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A STUDY OF SURFACE CURRENTS IN THE SPAWNING AREA OF BRAZILIAN SARDINE*

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SYNOPSIS

To obtain the movement of surface currents in the spawning area of Brazilian sardine, drift card release experiments were conducted in south Brazilian waters during the spawning seasons of 1969-1971. The results of these experiments and some considerations about the drift of sardine eggs and larvae are described. On the cruises of late spring, summer and early autumn all cards from stations west of Long. 44°45' W drifted southwest and were recovered near São Sebastião and those from stations east of Long. 44°45' W drifted northeast and were recovered on the coast line between Ilha Grande and Cabo Frio. The drift pattern of the cruise of September 1969 was somewhat different from the others. Most cards recovered were released from stations near shore (up to 30 nm).

INTRODUCTION

It is well known that recruitment of young to a fish stock is correlated with environmental conditions, especially to surface currents in the spawning area. With regards to the influence of currents on the survival of fish larvae, we note that complex interacting factors are related.

Correlations among the predominant wind direction, surface currents, transportation and distribution and survival of larvae, were demonstrated by many authors (Walford, 1938; Sette, 1943; Carruthers *et. al.* 1951; Rae, 1957; and Nakai, 1960), but recently Gulland (1965) concluded that apparent correlations between the environmental factors and year-class strength shown were not firmly confirmed.

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To obtain some basic data on the physical conditions, we have been studying surface currents in the spawning area of Brazilian sardine, *Sardinella brasiliensis* (=*S. aurita*) for three years using drift envelopes, as a part of the sardine project SOL.

MATERIAL AND METHODS

In order to study a surface current system, drift bottles are frequently used. Kasahara (1957) showed that drift envelopes could also be used for the same purpose, since similar results were obtained.

The advantages of drift-cards are their low cost and ease of mass preparation, and disadvantages are that they suffer from the influence of wind and allow penetration of water after a long period in the sea.

Using drift bottles, some studies of the Brazil current were made in southern Brazilian coast (from Lat. 22° S to 33° S) (Luedemann & Rock, 1971; Magliocca & Luedemann, 1970), but our purpose was to study the drift of sardine eggs and larvae in the coastal region and to learn the principal surface current direction.

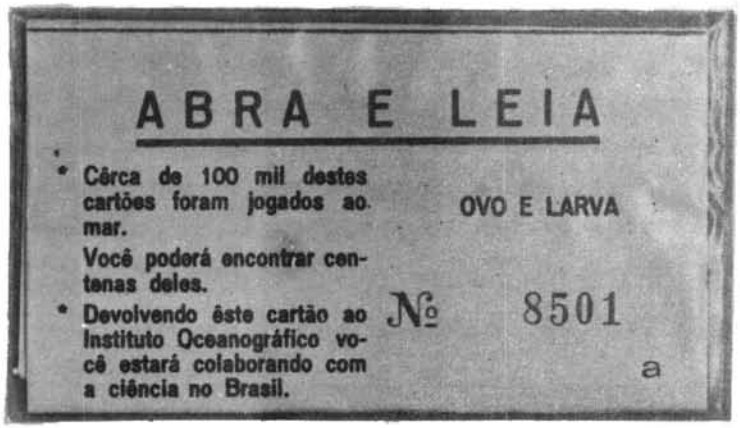
The drift envelopes were made of a polyethylene film, 0.06 mm thick (specific gravity: 0.94-0.96). The drift cards were made from cardboard 8 x 14 cm on which an announcement of a reward for recovery was printed. During the cruises from January 1969 to March 1970, cards were three-folded and enclosed in polyethylene envelopes, 5 x 11 cm. During the cruises from November 1970 to March 1971, they were enclosed in polyethylene envelopes, 15 x 8.5 cm unfolded (Fig. 1).

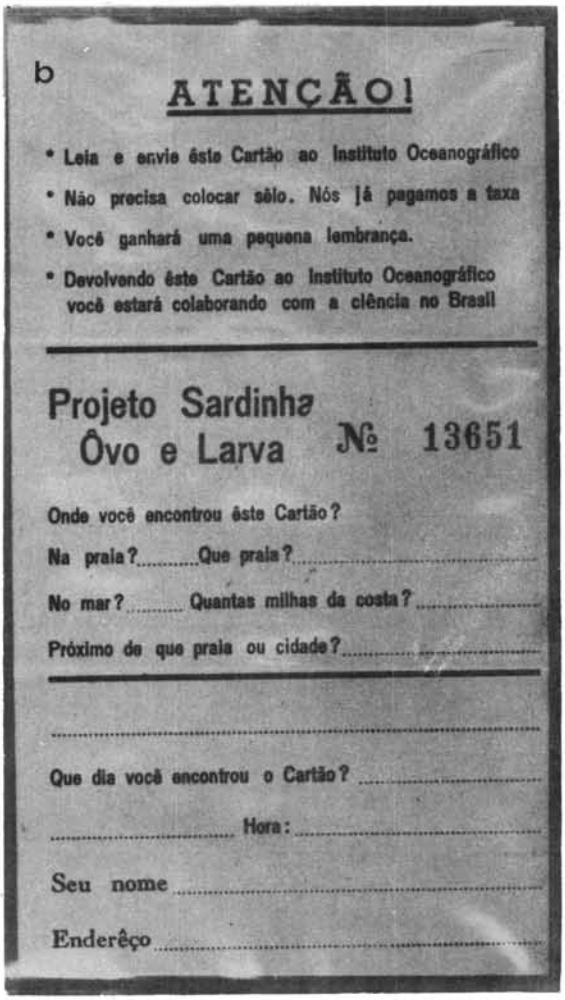
On cruises Nov.-Dec. 1970 and January 1971, half of fifty cards at each station were ballasted with a small piece of lead allowing the card to float upright with about two centimeters of the envelope above the sea surface. The remaining twenty five at each station were released without ballast.

