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

(Received 3/19/1971)

YASUNOBU MATSUURA
Instituto Oceanográfico da Universidade de São Paulo

SYNOPSIS

Distribution and abundance of sardine eggs in the Ilha Grande region, Rio de Janeiro, Brazil, were studied during five cruises for the 1969 - 1970 period. Using the shipboard fertilized eggs and the planktonic eggs, morphological descriptions of Brazilian sardine eggs are given.

Spawning occurs during the summer from September to March in the coastal water off Ilha Grande to Ilha de São Sebastião down to a depth of 100 meters. Spawning may take place a few hours prior to midnight.It was noticed that spawning has a close relationship to an area of cold water upwelling. Spawning groups are isolated and spawning is small in scale in this region. Temperature and salinity in the spawning area range between 18-24°C and 35.1-35.9°/oo respectively.

INTRODUCTION

Although the sardine is one of the most important commercial fishes,little was known concerning their spawning areas along the South Central Brazilian Coast. The spawning season of the Brazilian sardine is during the summer from October to March (Moraes, 1963; Vazzoler & Vazzoler, 1965).

Sardine fishing netted a total landed weight of 54,700 ton in 1968 (SUDEPE,1969). Fishing is done by purse seine ("traineira") in the region from Cabo Frio (23°00'S - 42°00'W) to Ilha de Santa Catarina (27°35'S-48°30'W).

Using Richardson & Sadowsky's work (1960), as a basis, a correlation was made between the landing of larger sardines in Rio de Janeiro (22°55'S-43°10'W) and the small sardines landed in Cananéia (25°00'S-47°55'W), the previous year.

Richardson (1959) stated: "the length distribution of the sardine landed at Santos (23°58'S-46°18'W) and Rio de Janeiro shows that larger fish are caught at Rio de Janeiro than at Santos. The fish at Santos, are shown to be mainly virgin or maturing fish whereas in the Rio de Janeiro samples the majority are more mature and closer to spawning."

These facts indicated that sardine spawning may be occurring in the region of Ilha Grande (about from Long. 43°30'W to 45°10'W) which is a main fishing ground for

Publ. no. 308 do Inst. Ocean. da USP.

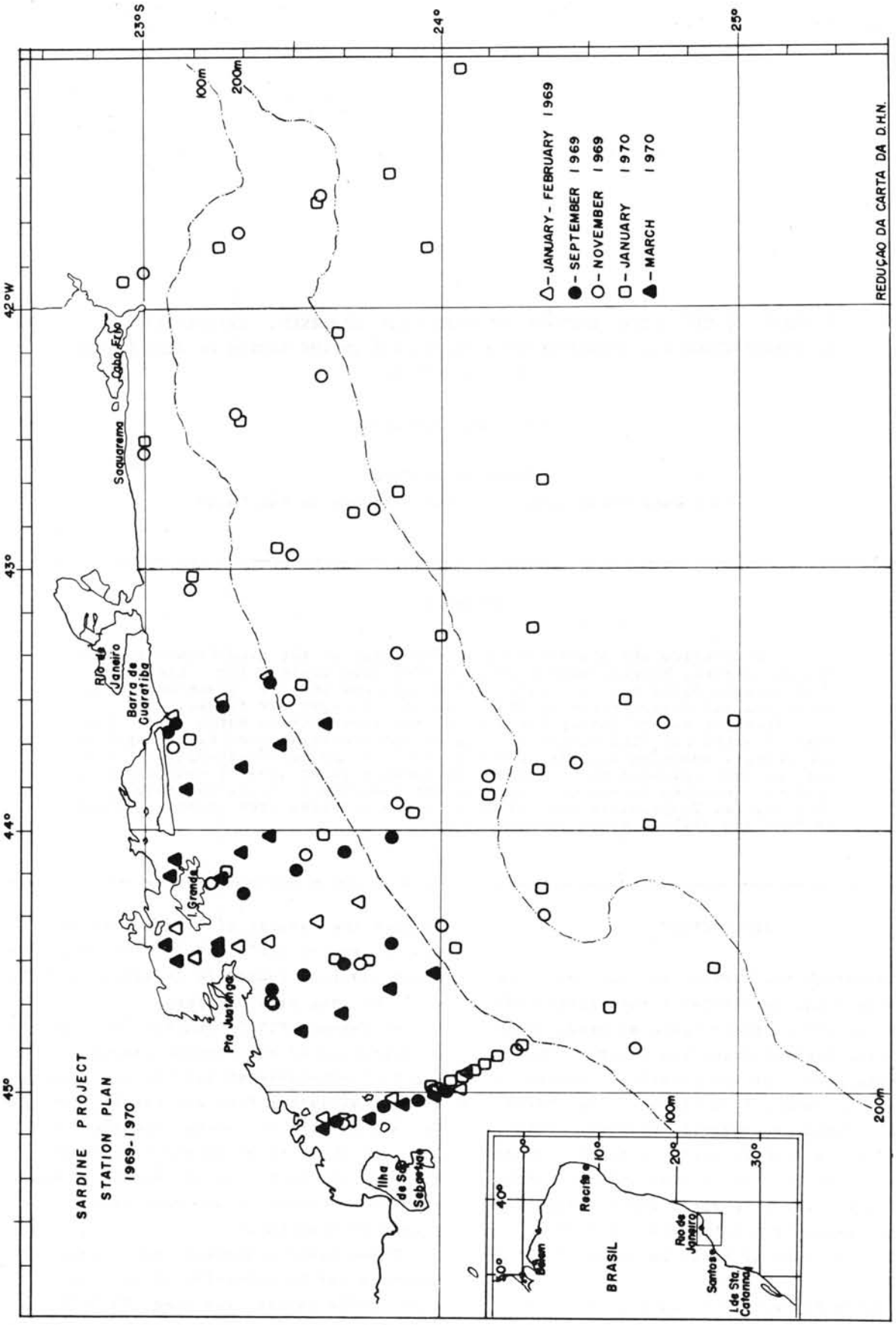

FIG. 1 - Locations of stations occupied during survey cruises made in 1969-1970.

the fleet from Rio de Janeiro. In order to test this possibility, fishing surveys and hydrographic works were done in the offshore area of Ilha Grande, Rio de Janeiro.

SHIPBOARD DATA COLLECTION

A preliminary cruise was made in January-February 1969 with the R/V "Emília". On this cruise, many sardine eggs were collected. In the next spawning season, 1969-1970, four cruises were made from September 1969 to March 1970. The cruises of September 1969 and March 1970 were realized by the R/V"Emília" in the region extending from Barra de Guaratiba (23°05'S-43°35'W) to Ilha de São Sebastião (23°50'S-45°20'W) down to a depth of 100 m. Those of November 1969 and January 1970 were done by the R/V "Prof. W. Besnard" on the continental shelf and open sea from Cabo Frio to Ilha de São Sebastião. Stations located during the five cruises are shown in Figure 1.

The net used to take samples was of the conical-cylinder type with a 113 cm mouth diameter with nylon monofilament gauze (mesh aperture 390x460 micra after use) as recommended by UNESCO (1966). To measure the strained water volume, a small flow meter was fixed 25 cm inside the net hoop.

In the preliminary cruise (January - February 1969) the net was horizontally towed at about two knots in the surface layer for five minutes. Fourteen stations and one fixed station of 24 hours duration were sampled.

In other cruises the sampling was done by vertical hauls at depths from 80 m to the surface or when the sea depth of the station was less than 80 m , from near the sea bottom to the surface. The net was towed by a hydromatic winch at 0.8 to 1.0 m/sec. During the tows, the ship was un - avoidably influenced by both currents and winds.

On the twenty two stations at which sea depths were more than 100 m, a closing type plankton net was used to collect eggs and larvae of the deeper layer.

A total of 178 samples were collected from 147 stations.

Oceanographic observations, i.e. the profiles of temperature, salinity and dissolved oxygen were made at each station.

During the cruise, an echo sounder was used continuously and when a fish school appeared in the middle layer, fishing with an otter trawl net or with a gill net was tried.

RESULTS AND DISCUSSION

IDENTIFICATION OF EGGS

FERTILIZED EGGS - At the Ponta de Juatinga station (23°44'S - 44°30'W), on January 15, 1970, at a depth of 65 m, sixteen adult sardines were caught by otter trawl net. Fifteen were females with ripe ovaries and one was male. Body lengths ranged from 184 to 201 mm.

In the ovary of one of the females,translucent eggs were recognized and artificial fertilization was tried by the wet method aboard ship at a room temperature of 25° C.

Thirty minutes after fertilization some eggs swelled and had a large perivitelline space. The perivitelline space at one side of the animal pole was larger than the other. The oil globule was found at the vegetal pole, and its color was yellow and translucent. Yolk was whitish yellow and segments on the yolk were recognized (See Figure 2).

It was not confirmed if our eggs were successfully fertilized or not, but some eggs started to develop. Parthenogenesis is known in the clupeid fishes (Blaxter & Holliday, 1963). Many of the unfertilized eggs of herring, when placed in sea water, start to develop and some of them follow a pattern of apparently normal development, producing active embryos (Volodim, 1956). In our samples, after fifty minutes, normal eggs started their first cleavage, while, on the other hand, some eggs already showed abnormal development. After four hours all the embryos stopped developing. After six hours all eggs showed abnormal development and were then fixed in a formalin solution. Table I shows the dimensions of the artificially fertilized eggs.

PLANKTONIC EGGS - The identification of planktonic eggs is based on a comparison between the shipboard fertilized eggs and the description of sardine eggs by other authors.

All the planktonic eggs of the five

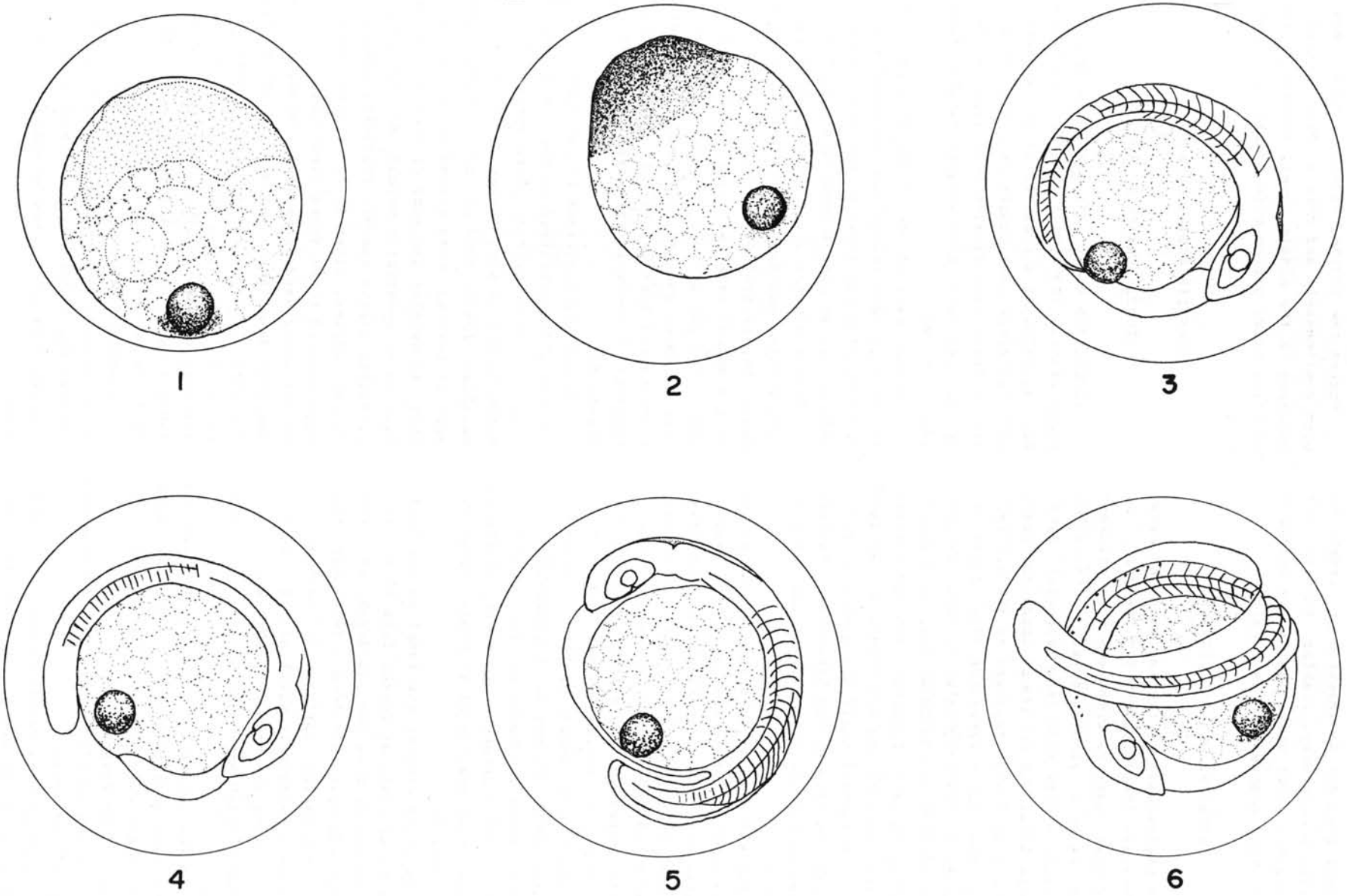

FIG. 2a - Sardine eggs of different developmental stages. Artificial fertilized egg: 1 - stage Aa. Planktonic eggs: 2 - stage Aa; 3 - stage Bb; 4 - stage Bc; 5 - stage Ca; 6 - stage Cb.

