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MAPS OF FAVORABLE AREAS FOR TUNA FISHING IN THE SOUTHWESTERN ATLANTIC PREPARED FROM SATELLITE DATA

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SUMMARY

Surface temperature intervals suitable for large fish catch of the tuna species: *Thunnus albacares*, *Thunnus alalunga* and *Thunnus obesus* were previously defined for the southwestern Atlantic. The ranges in temperature were located on thermal infrared images from the SMS-2 satellite and maps of favorable areas for tuna fishing based on these ranges were prepared for the period February-July, 1980. In the development of these maps, infrared images received from the SMS-2 satellite were automatically processed by computer in the Image-100 System. Comparisons were made between fishing areas and tuna CPUE data for the years 1980, 1981 and 1982. The favorable areas for fishing for yellowfin tuna were found distributed all over the study area. The favorable areas for fishing for albacore and bigeye tunas appeared in the southern part of the study area, mainly in regions where the Malvinas Current occurs.

RESUME

Des intervalles de température de surface favorables à la prise de grands poissons des espèces *Thunnus albacares*, *Thunnus alalunga* et *Thunnus obesus* ont été définis pour l'Atlantique sud-ouest. La structure thermique a été localisée sur les images infra-rouges thermiques provenant du satellite SMS-2, et des cartes des secteurs propices à la capture de thonidés ont été établies à partir de cette information pour la période février-juillet 1980. En élaborant ces cartes, les images par infra-rouge transmises par le satellite SMS-2 ont été automatiquement traitées sur ordinateur avec le système Image-100. Les zones de pêche et les données de CPUE ont été comparées pour les années 1980, 1981 et 1982. Il s'est avéré que les secteurs propices à la capture d'albacore sont répandus sur toute l'aire étudiée. Les zones favorables à la prise d'albacore et de thon obèse apparaissent dans la partie sud de la région examinée, principalement là où est présent le courant des Falklands.

RESUMEN

Los intérvalos de la temperatura en superficie más favorables para obtener grandes capturas de las especies *Thunnus albacares, Thunnus alalunga* y *Thunnus obesus*, ya habían sido definidos en lo que se refiere al Atlántico Sudoeste. Las escalas de temperatura se localizaron en imágenes térmicas de infrarrojos del satélite SMS-2 y en base a dichas escalas se prepararon mapas de las zonas favorables a la pesca de túnidos durante el periodo Febrero-Julio 1980. En la preparación de estos mapas, las imágenes de infrarrojos recibidas del SMS-2 se procesaron automáticamente en un ordenador con el Image-100 System. Se establecieron comparaciones entre las zonas de pesca y los datos de CPUE de túnidos referentes a los años 1980, 1981 y 1982. Las zonas favorables para la pesca de rabil se encontraban distribuídas en toda el área estudiada. Las zonas favorables para la pesca de atún blanco y patudo se encontraban en la región Sur de la misma, especialmente por donde transcurre la Corriente de las Malvinas.

1. INTRODUCTION

This work is an attempt to determine appropriate areas for fishing of some tuna species in the area off Southern Brazil, Uruguay and Northern Argentina, considering the surface temperature distribution of the ocean, in the period between February and July, 1980. This work is a continuation of studies initiated in 1982 (Abdon, 1982a, b, 1983), in which surface temperature ranges, ecologically favorable to regional tuna fisheries, were defined. These studies were based on the relation between mean monthly temperature and CPUE data.

Of the various environmental parameters, only sea surface temperature data were used in this study. These data were obtained from archived oceanographic data and from the infrared channel of the Visible Infrared Spin Scan Radiometer (VISSR) sensor of the SMS-2 satellite. By the time of completion of this work, the importance of also using visible channel data from this same sensor was realized. Thus, the maps shown here are not to be considered as final, but are being subjected to further refinements. The objective of the present study is to produce maps showing the geographic location of temperature ranges appropriate to three tuna species, in order to optimize the fuel and time spent in searching for good fishery areas.

2. MATERIAL AND METHODS

The study area is located in the Southwestern Atlantic, between the latitudes 20°00'S and 40°00'S and longitudes 30°00'W and 60°00'W. This area consists of approximately 7.260.000 km². It is considered the most important fishery area of Brazil.

