

Seasonal Variation Observed in Surface Water Temperature of Samborombón Bay, Argentina, Using NOAA-AVHRR and Field Data

C. Lasta[†], D. Gagliardini[‡], J. Milovich[‡] and E.M. Acha^{††}

[†]INIDEP

Playa Grande s/n
7600 Mar del Plata, Argentina

[‡]CAERCEM

J. Alvarez 1218
1414 Buenos Aires, Argentina

^{††}UNMP

Dto. Cs. Marinas
7600 Mar del Plata, Argentina

ABSTRACT



LASTA, C.; GAGLIARDINI, D.; MILOVICH, J., and ACHA, E.M., 1996. Seasonal variation observed in surface water temperature of Samborombón Bay, Argentina, using NOAA-AVHRR and field data. *Journal of Coastal Research*, 12(1), 18-25. Fort Lauderdale (Florida), ISSN 0749-0208.

Samborombón Bay (30°S, 57°W) is located on the southern boundary of La Plata River estuarine system. Long-term ecological fishery projects carried out in the estuary, pointed out the importance of this bay as a major nursery ground for estuarine fishes; most of them have a high economical value for the Uruguayan and Argentine fishing fleets. Given the biological significance of water temperature necessary for growth of juvenile fishes, the main objective of the present paper is to study the surface water temperature fluctuations throughout the year, and also to test these fluctuations in a five consecutive years series.

ADDITIONAL INDEX WORDS: *Surface water temperature, monthly fluctuations, interannual variations, field and satellite data, Argentina.*

INTRODUCTION

Climatologically, the La Plata River estuarine ecosystem is at the temperate warm zone. That implies a well marked cyclicity in thermal variation between cold winter and warm summer months. Samborombón Bay (30°S, 57°W) is inside the system of the La Plata River estuary (Figure 1). This bay is a coastal basin; its maximum depth is less than 10 m with a width/depth ratio of 1/10,000. Consequently, it is easily influenced by external forcings such as winds and tides. The physical characteristics of the waters are influenced by La Plata River run off, sea water from the continental shelf, and continental water from its own drainage basin; this basin covers 120,000 hectares and is formed by several canals and the Samborombón and Salado rivers (Figure 1). Estuarine environments are generally believed to be important nursery areas for many fishes (MILLER and DUNN, 1980). Several years of continued fishery research on Samborombón Bay have made it possible to point out that the bay is the most important nursery ground for the fishes inhabiting the La Plata River estuarine system (BOSCHI, 1988; COUSSEAU, 1985; LASTA and CIECHOMSKI,

1988; SÁNCHEZ *et al.*, 1991). Most of these species are of important economic value for the Uruguayan and Argentine fishing fleets. Fishes inhabiting Samborombón Bay are mainly euryhaline marine species, which spawn outside the bay but make extensive use of it during juvenile and/or adult periods of development. JOSEPH (1973) characterized these nursery grounds as areas that (1) are physiologically suitable in terms of chemical and physical features, (2) provide an abundant food supply, and (3) provide some degree of protection from predators. Yet, estuaries are also potentially stressful environments in terms of the often unpredictable fluctuations in their biotic and abiotic features (MILLER and DUNN, 1980).

Taking into account that temperature is one of the more important parameters affecting growth, the object of the present paper is to study the annual thermal pattern of the bay to provide an adequate background for ecological and population studies of the fishes.

The annual fluctuations in the surface temperature of the waters of Samborombón Bay as a whole, has been studied during several consecutive years, weighing its origins in relation to the influences of continental or marine waters flowing into the system.

Likewise, a description is given of the local thermal variations due to continental waters that are significant for different sectors of Samborombón Bay.

DATA AND METHODS APPLIED

The data analyzed comprise a series of surface temperature values collected in research cruises from February 1983 to January 1984 (LASTA and CIECHOMSKI, 1988) and from March 1987 to October 1988. During both research periods, data were collected monthly from 25 systematically distributed stations in the bay, throughout the water column at fixed depths. Data collection took 48 hours each time and values were determined using a YSI portable thermosalinometer with a 0.2 °C precision. Also, a NOAA-AVHRR data series between July 1984 and July 1987 was employed.

