Minería y Geología / v.27 n.2 / April-June / 2011 / p. 42-66 ISSN 1993 8012

Hydrochemical characterization of the Northern Great Wetland of Ciego de Ávila, Cuba

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Abstract
A hydrochemical characterization of the North Great Wetland of Ciego de Ávila province, Cuba, was carried out in order to identify the factors changing water physical and chemical properties and the current status of conservation or deterioration of the aquatic environment. Temporal and spatial behavior of temperature, salinity, oxygen saturation percentage and pH was evaluated based on analytical results from eleven water samples and temporal and spatial distribution maps generated using Surfer 8.0. It was found that interchange of ocean water, depth of aquatic bed and, to a lesser extent, surface water drainage in inland bays Los Perros and Jiguey are the factors which most influence temporal and spatial behavior of the properties analyzed; therefore, it is recommended to interconnect inland lakes with ocean water to contribute to the decrease of salinity and increase of pH and have more stable temperatures throughout the year.

Key words
Hydrochemistry; wetland; temperature; salinity; oxygen saturation; pH.

Received: 1 April 2010 / Accepted: 15 March 2011

Caracterización hidroquímica del Gran Humedal del Norte, Ciego de Ávila, Cuba

Resumen

Se realizó una caracterización hidroquímica de las bahías interiores Los Perros y Jigüey, del Gran Humedal del Norte de Ciego de Ávila para establecer los factores que provocan modificaciones en las propiedades físico-químicas del ambiente hídrico y el estado de conservación o de deterioro actual del acuatorio. El comportamiento espacio-temporal de la temperatura, salinidad, porcentaje de saturación de oxígeno y pH se evaluó a partir de los resultados analíticos de once muestras de agua y de los mapas de distribución espacio-temporal generados en Surfer 8.0. Se encontró que en las bahías interiores Los perros y Jigüey el intercambio con el agua del océano, la profundidad de fondo del acuatorio y, en menor medida, el escurrimiento superficial de las aguas son los factores que más influyen en el comportamiento espacio-temporal de las propiedades analizadas, por lo que se recomienda conectar las lagunas interiores con las aguas del océano para favorecer la disminución de la salinidad, el aumento del pH y temperaturas más estables durante todo el año.

Palabras clave

Hidroquímica; humedal; temperatura; salinidad; saturación de oxígeno; pH.

Recibido: 1 abril 2010 / Aceptado: 15 marzo 2011

INTRODUCTION

The changes in the hydric regime, the contamination of waters and physical modification are among the factors causing unfavorable changes in the ecological character of a wetland (http://www.ramsar.org/index.html). The construction of civil engineering structures was started in 1985 linking Cuba with northern cays as part of a program aimed at developing tourism in the Sabana-Camaguey archipelago and creating the infrastructure to support such development. In 1989, the causeways Turiguanó-Cayo Coco and Cayo Coco-Paredón Grande were completed. These works have changed some of the physical-chemical properties in relation to the biotic communities (Figure 1).

In the convention on wetlands which took place from March 19 to the 27 th, 1996 in Brisbane, Australia several recommendations were made; which included number 6.8 related to strategic approach to coastal zone planning and section 3 stating that costal zone planning shall include all types of wetlands and surrounding refuge sites for coastal birds and other aquatic species including, among them, those of the freshwater wetland systems that are related, coastal lakes, bays, small bays, mangroove swamps, algae forests, suspended lakes, freshwater swamps and estuaries, as well as intertidal zones including the areas where the depth of water at low tide is 6 meters. Section 4 recognizes the fundamental ecological functions of coastal zones and their economic, cultural and recreational values, especially for those small island developing states and other countries (http://www.ramsar.org/index.html).

The wetland ecosystems are adapted to the prevailing hydrologic regime (Valdés & Campoy 1994). The spatial and temporal variation in water depth, flow patterns and the quality of hydric resources as well as the frequency and duration of inundation are often the most important factors determining the ecological character of a wetland. Coastal and marine wetlands are often highly dependent on freshwater, associated nutrients and sediment inputs from rivers (http://www.ramsar.org/index.html).

