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14. Abstract/Notes

The principal objective of this study was de delimitation of favorable zones for the fishing of three species (Thunnus albacares, Thunnus alalunga and Thunnus obesus) in the waters southeast and south os Brazil utilizing oceanographic and SMS-2 satellite data. The oceanographic and fishery data were worked by monthly mean and 5^o *X* 5^o *squares. Correlations were made between oceanographic data of surface temperature and fish catch (CPUE) data. Surface temperature intervals corresponding to larger fish catch for each species were determined. After that, these intervals were transformed into data corresponding to that registered by the SMS-2 through regression lines constructed with coastal stations (fixed) and SMS-2 data. These intervals were located in the satellite images and related to the water masses present in the study area. The results showed that temperature cannot be considered by itself as the only indicator of the presence of tuna in specified regions. It is necessary to work with more precise sea surface temperature and CPUE data, collected in real time, in order to relate the last ones to oceanographic and environmental conditions at greater depths, where the studied tuna species are found.*

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A STUDY OF THE RELATIONSHIP BETWEEN SURFACE TEMPERATURE AND TUNA FISH CATCH DATA IN SOUTH AND SOUTHEAST OF BRAZIL USING OCEANOGRAPHIC AND SATELLITE DATA

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Abstract

The principal objective of this study was the delimitation of favorable zones for the fishing of three species (Thunnus albacares, Thunnus alalunga and Thunnus obesus) in the waters southeast and south of Brazil utilizing oceanographic and SMS-2 satellite data. The oceanographic and fishery data were worked by monthly mean and 5^{o} X 5^{o} squares. Correlations were made between oceanographic data of surface temperature and fish catch (CPUE) data. Surface temperature intervals corresponding to larger fish catch for each species were determined. After that, these intervals were transformed into data corresponding to that registered by the SMS-2 through regression lines constructed with coastal stations (fixed) and SMS-2 data. These intervals were located in the satellite images and related to the water masses present in the study area. The results showed that temperature cannot be considered by itself as the only indicator of the presence of tuna in specified regions. It is necessary to work with more precise sea surface temperature and CPUE data, collected in real time, in order to relate the last ones to oceanographic and environmental conditions at greater depths, where the studied tuna species are found.

1. Introduction

Some authors made observations to determine the sea water temperature intervals that propitiate the tuna fishery (Laevastu and Rosa, 1962; Squire Jr., 1963; Evans, 1980).

This work is an atempt to define temperature ranges and, consequently, areas where the tuna fisheries are favourable. Fish catch data, satellite data and information on the sea surface temperature collected in the study area were utilized.

The study area is located in waters south and southeast of Brazil, between the latitudes 20°00'S and 34°00'S and longitudes 35°00'W and 54°00'W. These waters are influenced by the Subtropical Convergence that contributes to their fertility. This area is considered the largest potential fishing ground of Brazil.

The species *Thunnus albacares* (Bonnaterre, 1788), (yellowfin tuna); *Thunnus alalunga* (Bonnaterre, 1788) (albacore), and *Thunnus obesus* (Lowe, 1839) (bigeye tuna); which are found in the study area (Zavala-Camin, 1978 a, b, c) were selected for this work.

2. Material and Methods

2.1 - Tuna Fish Catch Data

Information about catch of the species *Thunnus albacares*, *Thunnus alalunga* and *Thunnus obesus*, related to the longlige fishery from 1974 to 1980, were supplied by the

Superintendência do Desenvolvimento da Pesca (SUDEPE) and by the Instituto de Pesca de São Paulo, Divisão de Pesca Marítima de Santos.

Each species was treated separately; the data were divided into 5^o x 5^o squares encompassing the study area which can be identified in "Figure 1". After that, the data were treated separately within each square. The values referring to fishing effort (number of hooks put into the sea) and catches (kg) were separated by month and added. Having the total value of catch within each month, the CPUE values (catch per unit effort) in units of 100 kg/100 hooks, representing each month and each 5^o x 5^o square, were calculated. The calculated values are found in "Tables 1-3".