In order to compare satellite and field data, the satellite information was arranged so that its coverage area coincided with the cruise coverage. Two weekly, satellite observations stored twice a day, of the highest temperature value for each pixel of resolution composed our elementary data base. This value was averaged for the three weeks following the observations giving a monthly average value. The mean number of average images used for each month totalled five.

Sequential data were treated using a Fourier series in order to describe the periodicity of the temperature values measured, using the following model:

$$y_t = a_0 + a_1 \cdot x_1 + a_2 \cdot \cos(2\pi m/A) + a_3 \cdot \sin(2\pi m/A)$$

where m = months; A = period; a_0 , a_1 , a_2 and a_3 = constants; $a_1 \cdot x_1$ = satellite effect ($x_1 = 1$ if it is satellite data and $x_1 = 0$ if it is field data). The third and fourth terms correspond to the first term of the Fourier series and describe the common wave either from the field or the satellite data.

Taking into account the non-linearity of this model regarding the parameter A (period), Marquardt's algorithm was used for the estimation of a_0 , a_1 , a_2 , a_3 and A . The fitting criterium being that of minimum square.

RESULTS AND DISCUSSION

Data Analysis

Thermal stratification is not observed throughout the water column at the bay. Differences be-

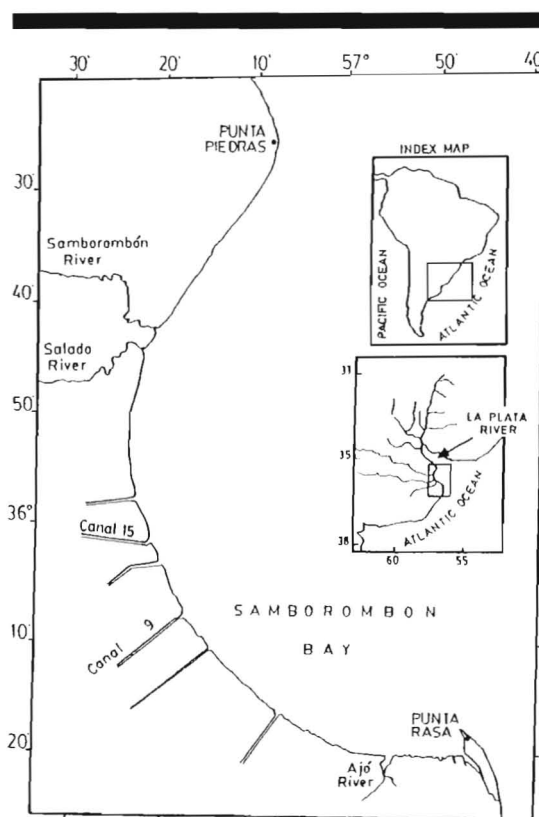


Figure 1. Samborombón Bay study area.

tween surface and bottom values, whenever they were observed, are due to local phenomena involving slight differences between both values and incidental features. Regarding the width/depth ratio of the bay (1/10,000), it can be assumed that calm, mild winds are enough to mix the water column. Therefore, given the absence of thermal vertical gradients, when describing surface temperature variations of the bay waters, it can be integrated to the whole water column. The whole study area has been analyzed on the basis of 129 pixels coinciding with the area covered by the cruises (Figure 2). Each resolution unit or pixel covers an area of 4.188 km² or 2.529 nm².

The monthly grouping of satellite values exhibits the general characteristics of a normal distribution with modal values and generally coincident mean values. Temperature deviation in the series of satellite observations shows the highest scattering for the spring months, where absolute temperature between months showed a variation

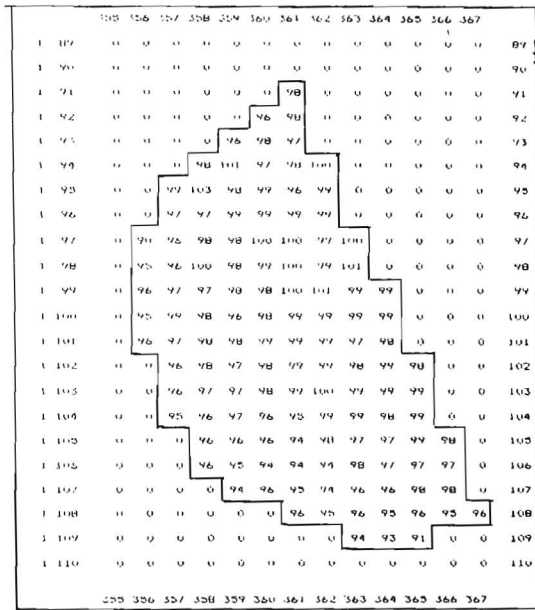


Figure 2. Coverage area of satellite data.