Maps of favorable areas for tuna fishing of the species: yellowfin tuna (*Thunnus albacares*), albacore (*Thunnus alalunga*) and bigeye tuna (*Thunnus obesus*) based on surface temperature intervals, were prepared for the period of February-July, 1980. These maps were obtained from infrared images of the SMS-2 satellite, according to methods developed by Abdon (1983), who defined surface temperature ranges favorable to three tuna fisheries in the oceanic waters South and Southeast of Brazil (Table 1).

The methods used in the development of the maps were:

1) Six infrared images from the SMS-2 satellite were selected, one for each month for the period of February to July, 1980. This period presented a smaller percentage of cloud cover over the study area than during the other months of the year.

2) The images were treated separately, using the Multispectral Image Analyzer System (Image-100). The images were enlarged without pixel repetition.

3) The three sea surface temperature ranges of the ocean (TSM) were calculated from oceanographic cruise data and were, then, correlated with temperature ranges corresponding to values registered by the SMS-2 satellite (TSM2). This comparison was made using temperature data collected at fixed coastal stations in Brazil and sea surface temperatures obtained from corresponding positions on SMS-2 images (Table 2).

4) The maximum temperature resolution in the thermal infrared band of the VISSR sensor is 0.5°C. Due to the precision of this sensor, the temperatures associated with the temperature intervals (TSM2) were rounded to ± 0.25°C.

5) The TSM2 ranges were associated with grey levels (Corbell et al., n.d.) registered on the satellite images (Table 3). The grey level range was 0 - 255 counts which corresponded to the thermal range of the sensor.

6) The favorable fishing areas were delimited in the images by grey level ranges using the computer programs "Cluster Synthesis" and "Slicer" (Ribeiro et al., 1982). The images that were utilized are listed on Table 4.

7) The program "PNTOUT" (Ribeiro et al., 1982) was used to associated an alphanumeric symbol with each grey level range and to produce the alphanumeric maps by computer printer.

8) Finally, the CPUE data for the years 1980, 1981 and 1982 were calculated for the same months as the maps.

3. RESULTS AND DISCUSSION

The areas favorable for fishing were delineated, based on the alphanumeric maps and are presented as shaded areas in Figures 1-18, with CPUE data included for the years of 1980-1982. The numbers written on top of each CPUE data square 20040, 25040, 25045, 30045, 30050 correspond to $5^0 \times 5^0$ squares. They begin at the following points, respectively: 20°00'S and 40°00'W, 25°00'S and 40°00'W, 25°00'S and 45°00'W, 30°00'S and 45°00'W, 30°00'S and 50°00'W. The border lines, present at the edge of the shaded areas, represent contact with water outside the different temperature ranges. When this line is not observed, it means that the boundary of a fishing area was difficult to establish, due to the presence of clouds in that region. The favorable areas for the three fisheries can be observed only in places with a small percentage of cloud over.

The dashed line (CS) is the 200 meter isobath and shows the limit of the continental shelf. This isobath is important, because the water depth associated with the longline method used for these tuna fisheries is usually greater than 200 m. After delineation of the continental shelf, some undesired information is eliminated in the maps: the coastal waters and Mar del Plata. The coastal waters exibit the same temperature intervals considered favorable for the funa fisheries, but these same waters are not ideal for the tunas being studied because they contain low salinity (Godoi, 1983).

In the first analysis one can observe that temperature ranges, delineated for yellowfin tuna, were found in all parts of the study area. To the south, in the warmer months, the fishing areas for yellowfin tuna extended almost to the southern limit between the Brazil Current and Malvinas Current (Godoi, 1983). The species that prefer cold waters, like albacore and bigeye tuna, had their fishery regions located in the southern part of the study area (in the Malvinas Current) and, sometimes, in the regions where the Subtropical Convergence occurs (Godoi, 1983). Nevertheless, in the colder months, the favorable areas for fishing of these species extended up to 20°00'S. The distribution of these tuna species, inferred here from the maps of temperature ranges, agree with results of other authors that have worked in the same regions (Paiva et al., 1975; Zavala-Camin, 1978a, b, c). One can also observe that from February to July, the favorable area for tuna fishing shifts toward the north, following the penetration of the Malvinas Current into Brazilian waters.

4. CONCLUSION

The sea surface temperature information, obtained from the thermal infrared band of the VISSR sensor aboard the SMS-2 satellite, showed these data to be suitable for use in a study of the variation of sea surface temperature applied to tuna fishing southeast of Brazil. A good correlation between sea surface temperature data measured at coastal stations and SMS-2 satellite derived temperatures, confirms the feasibility of utilizing temperature data from satellite as a substitute for conventional data. Satellite derived temperatures may, then, be used in temperature related studies such as the present study.