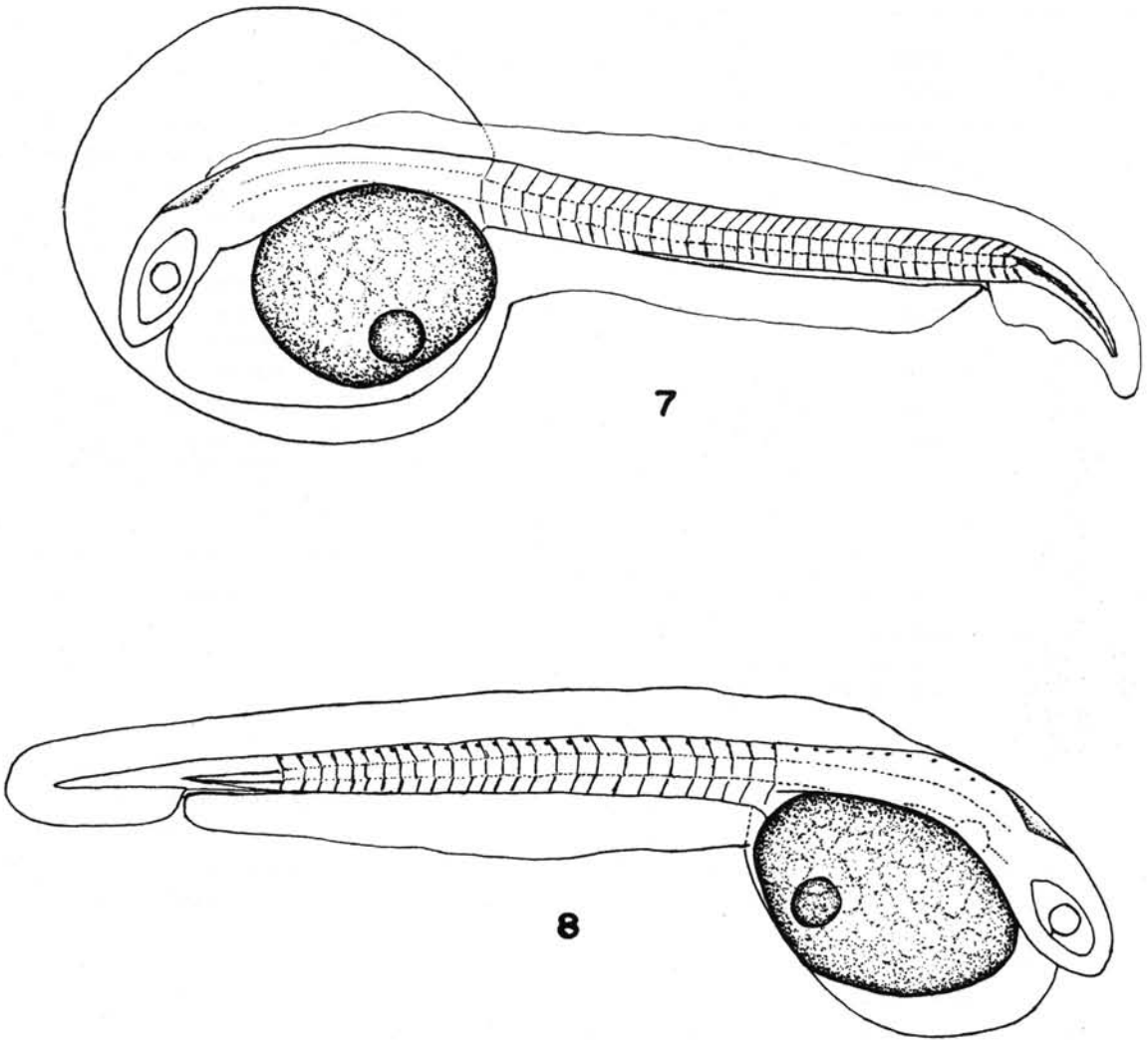

FIG. 2b - 7 & 8 - Planktonic eggs newly hatched.

cruises were maintained separately according to their particular spawning groups and distribution. Furthermore, they were related in time based on the study of their developmental stage. The distribution of egg diameters of each spawning group is shown in Figure 3.

The eggs were measured in an ocular micrometer by a binocular microscope. For egg diameters, a magnification of 25 (ocular unit: 0.040 mm) was used, and in case of oil globules a magnification of 50 (ocular unit: 0.0202 mm) was used. Fifty or more eggs in each spawning group were measured.

Distribution of egg diameters show small differences within each developmental stage (Fig. 3). The egg diameters of the cruise January-February 1969 are smaller than those measured from other cruises. The eggs of the former cruise were measured fourteen months after sampling. The eggs of the other four cruises of the next spawning season were measured four months after sampling. Differences may be caused by an influence of preservation time in a formalin solution.

To describe the egg morphology, only those collected during the four cruises of the 1969-1970 season were used.

Embryonic development resembled those described for sardine species from other regions of the world (Kamiya, 1916;Delsman, 1926; D'Ancona, 1937; Nakai, 1962; Simpson & Gonzales, 1967). The developmental stages

TABLE I - Dimensions of fertilized eggs of mature sardines from Ilha Grande

Serial number of individual eggs	Egg diameter (mm)	Oil globule diameter (mm)	Embryo diameter (mm)	Fixed time* (h)	Observation
1	1.195	0.152	0.911 - 0.891	14:30	Normal development
2	0.860	0.142	0.648 - 0.688	14:30	Perivitelline space narrow
3	1.092	0.117	0.870 - 0.790	16:30	Normal development
4	1.183	-	0.931 - 0.911	16:30	Normal development
5	0.981	-	0.931 - 0.931	16:30	Perivitelline space narrow
6	0.780	0.111	0.568 - 0.568	16:30	Embryo abnormal
7	1.052	-	- - -	18:45	Embryo abnormal
8	1.265	0.182	- - -	20:00	Embryo shows abnormal development after first cleavage
9	1.002	0.142	- - -	20:00	Idem
Average	1.037	0.141	0.810 - 0.796		

* Eggs were fertilized at 14:00 h of January 15, 1970

Mean egg diameter is smaller than the planktonic eggs because these fertilized eggs include some abnormally developed whose perivitelline space did not elevate.

of the embryo were classified by Nakai(1962), i.e. stage A includes the egg both unferti - lized and fertilized. The fertilized eggs are specified by Aa, Ab and Ac from the earliest stage of development up to closure of the blastopore. Stage B includes stages from the end of A up to the beginning of the separation of the tail bud from the yolk. B may be substituted for the subdivisions Ba, Bb and Bc. Stage C extends the end of B to hatching and is divided into Ca and Cb.

The egg stages observed in this investi- gation were Aa, Ba, Bb, Bc, Ca, Cb and newly hatched larva, as shown in Figure 2.

MORPHOLOGICAL DESCRIPTION

The eggs are spherical with a thin, unsculptured, translucent membrane faintly pink, blue or green in color. The eggs of the four cruises have a mean egg diameter of 1.18 mm, with a range of individual eggs between 1.00 - 1.32 mm. The range of the mean egg diameters for each spawning group was between 1.143 to 1.207 mm. The 99% confidence limit of these sample means was 1.180± 0.008 mm, or a range of between 1.172 to 1.188 mm.

The eggs have a wide perivitelline space with a mean width of 0.143 mm and range from 0.061 to 0.254 mm.

Yolk mass is spherical and irregular segments were recognized on the surface of the yolk mass. The size of the segments is smaller than the oil globules.

Generally, the eggs have only one oil globule but specimens with two or three were also found. In stage Aa of development, the oil globule is situated at the vegetal pole, in stage B and Ca near the tail of the embryo in the yolk mass and in stage Cb and newly hatched larva, at the center of the ventral side of the yolk mass. Oil globules are spherical but often they are not of the regular spherical type. In this case the diameter of the oil globule measur- ed the mean between the long and short axis. The distribution of the oil globule diameters at each stage is shown in Figure 4. Diameter of the oil globules decreases as development proceeds. Mean oil globule diameter is 0.140 mm, with a range between 0.091 to 0.182 mm.

Pigmentation of the embryo was recog - nized in stage B and C in the dorsal part of the embryo.

DISTRIBUTION AND ESTIMATED ABUNDANCE OF SARDINE EGGS

Estimated abundance of sardine eggs by stations in the five cruises is given in Table II. The distribution and density of

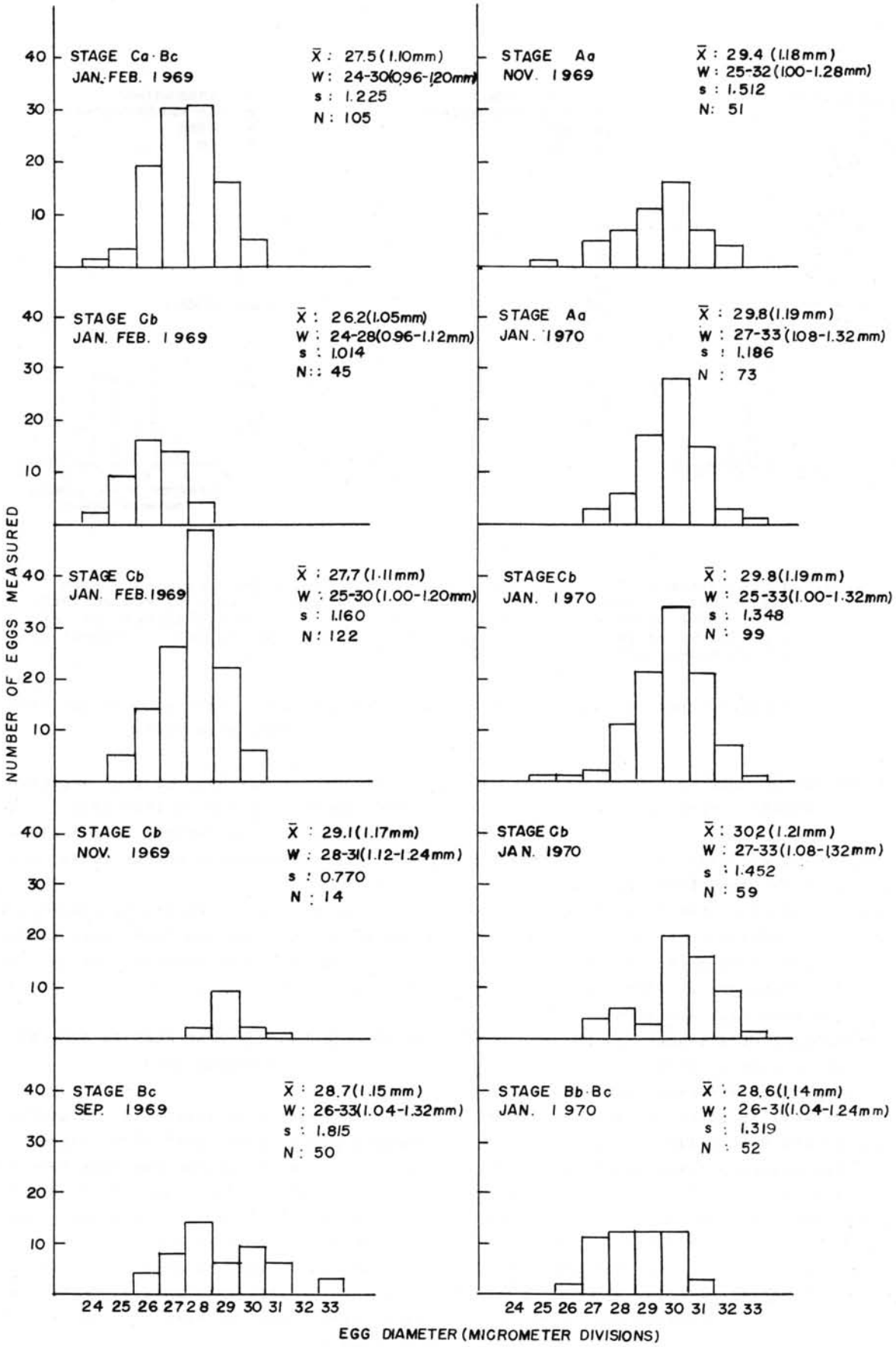

FIG. 3 - Diameter distributions of sardine eggs of each spawning group in 5 cruises during 1969-1970 surveys from Ilha Grande region. (1 micrometer division: 0.040 mm). $\bar{x}$: Mean egg diameter; w: Range distribution; s: One standard deviation; N: Total number of eggs measured.

