Bull. Jap. Soc. Fish. Oceanogr., No. 34, 1979

Distribution and Abundance of Eggs and Larval of the Brazilian Sardine, *Sardinella brasiliensis*, During 1974-75 and 1975-76 Seasons

Yasunobu MATSUURA
(Instituto Oceanográfico da Universidade de São Paulo)

Abstract

Eggs and larvae of the Brazilian sardine, *Sardinella brasiliensis*, were collected with the Bongo net sampler on survey cruises conducted during 1974 through 1976 in south Brazilian waters. Spawning areas and distribution pattern of eggs and larvae were studied and spawning stock biomass was estimated using the estimates of egg abundance for two spawning seasons. Spawning takes place on the continental shelf, mainly in the 51-100 m depth zone during summer, when water temperatures were 22 to 26 °C and salinity ranged from 34.5 to 36.0 ‰. Two places with heavy spawning were located: one between Ilha Grande and Ilha de São Sebastião and another between Santos and Paranaguá. The main spawning area changes from year to year. The larvae after hatching drift in all direction over the continental shelf and inhabit mainly the shelf waters, at least, up to the juvenile stage. Spawning stock biomass in the region was roughly estimated at one to two million metric tons. The sampling efficiency of the Bongo net was compared with other types of plankton nets used in previous surveys.

1. Introduction

The Brazilian sardine, *Sardinella brasiliensis*, is one of the most important comercial fish in the southern Brazil and inhabits coastal waters from Cabo de São Tomé (22°S) to south of Cabo de Santa Marta Grande (29°S). The total catch of Brazilian sardine reached 228,000 tons in 1973, but recently decreased to 94,000 tons in 1976 (PDP/SUDEPE, 1977).

Since 1968 a series of survey cruises was carried out to investigate distribution of eggs and larvae and spawning potential of this species. Results of sardine abundance and the influence of oceanographic conditions on the spawning behavior, based on these surveys, have been published (MATSUURA, 1971; 1975a, b; 1977a, b, c).

The objective of this study was to estimate egg and larval abundance during 1974 through 1976, using the Bongo net sampler. Analysing the size frequency and horizontal distribution of larvae, the dispersal of early stages was studied and a pattern of the early life history of Brazilian sardine was discussed.

2. Material and Methods

Most specimens for this study were collected using the Bong net from November 1974 to January 1976 in southern Brazil with the R/V "Prof. W. Besnard". The sampling method was based on that described by AHLSTROM *et al.* (1973). The net had a mouth diameter of 61 cm, its meshes were of 505 micra and 333 micra nylon monofilament gauze. Only the Samples collected with the 505 micra net were used for the study of eggs and larvae. One digital flow meter (General Oceanic Inc.) was attached at the center of the sampler's mouth.

Plankton hauls were made obliquely starting from surface to bottom and again to surface with the ship speed of about two knots and wire angle was adjusted to maintain 45° during tow. No net depth recorder was used and the net depth was estimated from wire angle and length. In stations less than 60 m sea depth, double towing was made with the hope to increase filtered water volume. In stations with 61-205 m depth, only one tow was made from surface, down to 5 m above the bottom

and again to surface. In stations more than 205 m deep, sampling was only to 200m depth.

Plankton samples were fixed and preserved in a solution of 10% formalin. After measuring the plankton volume, all eggs and larvae of fishes were sorted out. Sardine eggs and larvae were identified according to MATSUURA (1971; 1975b). For size frequency study, all larvae were measured using plastic rule under binocular microscope.

During two spawning seasons, four survey cruises were conducted (Fig. 1). The cruise of November-December 1974 covered the area between Cabo de São Tomé and Cabo de Santa Marta Grande, however that of January 1975 covered only the area between Cabo Frio (23°S) and Santos (24°S). The two cruises conducted during 1975-76 spawning season covered over the continental shelf between Carbo Frio and Cabo de Santa Marta Grande.

For estimation of egg and larval abundance, the entire survey area was divided into six subareas and each one was divided into four depth zones: 15-50 m, 51-100 m, 101-200 m, and more-than-200 m. The method described by TANAKA (1955; 1973) for egg estimates and that described by SMITH (1972) for larval abundance were used. The procedure of computation for each subarea was made as in previous papers (MATSUURA, 1975a; 1977a). The mortality rate of sardine eggs which is needed for the computation of egg abundance is not yet known, therefore the correction factor, k=1.0 was used.