It is apparent that it is necessary to work with visible band information, in the face of difficulties in the delineation of favorable fishing areas, when these are partially cloud covered. Although the temperature ranges favorable for tunas have been defined, it is believed that one can achieve more detailed and precise results when including other oceanographic parameters as environmental predictors.

5. ACKNOWLEDGEMENTS

Thanks are due to Dr. Luis Alberto Zavala-Camin for his suggestions.

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Table 1 Surface temperature ranges favorable for tuna fisheries

Tuna Species	Yellowfin tuna	Albacore	Bigeye tuna
CPUE (kg/100 hooks)	> 60	> 30	> 30
Real temperature Intervals (°C)	21.36 - 24.04	17.38 - 20.17	13.96 - 20.50

SOURCE: Abdon, 1983

Table 2 Regression equations used to correlate TSM and TSM2 temperature ranges

Month	Regression Equation	Correlation (r)	Obs (N)	Prob (P)
February	TSM = 2.67 (TSM2) -27.74	0.66	8	>0.1
March	TSM = 2.48 (TSM2) -33.94	0.77	7	>0.05
April	TSM = 1.61 (TSM2) -9.11	0.85	5	>0.1
May	TSM = 1.73 (TSM2) -13.7	0.87	6	>0.05
June	TSM = 0.94 (TSM2) +2.74	0.89	5	>0.05
July	TSM = 0.95 (TSM2) - 4.51	0.95	8	> 0.001

SOURCE: Abdon, 1983

Table 3 Correspondence between TSM2 and grey level

Tuna Species	Temperature Range (°C)	Grey Level Interval
Yellowfin tuna	18.3 - 21.8	77 - 70
Albacore	15.3 - 18.3	83 - 77
Bigeye tuna	11.3 - 18.3	91 - 77

SOURCE: Abdon, 1983

Table 4 Dates of SMS-2 images

12:00 LT	February,	13	1980
12:00 LT	March,	27	1980
12:00 LT	April,	23	1980
12:00 LT	May,	28	1980
12:00 LT	June,	19	1980
12:00 LT	July,	24	1980

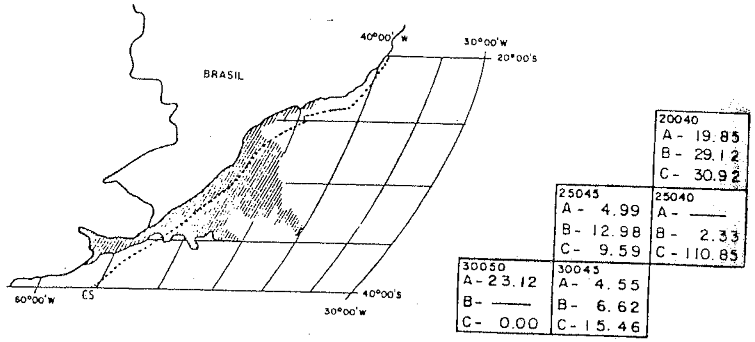

Figure 1 - Favorable fishing areas for yellowfin tuna. February, 1980. CS = 200 meter isobath. CPUE data in kg/100 hooks. A = 1980, B = 1981 and C = 1982. —— = no fishing effort.

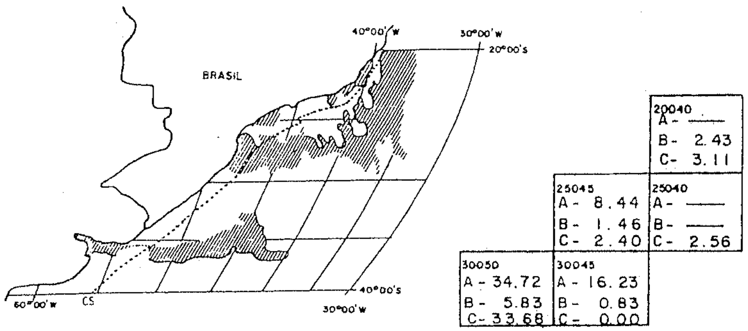

Figure 2 - Favorable fishing areas for yellowfin tuna. March, 1980.
CS = 200 meter isobath. CPUE data in kg/100 hooks. A = 1980,
B = 1981 and C = 1982. —— = no fishing effort.