up to 6/7 °C ± 0.43 to 0.54 standard deviations. In the summer and winter months, with the maximum and minimum temperatures, the variation within months was up to 2 to 3 °C ± 0.25 standard deviations. This implies a system characteristic where, at thermally extreme moments, the variation in mean temperature of the bay is less than at transitional moments, as in the spring.

Table 1 shows the set of total satellite and sea data considered. A significant correlation was detected (r = 0.959*) between satellite and field measurements, corresponding to March, May, June and July 1987. The slight differences are

Table 1. Mean monthly surface temperature values from Samborombón Bay. a) Sea data and b) NOAA-AVHRR corrected data.

Year	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
1983 a		23.8	20.1	20.1	16.7	10.0		9.8		17.2	20.4	
1984 b							8.3	9.8	11.4	16.2	18.4	18.5
1985 b	23.4	23.2	20.7	17.8	13.7	10.9	10.6	11.5	12.8	15.6	19.2	21.4
1986 b	23.4	23.2	20.8	19.6	15.6	12.6	11.9	11.1	13.8	16.3	18.6	21.9
1987 b	23.2	23.3	22.4	19.3	14.5	11.2	11.0					
a			20.8		16.0	11.8	9.6	10.8	11.5	13.4	17.4	21.7
1988 a		21.7	21.8									

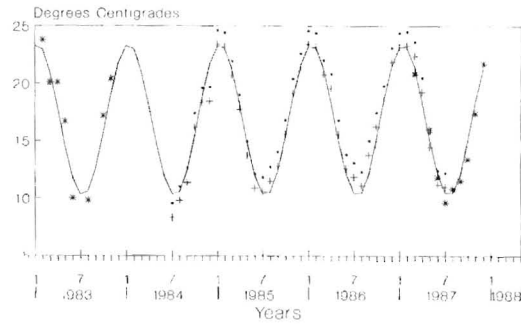


Figure 3. Mean monthly sequential surface temperature data. Points NOAA-AVHRR data; crosses NOAA-AVHRR corrected data; asterisks field data; line theoretical model.

possibly due to the sampling procedure in the satellite data acquisition.

The sequential treatment of the data in order to estimate the amplitude and period of the Fourier series was performed using the equation:

$$y_t = 16.80 + 1.2261 \times (x_1) + 5.0982 \times \cos(2\pi m/12.048) + 4.1491 \times \sin(2\pi m/12.048)$$

The criterium for calculating the best fitting values was that of interrupting the iterative process when the correlation indexes between two successive tests was less than 10 E⁻⁷. The correlation index between the equation and the values was 0.951609.

The second term of the equation cancels in the case of sea data, since x1 becomes zero. When temperature data was obtained from the satellite, an iterative process was used and a constant was thus found that corrects this data and the values estimated by the model for a better estimate. This