3. Occurrences of eggs and larvae

1974-75 Spawning Season

The first cruise of November-December 1974 covered the entire spawning area from Cabo de São Tomé to Cabo de Santa Marta Grande

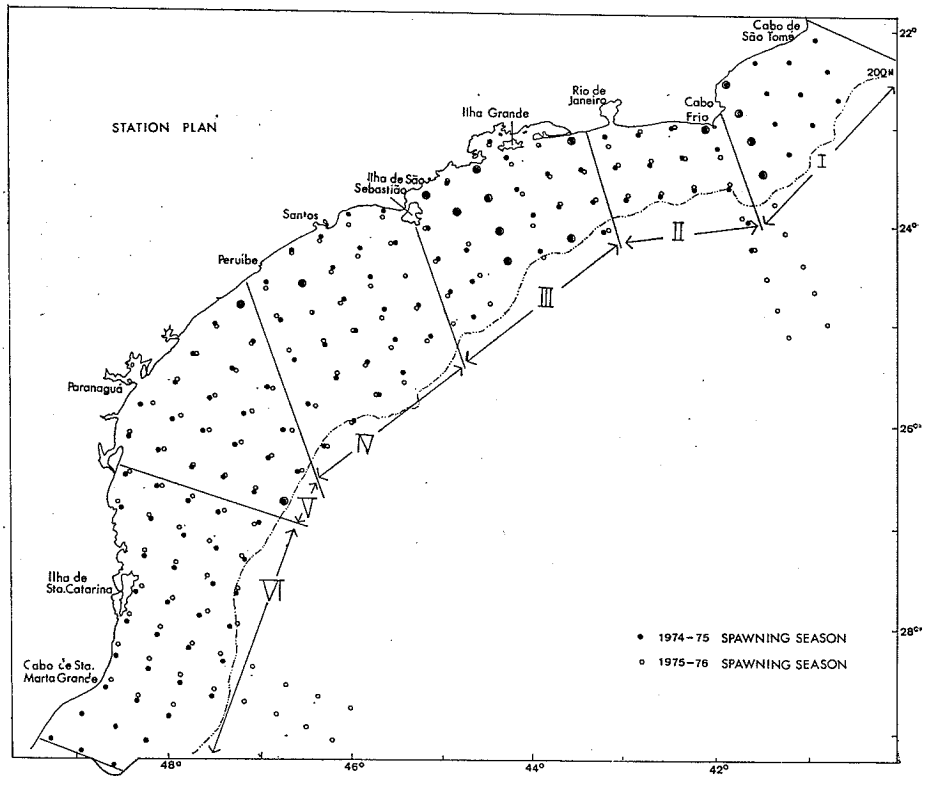

Fig. 1. Stations occupied by the R/V "Prof. W. BESNARD" during survey cruises made in 1974 through 1976.

and acomplished 139 stations on the continental shelf and beyond it. The second cruise on January 1975 covered only the northern part of the survey area, acomplishing 55 stations. Using the occurrences of eggs taken during the two cruises, the spawning areas of this season were determined (Fig. 2). The main concentration of eggs was found in the area between Ilha Grande and Ilha de São Sebastião. The spawning intensity in the southern part of Ilha de São Sebastião was weaker than in the northern part, but I could not conclude that the former had less spawning due to the lack of information from the southern part in the cruise of January 1975.

The occurrences of sardine larvae from two cruises were determined (Fig. 3). Three areas of high larval concentration were located: the first in the coastal region between Ilha Grande and Ilha de São Sebastião where egg concentration was observed, the second near Paranaguá at the 50 m depth line, and the third near Ilha de Santa Catarina at the 100 m depth line.

1975-76 Spawning Season

Two cruise were carried out in the region between Cabo Frio and Cabo de Santa Marta Grande. Figure 4 shows spawning areas, based on the occurrences of eggs. A major concentration of eggs was located between Ilha de São Sebastião and Itajaí (27°S) at mainly the 51-100 m depth zone. Two small egg occurrences were located at Cabo Frio and at Cabo de Santa Marta Grande.

In the cruise of November-December 1975, the major spawning took place at the region between Ilha de São Sebastião and Paranaguá, where consecutive spawning occurred during 7 days of observation. To show the spawning time of sardines, sampling hours and developmental stages of eggs were plotted and the result shows that the Aa-stage eggs were collected at few hours interval around midnight and the Cb-stage eggs were taken at the period between sunset and midnight. Thus, spawning occurred in few hours prior to midnight and the time-to-hatching of eggs was about one day, as described previously (MATSUURA, 1971).