2.2 - Oceanographic Station Data

All historical temperature data (^oC) that exist in the Banco Nacional de Dados Oceanográficos (BNDO) at Diretoria de Hidrografia e Navegação (DHN) until 1980, referring to Marsden squares 376 (20^o00'S to 30^o00'S and 40^o00'W to 50^o00'W), 412 (30^o00'S to 40^o00'S and 40^o00'W to 50^o00'W) and 413 (30^o00'S to 40^o00'S and 50^o00'W to 60^o00'W) were utilized.

Mean monthly surface temperatures were calculated for each 5^o x 5^o square of the study area. The values are shown in "Table 4".

2.3 - Fixed Station Data

Information about sea surface temperature from the fixed coastal stations of Brazil were utilized for correlation with SMS-2 satellite data. Only the information collected in the interval 09:00h to 15:00h, the closest possible time to recorded SMS-2 images, were utilized. The fixed coastal stations where the data were obtained are shown in "Table 5".

2.4 - SMS-2 Satellite Data

2.4.1 - Image Treatment on the Multispectral Image Analyzer System (GE I-100 System)

Abdon (1982 a) has adapted methodologies for automatic treatment of SMS-2 images for fishing studies applications. These methodologies have the objective of dividing the study area into sea surface temperatures ranges corresponding to the grey level intervals on the infrared images, using the Multispectral Image Analyzer System. For this, the following programs were utilized: "Contrast Stretch" which increases the contrast between images grey levels; "Cluster Synthesis" which identifies the similar grey levels in the study area; and the program "Gercor" which creates standard colors for distinct grey level intervals (Dutra et al., n.d.). The analyzed images were on the following dates: February 13, March 27, April 23, May 28, June 20, and July 24, all for 1980. An example of the above described procedure can be observed in "Figure 2", for the image of July 24, 1980.

2.4.2 - Accuracy of the SMS-2 Satellite Data

Due to the following phenomena: absorption of the infrared radiation by the atmosphere, heat flux, evaporation, reflection, cloud contamination and atmospheric humidity, the surface temperature of the sea water registered by satellite tends to be different from the real temperature (Maul, 1981).

In order to relate the real sea temperature data with the temperature yielded by the SMS-2 satellite, fixed station data and corresponding SMS-2 pixels were utilized, for the day and hour of the information collected. The correlation between them was calculated and, after that, the regression equation for each correlated data series was determined. The regression equations are shown in "Table 6", where "Tre" is the real sea surface temperature value "Tsms" is the sea surface temperature value obtained by the SMS-2 satellite, "r" is the correlation coefficient and "N" is the number of observations.

2.5 - Correlation Between Fish Catch Data and Surface Temperature at the Oceanographic Stations

According to some authors (Laevastu and Rosa Jr., 1962; Squire Jr., 1963; Radovich, 1963; Blackburn, 1969; Laurs and Lynn, 1977; Evans, 1980) temperature has an influence on the distribution of the tuna species considered in this work.

As the objective is the determination of the optimuns surface temperature intervals where a large concentration of each species is present, a criterion for the study of this relationship was established. Each species was treated separately. The representative CPUE values for each month were arranged and the sea surface temperature values calculated with oceanographic station data. The correlation between them was calculated according to Panofsky and Brier (1965) with "r" (correlation coefficient), "P" (significance level) and "N" (number of observation) values shown in "Table 7".

3. Results and Discussions

The CPUE values for each tuna species were arranged in intervals of 30 kg/100 hooks and related to mean sea temperature intervals calculated with oceanographic station data as can be observed at "Tables 8 to 10". "I.LIM." and "S.LIM." are the values of the inferior and superior limits respectively, for the calculated means, for a confidence intervals of 95%.

Each specie was analized separately because of their different distribution characteristics in time and space.

3.1 - Yellowfin Tuna

The squares 20040, 25040 and 25045 were selected to relate the largest CPUE intervals with sea surface temperature ranges ("Table 11") because the square 20040 presented the greatest CPUE values of the yellowfin tuna during the year and the other ones presented the greatest correlation coefficients.

According to Sverdrup et al. (1942), Emilson (1961) and Thomsen (1962) the relation the yellowfin tuna and the water masses present on the studied region was determined. It was observed that this species had its greatest CPUE in square 20040 on South Atlantic Tropical Water which is transported by the Brazil Current.

