

FIRST ATTEMPT TO IDENTIFY AREAS FAVORABLE FOR THE SURFACE OCCURRENCE OF SKIPJACK (KATSUWONUS PELAMIS)
OFF THE SOUTHEASTERN COAST OF BRAZIL

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RESUME

SUMMARY

The present work is an attempt to identify the areas of highest probability for the occurrence of surface skipjack schools (*Katsuwonus pelamis*, Linnaeus, 1758), off the southeastern coast of Brazil. The average quarterly values of the depths of the 18°C isotherm and the dissolved oxygen content below 3.5 ml/l, within 1° latitude by 1° longitude squares were determined by means of a computer. Quarterly charts of the spatial distribution of these two parameters were developed from these data. Special emphasis was given to the 50, 100 and 150 m isobaths. The areas favorable for the occurrence of surface skipjack schools were generally distributed along and parallel to the coast of the study region, in the four quarters. A preliminary comparison between the mapped areas and skipjack catch data available for the same areas, for the third quarter, suggests good agreement between the two. The largest area favorable for the occurrence of surface skipjack schools was in the first quarter (austral summer), with 54,800 km² and the smallest one was in the fourth quarter (austral spring), with 49,400 km².

Le présent document tente d'identifier les zones où il est le plus probable de trouver des bancs de listao (*Katsuwonus pelamis*, Linnaeus, 1758) en surface, au large des côtes sud-est du Brésil. Les valeurs trimestrielles moyenne de profondeur de l'isotherme 18°C et du contenu d'oxygène dissous de moins de 3,5 ml/l, dans des carrés de 1° de longitude par 1° de latitude, ont été déterminées au moyen d'un ordinateur. Des tableaux trimestriels de la distribution dans l'espace de ces deux paramètres ont été élaborés à partir de ces données. Une attention particulière a été prêtée aux isobathes 50, 100 et 150. Les zones propices à la présence de bancs de listao en surface sont en général réparties parallèlement le long des côtes de la région sous étude, et ce pendant les quatre trimestres. Une première comparaison des zones reportées sur les cartes et des données de capture de listao disponibles pour ces mêmes zones, pour le troisième trimestre, laisse entrevoir une bonne concordance. La plus ample zone propice à la présence de bancs de listao en surface couvrait, pendant le premier trimestre (été austral), 54.800 km²; la plus petite couvrait, pendant le quatrième trimestre (printemps austral), 49.400 km².

RESUMEN

El presente trabajo trata de identificar las áreas con mayor posibilidad de aparición de cardúmenes de listado (*Katsuwonus pelamis*, Linnaeus, 1758) en la superficie, frente a las costas sudorientales de Brasil. El promedio de los valores por trimestre de la profundidad de la isoterma de 18°C, y el contenido en oxígeno disuelto por debajo de 3,5 ml/l, comprendidos en áreas de 1º latitud x 1º longitud, fueron calculados mediante ordenador. Los diagramas, por trimestre, de la distribución espacial de estos dos parámetros, se desarrollaron a partir de estos datos. Se hizo particular hincapié en las isobatas de 50, 100 y 150 m. Las áreas propicias a la aparición superficial de cardúmenes de listado, se

encontraban generalmente distribuídas a lo largo y paralelamente a la costa de la región estudiada, durante los cuatro trimestres. Una comparación preliminar entre las áreas representadas y los datos de captura de listado disponibles, muestra una buena coincidencia entre ambos. La zona de mayor extensión, favorable a la aparición de cardúmenes de listado en la superficie, comprendía 54.800 km² durante el primer trimestre (verano austral), y la menor, durante el cuarto trimestre, (primavera austral), alcanzaba los 49.400 km².

INTRODUCTION

With the aim of obtaining a better knowledge of the areas favorable for the occurrence of skipjack (*Katsuwonus pelamis*, Linnaeus, 1758), various studies have been made in the Pacific and Atlantic Oceans, mainly during the last decade. Those studies have shown the feasibility of predicting those areas favorable for the occurrence of skipjack, through an analysis of the horizontal and vertical structure of temperature and dissolved oxygen of the sea water (Blackburn, 1965; Nakamura, 1969; Williams, 1970; Neill et al., 1976; Dizon et al., 1977 and 1978; Ingham et al., 1977).

From previous laboratory studies and field measurements, it has been concluded that 18°C is the minimum temperature tolerated by skipjack and that its minimum oxygen content requirement is 3,5 ml/l. Below those two limits, the species suffers a large "stress" and cannot survive a long time.

By utilizing average values of temperature and dissolved oxygen from their physiological studies, Barkley et al. (1978) mapped the habitat of the skipjack, for the region of the Eastern Pacific. Evans et al. (1980) mapped the depth of the skipjack habitat for the Atlantic Ocean between 40°N and 40°S. Off the Brazilian coast, Evans et al. (1980) found that the skipjack habitat is between the south of Bahia State and Santa Catarina Island.