During the cruise of January 1976, eggs were taken more in the region between Rio de Janeiro and Ilha Grande, where only few eggs

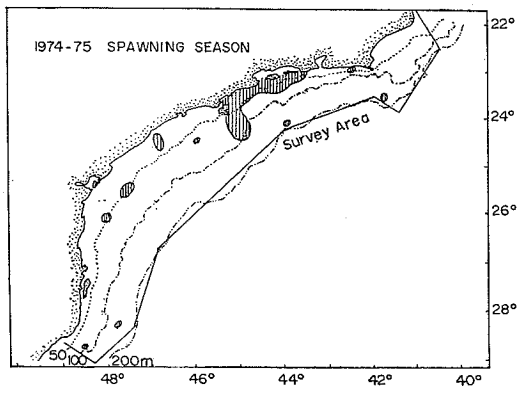

Fig. 2. Spawning areas of the sardine in 1974-75 spawning season.

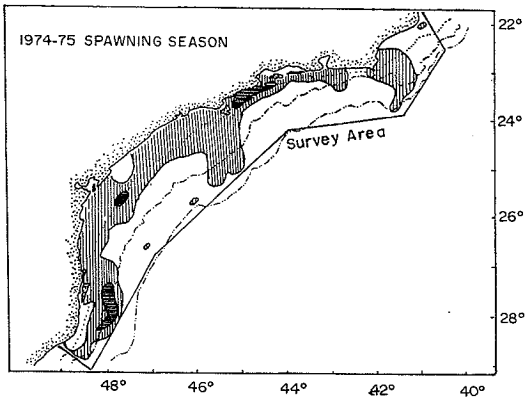

Fig. 3. Distribution of sardine larvae in 1974-75 spawning season.

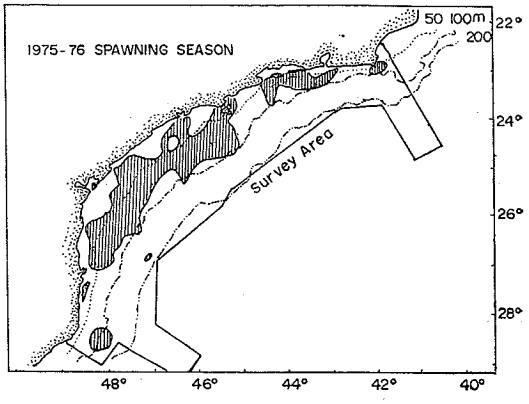

Fig. 4. Spawning areas of the sardine in 1975-76 spawning season.

were taken in the previous cruise. The region between Paranaguá and Ilha de Santa Catarina also had considerable spawning, but the Santos region showed only few occurrences.

Table 1 gives the number of sardine eggs taken during two spawning seasons. Mean number of eggs per station and ratio of positive stations is less in the 1975–76 spawning season than the previous year.

Occurrences of larvae from the two 1975–76 cruises are given in Figure 5. In the cruise of November-December 1975, large concentrations of larvae were located between Ilha de São Sebastião and Paranaguá. The region between Cabo Frio and Ilha Grande had only a few occurrences. In January 1976 two large concentrations were located: one between Ilha de São Sebastião and Santos, and another between Paranaguá and São Francisco do Sul (26°10′S). The areas of occurrence of eggs and larvae coincided fairly well in the two cruises.

Egg abundance estimates

The estimated abundance of sardine eggs spawned in subareas, represented by bimonthly periods, are shown in Table 2. The estimated number of eggs in 1974–75 spawning season was 240×10^{12} in the region from Cabo de São Tomé to Cabo de Santa Marta Grande, however, the estimate from the cruise of January 1975 did not include subareas I, V and VI. During the bimonthly period of November-December 1974, subarea III (Ilha Grande) had the greatest egg abundance and during January-February 1975, no large spawning was observed in any of the subareas.

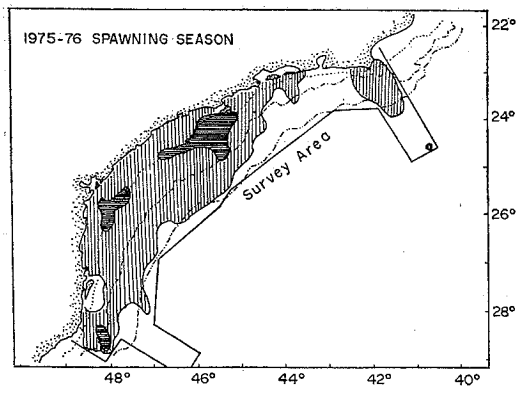

Fig. 5. Distribution of sardine larvae in 1975–76 spawning season.

The estimated number of eggs in 1975–76 spawning season was 449×10^{12} in the region from Cabo Frio to Cabo de Santa Marta Grande.

