

VARIABILITY OF THERMOHALINE PROPERTIES IN PEARL LAGOON, NICARAGUA

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ABSTRACT

Several hydrographic surveys were carried out in Pearl Lagoon, Nicaragua between april 1995 and december 1997 under the DIPAL (Proyecto para el Desarrollo Integral de la Pesca Artesanal en la Región Autónoma del Atlántico Sur) project. Surface temperature, salinity, dissolved oxygen and turbidity have been measured in 88 hydrographic campaigns. The annual cycle shows maximum and minimum temperatures in May (29.4 °C) and December (25.6 °C) respectively, maximum salinity (25.6 ‰) in April, one month before the thermal peak, and minimum salinities (2‰) between July and August, when the annual precipitation index attains its seasonal maximum in the study area. In the case of dissolved O₂ the maximum values of oxygen saturation were observed between March and May (90%), when the water turbidity in the lagoon is at its lowest and freshwater contributions from the rivers attains its minimum value. During the rainy season, in the second half of the year, there is an important decrease in oxygen contents, mainly as a consequence of the degradation of organic matter of riverine origin.

Keywords: Coastal lagoon, hydrography, water masses.

Variabilidad de las propiedades termohalinas en la Laguna de Perlas, Nicaragua

RESUMEN

Con la coordinación del Proyecto DIPAL (Proyecto para el Desarrollo Integral de la Pesca Artesanal en la Región Autónoma del Atlántico Sur), se realizó entre abril de 1995 y diciembre de 1997 un levantamiento hidrográfico en la Laguna de Perlas. Se llevaron a cabo 88 cruceros hidrográficos, en los cuales se determinaron

la temperatura, salinidad y oxígeno disuelto superficiales, así como la turbidez de dicho cuerpo de agua. En el ciclo anual de las propiedades termohalinas de las aguas superficiales, el máximo de temperatura se ubica en el mes de mayo (29.4 °C) y el mínimo durante diciembre (25.6 °C). La laguna exhibe sus mayores salinidades en abril (34‰), un mes antes del máximo térmico, mientras que las salinidades más bajas ocurren entre julio y agosto (2‰), cuando los índices de precipitación anual sobre el área estudiada alcanzan también sus máximos estacionales. Para el caso del oxígeno disuelto, los valores más altos de saturación de oxígeno se observaron entre marzo y mayo (90%), cuando la turbidez en la laguna alcanza los niveles más bajos y el aporte de agua dulce proveniente de las escorrentías es mínimo. En la época lluviosa durante el segundo semestre del año, las aguas de la laguna muestran una importante disminución en su contenido de oxígeno, debida principalmente a la degradación de materia orgánica proveniente de la descarga de los ríos.

Palabras claves: Laguna costera, hidrografía, masas de agua.

1. INTRODUCTION

The shallow waters of lagoon systems are generally dedicated to the fishing industry. More than any other part of the ocean such systems are extremely vulnerable to human actions. It has been stressed, time and again, that fisheries would be severely affected by the degradation or destruction of those ecosystems.

The study of estuarine environments received

much attention during the last fifteen years. To some extent such interest is due to the importance that the coastal zone has for many human activities. Its utilization as natural ports, reservoirs for industrial waste, fish farming, commercial fisheries and for recreational purposes largely justify the predominant role of coastal science in present-day marine research.

For being sites of exceptionally high rates of primary productivity and for providing protected habitats for many species, lagoon systems play a key role in the occurrence of several marine populations. Notwithstanding the above, the rate of increase in the utilization of such ecosystems exceeds by far the rate of increase in knowledge about these coastal environments.

The continental shelf off Nicaragua in the Caribbean is the largest in Central America and is regarded as one of the most productive zones of the Caribbean Sea (Gable, 1993). Its high productivity obeys not only to the particular dynamics of its water (Brenes et al., 1998) but to the occurrence of an extensive lagoon system along virtually the whole shoreline. Pearl Lagoon (~550 km²), including the Top Lock Lagoon (~30 km²) shown in figure 1, is the largest of the eight lagoon complexes in the area.

The basin of the Pearl Lagoon is located in the central zone of the shoreline. The annual precipitation regime varies between 2000 mm and 6000 mm (INETER, 1999). Rain is less intense during the first months of the year but is present virtually 12 months. There are moderate dry intervals at the end of February, more pronounced ones in March, and by the end of April the relative dry period comes to an end. The most intense precipitations occur between June and August.