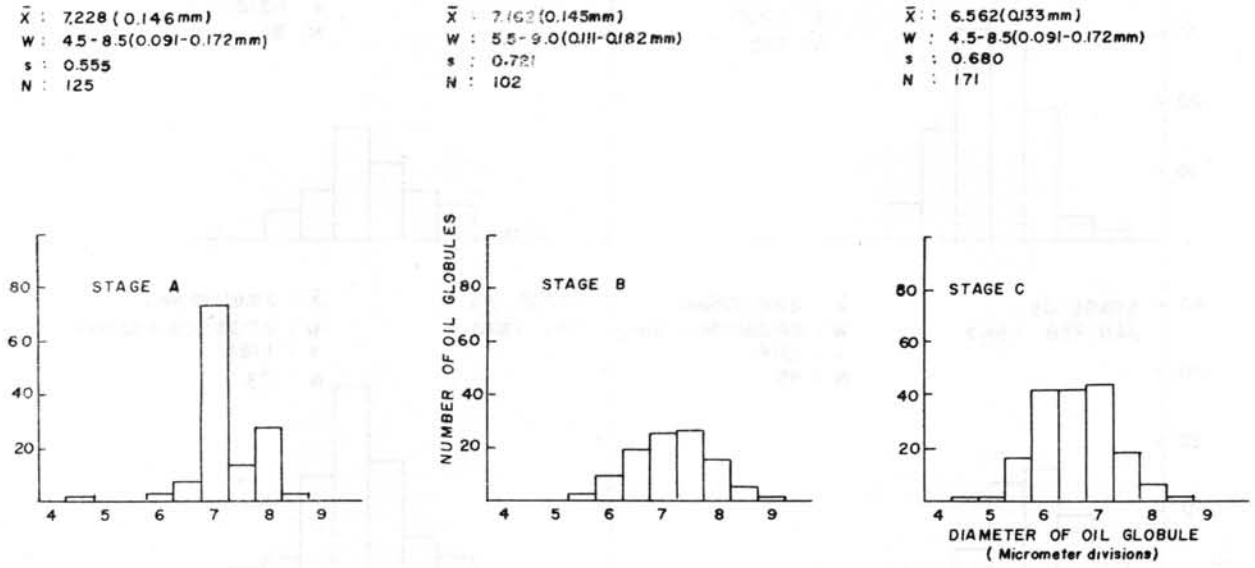

FIG. 4 - Distribution of the oil globule diameters of planktonic eggs in each developmental stage of embryo, from four cruises in spawning season 1969-1970. (One micrometer division: 0.0202 mm). $\bar{x}$: Mean diameter of oil globule; w: Range distribution; s: One standard deviation; N: Number of oil globules comprising the distribution.

sardine eggs is illustrated in Figures 5, 6, 7, 8 and 9.

DISTRIBUTION OF SARDINE EGGS IN THE CRUISE JANUARY - FEBRUARY 1969

The cruise was made in an active spawning period of the 1968-1969 season as a preliminary survey of the Ilha Grande region. Samplings of plankton on this cruise were done by horizontal haul in daytime from January 30 to February 5, 1969. Developmental stages of sardine eggs appearing in the plankton samples were stages Bc, Ca and Cb.

As can be seen in Figure 5, eggs occurred at the stations south of Ponta de Juatinga as well as south of Barra de Guaratiba and in the Bay of Ilha Grande.

Sardine spawning takes place during the four hour period prior to midnight and, therefore, the eggs can be classified in different nightly age categories.

The eggs of this cruise were grouped into three different spawning groups based on their stage of development and distribution in the sea.

DISTRIBUTION OF SARDINE EGGS IN THE CRUISE SEPTEMBER 1969

This cruise was made at the beginning of the spawning season of 1969-1970. The sampling was done in daytime from September 26 to 30. Developmental stages found were Bc and Ca.

As can be seen in Figure 6, sardine eggs occurred at only two stations south of Ponta de Juatinga. Only one spawning group was recognized.

DISTRIBUTION OF SARDINE EGGS IN THE CRUISE NOVEMBER 1969

To cover a large region in an active spawning month in the 1969-1970 summer season, the second cruise was made from Cabo Frio to Ilha de São Sebastião from November 21 to 25, 1969. The sampling was done continuously, both day and nighttime. Developmental stages found were Aa and Cb.

As can be seen in Figure 7, dense spawning occurred south of Ponta de Juatinga (23 n.m. from the coast).

TABLE II - Estimated number of sardine eggs by station

Sample No.	Date	Time	Position	Local depth (m)	10 m depth Temper. (°C)	10 m depth Salinity °/oo	Sampling method**	Eggs dev. stage+	Total no. eggs / plankton sample	Volume filtered water(m^3)	No.eggs /100m^3
			CRUISE JANUARY 30 - FEBRUARY 5 1969								
138	30/1	14:15	23°15'S-43°30'W	62	(27.2)*	-	H	Cb	52	(310)	17
139	30/1	16:10	23°25'S-43°26'W	99	(26.9)*	-	H	Cb	70	(310)	23
152	2/2	08:00	23°10'S-44°28'W	32	(28.6)*	-	H	Cb	337	(310)	109
								Ca	38	(310)	12
153	2/2	11:00	23°25'S-44°26'W	65	(29.1)*	-	H	Ca	10,816	(310)	3,490
154	2/2	13:00	23°34'S-44°21'W	62	(28.5)*	-	H	Ca	2,220	(310)	716
								Bc	493	(310)	159
			CRUISE SEPTEMBER 26-30, 1969								
219	28/9	14:20	23°39'S-44°30'W	62	21.2	35.87	V	Bc	1,120	(35)	3,200
220	28/9	15:50	28°32'S-43°33'W	48	20.9	35.77	V	Ca	1	(35)	3
			CRUISE NOVEMBER 21-25, 1969								
239	22/11	03:20	23°00'S-42°33'W	52	18.6	35.8	V	Aa	1	41	2
259	23/11	22:40	23°33'S-44°02'W	82	19.5	35.6	V	Cb	1	95	1
269	24/11	19:10	23°14'S-44°12'W	43	23.6	35.4	V	Cb	9	47	19
270	25/11	00:30	23°25'S-44°39'W	42	23.0	35.2	V	Cb	4	135	3
271	25/11	02:45	23°43'S-44°30'W	74	23.6	35.5	V	Aa	6,020	59	10,130
279	25/11	23:00	23°39'S-45°07'W	31	23.2	35.1	V	Aa	1	38	3
			CRUISE JANUARY 6-16, 1969								
326	15/1	05:00	24°03'S-44°27'W	125	21.6	35.74	V	Cb	52	111	47
329	15/1	15:00	23°38'S-44°30'W	62	-	-	H	Bc	40	176	23
								Bb	10	176	6
330	15/1	15:55	23°25'S-44°39'W	42	19.3	35.23	V	Bc	6	32	19
333	15/1	22:45	23°58'S-44°58'W	72	17.6	35.33	V	Cb	6	68	9
334	16/1	00:45	24°00'S-44°57'W	72	-	-	V	Cb	28	64	44
								Aa	225	64	396
335	16/1	01:10	24°01'S-44°56'W	72	-	-	V	Cb	182	121	150
								Aa	104	121	86
336	16/1	01:25	24°03'S-44°55'W	72	-	-	V	Cb	127	39	325
								Aa	14	39	36
337	16/1	01:50	24°05'S-44°54'W	72	-	-	V	Cb	10	56	18
			CRUISE MARCH 21-28, 1970								
370	28/3	07:50	24°06'S-44°56'W	70	24.4	35.65	V	Ba	1	146	1

* Surface water temperature
** Sampling method: V - vertical haul; H - horizontal haul
\+ According to Nakai, 1962
++ Volume of filtered water calculated from flow meter readings except for cruises Jan.-Feb. 1969 and Sep. 1969 which was calculated by (towing distance) x (mouth area of plankton net) because the flow meter was not used and the estimated number of eggs per 100 m^3 was computed for comparative purposes.

Eggs of different age category representing other groups, were collected at two stations closer to Ponta de Juatinga and Ilha Grande. From 12 samples, made every two hours, on a routine station to the south of Ilha Grande, only one egg was collected at 22:40 h.

A third spawning group was observed at a station north-east of Ilha de São Sebastião.

A fourth spawning group was observed near Saquarema, Rio de Janeiro.

In all, four spawning groups were found on this cruise.

DISTRIBUTION OF SARDINE EGGS IN THE CRUISE JANUARY 1970

A third cruise in the same region as the second cruise (November 1969) sampled day and nighttime from January 5 to 16, 1970.

The distribution of eggs found on this cruise is shown in Figure 8. Dense spawning occurred at the station 20 n.m. south-east of Ilha de São Sebastião. From this station, five extra samples were taken from 70 m to the surface. The distance between the special samples was 2 n.m. From these samples, two different age categories of eggs were col-

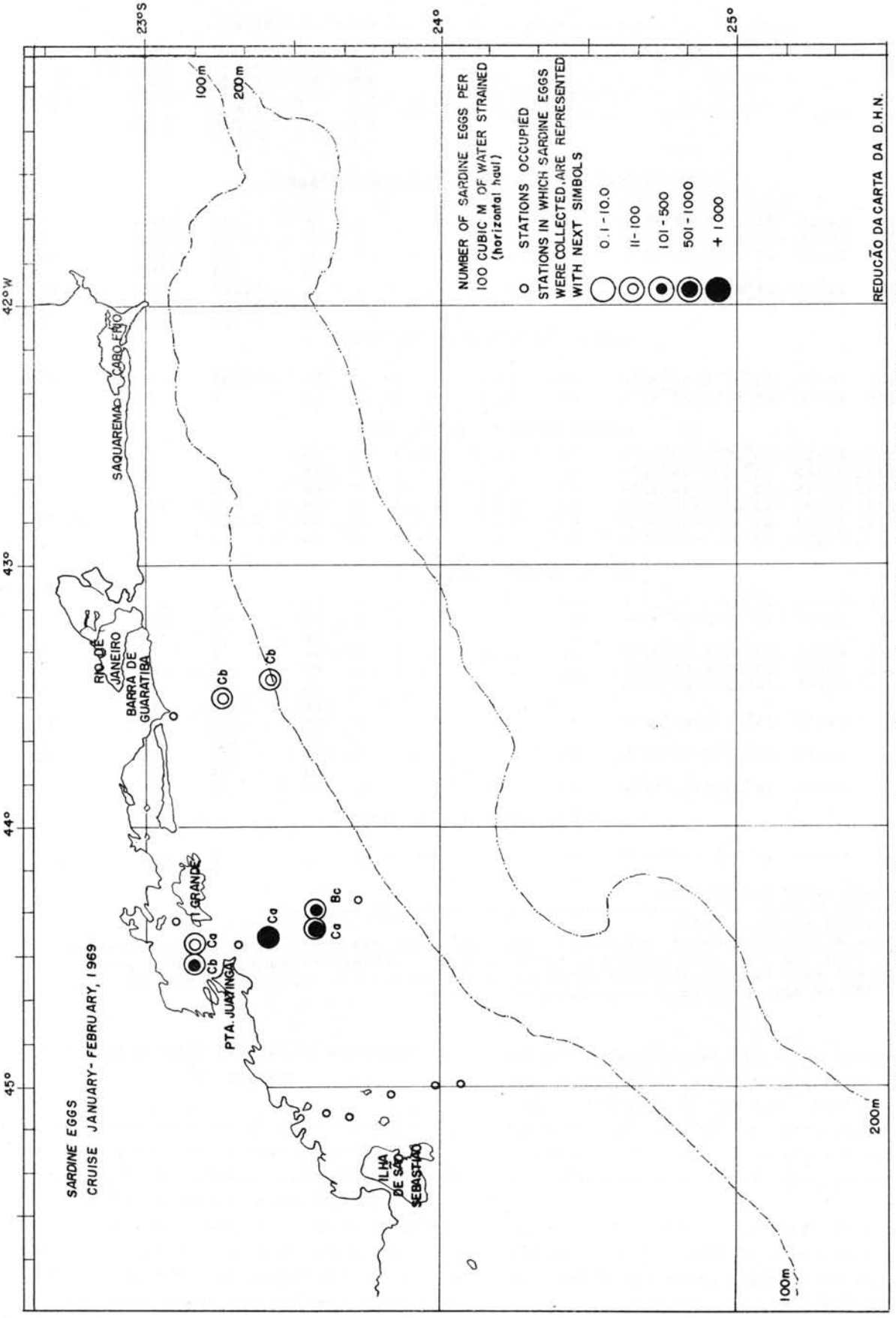

FIG. 5 - Distribution and abundance of sardine eggs in the cruise January - February 1969. (Alphabet under large circle shows a developmental stage of eggs)