Table 1. Number of sardine eggs taken during two spawning seasons.

Spawning season	A	B	(B/A)×100	C	C/A	C/B	Cruise	Survey area
1974—75	194	33	17.0%	37524	193	1137	Nov. Dec. '74 Jan. '75	From São Tomé to Sta. Marta Grande
1975—76	280	44	15.7%	11563	41	263	Nov. Dec. '75 Jan. '76	From Cabo Frio to Sta. Marta Grande

A=number of routine stations, B=number of positive stations with sardine eggs,
C=total number of eggs collected during spawnig season.

Table 2. Estimate of eggs spawned by the Brazilian sardine (k=1.0). Unit=10^{12} eggs

Spawning season	Months	I	II	III	IV	V	VI	Total
1974—75	Nov.-Dec.	0	0.021	235.425	0.250	0.820	0.128	240.5
	Jan.-Feb.	—	1.319	0.030	2.542	—	—	
1975—76	Nov.-Dec.	0.023	0.037	0.182	255.849	33.406	19.152	449.3
	Jan.-Feb.	0	0.994	8.657	4.457	0.612	125.884	

— : No sampling in the subarea, O : No eggs in the subarea.
Note : The samples which contain eggs spawned in two successive days were treated as of one -day spawning.
Subareas : I=São Tomé region, II=Rio de Janeiro region, III=Ilha Grande region, IV=Santos region, V=Paranaguá region, VI=Santa Catarina region.

Comparing the two periods, egg abundance in November-December period was 69% of total, having the largest value in subarea IV (Santos). The January-February period had only 31%, having the largest value in subarea VI (Santa Catarina region).

4. Estimate of spawning stock size

To facilitate a computation of egg abundance, a hypothetical value k=1.0 was used supposing the mortality rate of embryonic stage being zero. However this value is unrealistic. SMITH (1973), analising the data taken during 9 years off California, concluded that the instantaneous mortality rate of the California sardine egg was 0.3074 per day over 3 days. This means the mortality rate of eggs was about 73.5% for three days. We have no idea on the mortality rate of the Brazilian sardine eggs. Because the time-to-hatching is about one day in this region, I tentatively supposed the mortality rate of eggs at 50%, and used the correction factor k=0.787 for computation of adult stock size.

The fecundity of one female is about 20,000 eggs and the sex ratio of adults is about 50:50 (MATSUURA, 1977a).

Using these parameters, biomass estimate of the two spawning seasons were made (Table 3). Estimated adult biomass were 1.74×10^6 metric tons in 1974-75 spawning season and 3.26×10^6 metric tons in 1975-76 season. The former was underestimated due to a lack of sampling stations in the northern and southern regions (subareas I, V and VI in the cruise of January 1975). The result of the 1975-76 season showed that the egg abundance of Jan.-Feb. period in three subareas (II, III and IV) occupied 10% of full survey area. Supposing that the spawning pattern of the same period in 1974-75 season was the same, the egg abundance of this period could be estimated at 38.77×10^{12} eggs and the total eggs spawned would be 275.4×10^{12} eggs during this spawning season. Then, the estimated adult biomass will be 2.10×10^6 metric tons in 1974-75 season.

As shown by ENGLISH (1964), the most important estimating error of spawning stock size based on egg abundance is derived from the numer of sampling cruises. Since only two cruises were conducted during one spawning season, covering a large survey area with one research vessel, the accuracy of our estimate could be low. However, from the results of two spawning seasons and those of previous seasons (MATSUURA, 1977a), the spawning stock of the Brazilian sardine was roughly estimated at one to two million metric tons.

5. Distribution of larvae by subarea and by depth zone

The mean number of larvae per station in different depth zones is presented in Table 4. The areas of larval concentration varied between years, e.g. in 1974-75 season, the 15-50 m depth zone had the highest value and in 1975-76 season, the 51-100 m depth zone was the highest. Very few occurrences were observed at more-than-200 m.

The size frequency of larvae from four depth zones is shown in Figure 6. The same trend as in previous results (MATSUURA, 1977b) was observed: i.e. smaller larvae in the size range between 6 and 9 mm, were concentrated in 51-100 m depth zone where the main spawning ground was located, and other depth zones showed occurrences of higher proportions of larger larvae. No difference among depth zones

Table 3. Tentative estimation of spawning stock size.