Pearl Lagoon is naturally open to the sea in its SE extreme through a point known as La Barra. The site is located opposite to the Laguna de Perlas village and measures 450 m in its narrowest part and 850 m in its broadest part. Roullot (1980) and INETER (2000) report a mean depth of 2.5 m for Pearl Lagoon.

Coastal marine ecosystems are extremely

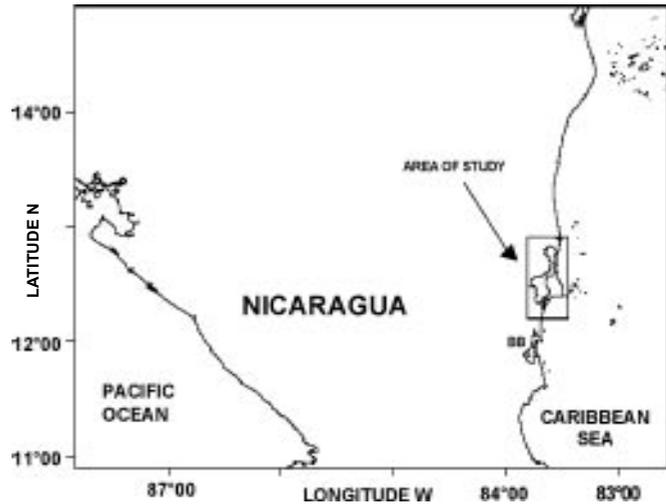


Figure 1. Study area.

complex. Basic studies on those water bodies provide, in a descriptive fashion, much of the required knowledge to implement more advanced work on specific physical and chemical processes of ecological relevance. Results from this hydrographic survey describe the annual cycle of the mean fields of temperature, salinity and dissolved oxygen in Pearl Lagoon.

2. METHODOLOGY

Hydrographic sampling took place during 88 campaigns from April 1995 to December 1997. Only surface temperature, salinity and dissolved oxygen were measured, together with secchi depth. Figure 2 shows the positions of the sampling stations, whose locations were chosen taking into account the geomorphology of the lagoon, the existence of traditional fishing locations and the sites of the mouths of rivers.

Temperature was determined with a 0.1 °C accuracy Fisher Scientific digital thermometer and a model 13-946-27, 1‰ accuracy Fisher refractometer was used to measure salinity. Dissolved oxygen was measured 15 cm below the surface with a portable Orion, model OD-840 digital meter. Turbidity estimation were obtained with a Lamotte secchi disk.

3. RESULTS AND DISCUSSION

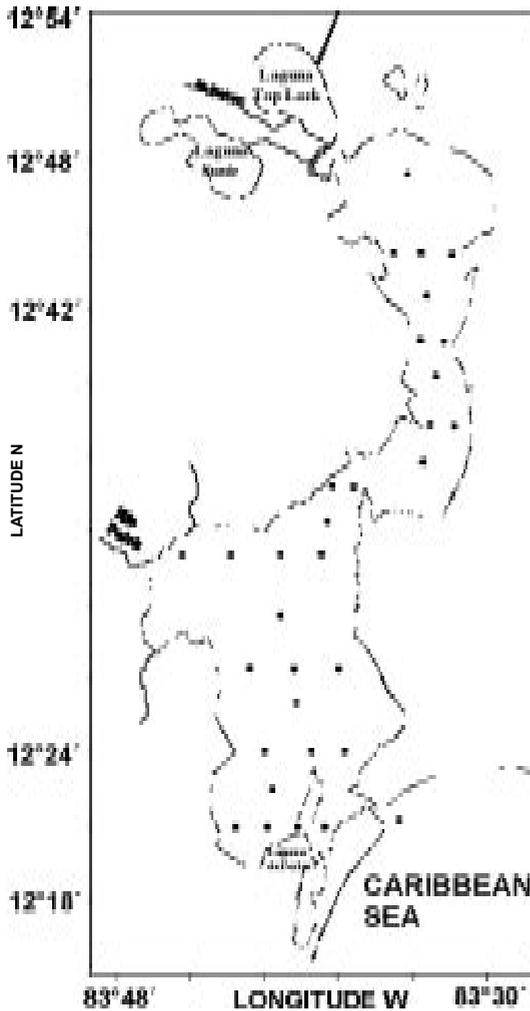


Figure 2. Hydrographic Stations.

Figure 3 shows the spatial and temporal variation of surface temperature in an axis centered along the lagoon.

The maximum observed temporal variations of surface temperature were 4 °C. High temperatures were observed between April and July ($T > 28$ °C), with a maximum centered in May. The lowest temperatures occur when the NE Trade winds blow with maximum intensity, between November and March, with a minimum centered in January. The results above are consistent with the conditions observed in the adjacent coastal water (Brenes and Hernández, 1999).