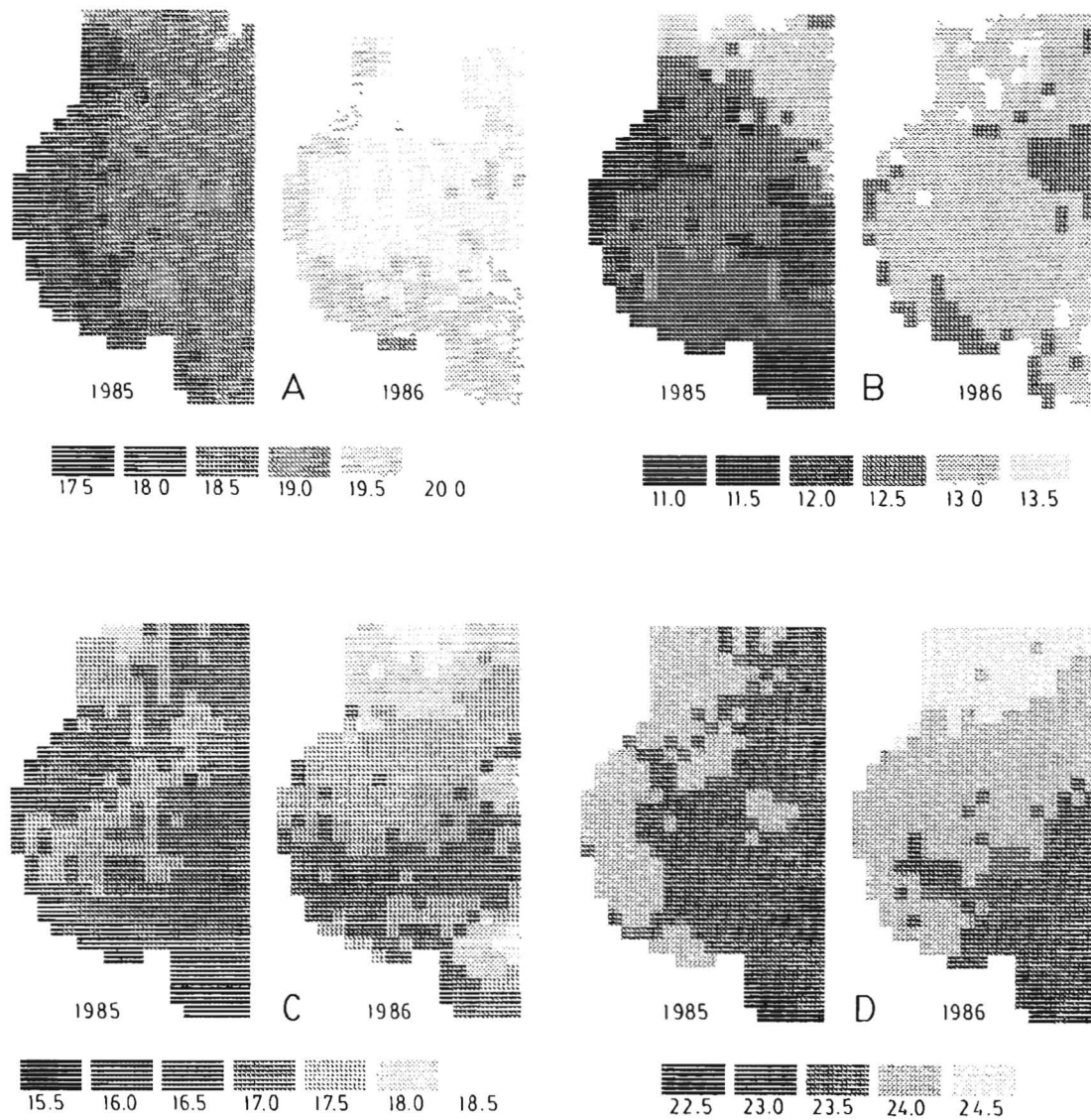


Figure 4. Seasonal surface temperature data sequence for years 1985 and 1986, (A) Fall: March, April and May; (B) Winter: June, July and August; (C) Spring: September, October and November, and (D) Summer: December, January and February.

way the following value was obtained for the second term constant:

$$1.22618 \pm (0.62082)$$

with an approximate confidence interval of 95%.

Figure 3 shows the corrected satellite data, the sea data and the theoretical model. For seasonal fluctuations of temperature, a wave period of A

= 12.048 months and an amplitude from 8.2 °C (July) to 23.3 °C (January), were estimated.

Image Analysis

The temperature of the three different types of water influencing Samborombón Bay exhibits a characteristic annual evolution which makes it possible to differentiate their individual influence

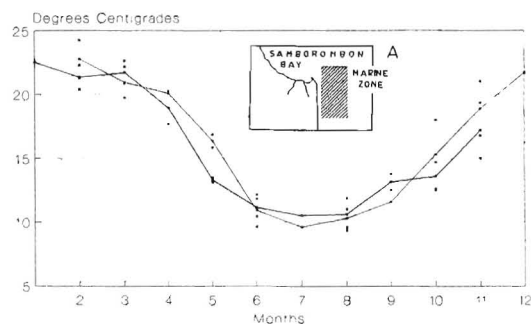


Figure 5. Samborombón Bay (solid line) and marine zone (heavy solid line) mean monthly surface temperatures, \pm standard deviation. (A) marine zone considered.

on the bay. Monthly satellite images have been processed seasonally in order to establish a sequence of the surface temperature changes. The images shown in Figure 4 correspond to the seasonal sequence from 1985 and 1986. Their comparison makes it possible to observe seasonal variations as well as inter-annual similarities.

