MAPS OF FAVORABLE AREAS FOR TUNA FISHING TO THE SOUTH AND SOUTHEAST OF BRAZIL PREPARED FROM SMS-2 SATELLITE DATA.

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Abstract

Sea surface temperature intervals suitable for large fish catch of yellowfin tuna, albacore and bigeye tuna were previously defined in oceanic water to the South and Southeast of Brazil. Maps of favorable fishing areas for these species were prepared for the period of February to July of 1980. In the development of these maps, infrared images received from the SMS-2 satellite were automatically processed by computer on the Image-100 System. Comparisons were made between the favorable fishing areas and tuna CPUE data of 1980 and it was observed that albacore and bigeye tuna appeared in the southern part of the study area, mainly in regions where the Malvinas Current occurs. A detailed comparison of albacore and bigeye tuna CPUE data of the years 1978 and 1979, with sea surface temperature, collected in real time, for a small area influenced by Subtropical Convergence was made. The study shows that the suitable sea surface temperature intervals for the fishing of these tuna species changes month-to-month, during the year.

Introduction

This work is an attempt to determine appropriate areas for fishing of some tuna species in oceanic water to the South and Southeast of Brazil and verify the variation and distribution of these regions during the year and as a function of the sea surface temperature. Previous studies (Abdon, 1982; 1983) were made to define sea surface temperature (SST) intervals appropriate for yellowfin tuna, albacore and bigeye tuna fishing, based on mean monthly temperature and CPUE data for the three species.

The objective of these studies is to produce maps showing the geographic location of temperature ranges appropriate to tuna species, in order to optimize the fuel and time spent in searching for good fishing areas.

Material and Methods

The area selected for the study of favorable regions for tuna fishing is the Southwestern Atlantic, between the latitudes 20°S and 40°S and longitudes 30°W and 60°W. It is considered the largest potential fishing ground of Brasil.

In this work are found maps of favorable areas for the fishing of the following tuna species: yellowfin tuna, albacore and bigeye tuna. The maps were prepared with infrared channel images obtained from the VISSR sensor (Visible and Infrared Spin Scan Radiometer) of the SMS-2 satellite.

The sea surface temperature (SST) intervals appropriate to tuna fishing were defined, based on methodology developed by Abdon (1983) (Table 1).

The methods used in the development of the maps were:

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

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

1.3 - The SST ranges of the ocean were calculated from oceanographic cruise data, and were then correlated with temperature ranges corresponding to values registered by the SMS-2 satellite(SST2). This comparison was made using SST data collected at fixed coastal stations in Brazil and SST2 obtained from corresponding positions on SMS-2 images (Table 2).

1.4 - The maximum temperature resolution in the thermal infrared band of the VISSR sensor is $0.5^{o}C$. Due to the precision of this sensor, the temperature associated with the SST2 intervals were rounded to $\pm 0.25^{o}C$.

1.5 - The SST2 ranges were associated with gray levels (Corbell et al., n.d.) registered on the satellite images (Table 3). The gray level range was 0-255 counts which corresponded to the thermal range of the sensor.

1.6 - The favorable fishing areas were delimited in the images by gray level ranges using the computer programs "Cluster Synthesis" and "Slicer" (Ribeiro et al., 1982).

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

1.8 - Finally, the areas favorable for fishing were delineated, based on the alphanumeric maps (Figures 1, 2 and 3) and are presented as shaded areas. 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.

TABLE 1

SEA SURFACE TEMPERATURE RANGES FAVORABLE FOR TUNA FISHERIES

TUNA SPECIES	YELLOWFIN TUNA	ALBACORE	BIGEYE TUNA
SST INTERVAL	21.4-24.0	17.4-20.2	14.0-20.5

Source:Abdon (1983)