Based on the studies of the above mentioned authors, the Instituto de Pesquisas Espaciais - INPE (Institute for Space Research) in São José dos Campos, São Paulo, Brazil and the Instituto Oceanográfico da Universidade de São Paulo - IOUSP (Institute of Oceanography of the University of São Paulo) also from São Paulo, Brazil, have been working to determine the areas of the largest probability for the occurrence of surface skipjack schools in the southeastern Brazilian waters. These studies are being developed through the analysis of the temperature and oxygen content of the waters.

The present work represents the preliminary results of those studies. Such results will be used in the development of methodologies for the application of satellite data in the elaboration of fishing chart models (Maluf, 1979 and 1980; Maluf et al., 1983; Abdon, 1983; Castro, 1983). Those models are intended to improve the methods used to identify the most favorable areas for the exploratory fishing of species of commercial value. That is, by introducing an economy in time and operation costs.

METHODOLOGY

Historical temperature and dissolved oxygen content data were obtained from the Banco Nacional de Dados Oceanográficos - BNDO (Brazilian Oceanographic Data Center), of the Diretoria de Hidrografia e Navegação - DHN (Brazilian Navy Hydrographic Service) which belong to the Brazilian Navy Ministry. Based on those data, a program was developed for INPE's BURROUGHS-6800 computer. With this program, the average quarterly values corresponding to the depths of the 18°C isotherm and the 3,5 ml/l dissolved oxygen content were computed for 1° Latitude by 1° Longitude squares.

The region of this study (shown in Figure 1) is in MARSDEN Square 376 (20° to 30°S and 40° to 50°W) and includes approximately 672,400 km². The region was divided in eight subregions in order to facilitate the identification of the areas favorable to skipjack (Figure 2).

Due to the lack of temperature and dissolved oxygen data in some months, it was decided to use a quarterly basis for those parameters. The months constituting the quarters were approximately the months corresponding to the four seasons of the year.

The quarterly averaged values obtained from the computer program were plotted in the 1° by 1° squares, according to the individual averaged positions for each square. Then, the values were interpolated by depth and the isobath lines were drawn. Special attention was paid to the quarterly isobath lines of 50, 100 and 150 m for each parameter. With those lines as a basis, the quarterly maps of the areas of largest probability of skipjack school concentration were drawn and they are shown in Figures 3, 4, 5 and 6. These areas were determined by graphically integrating the data, corresponding to the depths of the 18°C isotherm and 3,5 ml/l oxygen content, greater than 50 meters. The method of contouring the two parameters was utilized where both of them were superimposed. The temperature lines were considered to be the limiting factor. The 50, 100 and 200 m isobaths, extracted from the Fishing Charts (Nº 23 700, 23 900 and 24 000) of DHN, were also included as a reference. These charts use a Mercator Projection with a scale of 1:1 000 000.

Table 1 contains the total number of average values corresponding to the depths of the 18°C isotherm and the dissolved oxygen values below 3,5 ml/l. Data are recorded in 1° geographic squares for each quarter of the calendar. Statistics, such as minimum and maximum (range) depths of each parameter, and the total number of sampled stations, are given.

RESULTS

Distribution of Areas Favorable for the Concentration of Surface Skipjack Schools

First quarter

Figure 3 shows the three areas most favorable for the occurrence of skipjack in the surface water (shaded areas) for the first quarter. It was observed that the largest region is distributed along the coast. The largest of these areas extends southwest from Cabo Frio to the southern part of the study region (subregions 3, 4, 5, 6, 7, and part of 8. See Figure 2), with a total approximate area of 52,200 km². This area is almost entirely above the 100 m isobath. There are also two small areas, one northeast of Cabo Frio (subregion 2), with an area of about 1,600 km² and extending for a distance of 50 km east of the coast, and the other located at 26°30'S and 41°00'W, with an area of about 1,000 km². Overall, the most favorable area for concentration of skipjack in the surface water, for the first quarter, has a total area of about 54,800 km².

Second quarter

The two areas most favorable for the occurrence of skipjack in the surface water, for the second quarter, are seen in Figure 4 (shaded areas). It was observed that all of the shaded areas are distributed along the coast. The largest zone extends from subregion 3 southward to Santa Marta Cape, in subregion 8 (Figure 2), with an area of about 49,600 km². In subregion 4, the area favorable to skipjack reaches the 200 m isobath and extends 140 km off the coast. The smaller second area is located to the northeast of Cabo Frio (subregion 2) and possesses an area of 1,000 km². For the second quarter, the area most favorable for the concentration of surface skipjack schools has a total area of about 50,600 km².

Third quarter

For the third quarter, there are three areas favorable for the occurrence of surface skipjack schools (Figure 5). The large area was again distributed along the coast. The largest area extends continuously from between São Tomé Cape and Cabo Frio, southward to

Santa Marta Cape (subregions 2, 3, 4, 5, 6 and 7, Figure 2), with a total area of about 45,000 km². In subregion 3, the area reaches the 200 m isobath and extends 90 km from the coast. There are two other smaller areas, one of them in subregion 8, with an area of about 4,400 km² extending 90 km east of the coast; the other area is located near 29°30'S, 44°10'W and has an area of about 4,000 km². The total area favorable for the concentration of skipjack schools, during the third quarter, is estimated at 53,400 km².