As the bay is influenced by shelf waters, annual thermal fluctuations of waters of the bay and those of the sea have been analyzed in order to evaluate their differences. So, it is possible to evaluate the influence of the shelf waters on the Samborombón Bay system and its interactions. The marine influence is observed basically on the southern area of the bay.

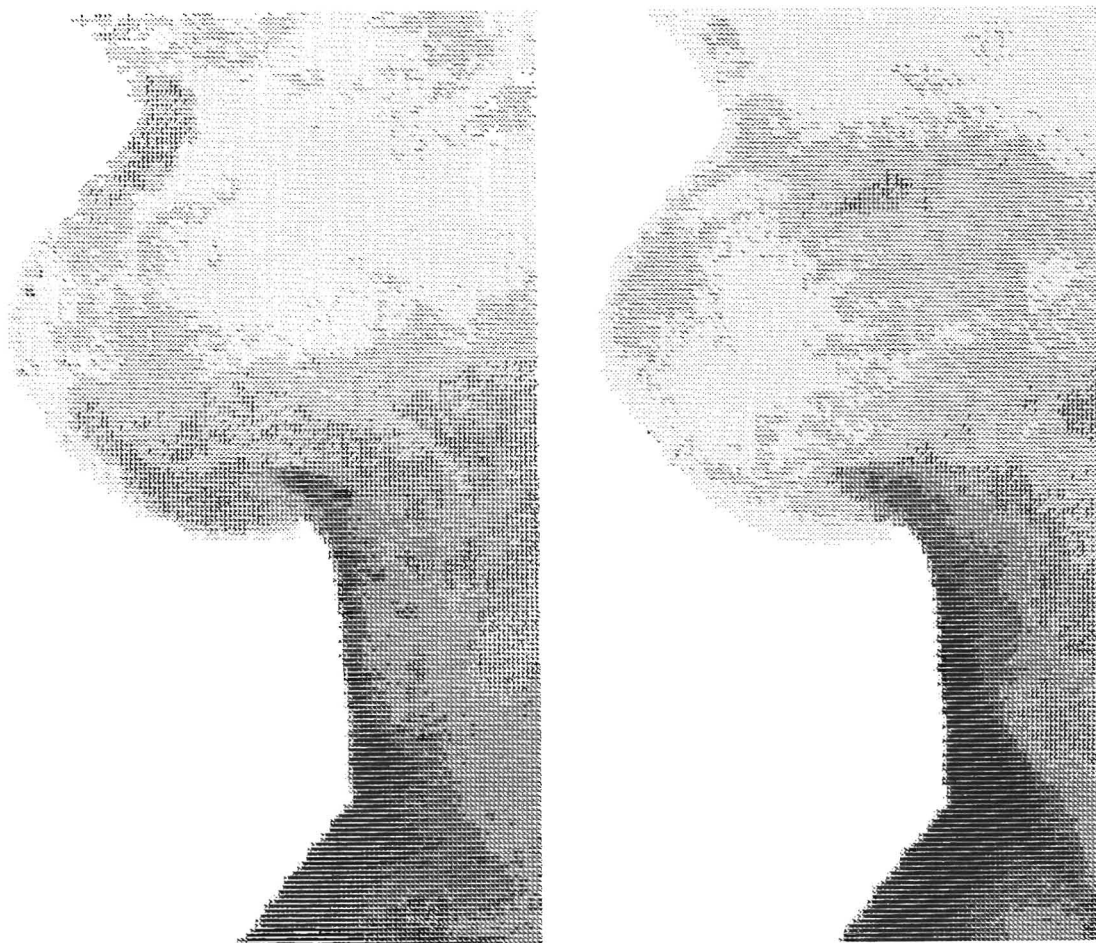


Figure 6. 1991 January 14th and 15th images, showing incoming flow of marine warmer waters.