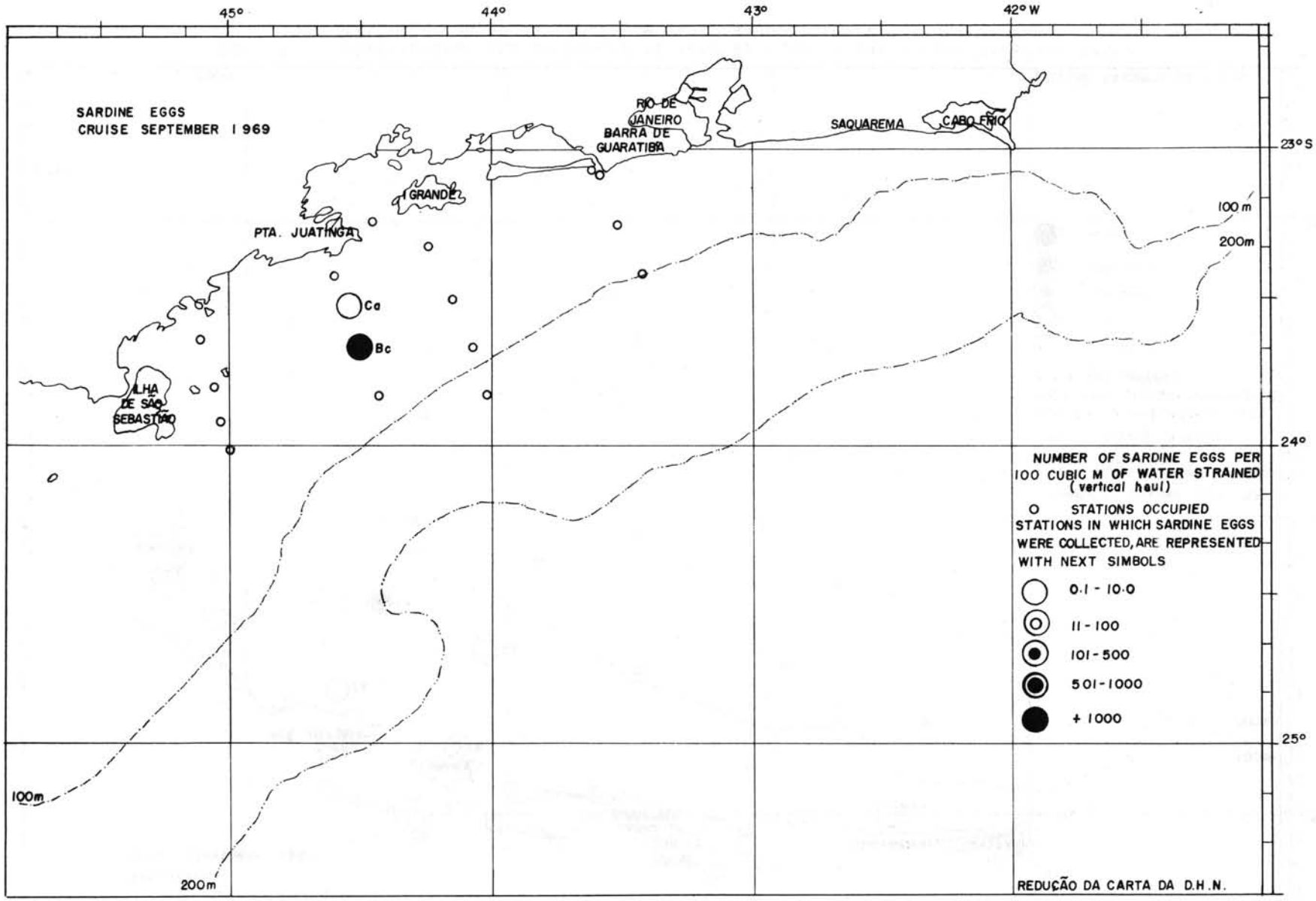

FIG. 6 - Distribution and abundance of sardine eggs in the cruise September 1969. (Alphabet under large circle shows a developmental stage of eggs).

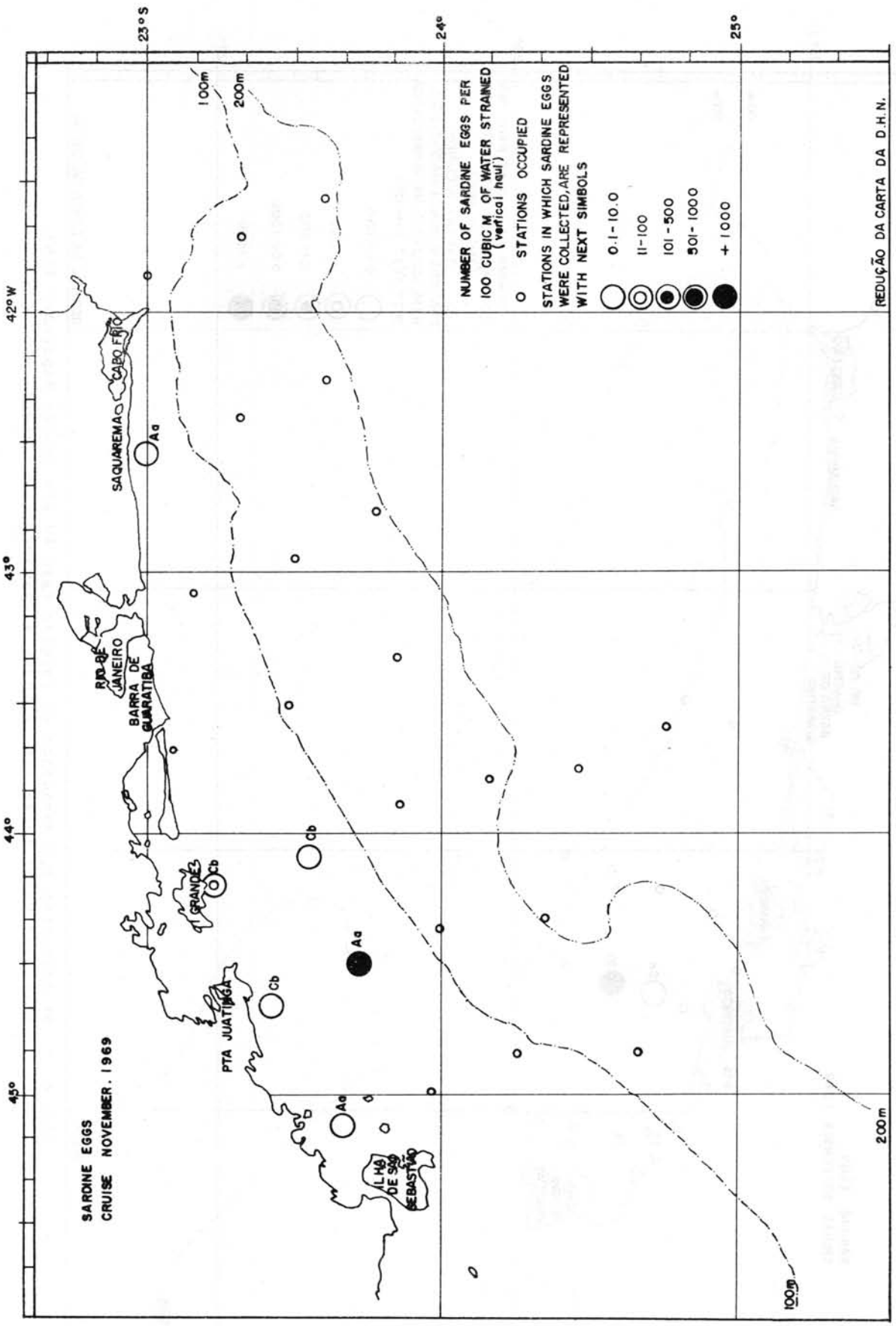

FIG. 7 - Distribution and abundance of sardine eggs in the cruise November 1969. (Alphabet under large circle shows a developmental stage of eggs).

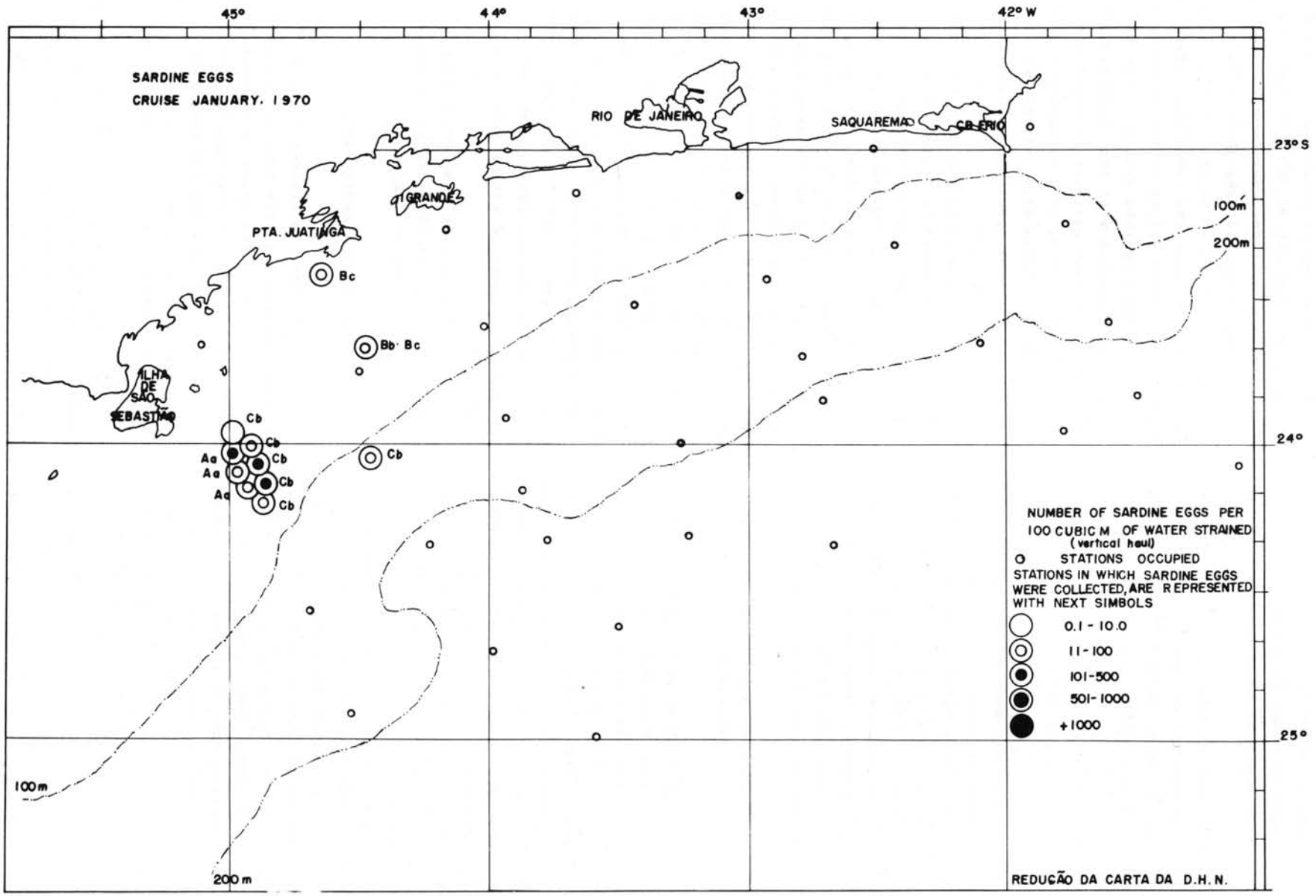

FIG. 8 - Distribution and abundance of sardine eggs in the cruise January 1970. (Alphabet under large circle shows a developmental stage of eggs).

lected (stage Aa and Cb).

Some eggs of stage Bb and Bc were collected on the stations south of Ponta de Juatinga.

On this cruise, however, no eggs were collected off the Rio de Janeiro and the Cabo Frio region. Three spawning groups were recognized in this third cruise.

DISTRIBUTION OF SARDINE EGGS IN THE CRUISE MARCH 1970

This cruise was made at the end of the 1969-1970 spawning season. The sampling was done in daytime from March 21 to 28, 1970. Only one egg was collected on the station 20 n. m. south-east of Ilha de São Sebastião (Fig. 9). Developmental stage of the egg was Ba and the embryo shows abnormal development. Sardine spawning in this region had come to an end for the 1969-1970 season.

SPAWNING AREA IN THE SUMMER SEASON OF 1969-1970

In the subtropical and temperate zones, the length of time required by sardine eggs to develop to the hatching stage is generally from 2 to 4 days (Ahlstrom, 1943; Ito, 1958). Nakai (1962) studied the development time of Japanese sardine eggs under different temperature conditions and concluded that they require from 38 to 50 hours in water temperatures between 20.3 to 17.5 °C respectively. To the end of stage Aa,4 hours, and to the end of stage Bc, 16 to 25 hours were required.

During our study, which was carried out at six stations, the eggs of stage Aa, which may have reached this stage in the 4 hours before collection, were collected at 23:00, 00:45, 01:10, 01:25, 02:45 and 03:20 h. It is well known that sardines spawn during a certain time of the day, i.e. generally from 20:00 to 24:00 h. Facts appear to confirm a similar spawning time for Brazilian sardines. Therefore, each daily spawning group can be classified into different age categories.

At a depth of 10 m, on the stations in the spawning area, the water temperatures vary between 18 to 24°C. If the time of development of Brazilian sardine eggs is similar to that of Japanese sardine's, we can assume that two or three days are needed for them to hatch out at these temperatures. Within these conditions, development to the end of stage Bc should take about a day.

The stations at which eggs of stage A were collected, were the immediate spawning ground. Scant data exists on the velocity of surface currents in this region. Based on verbal communication with Mrs. Luedemann*, the velocity of surface currents is about 4 n.m. per day in the region of Ilha Grande in the summer season. Using this information we can assume that the spawning occurred very close to the stations.

The spawning area of the 1969-1970 summer season is illustrated in Figure 10 by diagonal lines. The stations at which many sardine eggs were collected and which sampled eggs on more than one cruise, are indicated by cross-lines as intensive spawning grounds.

From Figure 10, it can be seen that the spawning area lies between Latitude 24°10'S and Longitude 44°00'W and the coast, which coincides approximately with the continental shelf between Ilha de São Sebastião to Ilha Grande down to the 100 m depth line. To the east of Longitude 44°00'W (i.e. the region of Rio de Janeiro and Cabo Frio),no samples were collected with the exception of a small spawning group near Saquarema on the cruise of November 1969. In the Bay of Ilha Grande and beyond the 100 m depth mark, no spawning was observed during this spawning season.

The most intensive spawning ground was found south-east of Ilha de São Sebastião and south of Ponta de Juatinga.