The nearly vertical shape of the isotherms in figure 3 reveals that the thermal gradient between the inner lagoon and the zone near the bar is very small. Differences in such surface temperatures are generally below 0.5 °C. The inner lagoon shows, all year round, the highest temperatures. The largest spatial thermal gradient along the central axis of the lagoon take place at the end and the beginning of the year.

The surface salinity field shows a different behaviour, with a well defined seasonal cycle (figure 4). This cycle obeys to dilution processes strongly determined by freshwater discharge in the lagoon by several rivers. In turn, such rivers show considerable temporal variability in their volumes associated to the annual cycle of precipitation.

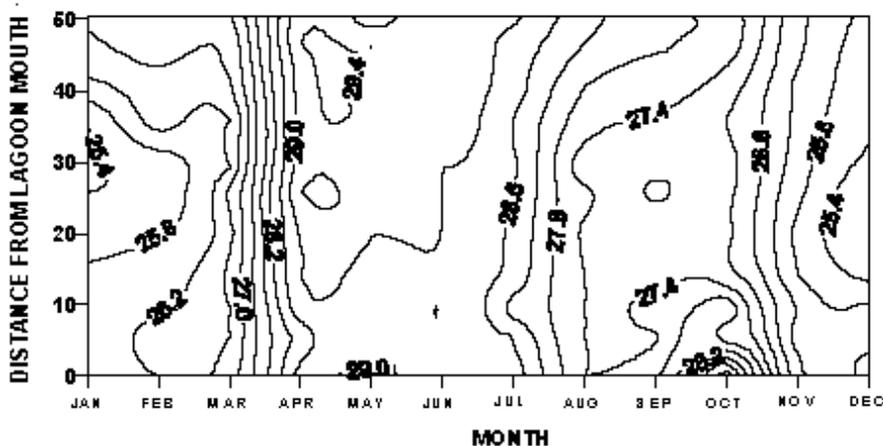


Figure 3. Temporal variation of the surface temperature (°C) in a transect along a central axis of the Pearl Lagoon corresponding to monthly mean values obtained during the sampling period.

Figure 4 shows an apparent temporal va-

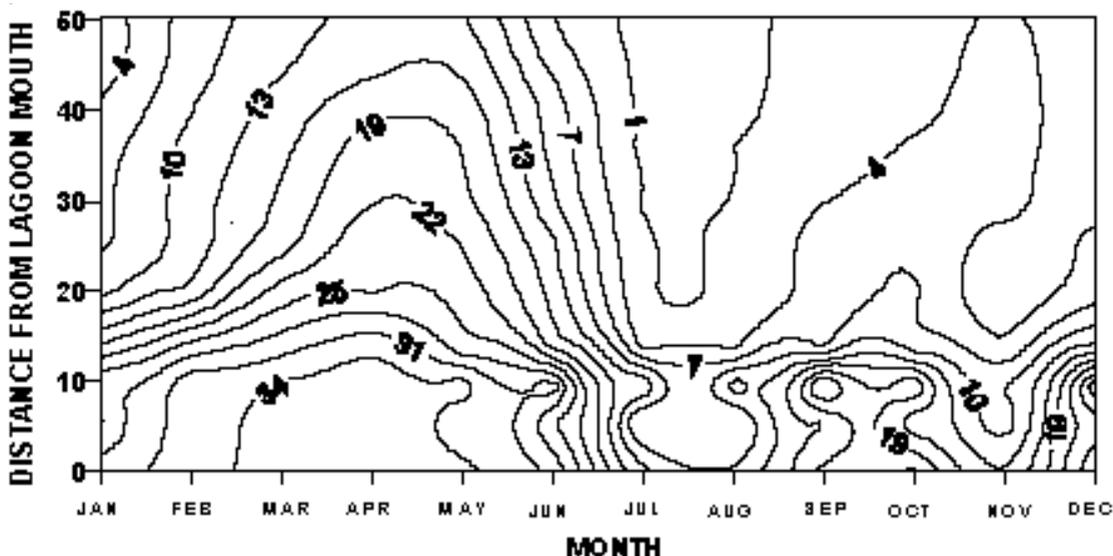


Figure 4. Temporal variation of surface salinity in a transect along a central axis of the Pearl Lagoon corresponding to monthly mean values obtained during the sampling period.

riation in the whole lagoon. The inner section is more strongly influenced by the tidal wave during the first months of the year when the tidal prism prevails over the fresh water volume. A seasonal salinity maximum is observed over the whole lagoon between March and May almost in phase with the temperature maximum. The external zone shows more oceanic conditions with salinities between 12‰ and 34‰.