Fourth quarter

The area most favorable for the concentration of skipjack in the surface (shaded area), for the fourth quarter, is seen in Figure 6. The area extends along the coast, between São Tomé Cape and Cabo Frio (subregions 2 and 3) southward to the limit of the subregions 4, 5, 6, 7 and 8. In subregions 3 and 7, the area extends deeper than the 100 m isobath. The total area favorable for the occurrence of surface skipjack schools, relative to the fourth quarter, is estimated at about 49,400 km².

Figure 7 presents a comparison of the size of the areas favorable for the concentration of surface skipjack schools, for the four quarters. From this graph, it is observed that the largest area favorable for the occurrence of surface skipjack schools occurs in the first quarter (austral summer), with 54,800 km² and the smallest area occurs in the fourth quarter (austral spring), with 49,400 km².

Table 2 summarizes the catch data from the fishery research vessel, "N/Pq MALACOSTRACA" of the PESAGRO-RIO (Agriculture Research Enterprise), from a cruise made between 06 and 18 of September 1982. During the cruise, skipjacks were fished with "live bait" along the coast, between Cabo Frio (RJ) and the southern end of São Paulo State, an area greater than 44,637 km² (PESAGRO-RIO, 1982). Catch data from the table were compared with the mapped areas presented in this work, relative to the third quarter (Figure 5). It was found that the areas where the skipjack was caught were located between the 50 m and 150 m isobaths, that is to say, within the potential areas for the occurrence of surface skipjack schools.

DISCUSSION

The present work is a first attempt to define the areas most favorable for the occurrence of surface skipjack schools. From the results obtained, it is possible to observe that the areas determined for the depths of 100 and 150 meters, are all in the study region and consequently are considered as potential areas for the presence of skipjack. The areas considered most favorable for the occurrence of skipjack, are those found between the 50 m isobath and the corresponding combined isobath of the two parameters. Those occur along and parallel to the coast.

In the first and second quarter, in subregion 3, the areas favorable for the presence of skipjack were interrupted. This loss of areal continuity may have occurred because, for the two quarters, the average quarterly depth of the 18°C isotherm was larger than 50 m (58 m in the first quarter and 84 m in the second quarter). The average quarterly value of the depth of the oxygen content lower than 3,5 ml/l was also large, being 134 m in the first quarter and 149 m in the second quarter.

In the third quarter, the same separation was observed; in this case, close to Santa Marta Cape and to the south, where the average value of the depth of the 18°C isotherm was 58 m and 65 m for the depth of the oxygen content lower than 3,5 ml/l.

The most favorable areas for the surface skipjack schools in the more oceanic part of the study, as determined from the available data, may be subject to some limitations:

- For the first quarter, in the area close to 26°30'S, 41°00'W, the depths related to temperature and oxygen content were less than or equal to 50 m (40 m and 50 m respectively), but those values refer only to the one station available.
- In the third quarter, only the depth related to temperature, presented values less than 50 m (13 m), for the single station available, but the area located at 29°30'S, 44°10'W was mapped only for temperature.

For these seasons, the results may not be meaningful. The above mentioned areas were mapped, however, because the values of the field data were within the range proposed at the beginning of this work.

A preliminary comparison made among the areas mapped by the methodology given in this work, with observed catches of skipjack, for some of the same areas, showed a good agreement between the two. It should

be noted, however, that the data sets are based on different time scales (quarterly for temperature and oxygen content values and daily for catch data) and are limited to only a few catch observations. In spite of these limitations, this agreement is encouraging. Future work utilizing a greater quantity of skipjack catch information and a more compatible time scale, might provide a stronger confirmation of the method used in the location of areas favorable for surface skipjack schools (developed within this work) and actual fish catch in those same areas.

CONCLUSIONS

From the results obtained with the present method, the following conclusions were reached regarding the identification of areas favorable for the occurrence of surface skipjack schools:

- The areas considered favorable for the occurrence of surface skipjack schools, are distributed along and parallel to the coast in all four quarters.
- The secondary areas, corresponding to depths of 100 and 150 m, are located in more oceanic part of the study region (starting with the isobath 200 m) and they are considered potential areas for the occurrence of skipjack.
- Some of the mapped areas for the third quarter, coincided with areas containing skipjack catches.
- The areas favorable for the occurrence of skipjack in the surface water, as determined in this work, amounted to about 8% of the overall area for every quarter.
- The largest area favorable for the occurrence of skipjack in the surface water, occurred during the first quarter (austral summer, with 54,800 km²) and the smallest area was during the fourth quarter (austral spring, with 49,400 km²).