Spawning season	E (k=1.0)	E (k=0.787)	E/F	M	B	Survey area
1974—75	240×10^{12}	305×10^{12}	14.5×10^9	29.0×10^9	1.74×10^6	Cabo S. Tomé-Santa Marta Grande
1975—76	449×10^{12}	571×10^{12}	27.2×10^9	54.4×10^9	3.26×10^6	Cabo Frio-Santa Marta Grande

E=estimated egg number in survey area, F=fecundity of a female, E/F=total number of females, M=estimate of spawning stock size, B=estimate of spawning stock in tons
Note : mean weight of one female=0.06 kg

Table 4. Mean number of sardine larvae per station in different depth zone.

Spawning season	Depth zone 15–50 m	51–100 m	101–200 m	+200 m
1974—75	36.2	20.8	23.0	0.1
1975—76	42.8	138.3	50.8	0.2

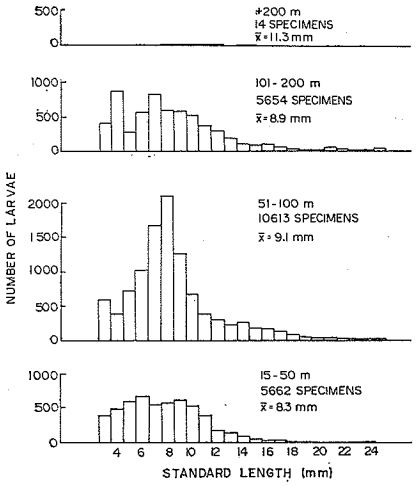

Fig. 6. Size frequency of sardine larvae taken in different depth zones in 1974-1976.

was observed in larval abundance in the size range between 3 and 5 mm.

With the hope to verify a larval dispersal, the occurrences of prejuveniles and juveniles were plotted (Figs. 7 and 8). They were taken mainly from 51–100 m and secondly from 101–200 m depth zones. According to the definition of water masses of this region by EMILLSON (1961), the water mass of positive stations in which juveniles were taken is the shelf water. A relatively small quantity of juveniles were taken from the coastal water in the 15–50 m depth zone.

In a previous paper (MATSUURA, 1977b) I suggested that there was a non-directional dispersal of larvae from the spawning ground throughout the continental shelf. The occurrences of prejuveniles and juveniles seem to support this suggestion. In the juvenile stage, sardines presumably have a considerable swimming ability. If the sardine juveniles have to approach the coastal region due to some physiological necessity, a concentration of them

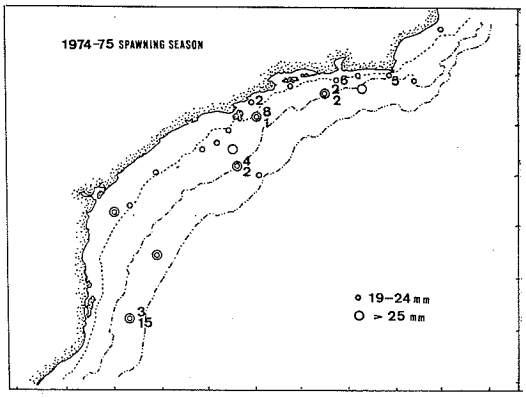

Fig. 7. Distribution of sardine juveniles and prejuveniles taken in 1974-75 spawning season.

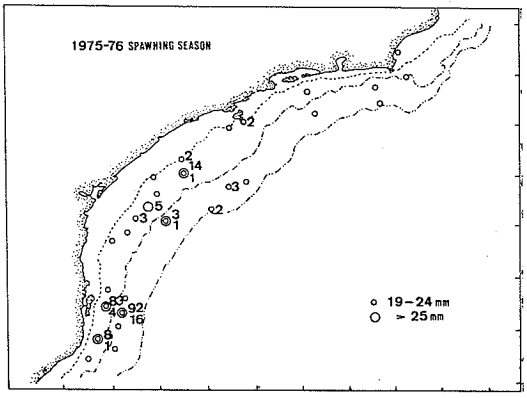

Fig. 8. Distribution of sardine juveniles and prejuveniles taken in 1975-76 spawning season.

would be expected in the coastal region. My observations indicate that both larvae and juveniles can live both in the tropical and coastal waters, but that the main habitat is the shelf water.

Size frequencies of larvae by subarea also showed no tendency of north-south inclination of larger larvae. The results seem to confirm a non-directional dispersal of larvae.

6. Temperature and salinity on the spawning and nursery grounds

Temperature and salinity at 10 m depth of the positive stations in which eggs were taken, are shown in Figure 9. During the two spawning seasons, the temperature ranged from 15.3 to

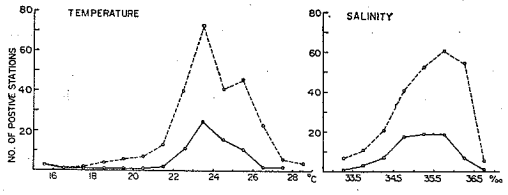

Fig. 9. Temperature and salinity ranges from all positive stations of eggs (solid line) and larvae (dash line).

