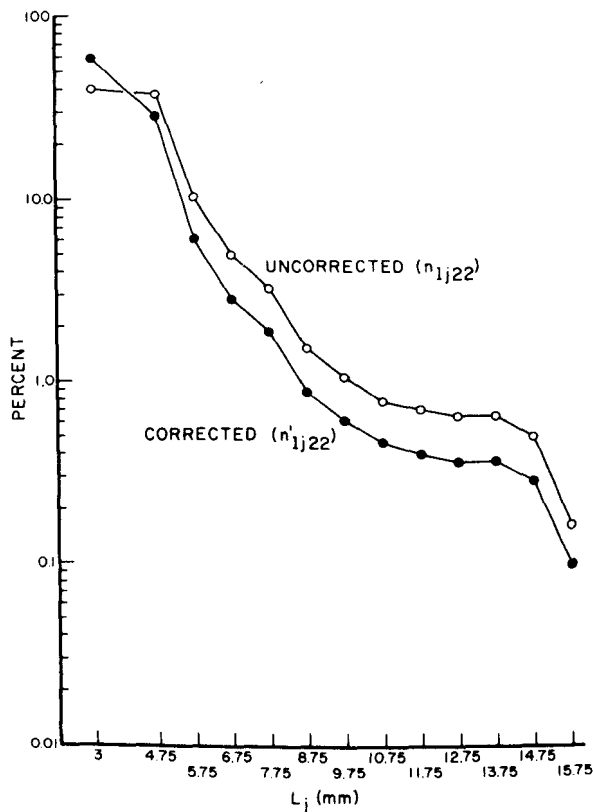


FIGURE 6.—Corrected ( $n'_{1j22}$ ) and uncorrected ( $n_{1j22}$ ) catches by standard length ( $L_j$ ) of northern anchovy taken during day with type 1 (0.55-mm mesh) net. Catches are expressed in percent of total.

abundance of larvae of different species of fish are attempted. The results indicate that adequate estimates of mesh retention can be made from less than 30 samples containing the desired species of fish larvae. If the mesh retention curve is curvilinear in the region of fish larvae of minimum size, more samples may be necessary.

The reasoning of Hjort (1926) in expecting a critical period in the early life of fish larvae is intuitively pleasing. Hunter (1972) showed experimentally that a much higher density of food organisms is necessary for survival of 4- to 6-mm anchovy than for larger larvae. However, there is no indication of a critical period at the 4- to 6-mm sizes in this study, i.e., there are no major



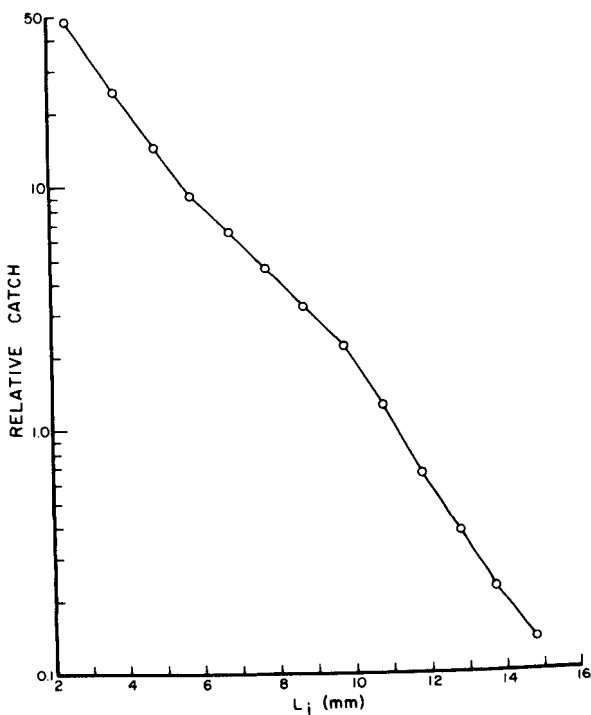


FIGURE 7.—Catches of northern anchovy by standard length ( $L_j$ ) taken by type 3 (0.505-mm mesh) net.

changes in the slopes of the catch curves. However, since the catches are plotted with size rather than age, a faster rate of growth at small sizes relative to large sizes could cause small size larvae to be relatively undersampled. If this were the case, a critical period could occur but not be indicated by catches plotted with size. Kramer and Zweifel (1970) indicated that the growth rate of anchovy larvae increases rather than decreases with size during the first few millimeters of growth. Another factor that could influence the catch rate of larvae differently with size is avoidance of the net. However, experience indicates that avoidance increases with size (Lenarz, in press). Thus, the large larvae should be relatively undersampled. I conclude, therefore, that available data does not provide any evidence of the critical period for sardine or anchovy larvae. This conclusion is

in agreement with other authors that have examined catch curves of fish larvae, e.g., Marr (1956).

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