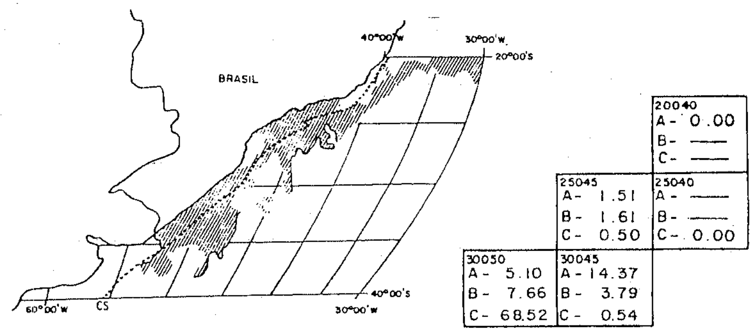

Figure 3 - Favorable fishing areas for yellowfin tuna. April, 1980.
CS = 200 meter isobath. CPUE data in kg/100 hooks. A = 1980,
B = 1981 and C = 1982. —— = no fishing effort.

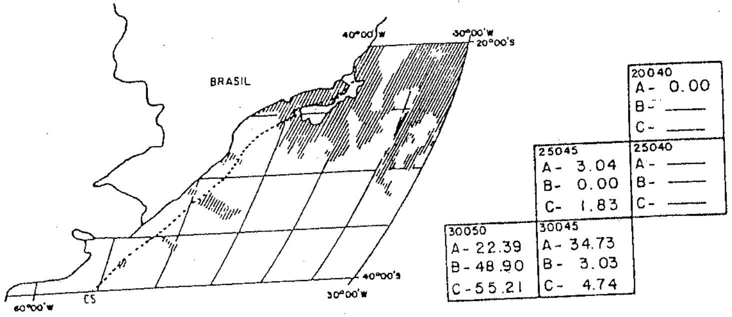

Figure 4 - Favorable fishing areas for yellowfin tuna. May, 1980.
CS = 200 meter isobath. CPUE data in kg/100 hooks. A = 1980,
B = 1981 and C = 1982. —— = no fishing effort.

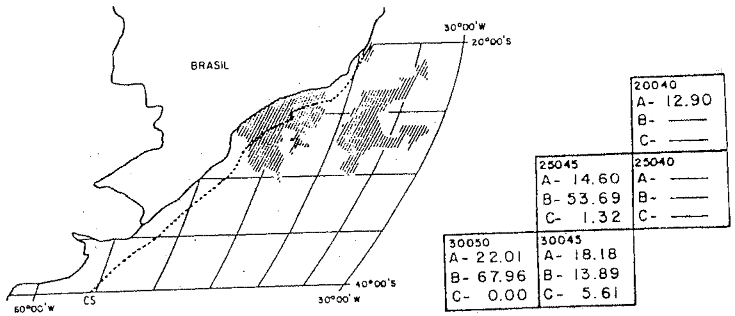

Figure 5 - Favorable fishing areas for yellowfin tuna. June, 1980.
CS = 200 meter isobath. CPUE data in kg/100 hooks. A = 1980,
B = 1981 and C = 1982. —— = no fishing effort.

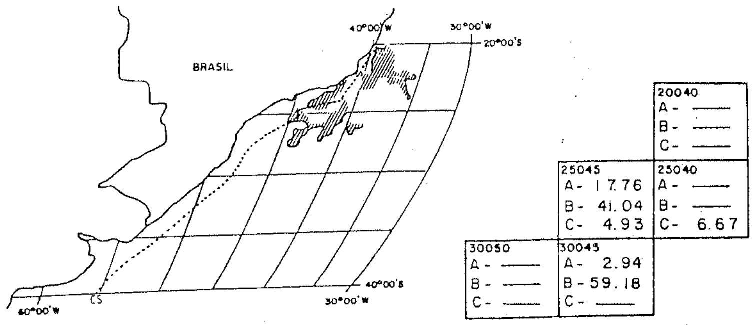

Figure 6 - Favorable fishing areas for yellowfin tuna. July, 1980.
CS = 200 meter isobath. CPUE data in kg/100 hooks. A = 1980,
B = 1981 and C = 1982. —— = no fishing effort.