28.3°C, with the mean temperature of 23.3°C. The salinity ranged from 33.4 to 36.9‰, with the mean salinity of 35.2‰. Most egg occurrences were at temperatures of 22–26°C and salinities of 34.5–36.0‰, which are characteristic of the shelf water.

Figure 9 also shows numbers of positive stations of larvae. The mean temperature and salinity for positive larva stations were 23.8°C and 35.4‰, respectively, which were a little higher than those of the eggs. The figure also shows an extension of occurrences at temperatures less than 20°C. This implies that some eggs and larvae were taken from the coastal upwelling area at which the temperature at 10 m depth was low.

7. Night-day catch ratio

In quantitative study of fish larvae, two sampling problems have to be considered: one is a "net avoidance" by large larvae during daytime and another is a "escapement" of small larvae through mesh opening. The undersampling ratio is dependent on type of sampling gear, towing velocity, fish species and larval size.

During a series of survey cruises, we used two types of plankton nets: the conical-cylinder type plankton net during 1969 through 1971, and the Bongo net during 1974 through 1976. The results of the data taken by the former net, were discussed in previous papers (MATSUURA, 1977a, b). The present study examined the night-day catch ratio of sardine larvae taken by the Bongo net during two spawning seasons. The materials collected during time period from 06:00 to 18:00 were considered as day-time samples and the other as night-time samples.

Total number of sardine larvae collected during night-time exceeded the day-time catch by 1.31 times. When compared with the value obtained with the conical-cylinder net (4.55 times), this value was very low, which demonstrates a better efficiency of the Bongo net for day-time sampling.

Mean number of larvae per positive stations for day and night times are shown in Table 5. In 1974–75 the night-day catch ratio was 1.07 and in 1975–76 it was 1.40.

Figure 10 shows the night-day catch ratio for different size classes of larvae collected from all routine stations. Up to 6.5 mm length class, the night-day catch ratio is approximately one. After that, the ratio increased to three in the 7.5–8.5 mm length classes and then decreased gradually down to less than two in the 19.5 mm length class.

Figure 11 shows the mean number of larvae given as a function of larval size in night and day hauls. The decreases in number of larvae with size for night and day hauls had a similar trend between 8.5 and 19.5 mm length classes.

Using the data taken during 1950 through

Table 5. Night-day catch ratio of sardine larvae collected by Bongo net.

Spawning season	Day			Night			N/D Ratio
	A	B	C	A	B	C	
1974—75	59	1855	31.4	45	1520	33.8	1.07
1975—76	77	6972	90.6	80	10142	126.8	1.40
Total	136	8827	64.9	125	11662	93.3	1.44

A = number of positive stations,
B = total larvae taken,
C = mean number of larvae per station.

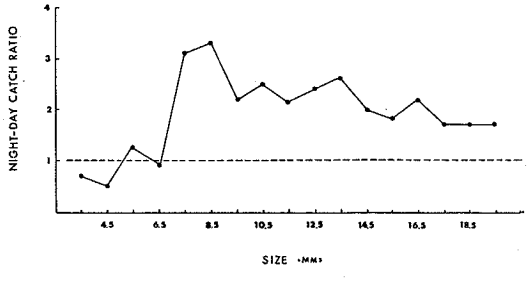

Fig. 10. Night-Day catch ratio of sardine larvae for different size classes, based on collections made in 1974 through 1976 with Bongo net.

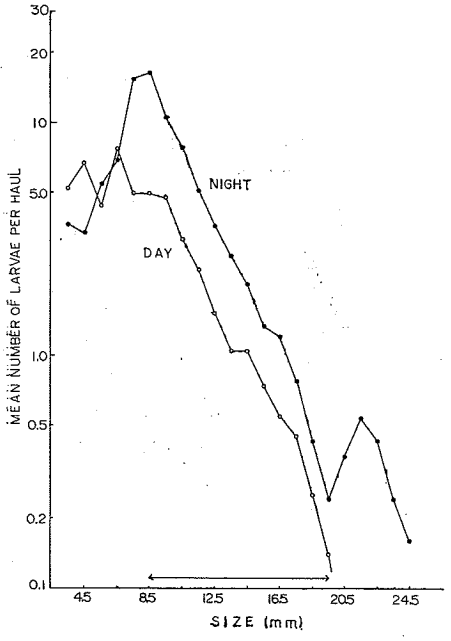

Fig. 11. Relative abundance of day-caught larvae and night-caught larvae, by size, based on the mean number of larvae per haul, during 1974 through 1976.