The CPUE values between 30 and 60 kg/100 hooks that are related to the water defined by intervals that have lower temperatures were found in square 25045 which is normally influenced by Falkland Current waters, by Plata Sea Waters and Waters formed in the Subtropical Convergence.

For the transformation of real mean values of the sea surface temperature in temperature values corresponding to the values found on SMS-2 satellite images, the regression equations calculated before were used.

The transformation of the surface temperature ranges of the real values to satellite values was possible only in square 20040. This is because the other limits of the surface temperature ranges corresponded to values of the months where the calculation of a regression equation was not possible, due to large cloud cover on these images. The above mentioned transformation are found in "Table 12". The temperature ranges calculated in "Table 12" for the SMS-2 were observed on the treated images. The predominance of these intervals in Brazil Current water was noted.

3.2 - Albacore

The squares 25045, 30045 and 30050 were considered for the determination of the sea surface temperature ranges related to large CPUE values of albacore because they presented the greatest correlation coefficients ("Table 13").

It was observed that this species had its greatest CPUE in squares 25045 and 30045 on South Atlantic Subtropical water found on the Subtropical Convergence area. In July and August, period of larger CPUE, this area is strongly influenced by Plata Sea waters and by further Falkland Current penetration on brazilian regions (Godoi, n.d.).

For the transformation of real mean values of the sea surface temperature into temperature values corresponding to the values found on SNS-2 satellite images, the regression equations calculated before were used ("Table 14").

The temperature ranges calculated in Table 14, for the SMS-2 were observed on the treated images and it was noted a predominance in regions where the Subtropical Convergence is present.

3.3 - Bigeye Tuna

The squares 25045, 30045 and 30050 were used for the determination of the surface temperature ranges related to large CPUE values of bigeye tuna because they presented the greatest correlation coefficients ("Table 15").

It was observed that this species had its greatest CPUE in square 30050 on South Atlantic Subtropical Water and Subantartic Water. This species seems to be the more related to

Falkland Current water and Subtropical Convergence. This is due to the fait that the largest CPUE was found in waters where the mean salinity is very low (Abdon, 1982 b), and this is avoided by tuna species. Therefore, the presence of bigeye tuna is restrict to the east of this square, coinciding with the presence of the oceanographic front.

For the transformation of real mean values of the sea surface temperature into temperature values found in the SMS-2 images, the regression equations calculated before were used ("Table 16"). The temperature ranges calculated in "Table 16" for the SMS-2 were observed on the treated images and it was noted the predominance in regions where the Falkland Current and Subtropical Convergence are present.

4. Conclusions

In this work sea surface temperature ranges related to CPUE values for each studied specie were determined, but these could not be considered, by themselves as the only indicator of tuna presence in certain regions.

The yellowfin tuna had its sea surface temperature range related to the greatest CPUE values coinciding with sea surface temperature related to the smallest CPUE values. The albacore had the greatest CPUE values related to the low temperature values between June and August. However, the temperature was low in May, September and October and the CPUE values were small The greatest CPUE values of the bigeye tuna were related to the lowest sea surface temperature values, but not of all the lowest temperatures were related to the greatest CPUE values.

Many factors can be associated to the variations found in the study of the relation between sea surface temperature and CPUE values of the three tuna species.

The dynamics of the water masses is very large in this region and strong variations of the sea surface temperature were found in each day. In this work mean year data were used and the daily variations were lost. If it was possible to work with CPUE data and temperature data collected in real time, this variation could be observed. Tuna species are able to termoregulate the body temperature and this control allows these species to stay a longer time in water with different body temperature (Carey, 1973); Neill et al., 1974).

Another factor is the termocline depth which defines limits between waters with different temperatures and concentrated food in this region. The tuna species present relations with the variation of the termocline depth. (Green, 1967; Grandperrin and Legand, 1971).

The relation between tuna presence and other physical and environmental parameters besides the temperature has already been studied. (Blackburn, 1969; Laurs and Lynn, 1977). Therefore, the area considered for the study of CPUE and temperature relations was very small if compared with the larger tuna distribution in the Atlantic Ocean.

Finally, the results showed that temperatures cannot be considered by itself as the only indicator of the presence of tuna in specified regions. It is necessary to work with more precise sea surface temperature and CPUE data, collected in real time, in order to relate the last ones to oceanographic and environmental conditions at greater depths, where the studied tuna species are found.