LITERATURE CITED

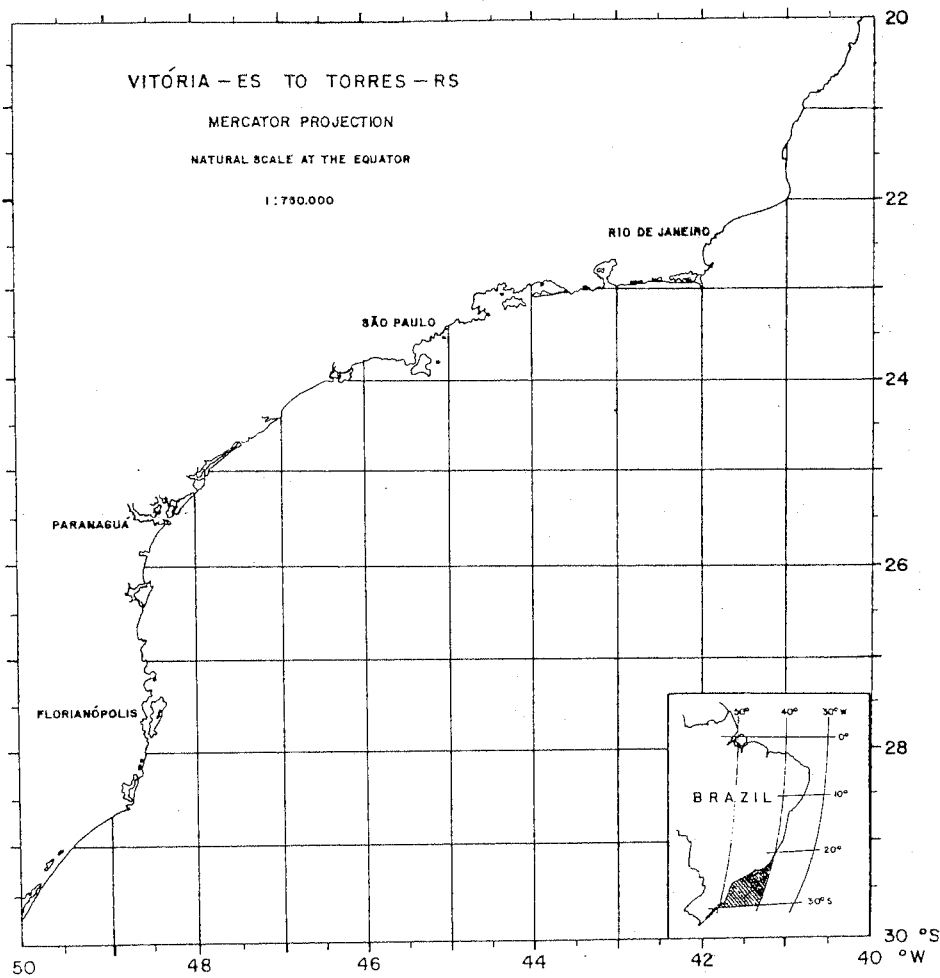
- ABDON, M. M. 1983. *Um modelo de cartas de pesca para tunídeos no sudeste e sul do Brasil utilizando dados oceanográficos e de sensoriamento remoto*. Tese de mestrado em sensoriamento remoto. São José dos Campos. (INPE-2627-TDL/110).
- BARKLEY, R. A.; W. H. NEILL; R. M. GOODING. 1978. Skipjack tuna, Katsuwonus pelamis habitat based on temperature and oxygen requirements. *U. S. Fish. Bull.*, 76(3):653-662.
- BLACKBURN, M. 1965. Oceanography and the ecology of tunas. *Oceanogr. Mar. Biol. Annu. Rev.*, 3:299-322.
- CASTRO, L. A. B. 1983. *Mapeamento de áreas favoráveis à ocorrência de albacora-de-laje no norte e nordeste do Brasil, com utilização de sensoriamento remoto e dados oceanográficos*. Tese de mestrado em sensoriamento remoto. São José dos Campos. (INPE-2632-TDL/112).
- DIZON, A. E.; R. W. BRILL; J. J. MAGNUSON. 1977. Rapid temperature compensation of volitional swimming speeds and lethal temperature in tropical swimming tunas (Scombridae). *Environ. Biol. Fishes*, 2:83-92.
- DIZON, A. E.; R. W. BRILL; H. S. H. YUEN. 1978. Correlations between environment, physiology and activity, and the effects on thermoregulation in skipjack tuna. In: SHARP, G. D.; A. E. DIZON, ed. *The physiological ecology of tunas*. New York, Academic Press, N.Y., 233-260.
- EMPRESA DE PESQUISA AGROPECUÁRIA (PESAGRO-RIO). 1982. *Relatório das atividades da Unidade de Pesquisa Marítima - UPM, Relatório Anual*, Niterói.
- EVANS, R. H.; D. R. McLIAN; R. A. BAUER. 1980. Atlantic skipjack tuna, influences of the environment on their vulnerability to surface gear. *Coll. vol. Sci. Pap.*, ICCAT, 9:264-274.
- INGHAM, M. C.; S. K. COOK; K. A. HAUSKNECHT. 1977. Oxycline characteristics and skipjack tuna distribution in the southeastern tropical Atlantic. *U.S. Fish. Bull.*, 75:857-865.
- MALUF, S. 1979. *Cartas de Pesca: Um modelo de cartas de pesca utilizando dados oceanográficos e de sensoriamento remoto, aplicado à sardinha (Sardinella brasiliensis)*. Tese de mestrado em sensoriamento remoto. São José dos Campos. (INPE-1423-TDL/03).
- MALUF, S. 1980. O sensoriamento remoto aplicado a um modelo de Cartas de Pesca. *Bolm. Inst. Oceanogr.*, São Paulo, 29(2):227-230.
- MALUF, S.; Y. MATSUURA, J.L. STECH. 1983. *Primeira tentativa de identificação de áreas favoráveis à ocorrência de bonito-listrado (Katsuwonus pelamis) através da análise de dados oceanográficos na região sudeste-sul do Brasil*. INPE, São José dos Campos. (In press).
- NAKAMURA, H. 1969. *Tuna: distribution and migration*. London, Fishing news, 766 p.
- NEILL, W. H.; R. K. C. CHANG; A. E. DIZON. 1976. Magnitude and ecological implications of thermal inertia in skipjack tuna, Katsuwonus pelamis (Linnaeus). *Environm. Biol. Fishes*, 1:61-80.
- WILLIAMS, F. 1970. Sea surface temperature and the distribution and apparent abundance of skipjack (Katsuwonus pelamis) in the eastern Pacific Ocean 1951-1968. *Inter-Am. Trop. Tuna Comm. Bull.*, 15:229-281.