SIZE OF SPAWNING GROUP

As can be seen in Figures 5, 6, 7, 8 and 9, spawning was far from uniform throughout the area. Most of the spawning occurred from the south of Ponta de Juatinga to Ilha de São Sebastião. Since the egg concentration was very high in a relatively small area, there were high counts from relatively few stations.

The daily spawning was observed in the spawning area. This fact confirms Besnard's statement (1950) that a series of consecutive spawning take place in this region.

---

* LUEDEMANN, E.F. Inst. Oceanogr. da USP

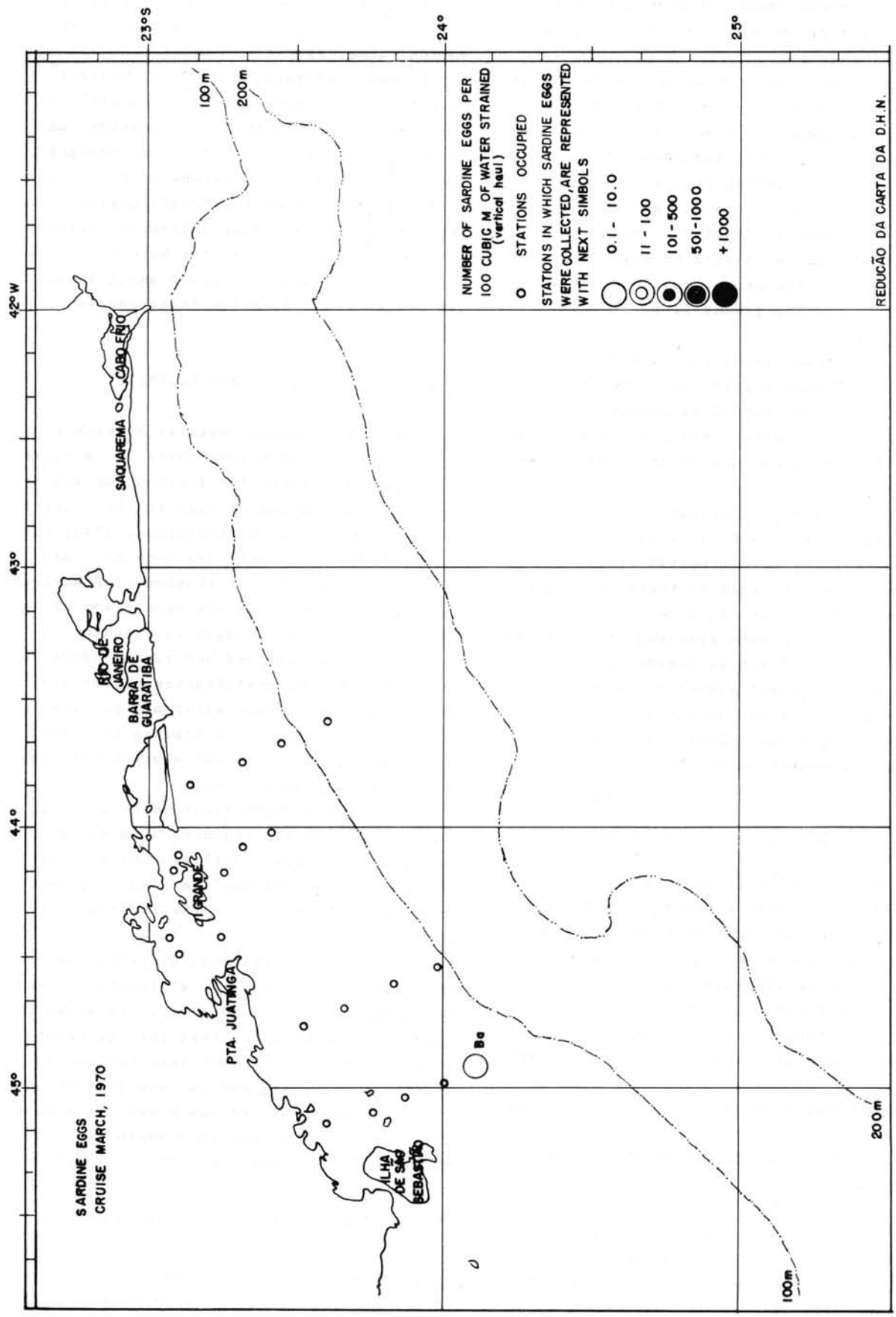

FIG. 9 - Distribution and abundance of sardine eggs in the cruise March 1970. (Alphabet under large circle shows a developmental stage of eggs).

The maximum number of spawning groups found on any cruise was four. The possibility exists that small spawning groups were not found since the station intervals varied between 7 to 25 n. m. Comparing the size of spawning groups in spawning areas off California (Sette, 1948) and Japan (Ito, 1961) with Brazilian spawning groups, we see that the latter are not as large, and we assume that daily spawning density is much lower.

The abundance of sardine eggs versus the vertical temperature profile in the intensive spawning ground is plotted in Figure 11.

In the study area, to estimate the abundance of eggs within each spawning group, we cannot use the method of computation which was designed by Sette (1948), for the reason of the discontinuous distribution of spawning groups.

On the cruise of January 1970, five extra stations, each 2 n. m. apart, were sampled. Eggs of developmental stage Aa were collected at three of these and stage Cb were collected at all five. The distribution of eggs of each spawning group in the sea may be visualized in Figure 12. Using this data, the total number of eggs was calculated. The total number of eggs (V) of each spawning group referenced to the developmental stages Aa and Cb, are:

$$V_1 = 8.24 \times 10^9 \quad \text{(stage Aa)}$$

$$V_2 = 9.78 \times 10^9 \quad \text{(stage Cb)}$$

These estimates assume that the sampling line cuts across a center of distri - bution of eggs and that this distribution is circular. But since, in reality, the distribution is irregular and the center line probably does not cross the exact center, the total number of eggs spawned is probably somewhat higher than this estimate.

ENVIRONMENTAL FACTORS OF THE SPAWNING AREA

GEOGRAPHY OF THE REGION FROM CABO FRIO TO ILHA DE SÃO SEBASTIÃO

To the north of Cabo Frio, the continental shelf is only about 40 n. m. wide. A main branch of the Brazil Current coming from the north passes near the coast. To the west of Cabo Frio the continental shelf is broad with a width of about 80 n. m. in front of Ilha Grande. The continental shelf is used as fishing ground for sardines and various other species of fish.

It was confirmed by Prof. F. Shaffer* that there are submarine canyons, off Cabo Frio and off Ilha Grande. A submarine canyon together with other factors, i.e. changes in the wind system, oscillations of the main axis and strength of the Brazil Current, or compensation by horizontal coastal currents, would be an important factor by which the upwelling off Cabo Frio would annually alter its presence and location (Mascarenhas *et all.*, ms)**.

TEMPERATURE AND SALINITY

Many papers about vertical distribution of sardine eggs show that there is a close relationship between the thermocline and the general distribution of eggs in the upper mixed layer of the sea (Silliman, 1943; Ahlstrom, 1959; Ito, 1961). We have no data about the vertical distribution of Brazilian sardine eggs, but from the comparison of the occurrence of sardine eggs in plankton samples of vertical and horizontal hauls at the same station, distribution in the mixed layer near the surface water may be assumed.

No sardine egg was collected in the hauls having more than 100 m depth with the closing type plankton net.

The vertical temperature profiles at the stations in the spawning area are shown in Figure 13. These profiles show a normal thermocline, epithermocline and surface thermocline occurring in the interval of 10-25 m depths.

To show the horizontal distribution of temperature and salinity, an isotherm and isohaline map at the 10 m depth is shown in Figure 14. It is known that the temperature at the 10 m level is much less influenced by diurnal changes and may be used to show the average temperature of the mixed layer. Range of temperatures at the 10 m depth in the spawning area during the survey was between 17.6 - 24.4°C.

Vertical sections of oceanographic obser-

* SHAFFER, F. Inst. Oceanogr. da USP.

** MASCARENHAS, Jr., A. S., MIRANDA, L. B. & ROCK, N.J. A study of the oceanographic conditions in the region of Cabo Frio (ms). Inst. Oceanogr. da USP.

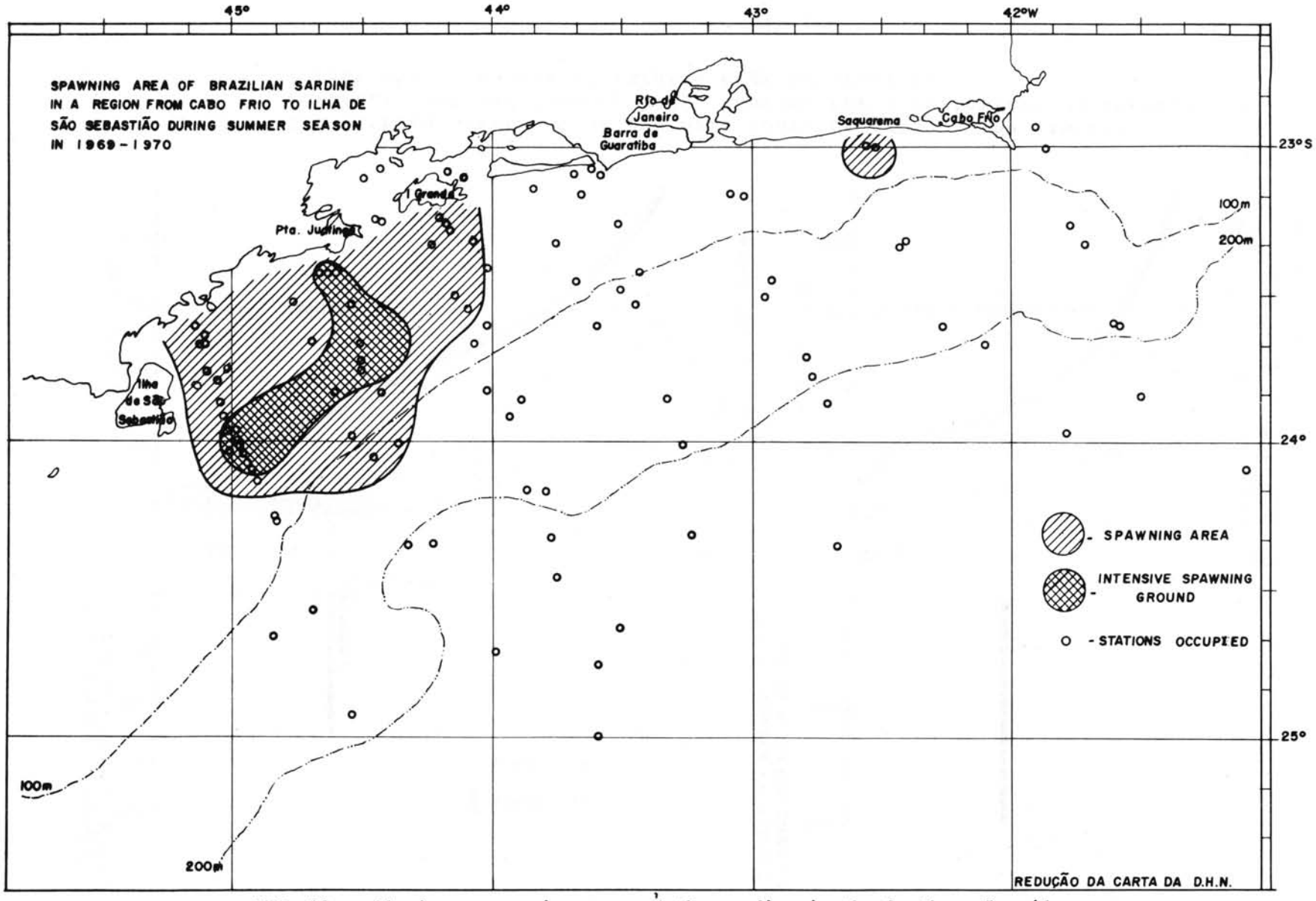

FIG. 10 - The known spawning area of the sardine in the Southern Brazil. (Cruises of September, November 1969 and January, March 1970).