1958, AHLSTROM (1965) showed that the day-caught larvae exceeded the diminution in number of night-caught larvae for the small size classes (6.75 and 7.75 mm), and thereafter are uniformly lower in numbers. Following the same procedure of AHLSTROM, the diminution of night-caught larvae by size was calculated and plotted in Figure 12. The day-caught larvae exceeded the diminution in numbers of night-caught larvae for all size categories except the 18.5 mm length class. The result of Ahlstrom's and mine showed reverse relationship between day-caught larvae and the diminution in numbers of night-caught larvae by size. This seems to prove that the Bongo net has collected sardine larvae more efficiently during daytime than the CalCOFI net.

An attempt to estimate a mortality rate of larvae through size frequency data is not yet succeeded (MAY, 1974). Diminution in numbers of larvae by size is not equivalent to mortality, because the growth curve of fish larvae is not linear (HOUDE & PALKO, 1970; HUNTER, 1976). Therfore I calculated only a reduction coefficient from its size frequency distribution.

Figure 13 shows the size frequency distribution of larvae for two spawning seasons. Only night haul samples were used for calculation of reduction curve. Abundance of larvae decreased exponentially in both years as length increased. Exponential functions were fitted to data in size range from 8.5 to 25.5 mm length,

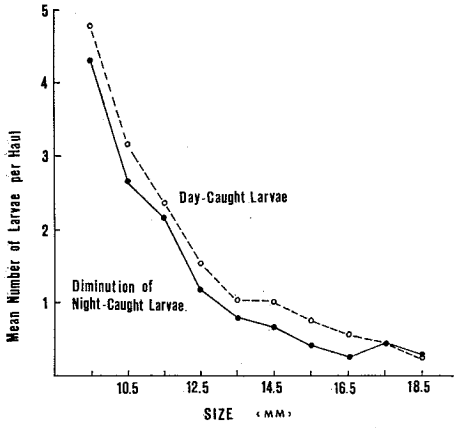

Fig. 12 Mean number per haul of day-caught larvae for each 1.0 mm size interval between 9.5 and 18.5 mm, compared to the diminution in numbers of night-caught larvae per millimeter of length over the same size range.

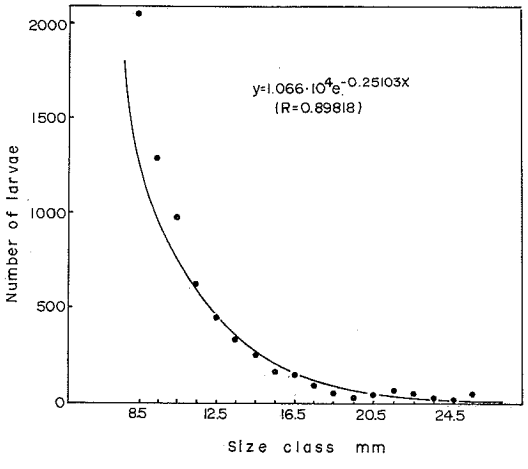

Fig. 13. Reduction curve adapted from the length-frequency distribution of sardine larvae taken during night-time in the southern Brazil. (R=coefficient of correlation)

giving estimates of the reduction coefficient in abundance of sardine larvae. The model is $y=a\cdot e^{-zx}$, where y=total number of larvae by size class, x=size class (mm), z=reduction coefficient and a=constant. The coefficients were $z=0.28670$ in 1974-75 and $z=0.27403$ in 1975-76 seasons.

8. Estimate of relative abundance of larvae

The occurrences of larvae during the survey cruises are given in Table 6. Using these data, the mean number of larvae per station was calculated and is shown in Table 7. The ratio of positive stations to all stations ranges from 24% to 80%. The ratio of positive stations for day hauls was 57% and that of night hauls was 54%. The result again confirms the efficiency of Bongo nets for daytime sampling.

In order to study relative abundance of larvae for each subarea, the regional census estimate of SMITH (1972) was applied for a three month period (November-December-January). The result is shown in Table 8. The estimate of larval abundance in 1974-75 season was generally low. The subareas VI (Santa Catarina), III (Ilha Grande) and I (São Tomé)

Table 6. Abundance of sardine larvae by cruise and by subarea, in 1974-1976 (Bongo net).