TABLE 2

REGRESSION EQUATIONS USED TO CORRELATE SST AND SST2 TEMPERATURE RANGES

MONTH	REGRESSION EQUATION	COEFFICIENT CORRELATION (r)	OBS. (N)	PROB.(P)
Feb.	SST=2.67 . SST2 - 27.74	0.66	8	<0.1
Mar.	SST=2.48 . SST2 - 33.94	0.77	7	<0.05
Apr.	SST=1.61 . SST2 - 9.11	0.85	5	<0.05
May	SST=1.73 . SST2 - 13.70	0.87	6	<0.05
June	SST=0.94 . SST2 + 2.74	0.89	5	<0.05
July	SST=0.95 . SST2 - 4.51	0.95	8	<0.001

Source: Abdon (1983)

TABLE 3

CORRESPONDENCE BETWEEN SST2 AND GRAY LEVEL

TUNA SPECIE	SST2	GRAY 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)

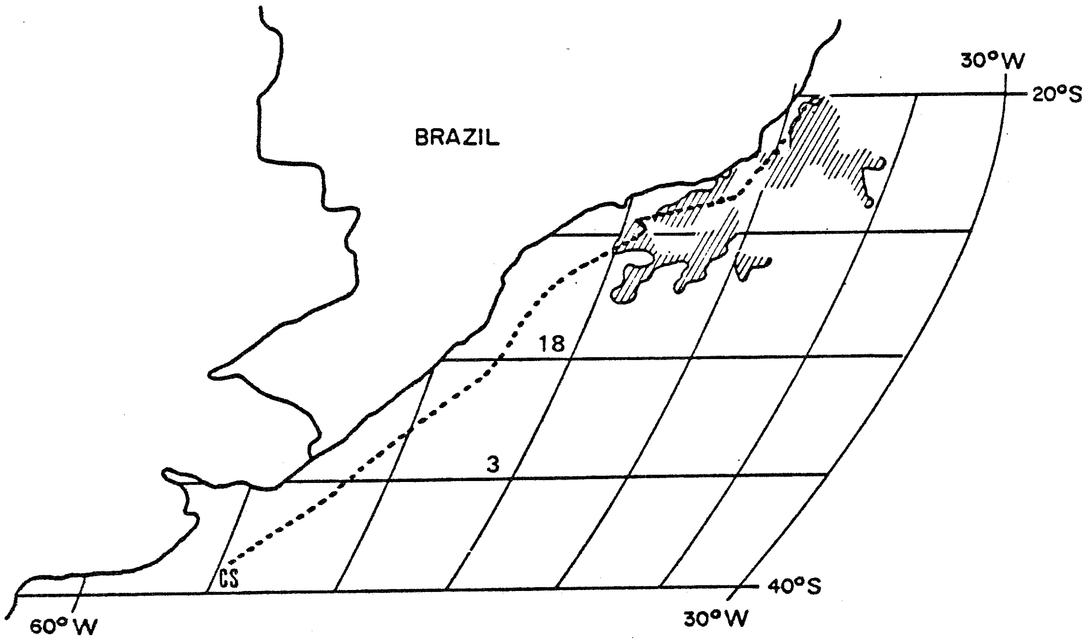

Fig. 1 - Favorable fishing areas for yellowfin tuna. July, 1980. CS=200 meter isobath. CPUE data in kg/100 hooks. CPUE values are written in the $5^{o}x5^{o}$ squares.