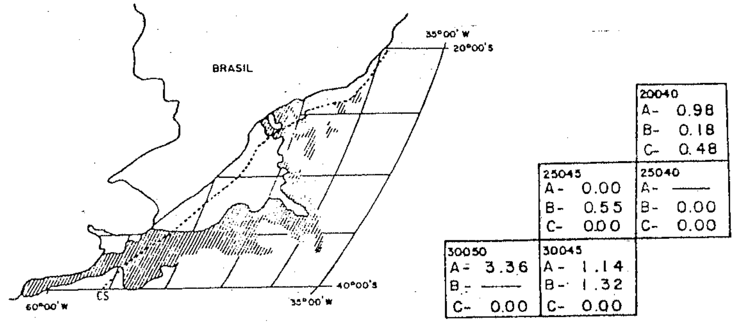

Figure 7 - Favorable fishing areas for albacore. February, 1980.
CS = 200 meter isobath. CPUE data in kg/100 hooks. A = 1980,
B = 1981 and C = 1982. —— = no fishing effort.

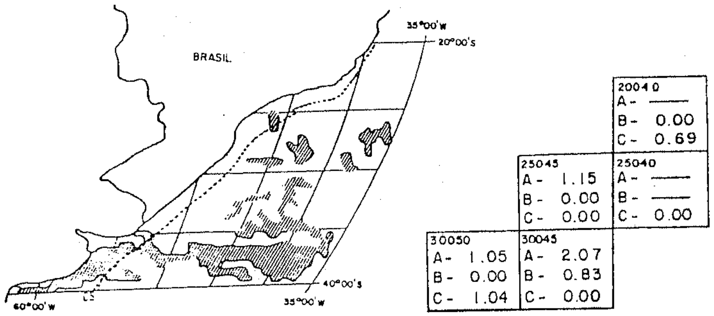

Figure 8 - Favorable fishing areas for albacore. March, 1980.
CS = 200 meter isobath. CPUE data in kg/100 hooks. A = 1980,
B = 1981 and C = 1982. —— = no fishing effort.

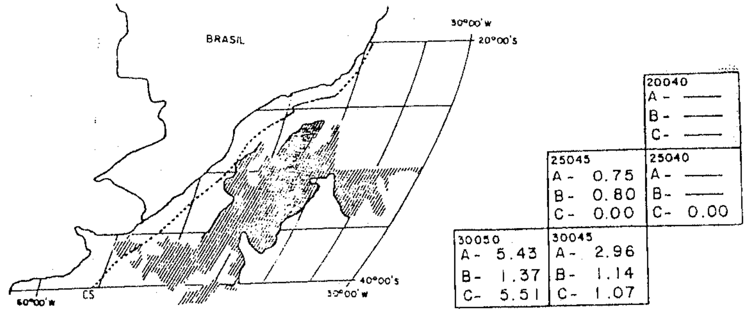

Figure 9 - Favorable fishing areas for albacore. April, 1980.
CS = 200 meter isobath. CPUE data in kg/100 hooks. A = 1980,
B = 1981 and C = 1982. —— = no fishing effort.

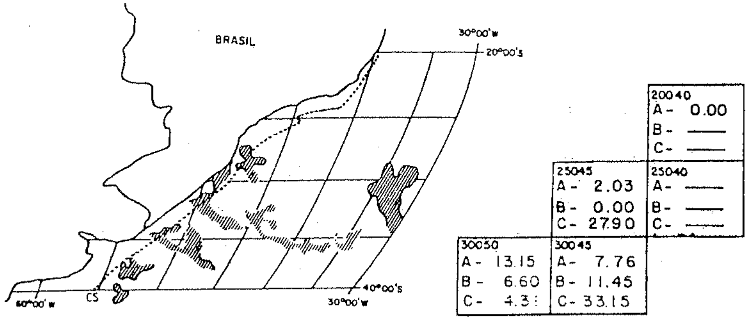

Figure 10 - Favorable fishing areas for albacore. May, 1980.
CS = 200 meter isobath. CPUE data in kg/100 hooks. A = 1980,
B = 1981 and C = 1982. —— = no fishing effort.