5. Acknowledgement

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Legends of Figures

Fig. 1 - 5^{o} X 5^{o} squares in the study area.

Fig. 2 - Treated infrared image obtained by the SMS-2.

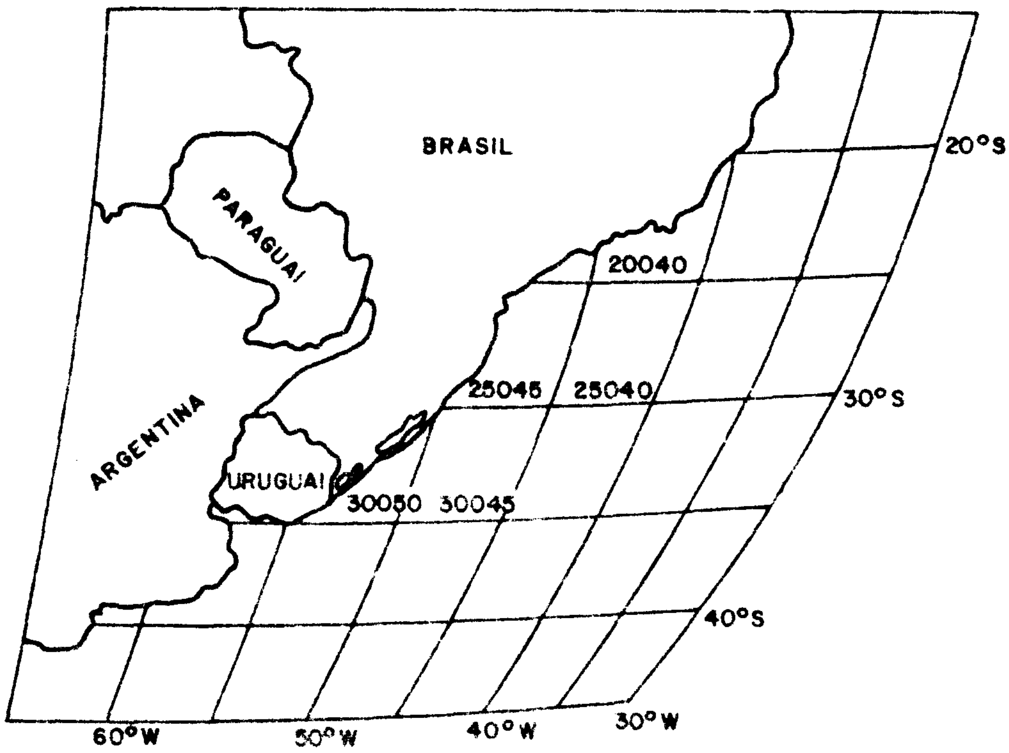

Fig. 1 - $5^0 X 5^0$ squares in the study area.

SMS-2 JULY 24, 1980 12:30 H.L.

SOUTH AND SOUTHEAST BRAZIL

gray level temp.(°C)

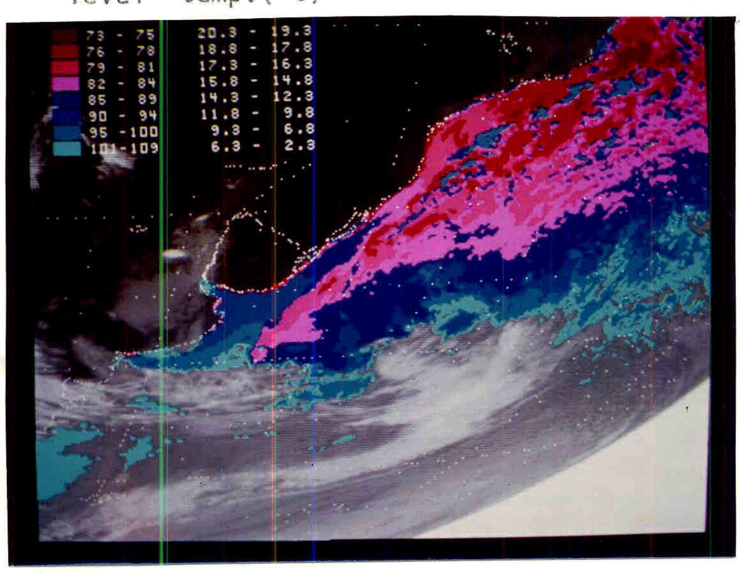

Fig. 2 - Treated infrared image obtained by the SMS-2.