The salinity minimum occurs during the second half of the year, centered in July and August, with values below 10‰. In these two months the precipitation in the area is more intense and consequently the fresh water contribution from the rivers is increased. The shape of the isohalines shows the prevalence of the fresh water over the salty water introduced by the tidal wave. Under such circumstances the energy required for mixing in the lagoon is provided by the rivers flow.

Salinity values throughout the dry season (January-May) are above 31‰ near the bar and between 4‰ y las 13‰ in the inner part of the lagoon. During the dry season fresh water input is very low and the tidal energy is enough to distribute the sea water over the whole lagoon. In the first half

of the year the Pearl Lagoon experiences a strong influence of the coastal water. The 1‰ isohaline, normally used in estuarine systems to define the limit of the riverine estuarine zone, is absent in the lagoon.

During the rainy season the surface salinity field in the lagoon is entirely modified with respect to the first months of the year and salinity values near the bar never exceed 10‰. In this period the lagoon virtually shows a fresh water lagoon nature, with the 1‰ isohaline extending sometimes to the south of Punta Ebo. The lagoon is shallow and probably behaves as a well mixed system.

Water clarity is extremely important in areas with aquatic vegetation and animals (Reid & Wood, 1976). In such ecosystems the level of water transparency is largely determined by suspended mater, with important consequences for the rate of primary productivity and the energy flux within the ecosystem. Water clarity shows, like salinity, a clear seasonal variability (figure 5). The greater transparency occurs during the dry months (February-May), when precipitation and suspended materials introduced by the rivers are lowest. The high water clarity observed in this period is related to the presence of sea water in almost the whole

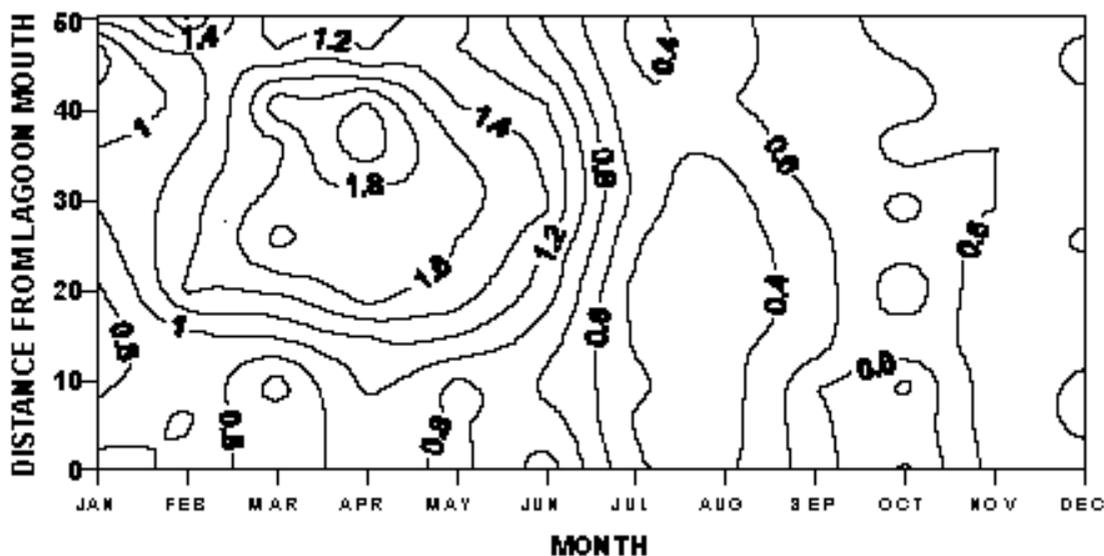


Figure 5. Temporal variation of Secchi Disk (m) in a transect along a central axis of the Pearl Lagoon corresponding to monthly mean values obtained during the sampling period.

lagoon.

In July and August, the peak of the rainy season, water transparency is drastically reduced in the whole lagoon as a result of abundant terrigenous materials introduced into by the rivers. Increased turbidity is present throughout the whole rainy season.

Oxygen levels in the system are determined by turbulence, currents, biological activity, salinity and temperature. The external part of the lagoon shows homogeneous oxygen saturation levels (~70%), below the levels observed in the inner region (~85%). In October high levels extend up to the most external zone of the lagoon. In the dry months (December-February) the lagoon shows the lowest values of oxygen saturation levels (figure 6).