PARAMETERS	PERIOD (QUARTER)	NUMBER OF AVERAGE VALUES PLOTTED	MAXIMUM DEPTH (m)	MINIMUM DEPTH (m)	TOTAL SAMPLED STATIONS
DEPTH OF THE 18°C ISOTHERM	1 ^o	55	225	12	499
	2 ^o	52	243	1	1334
	3 ^o	51	254	0	959
	4 ^o	57	254	20	634
DEPTH OF THE DISSOLVED OXYGEN CONTENT LOWER THAN 3,5 ML/L	1 ^o	55	1700	4	499
	2 ^o	52	2380	3	1334
	3 ^o	51	1695	14	959
	4 ^o	57	2458	3	634

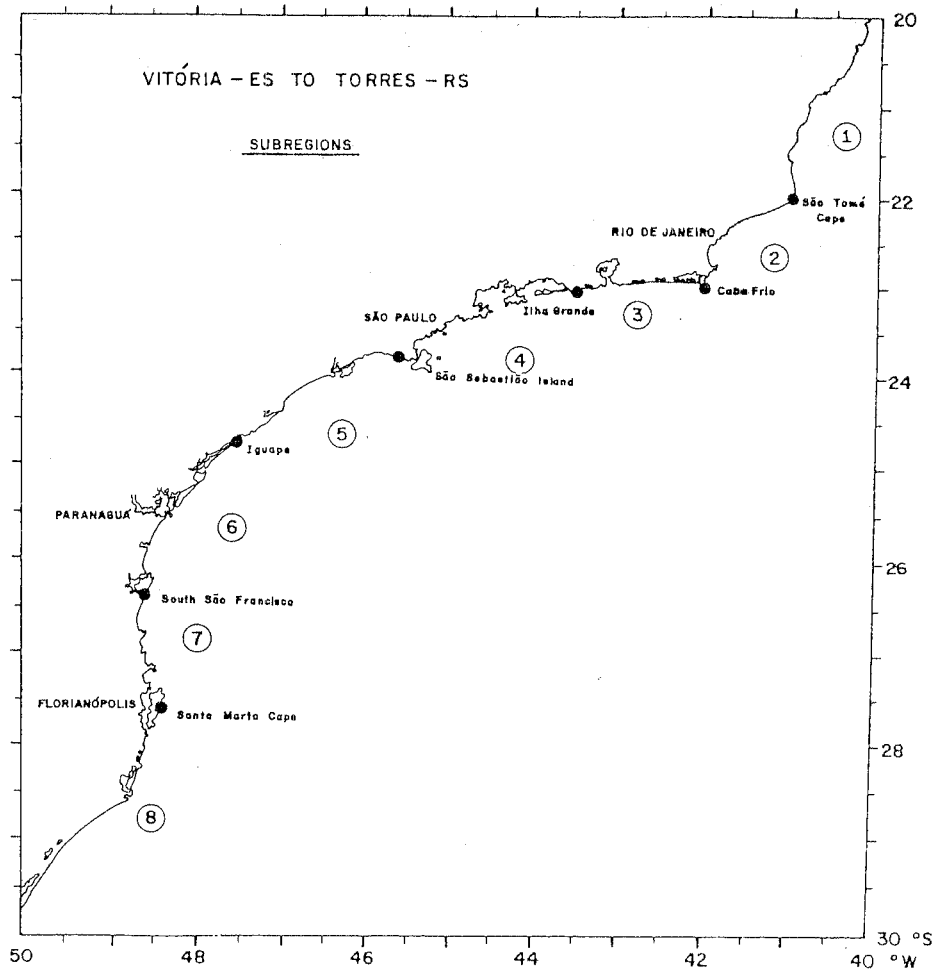
Table 1 - General information, per quarter, of the depths of the 18°C temperature and oxygen content lower than 3,5 ml/l.