Table 1. Thunnus albacares CPUE values (kg/100hooks) for each $5^0 \times 5^0$ square of the study area

MONTH \ SQUARE	20040	25040	25045	30045	30050
JAN.	16.78	10.79	39.01	23.42	19.57
FEB.	40.04	7.05	16.03	5.23	28.03
MAR.	48.30	13.92	13.27	13.86	19.13
APR.	17.70	23.30	15.79	11.96	9.90
MAY	87.81	10.93	5.33	28.32	26.64
JUNE	153.91	*	17.03	14.84	19.87
JULY	72.62	15.43	30.59	36.45	19.07
AUG.	75.36	21.45	45.32	17.12	22.41
SEPT.	42.54	25.40	19.46	14.05	13.06
OCT.	55.62	60.82	30.24	14.90	13.42
NOV.	53.22	78.60	32.69	32.24	29.20
DEC.	34.20	18.91	31.63	50.03	25.44

The CPUE values correspond to the mean data of the 1974-1980 period

* Lack of data

Table 2. Thunnus alalunga CPUE values (kg/100hooks) for each $5^o \times 5^o$ square of the study area

SQUARE / MONTH	20040	25040	25045	30045	30050
JAN.	4.05	3.37	2.07	2.88	5.03
FEB.	1.01	1.76	1.74	0,79	4.16
MAR.	5.98	0.44	1.81	2.73	2.83
APR.	4.49	2.91	4.53	11.81	10.26
MAY	3.13	2.19	21.41	17.29	18.95
JUNE	1.68	*	43.68	40.53	12.93
JULY	3.31	21.60	48.73	88.23	34.73
AUG.	1.24	7.57	34.97	43.56	19.98
SEPT.	4.20	2.38	12.15	8.93	13.83
OCT.	2.56	1.51	7.71	10.93	14.99
NOV.	3.30	1.48	3.99	4.85	4.95
DEC.	0.46	2.95	1.44	3.37	3.81

The CPUE values correspond to the mean data of the 1974-1980 period

* Lack of data

Table 3. <u>Thunnus obesus</u> CPUE values (kg/100hooks) for each $5^{o} \times 5^{o}$ square of the study area

MONTH \ SQUARE	20040	25040	25045	30045	30050
JAN.	0.75	1.38	1.25	2.88	28.64
FEB.	0.20	0.00	1.99	2.82	16.31
MAR.	1.83	1.09	4.18	5.68	7.04
APR.	1.06	0.00	6.20	9.25	33.70
MAY	0.00	8.74	23.68	19.73	46.57
JUNE	0.84	*	31.03	25.29	39.31
JULY	1.60	14.81	25.30	14.93	73.04
AUG.	0.00	1.26	22.88	17.89	35.36
SEPT.	1.87	0,79	19.35	20.03	39.02
OCT.	2.21	11.06	9.87	17.21	56.04
NOV.	0.84	0.37	9.57	25.32	33.17
DEC.	0.26	0.49	1.83	12.63	26.87

The CPUE values correspond to the mean data of the 1974-1980 period

* Lack of data

Table 4. Mean sea surface temperature data (^{o}C)

MONTH \ SQUARE	20040	25040	25045	30045	30050
JAN.	24.76	25.39	25.15	25.07	24.53
FEB.	26.08	25.80	26.00	22.66	24.37
MAR.	26.82	26.09	24.98	23.76	23.91
APR.	24.93	24.55	24.33	23.79	20.50
MAY	24.04	23.75	22.79	20.25	17.71
JUNE	23.18	22.72	20.17	19.50	13.96
JULY	21.36	22.22	19.72	17.38	11.53*
AUG.	21.42	20.86	17.58	18.57	14.71
SEPT.	21.31	21.61	20.77	18.23	17.86
OCT.	22.39	20.78	19.46	19.93	17.92
NOV.	21.10	22.31	22.64	19.55	19.78
DEC.	20.46	23.05	22.61	21.36	23.69

* This value was obtained by only one observation. The sea temperature values correspond to the mean data within each month based on the historical data.