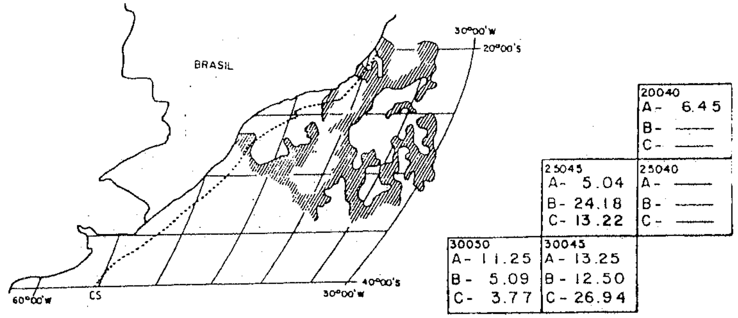

Figure 11 - Favorable fishing areas for albacore. June, 1980.
CS = 200 meter isobath. CPUE data in kg/100 hooks. A = 1980,
B = 1981 and C = 1982. —— = no fishing effort.

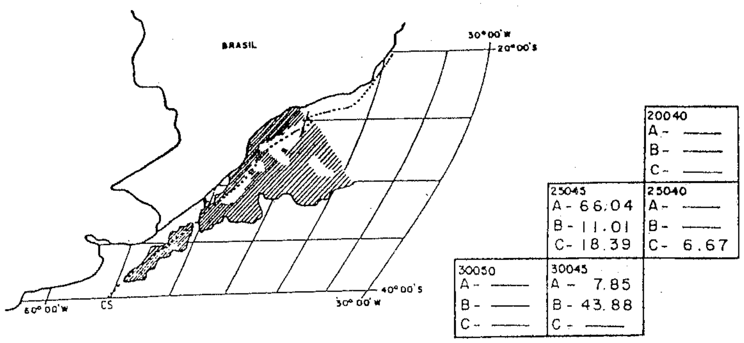

Figure 12 - Favorable fishing areas for albacore. July, 1980.
CS = 200 meter isobath. CPUE data in kg/100 hooks. A = 1980,
B = 1981 and C = 1982. —— = no fishing effort.

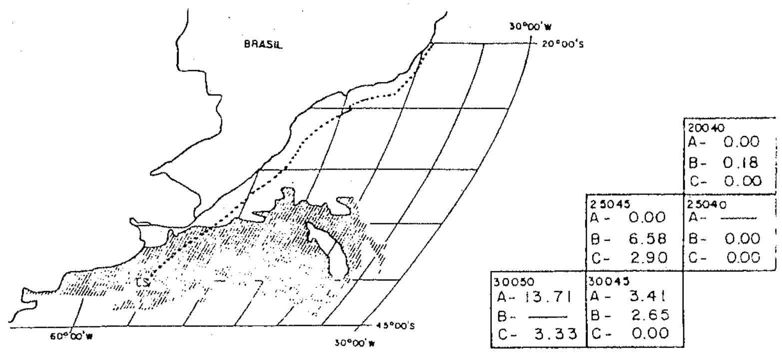

Figure 13 - Favorable fishing areas for bigeye tuna. February, 1980.
CS = 200 meter isobath. CPUE data in kg/100 hooks. A = 1980,
B = 1981 and C = 1982. —— = no fishing effort.

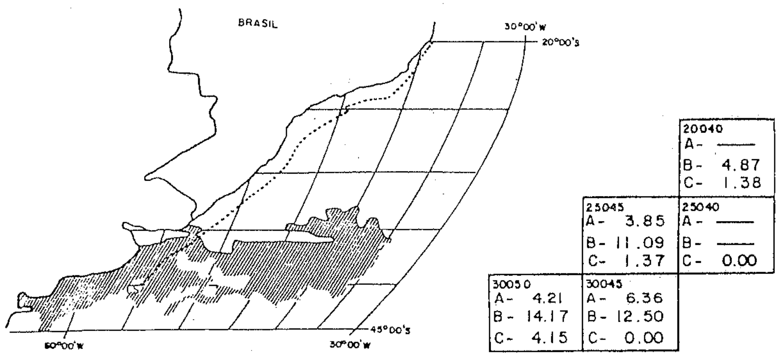

Figure 14 - Favorable fishing areas for bigeye tuna. March, 1980.
CS = 200 meter isobath. CPUE data in kg/100 hooks. A = 1980,
B = 1981 and C = 1982. —— = no fishing effort.