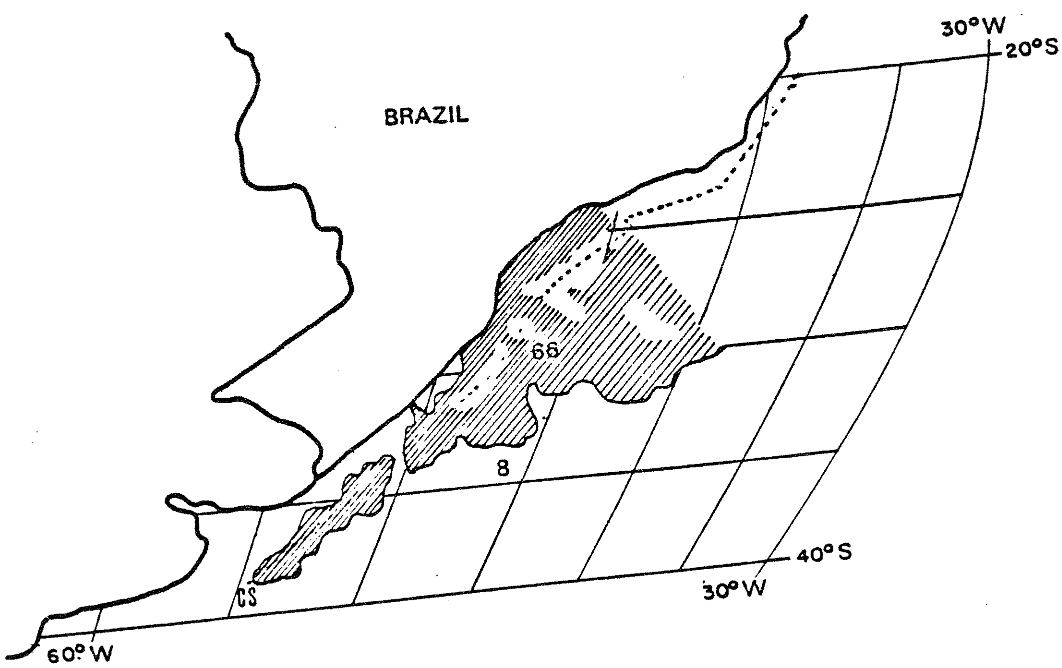

Fig. 2 - Favorable fishing areas for albacore. July, 1980. CS=200 meter isobath. CPUE data in kg/100 hooks. CPUE values are written in $5^{o}x5^{o}$ squares.

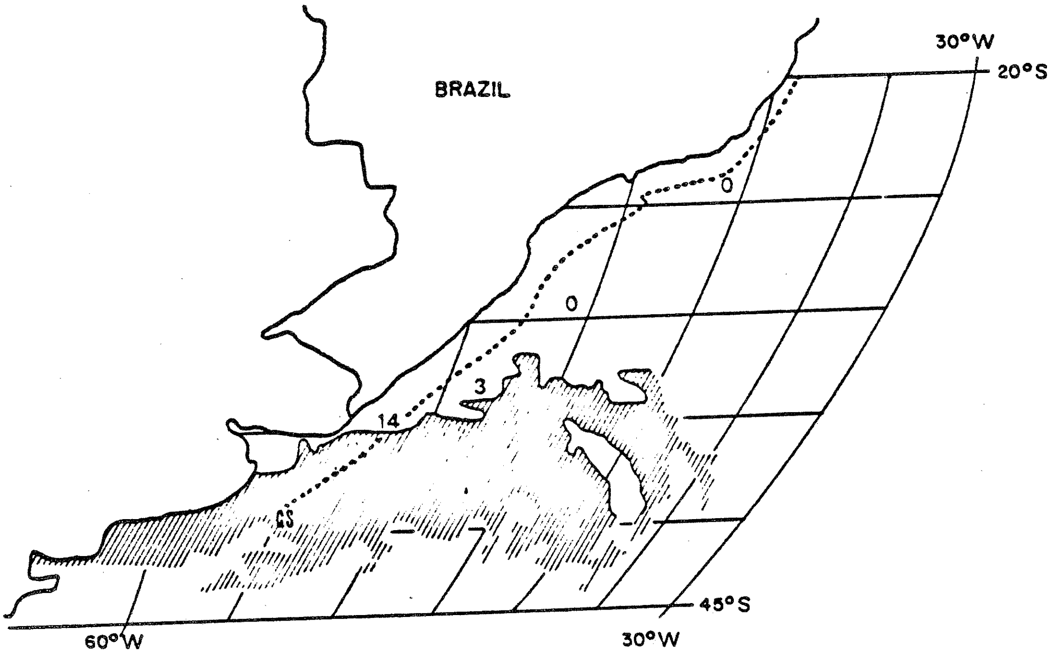

Fig. 3 - Favorable fishing areas for bigeye tuna. February, 1980. CS=200 meter isobath. CPUE data in kg/100 hooks. CPUE values are written in $5^o x 5^o$ squares.