To compare results of drift bottles and envelopes, both were released at the same station, off Cabo Frio on the cruise January 1969.

RESULTS

The number of cards released and recovered are shown in Table I. The number of stations from which cards were released amounted 183. Two fixed stations (24-hour observation) were made; one during the cruise January-February 1969 and the other in November 1969. The number of cards recovered totaled 359, or 3.0% of a total of 11,825 cards released.





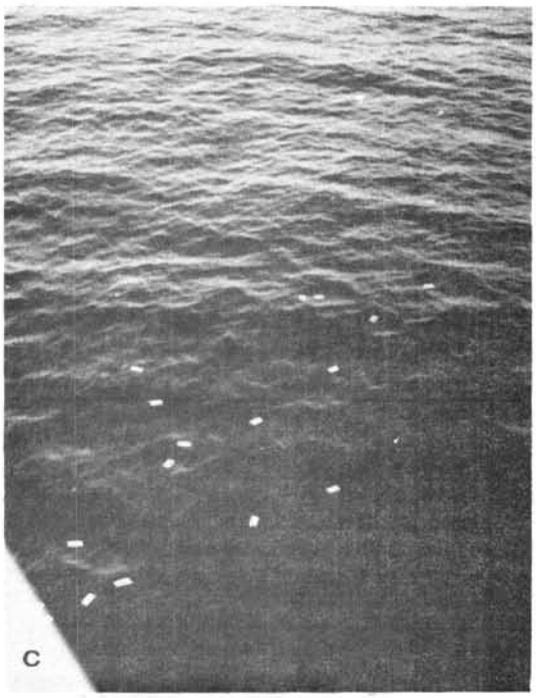


Fig. 1 – Drift cards. a) type A, b) type B, c) drift cards on the sea surface.

The recovery ratio of drift cards in our survey is low when compared to some other studies (Ito & Kasahara, 1958). This probably was caused by the sparse distribution of human population on the coastline of Brazil.

To analyze the surface current system and predominant wind direction, eight cruises were grouped by seasons: early spring season = cruise September 1969; late spring season = cruises in November 1969 and November-December 1970; summer season = cruises in January-February 1969, January 1970, January 1971 and February-March 1971; early autumn season = cruise in March 1970.

Early Spring (Fig. 2)

1) Cruise September 1969 - The cruise was conducted in the region of Ilha Grande. Some cards were recovered from all stations except from four offshore stations. All cards drifted in a northeast direction. The recovery rate was 4.2% and it was relatively high compared to other cruises in the survey (Tab. I).

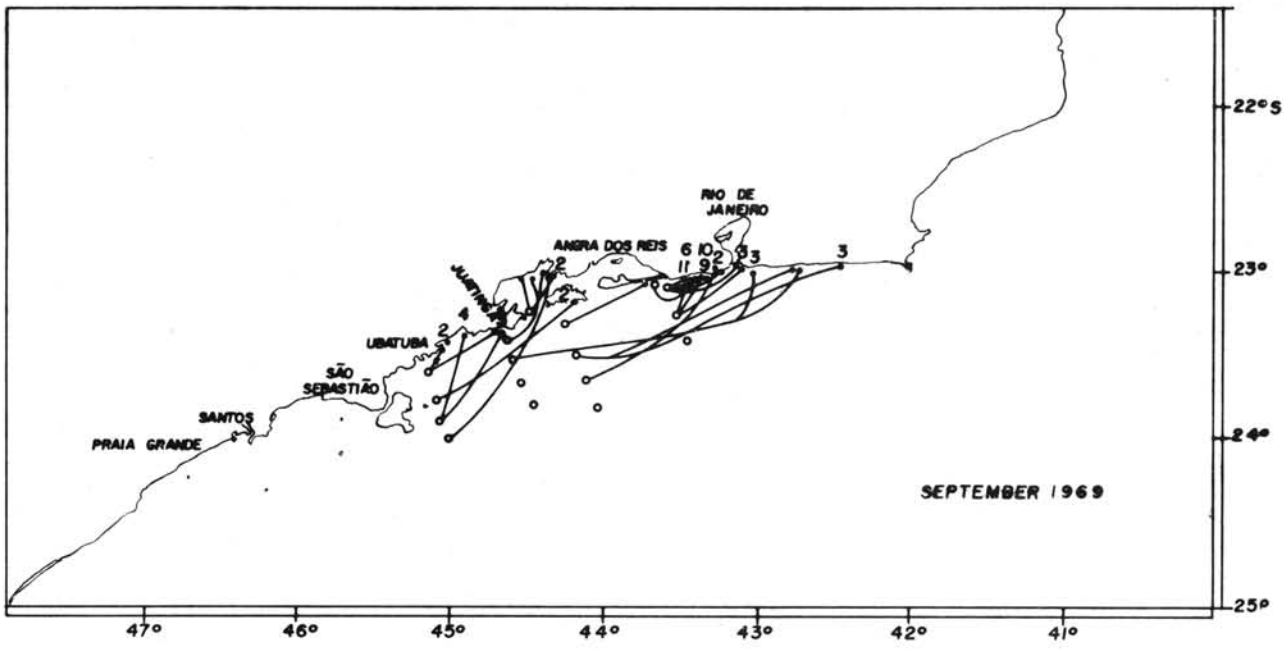


Fig. 2 - Drift card release stations and their drift pattern in the cruise of early spring.