Between March and May, when turbidity values are the lowest and solar radiation is increased, the surface water shows levels of percent of oxygen saturation between 75% and 90%. High rates of photosynthetic primary productivity during this period are the likely reason of the elevated oxygen content measured at the surface.

Starting in June, when the rainy season is

clearly defined, surface waters show an important diminution in oxygen levels (60%-70%) until February, with a relative increase from September through November, with percent saturation values over 75%.

The load of suspended and dissolved organic matter augments in the lagoon during the rainy season as a result of increased rivers flow. The degradation of such organic matter contributes to the decreased levels of oxygen observed in this period. The elevated levels of percent saturation oxygen observed in September, October and November coincide with the period of maximum turbidity associated to large quantities of particulate organic matter. As salinity is very low in the lagoon during those months, an important fraction of the oxygen introduced by the rivers remains dissolved. Even when the rain decreases from December, the degradation of the excess organic matter persists together with oxygen consumption until February (levels of 60%-70%). The Secchi Disk values are similar to the values measured between June and August (figure 5).

4. CONCLUSIONS

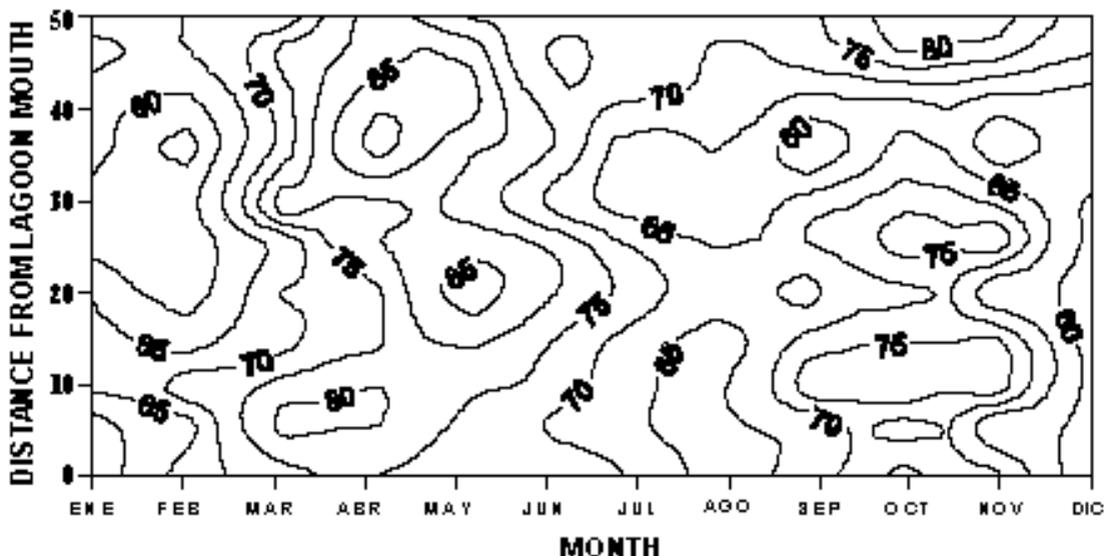


Figure 6. Temporal variation of the percent of oxygen saturation in a transect along a central axis of the Pearl Lagoon corresponding to monthly mean values obtained during the sampling period.

The annual cycle of thermohaline conditions at the surface shows a temperature maximum (29.4 °C) in May and a minimum during December (25.6 °C). Maximum salinities occur in April (34‰) and between July and August observed salinities are lowest (2‰), when there is a annual maximum in precipitation in the area.

The spatial distribution of surface temperature shows the largest differences between the external and internal parts of the lagoon at the end and at the beginning of the year. The salinity field is determined by the balance between the tidal prism and the fresh water volume from river discharge. During the dry months, salinities in the inner zone and near the bar attain values of 4‰ and 31‰ respectively. In the rainy season, the 1‰ isohaline extends sometimes to the south of Punta Ebo, and the lagoon is virtually a fresh water body.

The highest levels of oxygen saturation (90%) occur between March and May, when water turbidity in the lagoon is lowest and fresh water input minimum. During the rainy season, in the second half of the year, the water of the lagoon shows an important diminution in oxygen contents as a result of the degradation of organic matter.

The spatial distribution of percent of oxygen saturation shows very small horizontal gradients, never above 1%/km. Generally, such percentages are between 60% and 90%. The maximum levels of turbidity (Secchi Depth < 0.4 m) were observed during the rainy months in the areas under the direct influence of fresh water discharge. In the dry season turbidity substantially decreases over the whole lagoon, with Secchi Depths over 1.5 m in some locations.

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