Table 5. Brazilian coastal stations

STATION	LAT	LONG
Cabo de São Tomé	22°03'S	41°03'W
Cabo Frio	22°52'S	42°01'W
Ilha Fiscal	22°59'S	43°02'W
Ilha Rasa	23°04'S	43°09'W
Ilha de São Sebastião	23°48'S	45°24'W
Ilha da Moela	24°03'S	46°16'W
Ilha do Arvoredo	27°18'S	48°21'W
Escola A.M.S.C.	27°34'S	48°35'W
Mostardas	31°15'S	50°54'W

Table 6. Regression equations

February	Tre = 2.67 · Tsms - 27.74	r=0.66	N=8
March	Tre = 2.48 · Tsms - 33.94	r=0.77	N=7
April	Tre = 1.61 · Tsms - 9.11	r=0,85	N=5
May	Tre = 1.73 · Tsms - 13.7	r=0.87	N=6
June	Tre = 0.97 · Tsms + 2.74	r=0.89	N=5
July	Tre = 0.95 · Tsms - 4.51	r=0.95	N=8

Table 7. Correlation values between fish catch data and sea surface temperature

TUNA SPECIES	SQUARE	CORRELATION VALUES	SIGNIFICANCE LEVEL	NUMBER OF OBSERVATION
Yellowfin tuna	20040	r = -0.17	P > 0.05	N = 12
	25040	r = -0.54	P < 0.1	N = 11
	25045	r = -0.43	P < 0.2	N = 12
	30045	r = -0.24	P < 0.5	N = 12
	30050	r = 0.19	P > 0.5	N = 12
Albacore	20040	r = 0.43	P < 0.2	N = 12
	25040	r = 0.30	P < 0.4	N = 11
	25045	r = 0.71	P < 0.01	N = 12
	30045	r = 0.64	P < 0.05	N = 12
	30050	r = 0.88	P < 0.001	N = 12
Bigeyt tuna	20040	r = -0.002	P > 0.5	N = 12
	25040	r = 0.38	P < 0.3	N = 11
	25045	r = 0.73	P < 0.01	N = 12
	30045	r = 0.79	P < 0.01	N = 12
	30050	r = 0.80	P < 0.01	N = 12

Table 8. CPUE intervals related to sea temperature ranges for *Thunnus albacares*

SQUARE	CPUE IN kg/100 hooks	MONTH	TEMPERATURE (°C)	I.LIM. S.LIM. (°C)
20040	< 30	1 and 4	24.76 - 24.93	24.49 - 25.17
	> 30 e < 60	2-3 and 9-12	20.46 - 26.82	20.02 - 27.33
	> 60	5-8	21.36 - 24.04	21.17 - 24.22
25040	< 30	12-9	20.86 - 26.09	20.29 - 26.74
	> 60	10-11	20.78 - 22.31	19.95 - 22.77
25045	< 30	2-6 and 9	20.17 - 26.00	19.38 - 27.27
	> 30	10-1 and 7-8	17.58 - 25.15	17.00 - 25.36
30045	< 30	1-6 and 8-10	18.23 - 25.07	17.62 - 25.22
	> 30	7 and 11-12	17.38 - 21.36	16.62 - 21.86
30050	< 30	1-12	13.96 - 24.53	13.33 - 24.87

Table 9. CPUE intervals related to sea temperature range for *Thunnus alalunga*

SQUARE	CPUE IN kg/100 hooks	MONTH	TEMPERATURE (°C)	I.LIM. S.LIM. (°C)
20040	< 30	1-12	20.46 - 26.82	20.02 - 27.33
25040	< 30	1-12	20.78 - 26.09	19.95 - 26.74
25045	< 30	9-5	19.46 - 26.00	19.18 - 27.27
	> 30	6-8	17.58 - 20.17	17.00 - 20.97
30045	< 30	8-6	18.23 - 25.07	17.62 - 25.22
	> 30	7	17.38 - 19.50	16.62 - 19.95
30050	< 30	8-6	13.96 - 24.53	13.33 - 24.87
	> 30	7	11.53 (only one observation)	