Late Spring (Fig. 3)

1) Cruise November 1969 - On the fixed station (23°32' S, 44°04'5" W) situated south of Ilha Grande, twenty five cards were released at each two hour interval during 24 hours. A total of 295 cards were released at the fixed station and no recovery was recorded.

From the other twenty five stations along the region from Cabo Frio (23°00' S, 42°01' W) to Ilha de São Sebastião (23°50' S, 45°20' W), fifty cards were released at each station. Forty five cards were recovered from five stations with a recovery rate of 3.6% for a total of 1,250 releases.

One group drifted in a north-east direction and another went west. From the station situated 45 nm south of Ilha Grande, one card was recovered after eighteen days near Ubatuba, drifting 78 nm; this was the farthest station offshore from which a card was recovered during the survey.

TABLE I - Summary of the drift card release experiment

Cruise	Date	Research Vessel	A	B	C	D	E	F	G
Jan.-Feb. 1969	30/01-05/02	"Emília"	13 1*	100 100	1,300 1,300	- -	6	153	5.9%
Sep. 1969	26/09-30/09	"Emília"	17	100	1,700	-	13	72	4.2%
Nov. 1969	21/11-26/11	"Besnard"	25 1*	50 25	1,250 295	- -	5	45	2.9%
Jan. 1970	05/01-15/01	"Besnard"	35	50	1,750	-	3	9	0.5%
Mar. 1970	21/03-28/03	"Emília"	21	30	630	-	4	8	1.3%
Nov.-Dec. 1970	28/11-10/12	"Besnard"	30	50	750	750	12	42	2.8%
Jan. 1971	16/01-22/01	"Besnard"	23	50	575	575	7	19	1.7%
Feb.-Mar. 1971	27/02-11/03	"Besnard"	19	50	950	-	4	11	1.2%

A = Number of stations * = Fixed station
B = Number of cards released per station
C = Total number of cards released (without lead)
D = Total number of cards (with lead)
E = Stations with recoveries
F = Total number of cards recovered
G = Recovery rate

2) Cruise November-December 1970 - The cruise was conducted from Cabo de São Tomé (21°58' S, 40°59' W) to Cabo de Santa Marta Grande (28°36' S, 48°50' W). Along the region from Cabo Frio to São Sebastião, similar results to those of November 1969 were obtained. From stations situated on the east side of Ilha Grande to Cabo Frio, all cards drifted in a northeast direction. A card recovered from a release station south of Ubatuba drifted southwest and was found in the channel of Ilha de São Sebastião.

Only one card from the station near Cabo Frio drifted north passing off Cabo dos Búzios (22°48' S), and some cards from two stations south of Cabo de São Tomé drifted west.

In the Paranaguá region, all cards drifted north or northeast, but in the Santa Catarina region all drifted south and one was found at Mostardas (31°08' S) after drifting 220 nm in 23 days, the longest distance recorded during the survey.

Of 38 cards recovered, ten were ballasted with lead. One of them was recovered from the sea bottom at 52 m depth by trawl net, with the drift distance of 35 nm from the release station. Comparing results from lead and non-leaded ballasted cards, we observed that leaded cards were found some days later than non-leaded ones, but drift direction did not differ.