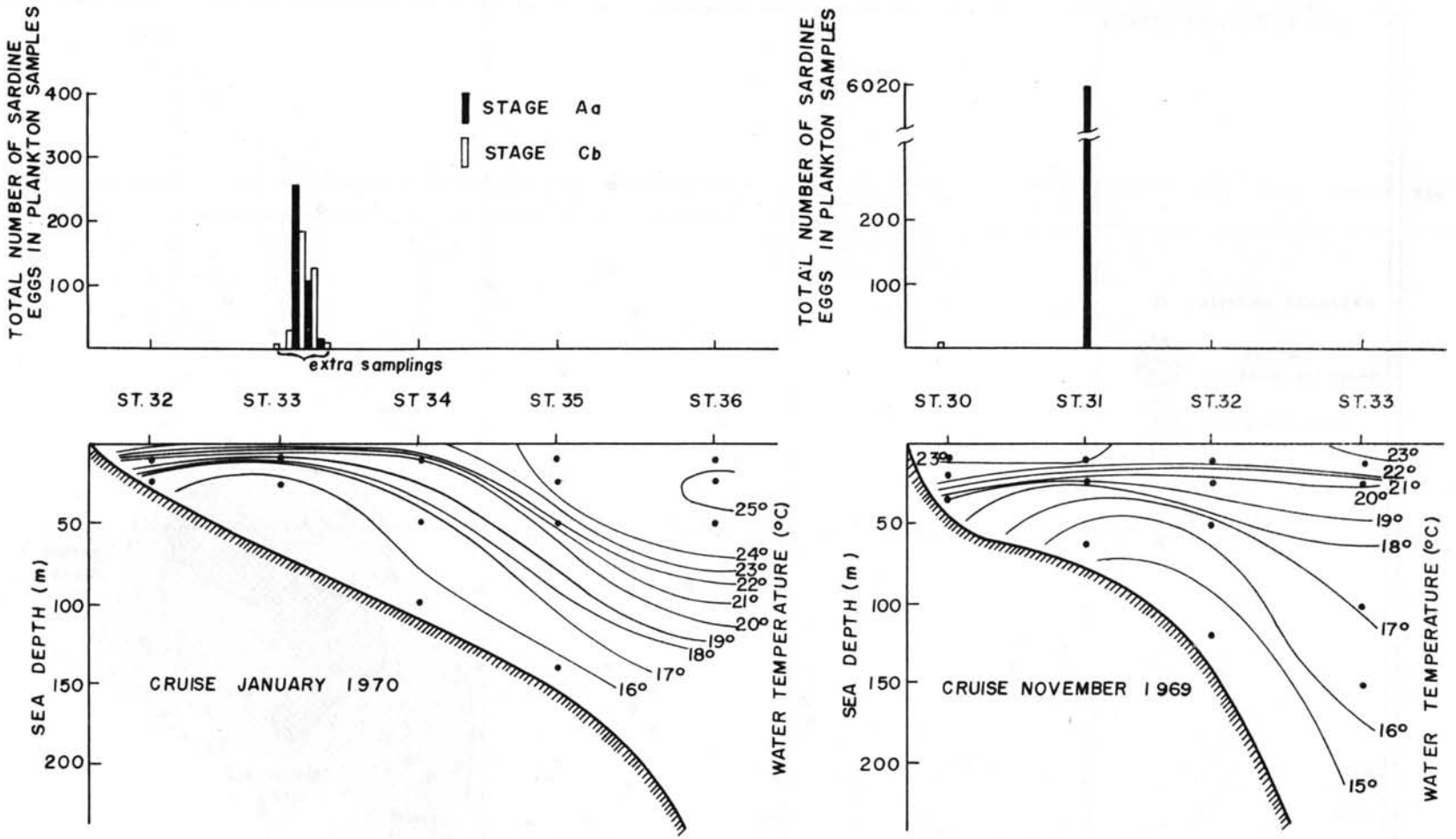

FIG. 11 - The vertical sections of the main spawning area of the cruises of November 1969 and January 1970, showing the distribution of temperature versus the abundance of sardine eggs by station.

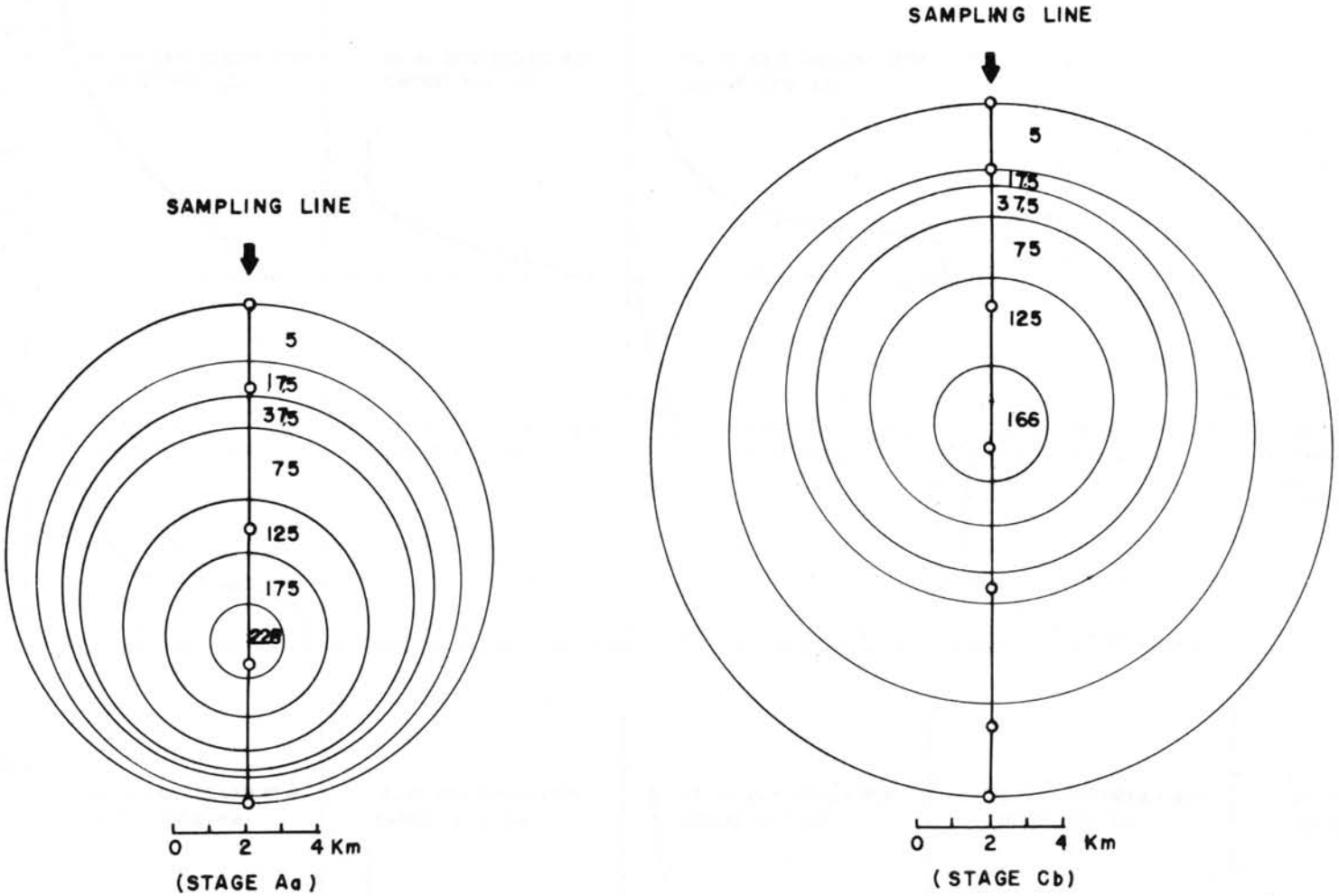

FIG. 12 - Horizontal distribution of sardine eggs in the sea on the cruise of January 1970. (Numbers in the circles represent mean egg number / 1 m^2 of sea area).

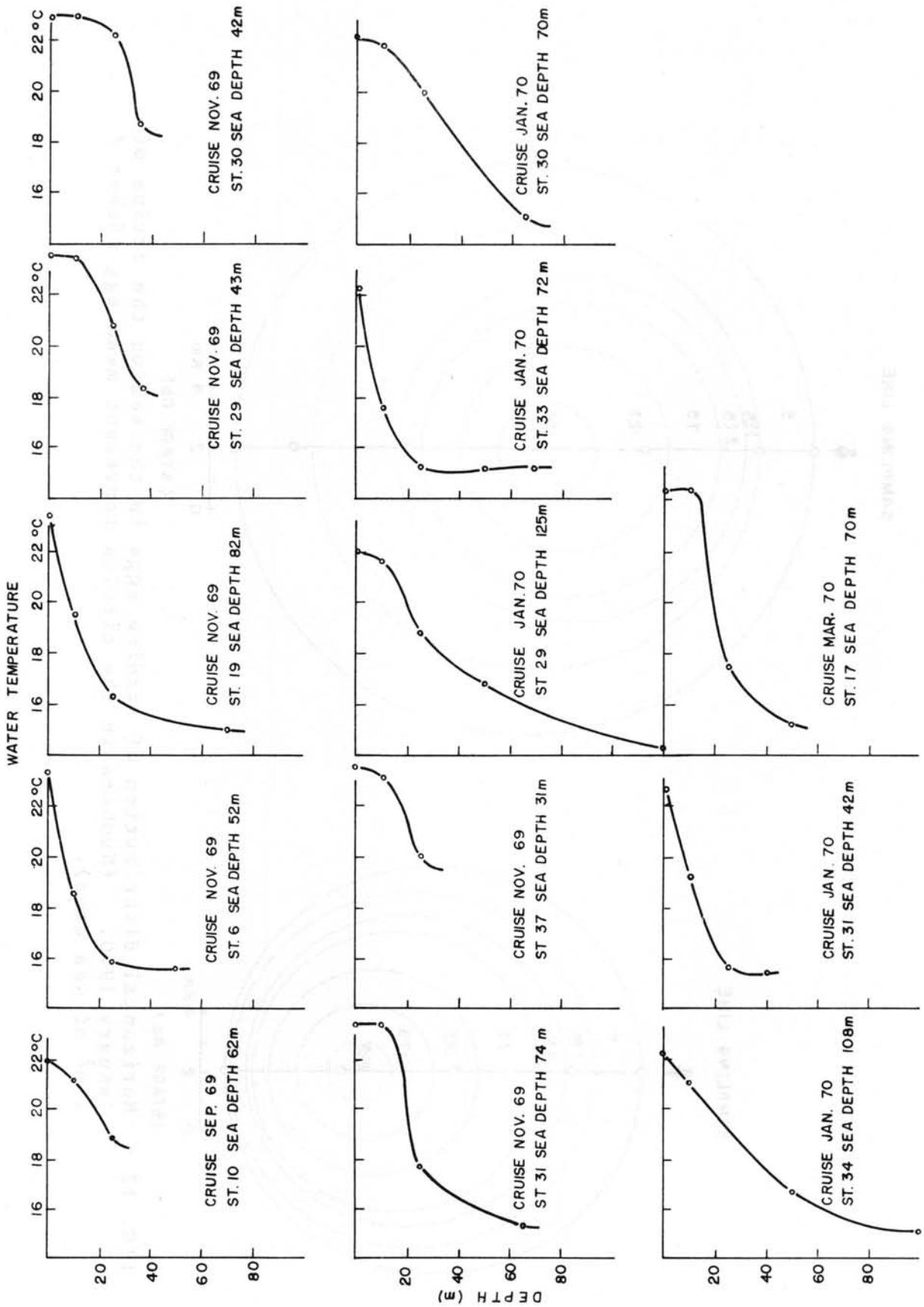

FIG. 13 - Vertical profiles of temperature at stations on the spawning area during surveys.

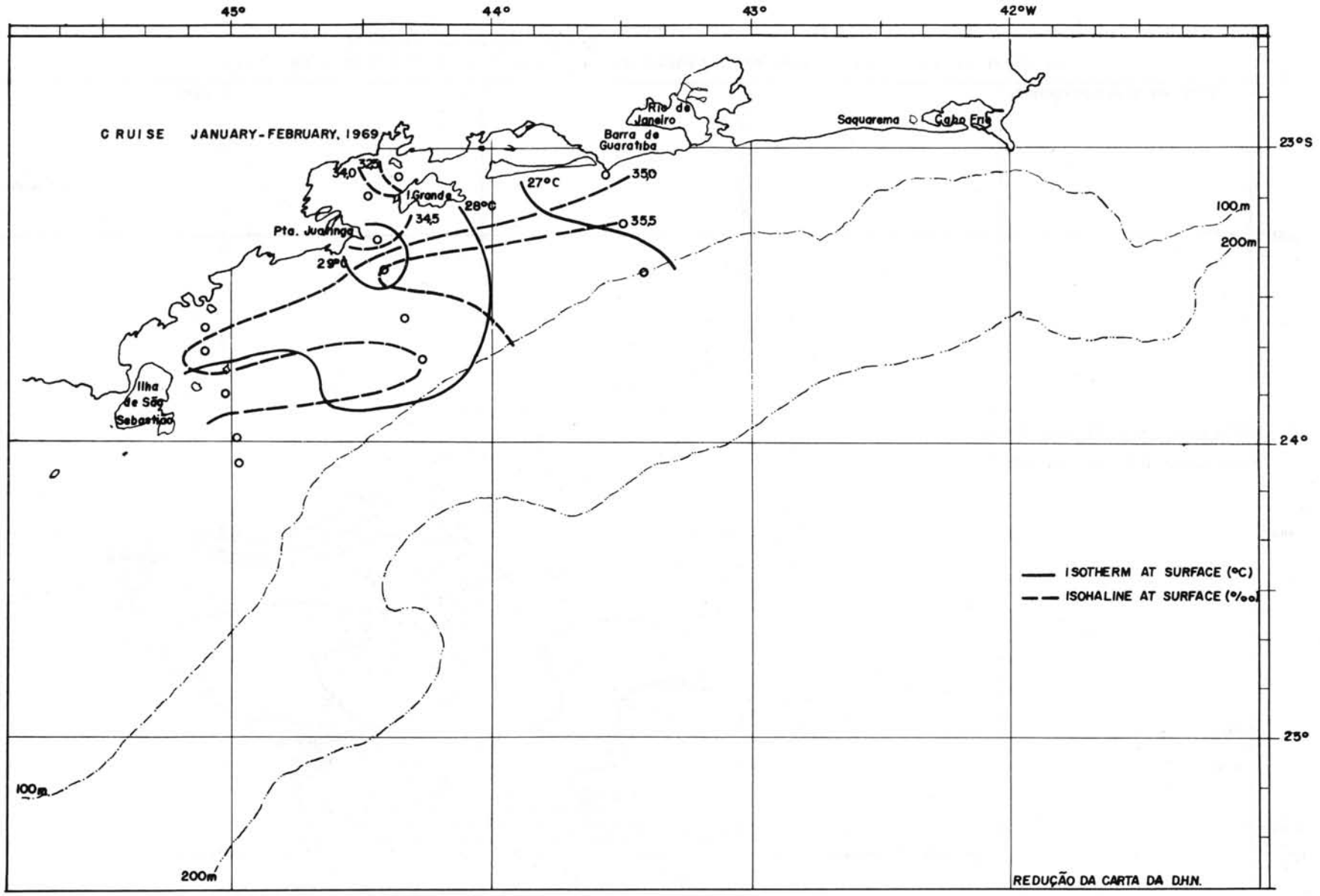

FIG. 14a - Horizontal distribution of temperature and salinity at surface. (Cruise January-February 1969. Since the plankton samplings on this cruise were done by horizontal surface haul, the isotherm and isohaline at surface layer are shown).