The analysis of the variation of the related SST intervals to the albacore and bigeye tuna CPUE values were made using data for the years 1978 and 1979. The data were obtained by Japanese fishing boats, that collected fishing and SST information, in real time. The study area is delimited by latitudes 33^oS and 35^oS and longitudes 50^oW and 52^oW, and has 213 observations.

The methods used in the treatment and analysis of the data were:

2.1 - Representative values of the albacore and bigeye tuna CPUE were calculated for each month in the period of April, 1978 to September, 1979.

2.2 - Monthly means of the SST related to the CPUE values were calculated.

2.3 - SST x Month and CPUE x Month time series were prepared for these two tuna species (Figures 4 and 5) and means values were calculated for the months that did not have information (Table 4).

2.4 - Correlation coefficients were calculated with SST related to albacore and bigeye tuna CPUE data using the BASIS routine (Burroughs Advanced Statistical Inquiry System), available on the B/6800 computer of the Instituto de Pesquisas Espaciais (INPE) of Brazil.

2.5 - After this, 20% of the greatest CPUE data, for each month and each species, was selected. Each group of CPUE data defined one SST interval (Tables 5 and 6).

2.6 - Finally, the monthly variation of the temperature related to the CPUE data of the two species was verified and could be observed on the Tables 5 and 6 too.

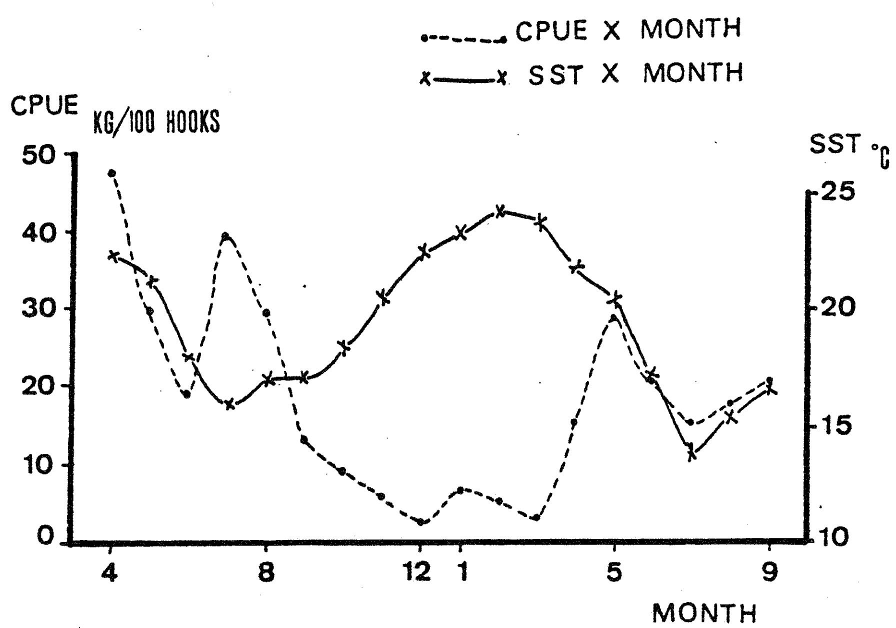

Fig. 4 - Monthly variations of albacore CPUE and SST for Apr., 1978 - Sept., 1979.