OPERATION NUMBER	FISHING STATIONS	DAY	OPERATION DURATION		CATCH (Kg)	WATER SURFACE TEMP. (°C)	
			BEGINNING	END			
1	24 ^o 10'	44 ^o 50'	13	17:00	17:12	35.0	21.5
2	25 ^o 58'	45 ^o 24'	15	09:56	10:00	70.0	21.5
3	25 ^o 50'	45 ^o 22'	15	15:24	15:36	78.2	23.0
4	26 ^o 07'	45 ^o 21'	15	16:15	16:25	600	22.0
5	South of Ilha Grande		16	07:26	07:40	16.5	--
TOTAL REAL CATCH					1.486		
TOTAL ESTIMATED CATCH					799,7		

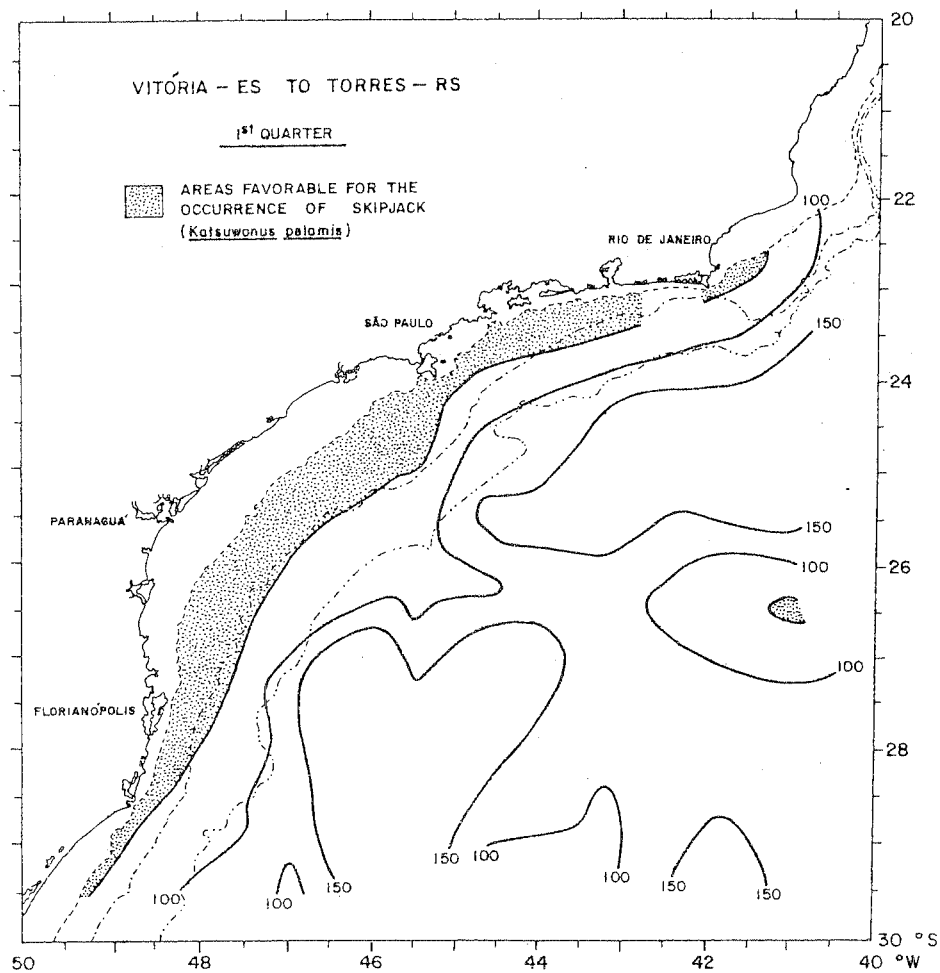
Table 2 - General observations of Cruise 08/82 (N/Pq "MALACOSTRACA", 06 to 18 September, 1982), according to PESAGRO-RIO, 1982.



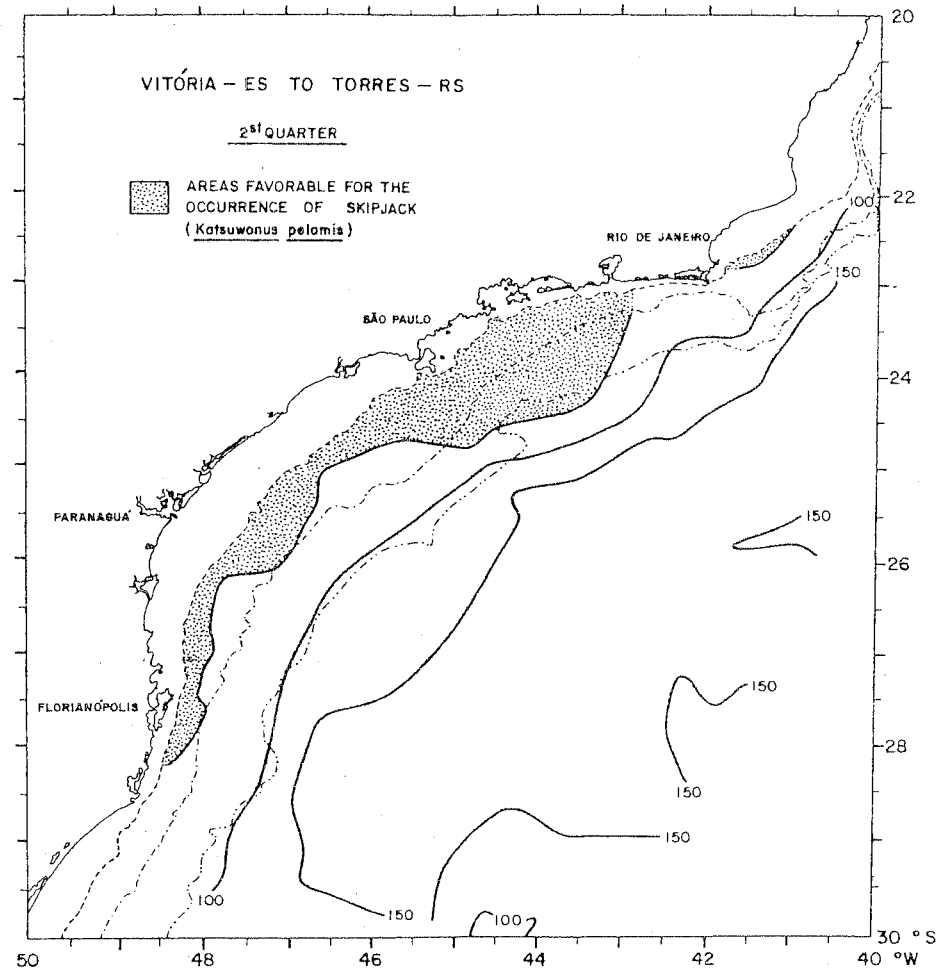
1 - Study region corresponding to MARSDEN Square 376, subdivided in squares of 1° Latitude x 1° Longitude.