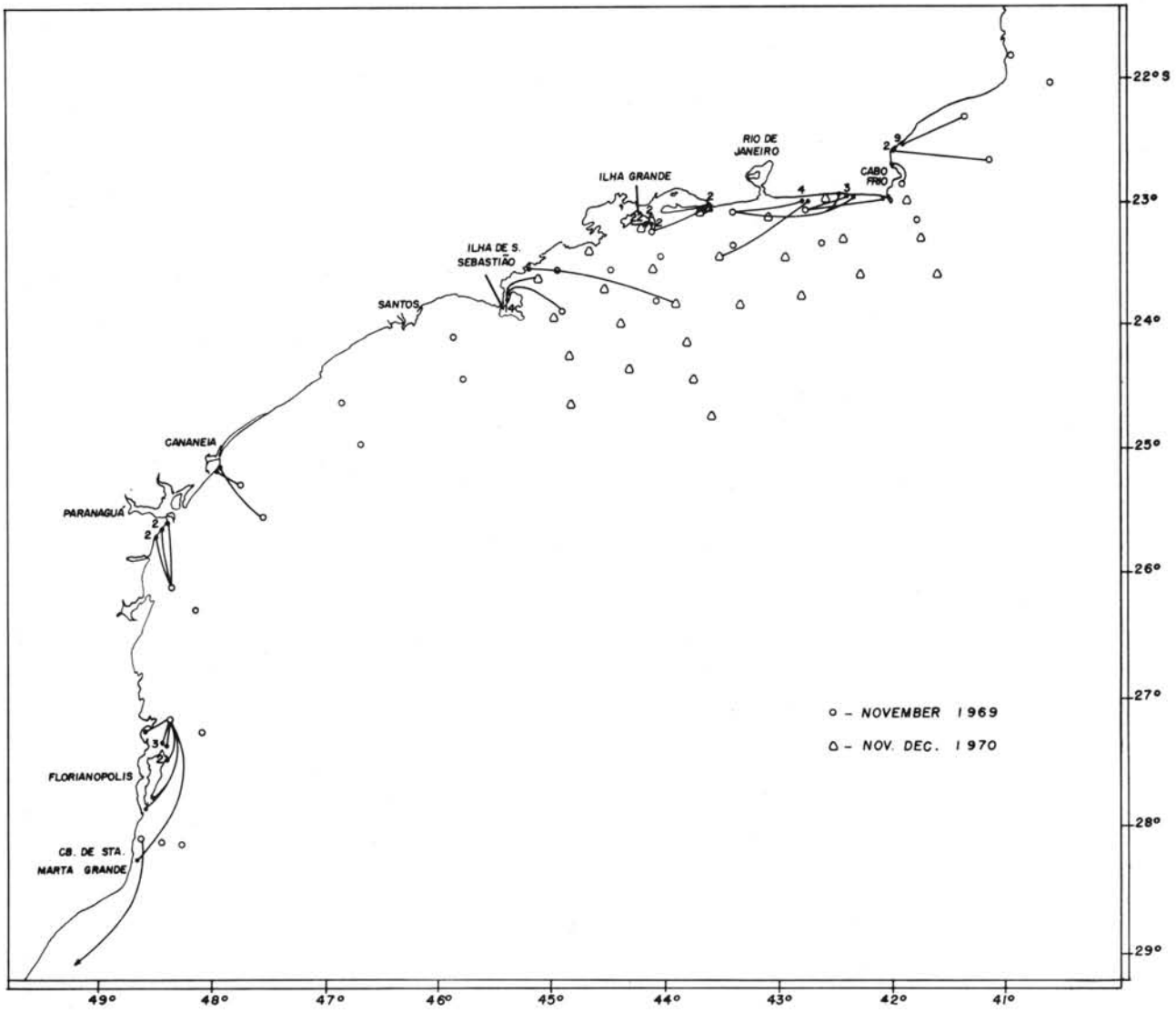


Fig. 3 - Drift card release stations and their drift pattern in the cruise of late spring.

Summer (Fig. 4)

1) Cruise January-February 1969 - Of 2,600 cards released, 153 were recovered, with a recovery rate of 5.9% for the cruise, including cards from the fixed station.

At the fixed station (23°18' S, 44°27' W) situated near Ponta de Juatinga, 100 cards were released every two hours during 24 hours. The recovery rate from the fixed station was 11.1% for 1,300 cards released. This rate was considered very high when compared with a recovery ratio of 1.6% obtained for other stations of the cruise. From the fixed station all cards drifted east and were recovered near Guaratiba (about 50 nm east of the station). A constant eastward surface current near the coastline probably existed during the period represented by this cruise. Based on the probable drift time, the first