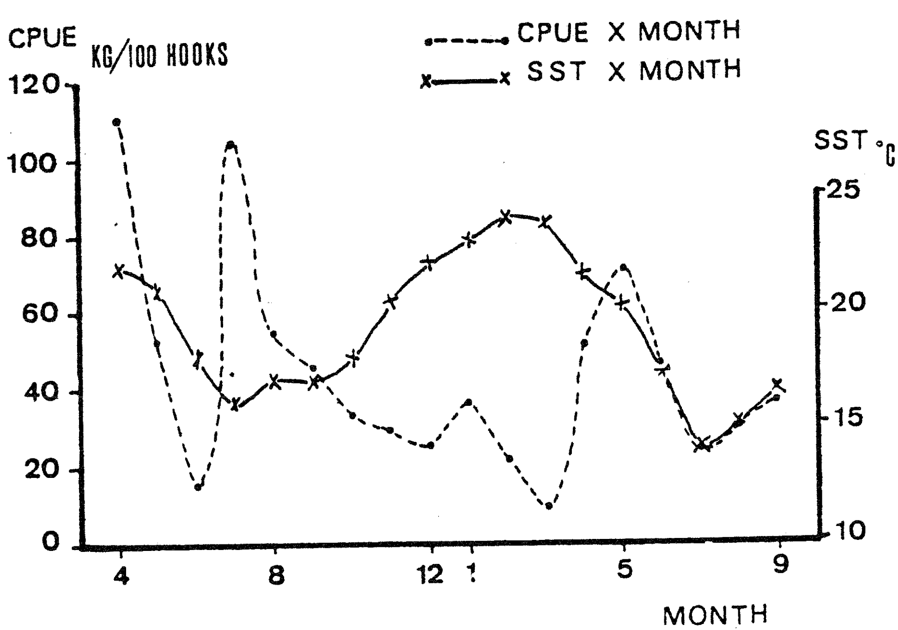

Fig. 5 - Monthly variations of bigeye tuna CPUE and SST for Apr., 1978 - Sept., 1979.

TABLE 4

MONTHLY MEAN DATA OF SST, ALBACORE CPUE AND BIGEYE TUNA CPUE FOR THE YEARS 1978 AND 1979, AND CORRELATION COEFFICIENTS FOR SST AND CPUE DATA

MONTH	YEAR	OBS (N)	SST (oC)	ALBACORE CPUE (kg/100 hooks	BIGEYE TUNA CPUE (kg/100 hooks)
Apr.	1978	10	22.1	47	111
May	1978	14	21.0	30	52
June	1978	01	18.1	18	16
July	1978	09	16.0	39	104
Ago.	1978	22	17.6	29	55
Sept.	1978	29	17.6	13	46
Out.	1978	12	18.6	9	34
Nov.	1978	0	20.6	6	30
Dec.	1978	8	22.7	3	26
Jan.	1979	18	23.1	7	37
Feb.	1979	25	24.0	5	22
Mar.	1979	10	23.7	3	8
Apr.	1979	15	21.5	16	50
May	1979	21	20.2	28	70
June	1979	0	17.1	22	46
July	1979	4	13.9	15	23
Ago.	1979	0	15.2	18	30
Sept.	1979	15	16.5	21	36

Obs.: r=-0.12(SSTxCPUE/albacore) 1978; r=-0.09(SSTxCPUE/bigeye tuna) 1978; r=-0.60(SSTxCPUE/albacore) 1979; r=-0.09(SSTxCPUE/bigeye tuna) 1979; r=-0.30(SSTxCPUE/albacore) 1978+1979; r=-0.08(SSTxCPUE/bigeye tuna) 1978+1979.

RESULTS AND DISCUSSION

The favorable areas for the three fisheries can be observed only in places with a small percentage of cloud cover. 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 from the maps: the coastal waters and Mar del Plata. The coastal waters exibit the same temperature intervals considered favorable for the tuna fisheries, but the same waters are not ideal for the tunas being studied because they contain low salinity (Godoi, 1983).

The CPUE values in the $5^{o}x5^{o}$ squares (kg/100 hooks), obtained in 1980, were included in the maps to verify the relation between CPUE and the ideal regions for tuna fisheries. The squares that are presented without CPUE values did not have fishing effort.

It was observed that the distribution of the albacore and bigeye tuna, inferred here from the maps of temperature ranges, agree with results of other authors that have worked in the same regions (Paiva and Le Gall, 1975; Zavala-Camin, 1978a,b). These species prefer cold waters and were 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). The temperature ranges, delineated for yellowfin tuna were found in all parts of the study area. To the south, in the warmer months, the fishings areas for this species extended almost to the southern limit between the Brazil Current and Malvinas Current (Godoi, 1983). 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.