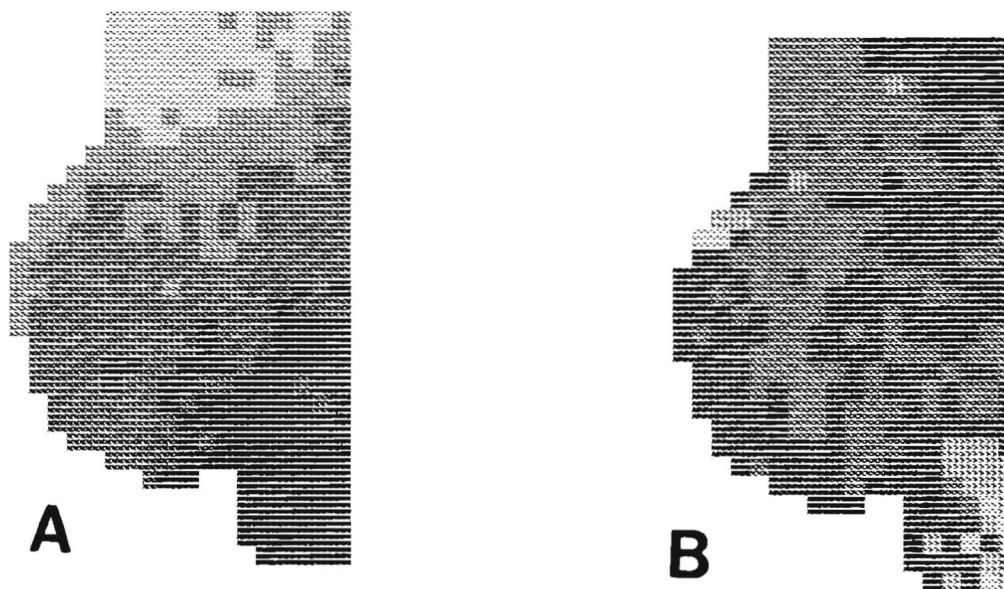


Figure 7. Mean monthly temperatures. (A) December 1986; (B) August 1984.

Figure 5 shows both marine and bay thermal patterns. The bay temperature data employed are those from cruises. The marine zone data correspond to the Marsden square 413, 1° square 66 and have been obtained on the basis of a historical series of water temperature records at standard depths.¹ Bay water temperatures are lower in July, August and September than shelf waters; while in the remaining part of the year, they are higher. In June and mid-September, the heat content for both systems seems to be the same.

The marine influence may be clearly seen in sequential images from the 14th and 15th of January 1991 (Figure 6) where there is an incoming flow of water with lower temperatures than those waters found in the bay at that time, resulting in a thermal difference greater than 3 °C.

Several monthly satellite images processed show evidences of the marine influence as mentioned. Images shown in Figure 7 are examples of this phenomenon. The December 1986 (Figure 7a) image shows a temperature gradient where temperature increases northwards; in that of August 1984 (Figure 7b), the phenomenon is reversed and the

temperature increases southwards. The marine influence shown in Figures 6 and 7 and the seasonal thermal pattern of both systems (Figure 5) indicate that in June and mid-September the influence of the shelf waters will only produce changes in salinity, because both water masses bear the same temperature throughout. In July and August, the marine influence will comprise changes in salinity, and at the same time, imply water with a higher heat content; while in the remaining part of the year, between October and May, this influence will mean waters with higher salinity and lower temperatures.

From the above, it may be seen that the fluctuations of the waters of Samborombón Bay follow a seasonal pattern marked by differences in the amplitude of the thermal variation of the adjacent shelf water masses. It is concluded that the Samborombón Bay thermal regime is typical of a temperate warm climate, with higher amplitude fluctuations between cold and warm months, and this thermal range is remarkably higher than that described for the adjacent marine system.

In addition, satellite images make it possible to describe phenomena taking place within the bay due to thermal differences in incoming continental waters which exhibit regional characteristics. Such influences may arise from lower or higher

¹ Data compiled by the Centro Argentino de Datos Oceanográficos (CEADO).