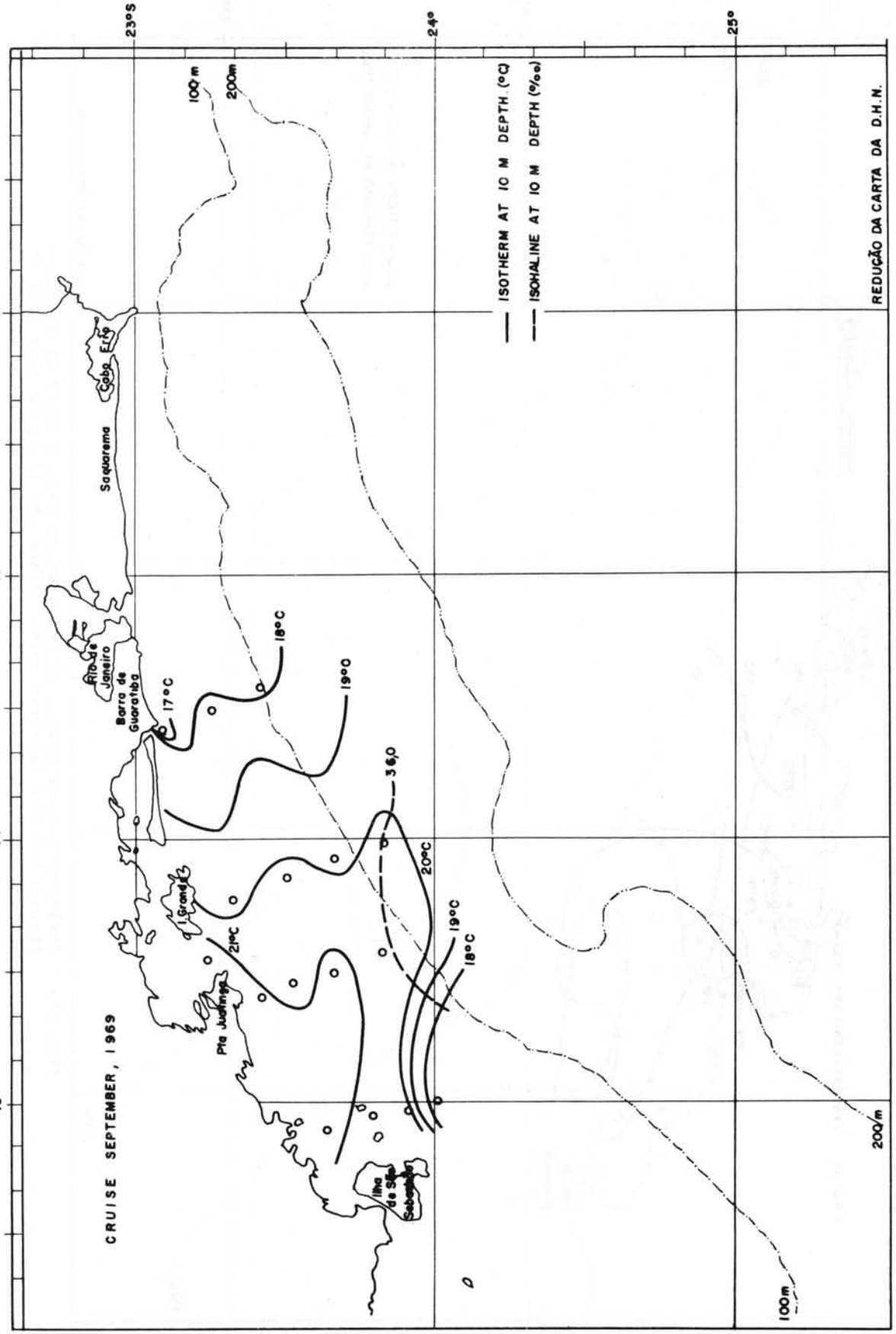

FIG. 14b - Horizontal distribution of temperature and salinity at 10 m depth. (Cruise September 1969).

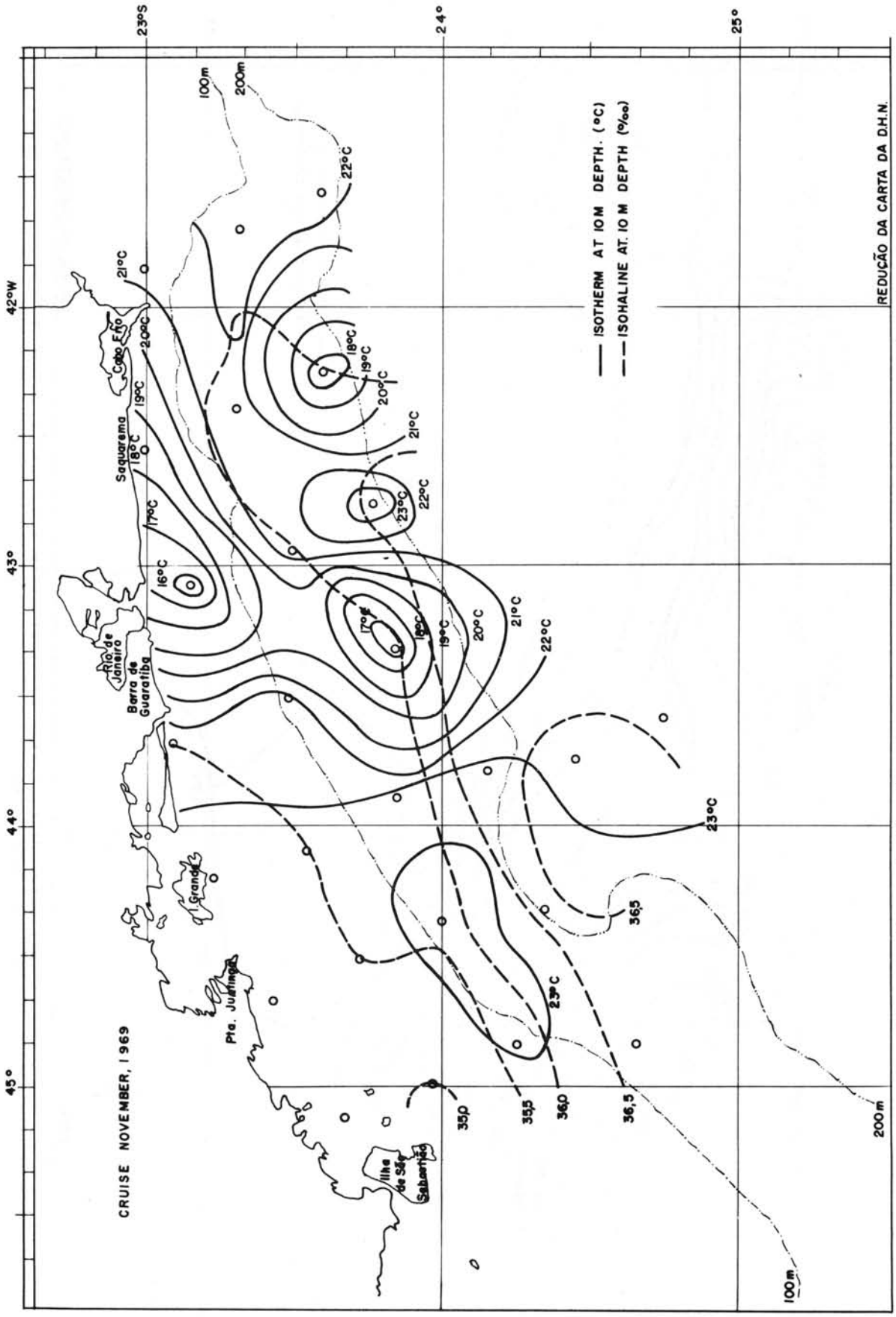

FIG. 14c - Horizontal distribution of temperature and salinity at 10 m depth. (Cruise November 1969).

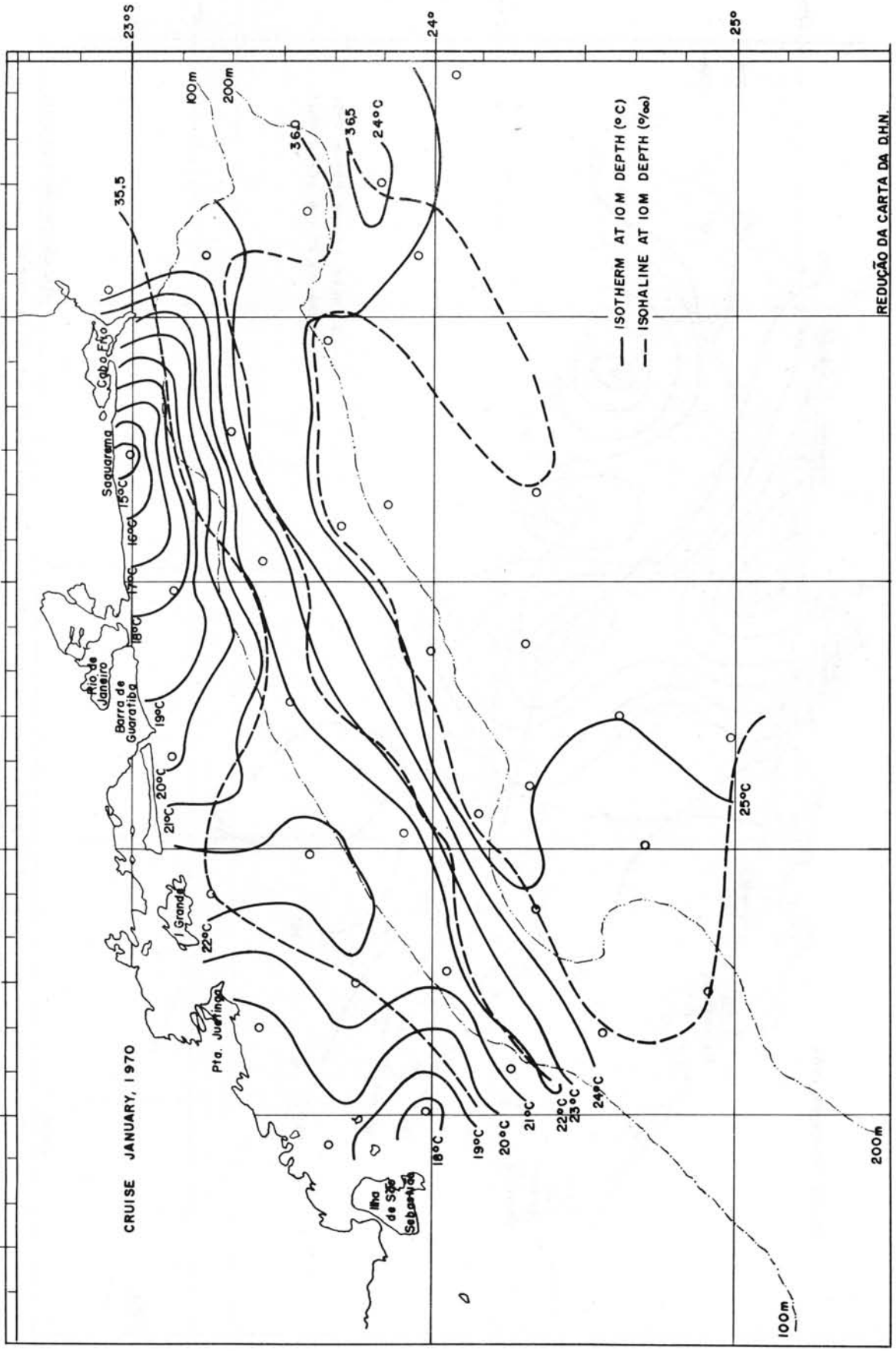

FIG. 14d - Horizontal distribution of temperature and salinity at 10 m depth. (Cruise January 1970).