Table 10. CPUE intervals related to sea temperature ranges for *Thunnus obesus*

SQUARE	CPUE IN kg/100 hooks	MONTH	TEMPERATURE (°C)	I.LIM. S.LIM. (°C)
20040	< 30	1-12	20.46 - 26.82	20.02 - 27.22
25040	< 30	1-12	20.78 - 26.09	19.95 - 26.74
25045	< 30	7-5	17.58 - 26.00	17.00 - 27.27
	> 30	6	20.17	19.38 - 20.97
30045	< 30	1-12	17.38 - 25.07	16.62 - 25.22
30050	< 30	12-3	23.69 - 24.53	23.35 - 24.87
	> 30 e < 60	4-6 and 8-11	13.96 - 20.50	13.33 - 20.79
	> 60	7	11.53 (only one observation)	

Table 11. Greatest CPUE intervals related to sea surface temperature ranges

SQUARE	CPUE IN kg/100 hooks	TEMPERATURE (^{o}C)	I.LIM. S.LIM. (^{o}C)
20040	> 30 e < 60	17.58 - 26.82	17.00 - 27.33
25040	> 60	20.78 - 24.04	19.95 - 24.22
25045			

Table 12. Real temperature range related to SMS-2 temperature range

CPUE > 60kg/100hooks (only on square 20040)			
Real temperature range (^{o}C)	= 21.36 - 24.04		
I.LIM. and S.LIM. (^{o}C)	= 21.17 - 24.22		
Tre = 21.36^{o}C;	JULY: Tre = 1.40 Tsms - 4.51;	Tsms = 18.48^{o}C	
Tre = 24.04^{o}C;	MAY : Tre = 1.73 Tsms - 13.70;	Tsms = 21.82^{o}C	
SMS temperature range (^{o}C)	= 18.48 - 21.82		
I.LIM. and S.LIM (^{o}C)	= 16.47 - 23.85		
CPUE > 30 and < 60kg/100hooks			
Real temperature range (^{o}C)	= 17.38 - 26.82		
I.LIM. and S.LIM (^{o}C)	= 16.62 - 27.33		
Tre = 17.38^{o}C;	JULY: Tre = 1.40 Tsms - 4.51;	Tsms = 15.64^{o}C	
Tre = 26.82^{o}C;	MAR.: Tre = 2.48 Tsms - 33.94;	Tsms = 24.50^{o}C	
SMS temperature range (^{o}C)	= 15.64 - 24.50		
I.LIM. and S.LIM. (^{o}C)	= 13.53 - 28.51		

Table 13. Greatest CPUE intervals related to surface temperature ranges

SQUARE	CPUE INTER. kg/100hooks	TEMPERATURE (^{o}C)	I.LIM. S.LIM. (^{o}C)
25045 30045 30050	> 30	17.38 - 20.17	16.62 - 20.97

Table 14. Real temperature range related to SMS-2 temperature range

CPUE > 30kg/100hooks		
Real temperature range (^{o}C)	= 17.38 - 20.17	
I.LIM. and S.LIM. (^{o}C)	= 16.62 - 20.97	
Tre = 17.38^{o}C; JULY: Tre	= 1.40 Tsms - 4.51;	Tsms = 15.64^{o}C
Tre = 20.17^{o}C; JUNE: Tre	= 0.97 Tsms + 2.74;	Tsms = 17.97^{o}C
SMS temperature range (^{o}C)	= 15.64 - 17.97	
I.LIM. and S.LIM. (^{o}C)	= 13.53 - 21.41	

Table 15. Greatest CPUE intervals related to surface temperature ranges

SQUARE	CPUE IN kg/100hooks	TEMPERATURE (°C)	I.LIM. S.LIM. (°C)
25045 30045 30050	> 30	13.96 - 20.50	13.33 - 20.97

Table 16. Real sea temperature ranges related to SMS-2 temperature ranges

CPUE > 30kg/100hooks

Real temperature range (°C) = 13.96 - 20.50
I.LIM. and S.LIM. (°C)

Tre = 13.96°C; JUNE: Tre = 0.97 Tsms + 2.74; Tsms = 11.57°C
Tre = 20.50°C; APR.: Tre = 1.61 Tsms - 9.11; Tsms = 18.39°C

SMS temperature range (°C) = 11.57 - 18.39
I.LIM. and S.LIM. (°C) = 3.73 - 21.84