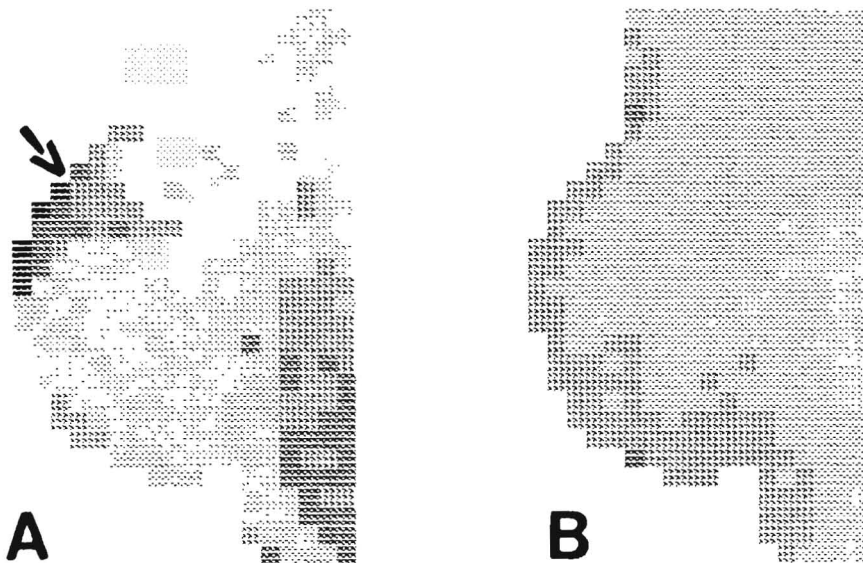


Figure 8. Mean monthly temperatures, (A) August 1985 (arrow shows Salado River); (B) June 1987.

temperatures in the water from rivers or canals flowing into the bay, depending on the time of year in which the water is being analyzed.

The continental water from rivers and canals

exhibits a greater heat exchange with the atmosphere than the bay waters. This results in continental water temperatures being lower than the average values of the water bay during winter

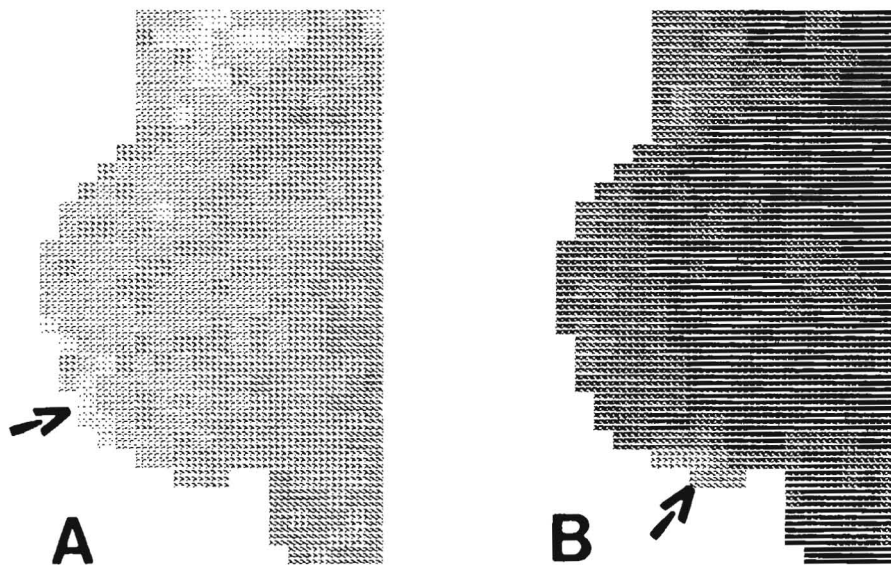


Figure 9. Mean monthly temperatures, (A) January 1985 (arrow shows Canal 9); (B) December 1985 (arrow shows Ajó River).

months and higher than the average during summer months. These events can be identified in the images that are described next.

In winter, June–July 1984, mean temperatures of the continental waters poured into the system were from 9.12 to 9.87 °C. If at this moment the river flow had been relatively important, the influence of temperature would have been marked at their mouths by a lowering of the temperature in the water bodies, and this was observed in certain cases. This is noticeable in satellite images from August 1985 (Figure 8a), at the mouth of the Salado River, where an area of approximately 9 pixels shows temperatures of 8.0 °C, while the rest of the water mass had an average temperature over 1 °C higher. This regional event will last while the volume of water contributed by the rivers sustains a flow that influences the adjoining waters; this influence could have a period of days or greater; for instance in July of 1984, an event observed at the mouth and lasted during the four weeks in that month observed by the satellite.

The shallow waters of the bay show higher heat exchange with the atmosphere than the rest of the bay waters. This phenomenon can be clearly detected in images from June 1987, where a 2–4 pixel area along the coast presented temperatures that were lower than the rest of the bay in more than 1.5 °C (Figure 8b).