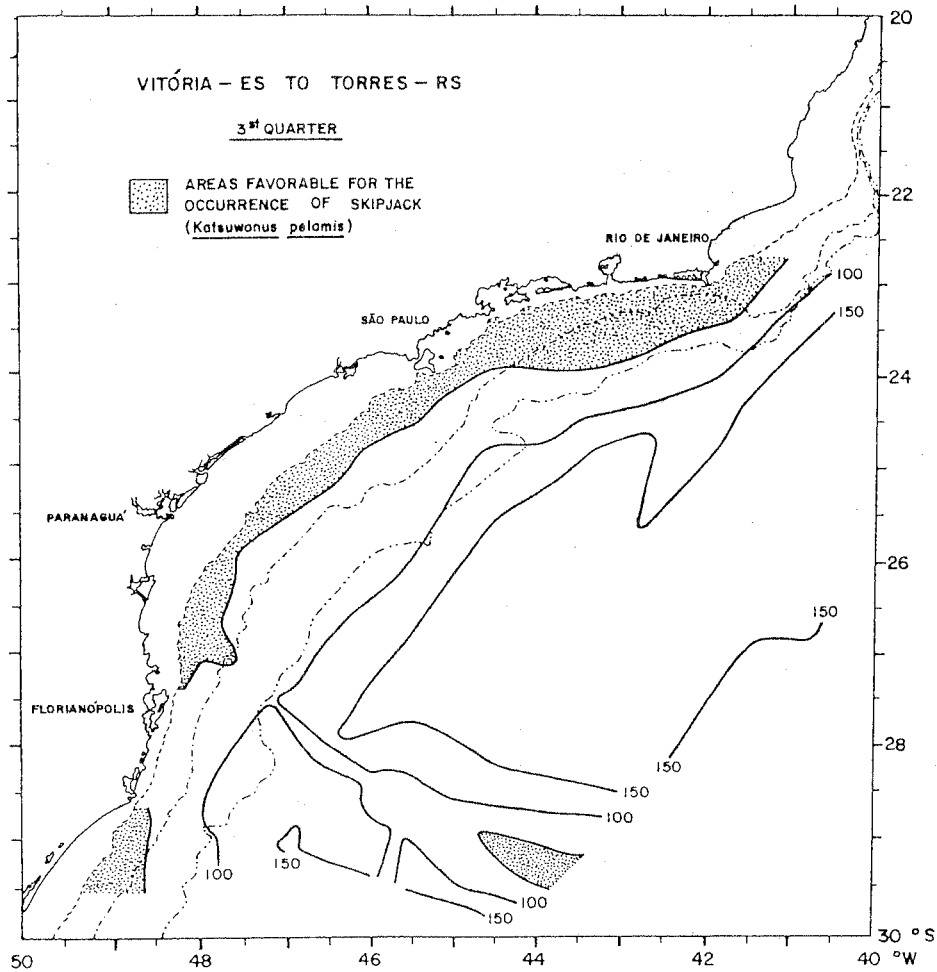
2 - Study region divided in eight (8) subregions.