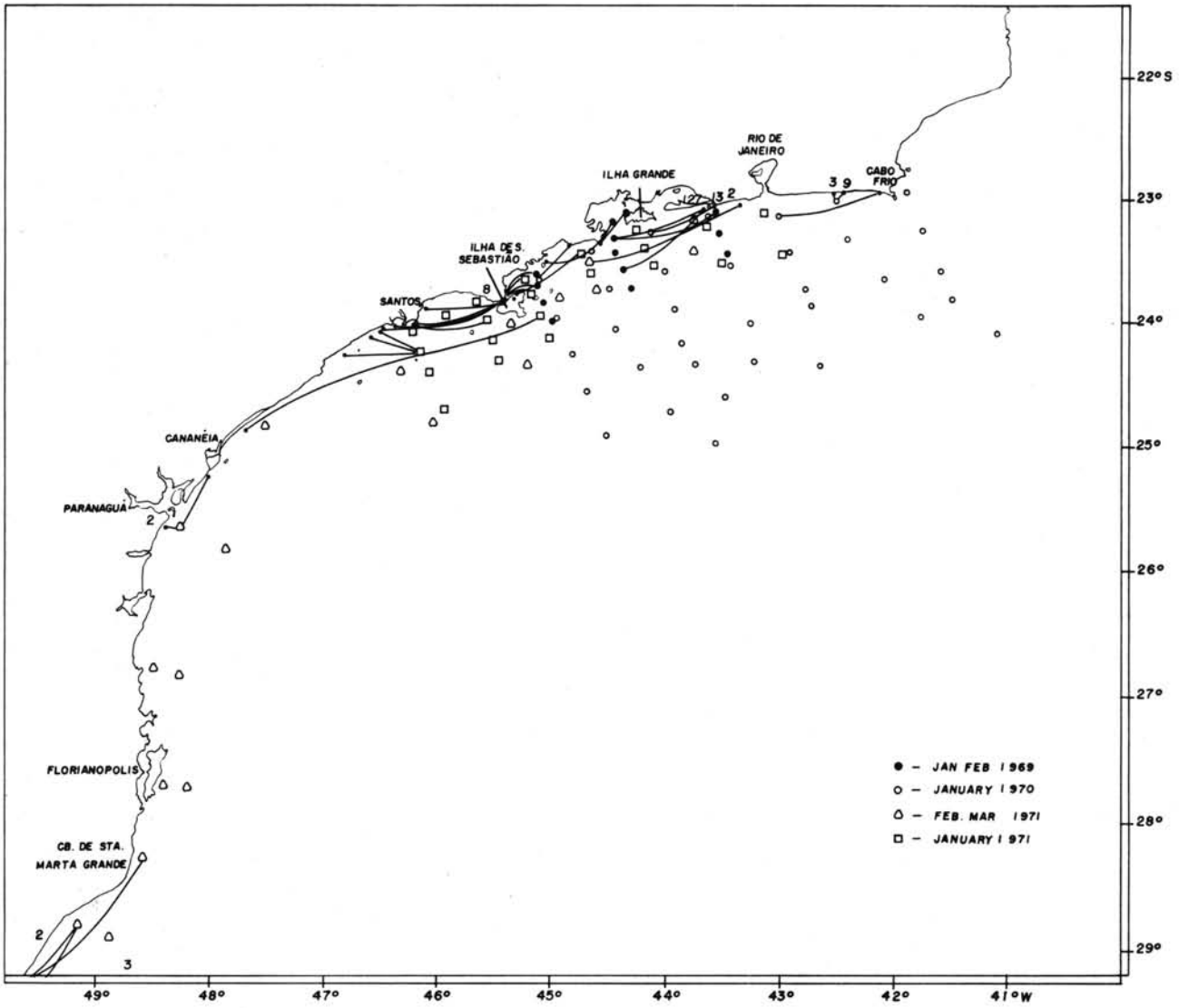


Fig. 4 - Drift card release stations and their drift pattern in the cruises of summer season.

card was recovered after 39 hours and had drifted 77 nm from the fixed station. This means that the current velocity was 1.9 knot per hour.

After a few days of study on the fixed station, two cards released from the station situated in the bay of Ilha Grande, drifted out of the bay and were found at Ubatuba (23°26' S, 45°05' W) and Juatinga (23°18' S, 44°30' W), drifting in a westerly direction. Apparently the coastal surface current in this area varies day to day and has a complicated movement, being affected by tidal current and/or coastal topography.

Four cards from two stations situated south of Ubatuba were found at the channel of Ilha de São Sebastião, and one possibly passed through the channel, reaching Praia Grande (24°08' S, 46°30' W) after 15 days. No cards from the offshore stations, more than 25 nm from the coast, were recovered on this cruise.

2) Cruise January 1970 - Only nine cards were recovered, with a recovery rate of 0.5% from a total of 1,750 cards released, the lowest rate obtained for all the cruises. All cards that were recovered had drifted northeast.

3) Cruise January 1971 - Nineteen cards from seven stations were recovered out of a total of 1,150 cards released at 23 stations. A recovery pattern similar to that of the cruises of January-February 1969 and January 1970 was observed for this cruise. Cards from six stations in the region from Ubatuba to Santos, drifted west, while only one from the station located south of Guaratiba went northeast. On this cruise half of fifty cards at each station were ballasted with a small piece of lead, leaded cards were not recovered.

4) Cruise February-March 1971 - From the station near Paranaguá one card drifted northeast and two went west. In the Santa Catarina region, all cards went south and were found on the coastline of the State of Rio Grande do Sul. One card from the station south of Juatinga, was found in Rio de Janeiro drifting northeast.

Early Autumn (Fig. 5)

1) Cruise March 1970 - Thirty cards were released at each station, eight being recovered from four stations out of a total of 630 cards released.

One card from the station south of Ubatuba was recovered at Ilha da Queimada Grande (24°29' S, 46°40' W) after 11 days drifting 140 nm. From the station in the Bay of Sepetiba, some cards went out off the bay and others went to the opposite direction.

Summary of Results

Summarizing the results, it is apparent that the drift pattern of the September 1969 cruise, in which all cards drifted northeast, was different from the others. On the other hand, in the cruises of late spring, summer and early autumn, all cards from stations west of Long. 44°45' W, drifted southwest and arrived near the channel of São Sebastião. Some passed through the channel and drifted west arriving near Santos. From the stations east of Long. 44°45' W, all cards except one from an offshore station, went northeast and were recovered on the coastline between Ilha Grande and Cabo Frio.

In the region north of Cabo Frio and south of Santos, we have only a few data. It is hardly possible, therefore, with the data now available to make any definite conclusions about surface currents in these areas.