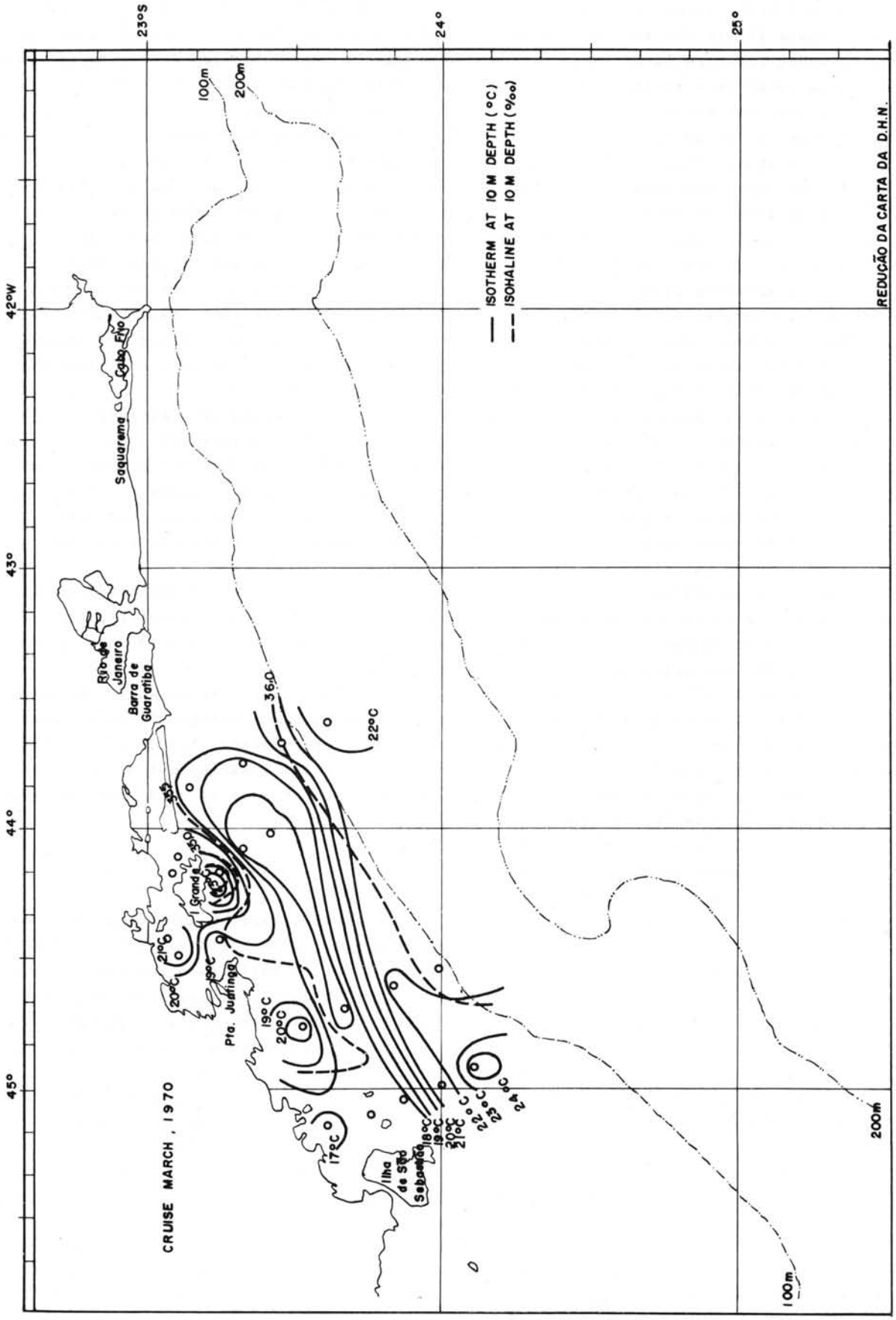

FIG. 14e - Horizontal distribution of temperature and salinity at 10 m depth. (Cruise March 1970).

vations in the main spawning ground are shown in Figure 11. In the two cases illustrated, spawning occurred in the area which showed a cold water mass rising from the bottom up to near the surface layer and with the thermocline in the 10-20 m layer.

Ito (1961) stated that the spawning of sardine in the Japan Sea showed a close relationship to eddy currents. With the presence of submarine canyon off Ilha Grande, the eddy currents may well have an effect on the location of spawning ground. For the time being, this, however, is purely conjectural.

On the other hand, since spawning of Brazilian sardine occurs in areas of upwelling, such as in front of Ponta de Juatinga, why has there been no spawning observed in the region of Cabo Frio where upwelling water masses are known and were observed on two of the present cruises? Perhaps it may be explained by the different origin of these two upwellings. For the time being, the author has no evidence for a relationship between spawning areas and upwelling. Therefore to further investigate these and other questions, a study of the relation between the oceanographic conditions and spawning areas is planned for the 1970-1971 spawning season.

On the stations at which spawning was recorded, results show a salinity range at a depth of 10 m of between 35.1-35.9°/oo. Relating salinity and temperatures shows that spawning occurred in the shelf waters (18-24°C and 35.1-35.9°/oo), but not in the Tropical Surface Oceanic Waters of the Brazil Current (22-25°C and 36.6-37.1°/oo) (Emílsson, 1961).

SUMMARY

The purpose of this investigation which is part of a sardine project designed to appraise the abundance of the sardine resources and to estimate its fluctuation, is to study the sardine's early life history and to estimate the abundance of eggs spawned in a spawning area.

Five cruises in the Ilha Grande region were realized and the following conclusions were obtained:

1. Eggs of Brazilian sardines are spherical and have a wide perivitelline space. The mean egg diameter is 1.18 mm and ranges between 1.00-1.32 mm. Mean perivitelline space is 0.143 mm and ranges between 0.061-0.254 mm. The number of oil globules is usually one, but often two or three occur. The mean diameter of the oil globules is 0.140 mm, and ranges from 0.091 to 0.182 mm.

2. From the developmental stage of the eggs and the time of collection, we can assume that the spawning time of Brazilian sardines may be a few hours prior to midnight. Therefore, the eggs which occur in each spawning group may be classified into different age category. Only few spawning groups were observed and usually they form one spawning group per day in an area. Spawning groups are isolated and spawning is small in scale.

3. The spawning area extends on the continental shelf between Ilha de São Sebastião to Ilha Grande (but not beyond the 100 m depth line). The intensive spawning ground lies between the area south-east of Ilha de São Sebastião and south of Ponta de Juatinga.

4. The estimates of the total number of sardine eggs of each spawning group are about 8.24×10^9 and 9.78×10^9 on the cruise of January 1970.

5. Spawning occurs in shelf waters with a temperature range between 18-24°C and a salinity range between 35.1-35.9°/oo. It was noticed that the spawning has a close relationship to an area of cold water upwelling.

RESUMO

O presente trabalho apresenta um estudo da fase inicial do ciclo de vida da sardinha (Projeto SOL) e verifica o seu potencial reprodutivo ("spawning power") na costa sul do Brasil. Cinco viagens à região da Ilha Grande foram realizadas com o N/Oc. " Prof. W. Besnard" e barco "Emília".

Os resultados estão resumidos, a seguir:

1. Os ovos são esféricos e o espaço perivitelino é amplo. O diâmetro médio dos ovos é de 1,18 mm, cuja distribuição é de 1,00 - 1,32 mm. O espaço perivitelino mede, em média, 0,143 mm, com distribuição entre 0,061-0,254 mm. Geralmente o glóbulo de óleo é único, porém, às vêzes apresenta-se segmentado em dois ou três. O seu diâmetro médio é de 0,140 mm, com distribuição entre 0,091 - 0,182 mm.

2. Podemos supor que a hora de desova da sardinha, nesta região, é pouco antes da meia-noite. Os ovos coletados numa mesma área e num mesmo dia, provenientes de um mesmo grupo de "desovantes", foram classificados em grupos de sardinhas que desovaram na área durante uma viagem de pesquisa. O tamanho dos cardumes de sardinha "desovante" não é grande como os da sardinha da Califórnia.

3. A área de desova, sôbre a plataforma continental, estende-se desde a Ilha de São Sebastião até a Ilha Grande (não ultrapassando a linha de profundidade de 100 m). Desova intensiva ocorre a sudoeste da Ilha de São Sebastião até o sul da Ponta de Juatinga.

4. A desova ocorre de setembro a março, sendo mais intensa durante o verão.

5. O número total estimado de ovos resultante da desova de dois cardumes foi de $8{,}24 \times 10^9$ para um e de 9.78×10^9 para outro, para a viagem de janeiro de 1970.

6. A desova ocorre em água da plataforma, de temperature entre 18-24°C e salinidade 35,1 - 35,9°/oo. A desova está em relação íntima com água fria de fundo, que ressurge até perto da superfície.

ACKNOWLEDGEMENTS

The author is indebted to Prof. Gelso Vazzoler for valuable advice and encouragement on the project, to Prof. Argeo Magliocca and Prof. Luiz B. Miranda for analysis of physical and chemical data, to Mr. Ademar D. Torrano and Miss Neuza das Graças Santos, laboratory assistants, for sorting eggs and larvae, to Mr. Zairo F. Pinto for drawing the figures of eggs, to Captain A. Godoi and other crews of the R/V "Prof. W. Besnard" and R/V "Emília" for sampling the material and to other staff members of the Oceanographic Institute.

I wish to thank Prof. Frank Shaffer for his kindness in correcting the manuscript and also wish to thank Dra. Marta Vannucci for her support on the Project.

This study was made while the author was on a Ford Foundation fellowship at the Instituto Oceanográfico da Universidade de São Paulo.

REFERENCES

AHLSTROM, E. H.

1943. Studies on the Pacific pilchard or sardine, *Sardinops caerulea*. 4. Influence of temperature on the rate of development of pilchard eggs in nature. Spec. scient. Rep. U.S. Fish Wildl. Serv., no. 23, 26 p.

1959. Vertical distribution of pelagic fish eggs and larvae off California and Baja California. Fishery Bull. U.S. Fish Wildl. Serv., no. 161, p. 106-146.

BESNARD, W.

1950. Nota preliminar sôbre uma particularidade da biologia de *Sardinella aurita* da costa brasileira. Bolm Inst. paul. Oceanogr., vol. 1, no. 1, p. 69-79.

BLAXTER, J. H. S. & HOLLIDAY, F. G. T.

1963. The behaviour and physiology of herring and other clupeids. *In:* RUSSELL, F. S., ed. - Advances in marine biology. London, Academic Press, vol. 1, p. 261-393.

D'ANCONA, U.

1937. Uova, larve e stadi giovanili di teleostei. Fauna Flora Golfo Napoli, Monogr. no. 38, part 1, p. 1-16.

DELSMAN, H. C.

1926. Fish eggs and larvae from the Java Sea. Treubia, vol. 8,no. 3/4, p. 199-239.

EMÍLSSON, I.

1961. The shelf and coastal waters off southern Brazil. Bolm Inst. oceanogr., vol. 11, no.2, p. 101-112.

ITO, S.

1958. On the relation between temperature and the incubation time of sardine, *Sardinops melanosticta*. Rep. Japan Sea reg. Fish. Res. Lab., vol. 1, no. 4, p. 25-31. (In Japanese).

1961. Fishery biology of the sardine, *Sardinops melanosticta* (T. & S.) in the waters around Japan. Bull. Japan Sea reg. Fish. Res. Lab., no. 9, p. 1-228. (In Ja

Japanese).

KAMIYA, N.

1916. Pelagic fish eggs and larvae in Tateyama bay. Suiko-shiho,vol. 11, no. 5, p. 1-92. (In Japanese)

MORAES, M. N.

1963. Observações sôbre a biologia da sardinha e sua captura ao longo da costa sul do Brasil de 1959-1961. Bolm Ind. anim., n.s., vol. 21, no. único, p. 3-16.

NAKAI, Z.

1962. Studies on influence of environmental factors upon fertilization and development of the Japanese sardine eggs. Bull. Tokai reg. Fish. Res. Lab.,no.9, p. 109-150.

RICHARDSON, I. D. *et all.*

1959. Report on sardine investigations in Brazil. FAO. Experience paper, no. 13, 7 p.

RICHARDSON, I. D. & SADOWSKY, V.

1960. Note on the sampling of sardine (*Sardinella allecia*) at Cananěia, State of São Paulo,Brazil. Bolm Inst. oceanogr., vol. 11 , no. 1, p. 87-97.

SETTE, O. E. & AHLSTROM, E. H.

1948. Estimations of abundance of the eggs of the Pacific pilchard (*Sardinops caerulea*) off southern California during 1940 and 1941. J. mar. Res., vol. 8 , no. 3, p. 511-542.

SILLIMAN, R. P.

1943. Studies on the Pacific pilchard or sardine, *Sardinops caerulea*. 6. Thermal and diurnal changes in the vertical distribution of eggs and larvae. Spec.scient. Rep. U.S. Fish Wildl. Serv.,no. 22, 17 p.

SUDEPE.

1969. Principais espécies de pescado desembarcado no ano 1968. Pesca Pesq., vol. 2, no. 1, p. 39.

SIMPSON, J. G. & GONZALES, G. G.

1967. Some aspects of the early life history and environment of the sardine, *Sardinella anchovia*,in eastern Venezuela. Inv. Pesq., ser. Rec. Explot. Pesq., vol.1, no. 2, p. 39-93.

VAZZOLER, A. E. A. de M. & VAZZOLER, G.

1965. Relation between condition factor and sexula development in *Sardinella aurita* (Cuv. & Val. 1847). Anais Acad. bras. Cienc., vol. 37, supl., p.353-359.

VOLODIM, V. M.

1956. Embryonic development of the autumn Baltic herring and their oxygen requirement during the course of development. Fish. Res. Bd Can., Transl. series no. 2 no. 252. Vop. Ikhtiol.,no.7, p. 123-133. (In Russian).

UNESCO.

1966. Reports of ICES SCOR-UNESCO Symposium of hydrodinamics of plankton samplers and the Meeting of Working Party 3.