The high thermal gain of continental waters takes place in the summer months; therefore, the water flowing from canals and rivers exhibits higher temperatures than the mean values at the bay (Figure 9). This situation is presented in an image from January 1985 (Figure 9a), where an area with temperatures higher than the rest of the bay appears in front of Canal No. 9, on the southwest section of the bay.

Shallow waters in the bay during summer months gain thermal energy faster than the rest of the bay waters (Figure 9b). At the image corresponding to December 1985, a zone approximately 3–5 pixels wide shows higher temperatures than the rest of the bay. At that time, an important influence from the Ajó River was detected on the south of the bay with waters at highest temperatures, values close to 24.5 °C (Figure 9b).

CONCLUSIONS

The analyzed NOAA-AVHRR and sea surface temperatures series were useful for describing the monthly temperature fluctuations and to determine the different waters influencing the environment. In months where simultaneous sea and

AVHRR data were obtained, there was a significant correlation among them. For seasonal fluctuations of temperature, a wave period of 12.048 months and an amplitude from 8.2 °C (July) to 23.3 °C (January), were estimated.

The thermal regime of Samborombón Bay is typical of a temperate warm climate with higher amplitude fluctuations between cold and warm months. The range between extreme temperatures at the bay is higher than that observed for the adjacent marine regime. Satellite images make it possible to describe phenomena taking place within the bay due to thermal differences in incoming continental waters, for different times of the year, indicating regional characteristics.

ACKNOWLEDGEMENTS

The authors acknowledge the NOAA-AVHRR data provided by the Servicio Meteorológico Nacional and Lic. D. Hernández (INIDEP) for data processing. We are also indebted to Mr. C. Bertelo for his helpful assistance with drawings.

LITERATURE CITED

- BOSCHI, E.E., 1988. El ecosistema Estuarial del Río de la Plata (Argentina y Uruguay). *An. Inst. Cien. Mar y Limnol., Univ. Nac. Aut. Mex.*, 15(2), 159–182.
- COUSSEAU, M.B., 1985. Los peces del Río de la Plata y de su Frente Marítimo. In: YAÑEZ-ARANCIBIA, A. (ed.), *Fish Community Ecology in Estuaries and Coastal Lagoons: Towards an Ecosystem Integration*. Mexico: UNAM Press, 654p.
- JOSEPH, E.G., 1973. Analysis of a nursery ground. In: PACHECO, A.L. (ed.), *Proceedings of a work-shop on egg, larval and juvenil stages of fish in the Atlantic Coast Estuaries. Technical Publication No. 1, NMFS Mid-Atlantic Coastal Center, Highland, N.J.*, pp. 118–121.
- LASTA, C.A. and CIECHOMSKI, J.D., 1988. Primeros resultados de los estudios sobre la distribución de huevos y larvas de peces en la Bahía Samborombón en relación con la temperatura y salinidad. *Pub. Com. Téc. Mix. Fren. Mar.*, 4, 133–141.
- MCHUGH, J.L., 1966. Management of estuarine fisheries. In: SMITH, R.F.; SWARTZ, A.H., and NEIL, W.H. (eds.), *A symposium on estuarine fisheries. American Fishery Society, Special Publication*, 3, 133–154.
- MILLER, J.M. and DUNN, M.L., 1980. Feeding strategies and patterns of movement in juvenile estuarine fishes. In: KENNEDY, J.S. (ed.), *Estuarine Perspectives*. N.Y., USA: Academic, pp. 437–448.
- MILLER, J.M.; REED, J.P., and PIETRAFESA, L., 1984. Patterns, mechanisms and approaches to the study of migrations of estuarine-dependent fish larvae and juveniles. In: MCCLEAVE, J.D.; ARNOLD, G.P.; DODSON, J., and NEILL, W. (eds.), *Mechanisms of Migration in Fishes*. New York: Plenum, pp. 209–226.
- SÁNCHEZ, F.; MARÍ, N.; LASTA, C., and GIANGIOBE, A., 1991. Alimentación de la corvina rubia, (*Micropogonias furnieri*) en lo Bahía Samborombón. *Publ. Com. Téc. Mix. Fren. Mar.*, 8, 43–50.