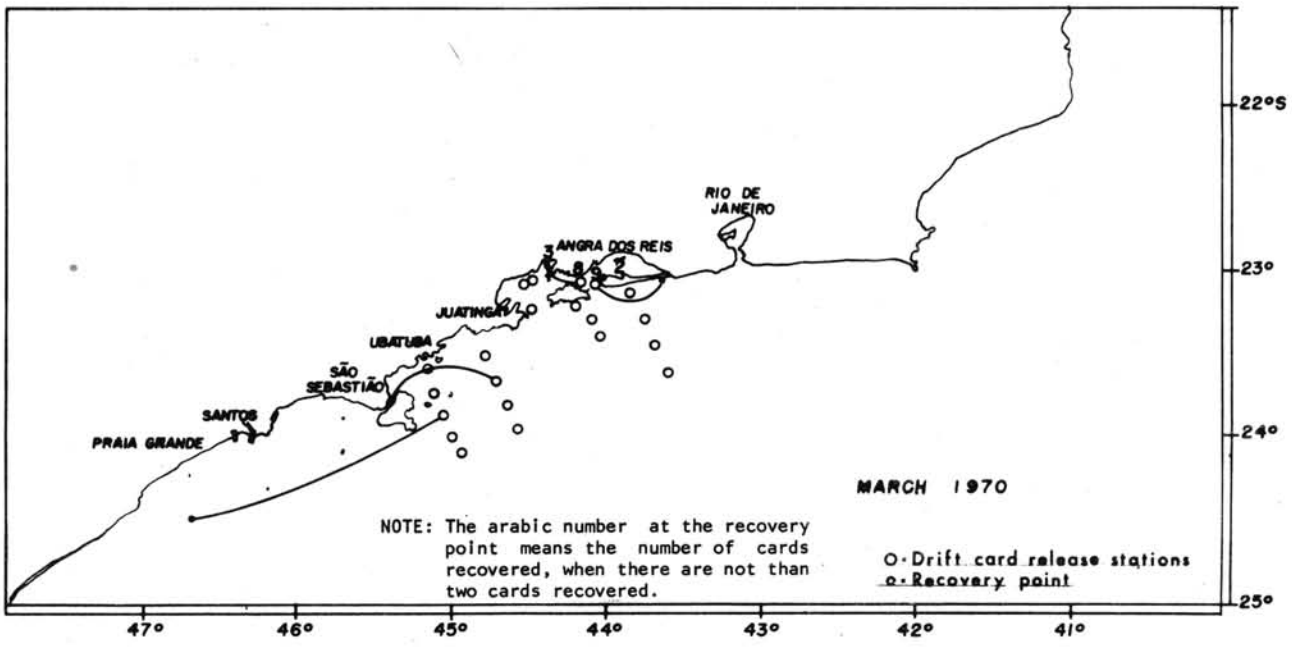


Fig. 5 - Drift card release stations and their drift pattern in the cruise of early autumn.

No cards from the offshore stations, more than 30 nm from the coastline were recovered, except one from the station situated 45 nm south of Ilha Grande in November 1969.

The drift envelopes released simultaneously with drift bottles for comparative purposes, at the same station in January 1969, were not recovered despite the recovery of some drift bottles from the station (Luedemann & Rock, 1971).

DISCUSSION

Hirano & Fujimoto (1971) stated that transportation and distribution of eggs and larvae affected by diffusion and transportation of currents and that the latter was much more important than the former in the movement of the eggs and larvae.

Ahlstrom (1959) stated that, in general, the eggs and larvae of many fishes, floated in the surface water and the extension of their vertical distribution was limited by the thermocline. If this is true for the Brazilian sardine, we can suppose that their drift may be affected principally by the surface current, since the mean depth of the thermocline in the spawning area was lower than 30 m (Matsuura, 1971). Based on these premises we discuss results of the drift cards and present below some considerations about the drift of sardine eggs and larvae in this region.

Spawning area and size vary from year to year, but the main spawning grounds are limited to the shelf waters from near the coast to a maximum of 60 nm from the coastline. Based on results of drift cards, and assuming that sardine eggs and larvae may take the same drift pattern, we can surmise that most of the eggs and larvae spawned in the region up to 30 nm from the coastline will approach the coast.

In plankton samples the standard length of larvae ranges from 4 to 16 mm and it sometimes reaches up to 21 mm. These larvae were found to have a somewhat wider distribution than the eggs and were collected from all over the continental shelf in the region under observation, especially from the spawning area. There were no tendencies for larger larvae to occur nearer to the coastal region. Larvae of about 15 mm standard length were collected at stations deeper than 100 m as commonly as at station in the coastal region. But the juveniles of sardines, larger than 35 mm standard length, can easily be captured by casting net in the estuaries.

Such results at first led us to hypothesize that the Brazil current, coming from the north, passing near the margin of the continental shelf and going south, had no direct influence on transportation and distribution of Brazilian sardine eggs and larvae, but that the counter current in which spawning was occurring and in which the shelf waters were formed, would influence the movement of eggs and larvae. The presence of a counter current, or large clockwise eddy, on the continental shelf can be assumed from data on current observation by Johannessen (1968), recorded from three stations at 100 m depth off Cabo Frio, Rio de Janeiro and Santos, and from the results of our drift cards. But the counter current has not been confirmed yet and its presence is still conjectural.

In spite of the hypothesis that the Brazil current has no direct influence on transportation and distribution of sardine eggs and larvae, we must acknowledge its indirect influence, e.g., oscillations of the main axis and meanders of the Brazil current may influence physical conditions of the spawning and nursery areas. Therefore, analysis of the oceanographic structure on the continental shelf is very important to understand which factors affect fisheries in the area.