Subarea	I			II			III			IV			V			VI			Total		
Cruise	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Nov.-Dec. '74	14	8	333	14	6	67	26	10	79	28	17	284	22	12	412	35	19	705	139	72	1880
January '75	—	—	—	12	7	137	26	13	1220	17	12	138	—	—	—	—	—	—	55	32	1495
Nov.-Dec. '75	9	5	273	17	3	95	27	7	48	28	19	4755	22	11	546	37	14	980	140	59	6697
January '76	9	4	30	17	5	27	27	18	1463	28	26	6033	22	21	1556	37	24	1308	140	98	10417
Total	32	17	636	60	21	326	106	48	2810	101	74	11210	66	44	2514	109	57	2993	474	261	20489

A=number of stations occupied, B=number of positive stations, C=total number of larvae taken.
Subareas : I=São Tomé region, II=Rio de Janeiro region, III=Ilha Grande region,
IV=Santos region, V=Paranaguá region, VI=Santa Catarina region.

Table 7. Comparison of mean number of sardine larvae per station.

Spawning season	Subarea	I	II	III	IV	V	VI	Total
1974—75	(B/A)×100	57%	50%	44%	64%	55%	54%	52%
	C/A	24	8	25	9	19	20	18
	C/B	42	16	56	15	34	37	32
1975—76	(B/A)×100	50	24	46	80	73	51	56
	C/A	17	4	28	193	48	31	61
	C/B	34	15	60	240	66	60	109

A=number of stations occupied, B=number of positive stations,
C=total number of larvae taken.

Table 8. Reginal census estimate of sardine larvae taken during main spawning period of November-December-January. (unit: 10^9 larvae)

Spawning season	Subarea*	I	II	III	IV	V	VI	Total	No. of stations
	Area**	19,019	13,269	27,683	31,482	28,568	39,815	159,836	
1974—75		120	24	134	78	97	221	674	194
1975—76		87	17	246	1777	291	405	2418	280

*Subarea : I=São Tomé region, II=Rio de Janeiro region, III=Ilha Grande region,
IV=Santos region, V=Paranaguá region, VI=Santa Catarina region.
**Area : in square killometers

8) MATSUURA, Y. (1971): A study of the life history of Brazilian sardines, *Sardinella aurita*. I. Distribution and abundance of sardine eggs in the region of Ilha Grande, Rio de Janeiro. Bolm. Inst. oceanogr., S. Paulo, **20**, 33-60.
9) MATSUURA, Y. (1975a): A study of the life history of Brazilian sardine, *Sardinella brasiliensis*. II. Spawning in 1970 and 1971. Bolm. Inst. oceanogr., S. Paulo, **24**, 1-16.
10) MATSUURA, Y. (1975b): A study of life history of Brazilian sardine, *Sardinella brasiliensis*. III. Development of sardine larvae. Bolm. Inst. oceanogr., S. Paulo, **24**, 17-29.
11) MATSUURA, Y. (1977a): O ciclo de vida da sardinha-verdadeira. (Introdução à oceanografia pesqueira). Publção esp. Inst. oceanogr. S. Paulo, São Paulo, **4**, 1-146.
12) MATSUURA, Y. (1977b): A study of the life history of Brazilian sardine, *Sardinella brasiliensis*. IV. Distribution and abundance of sardine larvae. Bolm. Inst. oceanogr., S. Paulo, **26**, 219-247.
13) MATSUURA, Y. (1977c): A study of the undersampling problem of fish larvae observed at the fixed stations in south Brazil. Bolm. Inst. oceanogr., S. Paulo, **26**, 273-283.
14) MAY, R. C. (1974): Larval mortality in marine fishes and the critical period concept. *In:* The early life history of fish, ed. J. H. S. Blaxter, Springer-Verlag (Berlin), 3-20.
15) PDP/SUDEPE (1977): Relatório da reunião do grupo permanente de estudos sobre sardinha. PDP/SUDEPE, 1-11.
16) SMITH, P. E. (1972): The increase in spawning biomass of Northern anchovy, *Engraulis mordax*. U. S. Fish. Bull., **70**(3), 849-874.
17) SMITH, P. E. (1973): The mortality and dispersal of sardine eggs and larvae. Rapp. P. -v. Réun. Cons. perm. int. Explor. Mer, **164**, 282-292.
18) TANAKA, S. (1955): Estimation of the abundance of the eggs of fish such as sardine. I. Method of estimation by the vertical haul of plankton net. Bull. Jap. Soc. Sci. Fish., **21**(6), 382-389.
19) TANAKA, S. (1973): Stock assessment by means of ichthyoplankton surveys. FAO Fish. Tech. Paper, **122**, 33-51.