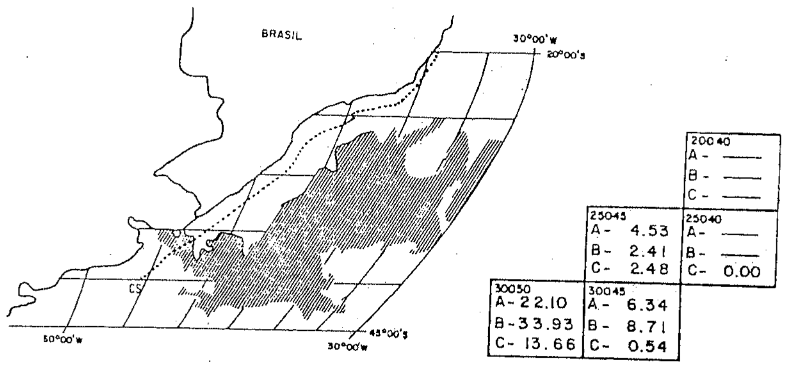

Figure 15 - Favorable fishing areas for bigeye tuna. April, 1980.
CS = 200 meter isobath. CPUE data in kg/100 hooks. A = 1980,
B = 1981 and C = 1982. —— = no fishing effort.

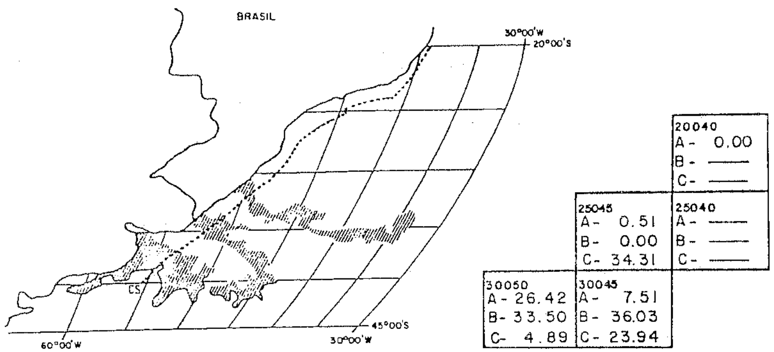

Figure 16 - Favorable fishing areas for bigeye tuna. May, 1980.
CS = 200 meter isobath. CPUE data in kg/100 hooks. A = 1980,
B = 1981 and C = 1982. —— = no fishing effort.

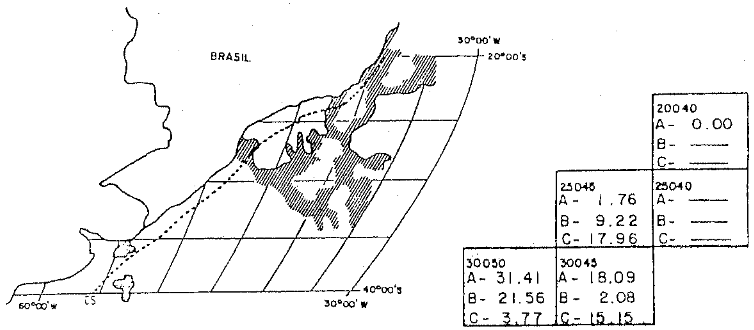

Figure 17 - Favorable fishing areas for bigeye tuna. June, 1980.
CS = 200 meter isobath. CPUE data in kg/100 hooks. A = 1980,
B = 1981 and C = 1982. —— = no fishing effort.

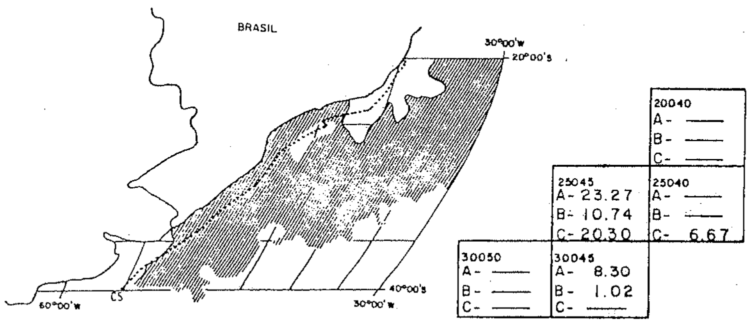

Figure 18 - Favorable fishing areas for bigeye tuna. July, 1980.
CS = 200 meter isobath. CPUE data in kg/100 hooks. A = 1980,
B = 1981 and C = 1982. —— = no fishing effort.