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RESUMO

O recrutamento do estoque de peixes marinhos é dependente da mortalidade, durante o estágio de ovos e larvas. A corrente de superfície, na área de desova, é um dos fatores importantes que afetam a mortalidade de larvas.

O presente trabalho é o resultado de estudos feitos na corrente de superfície por meio de cartões-de-deriva, na região sul do Brasil (entre 22° S e 30° S). Oito viagens oceanográficas foram realizadas com os N/Oc. "Prof. W. Besnard" e "Emília" nos anos de 1969 a 1971.

Na região de Ilha Grande, considerada uma das principais áreas de desova, o resultado na época do fim da primavera ao início do outono, mostra que os cartões lançados na área este de Long. 44°45' W, derivaram a nordeste e foram encontrados na costa, entre Ilha Grande e Cabo Frio e os cartões lançados na área oeste de Long. 44°45' W, derivaram a sudoeste e chegaram à costa de São Sebastião e Santos. O resultado do cruzeiro de setembro de 1969 (início da primavera) é diferente dos outros.

Da região sul de Santos e da região do Cabo de São Tomé, temos poucos dados, portanto, não chegamos a uma conclusão definitiva. Será necessário o estudo contínuo desta área.

A maioria dos cartões encontrados foram lançados de estações situadas perto da costa (no máximo, 30 mn). A maioria dos cartões, lançados a uma distância superior, não foi recuperada.

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A P P E N D I X

Station no.	Lat.	Long.	Date	Time	No. of cards		1st card rec. Date & Time	Recovery Place
					Released	Recovered		
Cruise January-February 1969								
Fixed Station	23°18'5 S	44°27' W	*31-01 *01-02	*15:30 *16:00	1,300	127 16 2	02-02 10:00 03-02 11:00 08-02 09:15	Restinga da Marambaia (RJ) Barra de Guaratiba (RJ) Tijuca (RJ)
17	23°10' S	44°28' W	02-02	08:00	100	1	15-02 16:25	Toninhas-Ubatuba (SP)
19	23°34' S	44°21' W	02-02	13:00	100	1	03-02 11:30	Restinga da Marambaia (RJ)
21	23°07' S	44°20' W	03-02	07:45	100	1	20-02 10:00	Cairuçu da Pedra (RJ)
25	23°41' S	45°07' W	05-02	14:45	100	3	06-02 12:00	Ilha Bela (SP)
26	23°35' S	45°07' W	05-02	15:55	100	1 1	08-02 14:00 20-02 16:15	Ilha Bela (SP) Praia Grande (SP)
Cruise September 1969								
2	23°15'5 S	43°30' W	26-09	14:40	100	8 11 1 1	28-09 18:00 29-09 15:00 29-09 10:30 02-10 16:00	Tijuca (RJ) Sernambitiba (RJ) Bandeirantes (RJ) Itaipu (RJ)
3	23°06'5 S	43°34' W	26-09	16:30	100	7 3 1 1 3	29-09 11:30 29-09 17:00 29-09 15:00 29-09 07:00 03-10 06:00	Tijuca (RJ) Bandeirantes (RJ) Sernambitiba (RJ) Leblon (RJ) Itaipu (RJ)
4	23°03' S	43°36' W	26-09	17:20	100	6	28-09 11:00	Tijuca (RJ)
6	23°39' S	44°04'5 W	27-09	12:20	100	1 1	08-10 08:00 19-10 11:30	Leblon (RJ) Bandeirantes (RJ)
7	23°30' S	44°09' W	27-09	13:50	100	3 1	07-10 06:00 27-10 16:00	Saquarema (RJ) Maricá (RJ)
8	23°19' S	44°14' W	27-09	15:30	100	1	06-10 12:00	Restinga da Marambaia (RJ)
11	23°32' S	43°33' W	28-09	15:50	100	1 3	12-10 08:00 08-10 06:30	Maricá (RJ) Itaipu (RJ)
12	23°24'5 S	44°36' W	28-09	17:00	100	1 1	11-10 10:00 *15-08 15:00	Mambucaba (RJ) Angra dos Reis (RJ) 15-08-70
13	23°14' S	44°27' W	29-09	15:25	100	1 2	*23-11 11:00 09-10 08:00	Mambucaba (RJ) 23-11-70 Angra dos Reis (RJ)
14	24°00' S	44°59' W	30-09	10:40	100	1	07-10 17:00	Angra dos Reis (RJ)
15	23°54'5 S	45°02' W	30-09	11:40	100	4 3	08-10 09:00 07-10 06:00	Picinguaba (SP) Praia do Sono (RJ)
16	23°47' S	45°03'5 W	30-09	13:00	100	2	17-10 06:00	Pta. Castelhano (RJ)
17	23°37'5 S	45°07' W	30-09	14:35	101	1 1 2	07-10 08:30 05-10 11:30 03-10 15:00	Praia do Sono (RJ) Toninhas-Ubatuba (SP) Ubatuba (SP)
Cruise November 1969								
745	23°05'5 S	43°40' W	22-11	16:45	49	2	*11-01 15:00	Guaratiba (RJ) 11-01-70
746	23°28'5 S	43°29'5 W	22-11	19:10	50	1	*15-01 14:10	Maricá (RJ) 15-01-70
751	23°51' S	43°53' W	23-11	14:35	50	1	11-12 07:00	Maranduba-Ubatuba (SP)
764	23°14' S	44°12' W	24-11	19:10	50	27	25-11 07:00	Pta. Castelhano (RJ)
772	23°39' S	45°07' W	25-11	23:00	50	14	25-11 11:00	Ilha Bela (SP)
Cruise January 1970								
802	23°00' S	42°30' W	08-01	07:00	50	7	10-01 09:30	Saquarema (RJ)
803	23°09' S	43°02' W	08-01	11:20	50	1	04-02 10:00	Cabo Frio (RJ)
825	23°39' S	45°07' W	15-01	19:20	50	1	20-01 10:30	Ubatuba (SP)

cont.