Impacts on wetlands can be caused by both human activities within them and, because of the interconnectedness of the hydrological cycle by the activities that take place within the wider catchment. Human modification of the hydrological regime, by removing water (including groundwater) or altering fluxes, can have detrimental consequences for the integrity of wetland ecosystems. Insufficient water reaching wetlands, due to abstractions, storage and diversion of water for public supply, agriculture, industry and hydropower, is a major cause of wetland loss and degradation. A key requirement for wetland conservation and wise use is to ensure that adequate water of the right quality is allocated to wetlands at the right time (http://www.ramsar.org/index.html).

The sustainable use of hydric resources in wetlands, the hydro-chemical variations that have occurred as a result of retention of natural river beds in addition to continuous inputs of freshwater with sediments from superficial drainage as well the limited connection with seawater have caused environmental problems as well as conflicts in main production sectors (tourism) that are dependent on such important natural areas. The construction of a causeway to link the Bay Los Perros with Cayo Coco is one of the anthropic activities that have had a major impact on this sector of the Great Wetland.

The wetland area is the third biggest tourist resort in Cuba with more than 200 000 visitors a year. Tourist activities in Cayo Coco and Cayo Romano exert enormous pressure on the North Great Wetland in Ciego de Ávila, which translates into the destruction of natural resources, contamination, conversion and refilling. All these, impact negatively on the biodiversity in the inland bays Los Perros and Jigüey.

The objective of this work is to characterize the hydrochemistry of the North Great Wetland (GHN) in Ciego de Ávila, located specifically at Los Perros and Jiguey Bays , based on the spatial and temporal variability of temperature, salinity, percent of oxygen saturation and pH in order to determine the factors that cause variation in the physical-chemical properties of the hydric environment and currently influence conservation or deterioration of the aquatic environment. To achieve this, the following three tasks were identified:

1. Physical and chemical characterization of the inland Bay water.
2. Establish the hydrogeochemical relationship between the different parameters which include temperature, salinity, percent of oxygen saturation and pH

3. Establish the mechanisms to better manage the North Great Wetland in Ciego de Ávila

1.1 Physical, geographical and economic characteristics of the area

The GHN is located to the north of the province of Ciego de Ávila (central region) and covers an area of 226 875 ha, stretching along almost the entire coast, intermediate maritime area and adjacent cays (Alcolado et al. 2007).

The investigated area covered the inland Bays Los Perros and Jiguey (Figure 1). This area is characterized by low- mud banks covering more than 40% of its total area, at depths ranging from 0,30 to 0,50 m to the north and central zones, specifically. Higher values of depths reported are between 2,10 -3,00 m (Academia de Ciencias de Ciego de Ávila 1985). The ocean water exchange in inland bays is limited due to the fact that they border on the cays north of the causeway in Ciego de Ávila and the Cayo Coco.