TABLE 5

SST INTERVALS DEFINED WITH THE 20% GREATEST VALUES OF ALBACORE CPUE

CPUE (20%) (kg/100 hooks)		SST (°C)
Apr.	67 - 71	21.6 - 22.0
May	48 - 76	20.5 - 21.7
July	46 - 88	15.8 - 16.8
Ago.	44 - 81	13.1 - 19.6
Sept.	24 - 34	16.6 - 19.7
Out.	15 - 21	17.6 - 20.1
Dec.	02 - 13	21.8 - 22.6
Jan.	10 - 15	23.0 - 24.7
Feb.	12 - 24	23.8 - 25.5
Mar.	03 - 12	23.5 - 24.2
Apr.	23 - 26	19.4 - 23.2
May	38 - 53	19.6 - 20.8
July	04 - 45	12.4 - 18.6
Sept.	30 - 40	17.3 - 18.3

TABLE 6

SST INTERVALS DEFINED WITH THE 20% GREATEST VALUES OF BIGEYE TUNA CPUE

CPUE(20%) Kg/100 hooks		SST (°C)
Apr.	175 - 314	21.8 - 22.0
May	86 - 157	19.1 - 22.0
July	145 - 205	15.9 - 18.7
Ago.	84 - 182	13.1 - 19.6
Sept.	60 - 90	15.4 - 19.7
Out.	73 - 105	16.2 - 17.6
Dec.	27 - 75	21.8 - 22.5
Jan.	54 - 89	22.6 - 23.1
Feb.	39 - 56	22.7 - 24.6
Mar.	13 - 16	23.0 - 24.2
Apr.	93 - 108	22.5 - 23.2
May	108 - 148	19.6 - 20.8
July	15 - 51	12.4 - 18.6
Sept.	65 - 73	14.2 - 19.9

By the analysis information of the smaller study region, about the SST intervals related to the greatest CPUE values, we can observe:

First, monthly mean data that were calculated from the 213 observations of the years 1978 and 1979 were used (Methods Sections 2.1 - 2.4). After calculating the correlation coefficients with SST and CPUE data, the necessity of one total CPUE x SST analysis, in each month, was observed. It is due to the low correlation coefficients found to the SST x albacore CPUE and SST x bigeye tuna CPUE.

After the selection of the greatest monthly CPUE values for each species, the CPUE points, that were related to temperature values, defined the intervals of SST favorable to two tuna fishing (Table 5 and 6). We can observe that the greatest CPUE values were located in the 2nd and 3rd trimesters, and, for the same range considered, we can find temperature interval that change month to month. It can be observed in Table 7.

TABLE 7

MONTHLY SST INTERVALS MOST FAVORABLE TO ALBACORE AND BIGEYE TUNA FISHING

ALBACORE			BIGEYE TUNA		
CPUE	MONTH/YEAR	SST INTERVAL	CPUE	MONTH/YEAR	SST INTERVAL
40-70	Apr. 1978	21.6-22.0 °C	>100	Apr. 1978	21.8-22.0 °C
(kg/100 hooks)	May 1978	20.5-21.7 °C	(kg/100 hooks)	May 1978	19.1-22.0 °C
	July 1978	15.8-16.8 °C		July 1978	15.9-18.7 °C
	Ago. 1978	13.1-19.6 °C			
				Feb. 1979	22.7-24.6 °C
	May 1979	19.6-20.6 °C		Mar. 1979	23.0-24.2 °C

These results were compared with the results of Abdon (1983), listed in Table 1. It was observed that the SST intervals favorable to the two tuna species fishing had bigger temperature values, on the order of 3 °C.

CONCLUSIONS

The following conclusions were made based on this work:

1. The SST 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 SST applied to tuna fishing southeast of Brazil.

2. The necessity of working with visible band information is apparent from the difficulties encountered in the delineation of favorable fishing areas, when these are partially cloud covered.

3. The detailed study with SST and tuna CPUE data collected in real time, showed that the SST intervals related to the greatest albacore and bigeye tuna capture, change month-to-month, during the year.

4. From the analysis of data collected in real time, it was observed that SST's favorable to the fishing of these tuna species are more precise.

5. The good correlation between SST 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.

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