Station no.	Lat.	Long.	Date	Time	No. of cards		1st card rec. Date & Time	Recovery Place
					Released	Recovered		
Cruise March 1970								
3	23°39' S	44°42' W	21-03	05:50	30	1	29-03 16:00	Ilha Bela (SP)
8	23°05' S	44°10' W	23-03	13:15	30	3	25-03 08:00	Angra dos Reis (RJ)
9	23°06' S	44°06' W	23-03	14:35	30	2	25-03 11:30	Restinga da Marambaia (RJ)
						1	28-03 10:00	Guaratiba (RJ)
19	23°52' S	45°03' W	28-03	11:55	30	1	08-04 06:00	Ilha da Queimada Grande (SP)
Cruise November-December 1970								
1.252	22°22' S	41°07' W	30-11	18:35	50	2	08-12 08:00	São João da Barra (RJ)
1.253	22°16' S	41°20' W	30-11	22:15	50	5	01-12 14:00	São João da Barra (RJ)
1.254	22°51' S	41°52' W	01-12	05:25	50	1	*02-01 08:30	Cabo Frio (RJ) 02-01-71
1.259	23°03' S	42°47' W	02-12	08:20	50	3	03-12 17:00	Saquarema (RJ)
						1	18-12 16:00	Cabo Frio (RJ)
1.260	23°05' S	43°25' W	02-12	14:20	50	4	05-12 11:00	Maricá (RJ)
						2	07-12 15:30	Saquarema (RJ)
1.267	23°14' S	44°07' W	03-12	20:55	50	4	08-12 15:00	Ilha Grande (RJ)
						1	*10-03 11:00	Guaratiba (RJ) 10-03-71
1.270	23°54' S	44°54' W	04-12	12:30	50	1	09-12 17:00	Ilha Bela (SP)
1.286	25°36' S	47°30' W	07-12	21:25	50	1	- -	Ilha do Bom Abrigo (SP)
1.287	25°20' S	47°42' W	08-12	01:35	50	1	21-12 08:00	Ilha do Cardoso (SP)
1.288	26°10' S	48°18' W	08-12	08:40	50	5	12-12 17:00	Paranaguá (PR)
1.294	27°13' S	48°20' W	09-12	12:50	50	5	10-12 16:00	Norte da Ilha Sta. Catarina (SC)
						1	17-12 14:00	Armação de Piedade (SC)
						1	20-12 10:00	Sul da Ilha Sta. Catarina (SC)
						1	25-12 11:40	Garopaba do Norte (SC)
						1	27-12 15:30	Itaperoba (SC)
						1	17-12 10:00	São João do Vermelho (SC)
1.295	28°10' S	48°35' W	09-12	20:30	50	1	*01-01 10:00	Mostardas (RS) 01-01-71
Cruise January 1971								
1.303	23°14' S	43°40' W	16-01	21:40	50	1	10-02 15:00	Guaratiba (RJ)
1.313	23°26' S	44°45' W	18-01	06:30	50	1	05-02 10:00	São Sebastião (SP)
1.315	23°29' S	45°15' W	18-01	11:15	50	2	07-02 10:00	Guarujá (SP)
						1	20-02 10:00	São Sebastião (SP)
1.316	23°46' S	45°11' W	18-01	13:35	50	8	20-01 09:00	São Sebastião (SP)
						1	04-02 09:00	São Vicente (SP)
1.317	23°57' S	45°06' W	18-01	18:25	50	1	16-02 15:45	Ilha Comprida (SP)
1.325	23°59' S	45°35' W	20-01	15:45	50	1	17-02 13:00	Guarujá (SP)
1.329	24°14' S	46°10' W	21-01	03:00	50	2	07-02 12:30	Praia Grande (SP)
						1	29-01 11:00	Itanhaem (SP)
Cruise February-March 1971								
1.434	28°49'5 S	49°07'5 W	27-02	08:45	49	3	07-03 11:00	Capão da Canoa (RS)
						2	06-03 11:00	Xangrilá (RS)
						1	04-03 11:00	Sta. Terezinha (RS)
1.441	28°18' S	48°34' W	01-03	07:40	50	1	17-03 09:30	Cidreira (RS)
1.450	25°40' S	48°13' W	03-03	08:05	50	2	13-03 14:00	Paranaguá (PR)
						1	24-03 18:00	Ilha do Cardoso (SP)
1.468	23°30' S	44°40' W	07-03	10:00	50	1	29-03 11:00	Guaratiba (RJ)