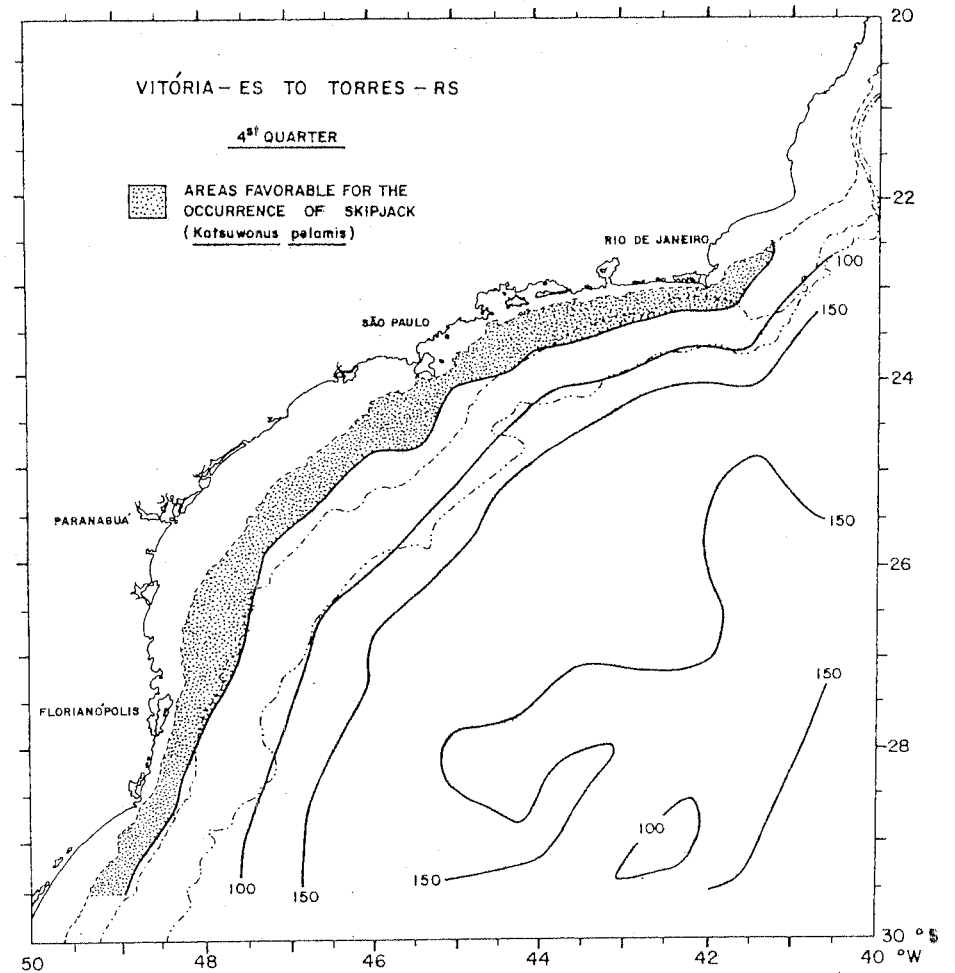
3 - Map of the areas favorable for the occurrence of surface skipjack (*Katsuwonus pelamis*) schools, for the first quarter. The numbered contour lines are isobaths (in meters) and correspond to the joint occurrence of temperature and dissolved oxygen as specified in the text.



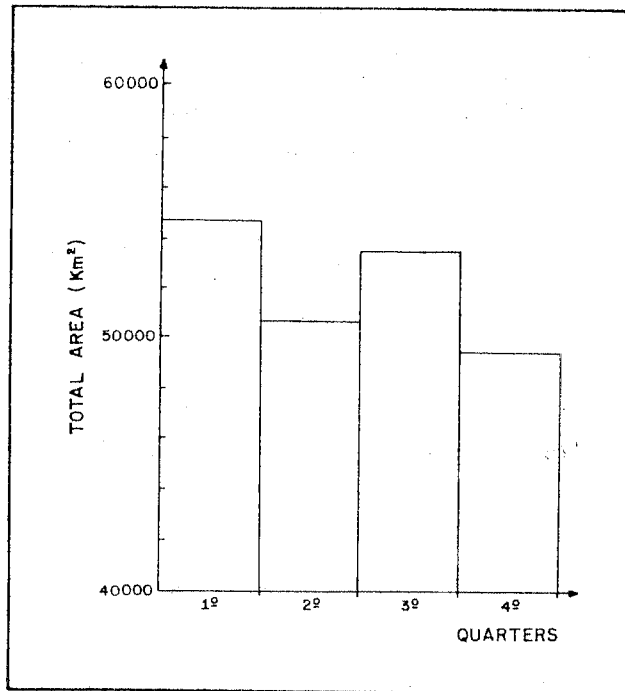
4 - Map of the areas favorable for the occurrence of surface skipjack (*Katsuwonus pelamis*) schools, for the second quarter. The numbered contour lines are isobaths (in meters) and correspond to the joint occurrence of temperature and dissolved oxygen as specified in the text.



5 - Map of the areas favorable for the occurrence of surface skipjack (*Katsuwonus pelamis*) schools, for the third quarter. The numbered contour lines are isobaths (in meters) and correspond to the joint occurrence of temperature and dissolved oxygen as specified in the text.



6 - Map of the areas favorable for the occurrence of surface skipjack (*Katsuwonus pelamis*) schools, for the fourth quarter. The numbered contour lines are isobaths (in meters) and correspond to the joint occurrence of temperature and dissolved oxygen as specified in the text.



7 - Graph of the total surface areas favorable for the occurrence of surface skipjack (Katsuwonus pelamis) schools, for the four quarters studied.