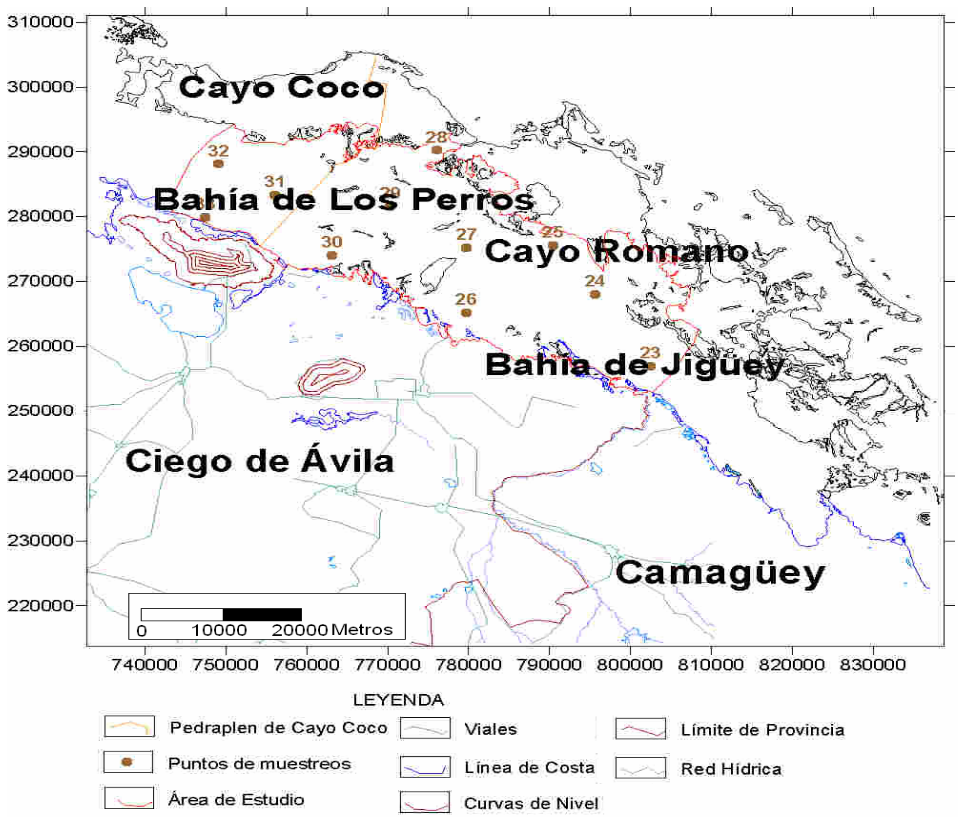

Figure 1. Location of the investigated area and sampling station.

The geographical characteristics of the zone have not contributed to abundant surface run-off into the investigated area (no more than 140 million cubic meters/year flowing through). El Calvario, El Junco-Los Naranjos in the province of Ciego de Ávila are the main rivers flowing into the area. There was also input of continental waters through the Chicota channels (from La Leche and La Redonda Lagoon drainage) in Manatí (La Yana Channel drainage) and waters coming from the permanently inundated zone and underground basins in Morón and Bolivia (Academia de Ciencias de Ciego de Ávila 1985).

The greatest input of continental water to the area was reported from1989 to1990 through the closures of marshes Socorro and Chicola and Manatí´s channel. In February 1990, la Pasa de Paredón Grande (area within station 28) was also shutdown on a temporary basis. This was the only existing passage for direct exchange of water between the inland bays and the ocean and was not restored to its original water level. All these anthropic conditions have reduced continental water input into the investigated area to incalculable values. Soil studies on the areas susceptible to inundation are being carried out by Empresa de Aprovechamiento Hidráulico, Ciego de Ávila in order to estimate the reserves of superficial water and control the periodical input towards inland bays (Gobierno Provincial, Ciego de Ávila, private communication).

The regional climate is classified, according to Koppen (1918), as a tropical humid climate, with two well defined periods based on precipitations, less-rainy or dry season from November to April and rainy or wet season from May to October.

The investigated area has warm temperatures year round, with an average annual temperature of 26 ^{0}C. The coldest month is February, with an average temperature of 23, 4 °C and the hottest is July, with an average temperature of 28.4 °C.

Average annual precipitation is less than 1 200 mm, with a minimum of 200 mm to 300 mm during the less-rainy period, from November to April, ad a maximum of 1 100 to 1 200 mm during the rainy season, from May through October (ACC, 1983).

The wind regime shows a predominance of trade winds from the east and northeast. During the winter, cold winds from the north and northeast generally bring low intensity rainfalls. Tides are of weak intensity, with amplitude ranging from 0.5 and 1.0 (ACC, 1983).

The prevailing vegetation in both bays is Bataphora oerstedii and Halodule weightii, typical representatives of euryhaline species. Its species diversity and richness depends on the degree of muddiness, salinity, exchange of water and regime of marine streams and its density decreases towards the Jiguey Bay. (Gandoy 1993)

The fauna is represented fundamentally by euryhalines as the black sea bream, diapterus rhombeus, porkfish and bonefish to a lesser extent, etc. Commerson's dolphin can be observed occasionally, and its variety decreases towards the Jiguey bay. There is a wide variety of migratory birds; such as, flamingo, double-crested cormorant, short-tailed hawk, white ibis, etc. (ACC & ICGC 1990b).

1. 2 Geological frame

According to the existing models of the geological constitution of the Island of Cuba, in this region there are folded substrate materials, both continental and oceanic, and Neo-autochthonous materials. (Figure 2)

The folded substrate materials of continental nature constituted the Bahamas Mesozoic platform and are composed of shallow water carbonate rocks and evaporites. The area of Cayo Coco and the coastline to the North of Ciego de Ávilla, has sequences of evaporites from the Jurassic, packages of dolomite, anhydrites and limestone of low power from the Upper Jurassic- Albiense. (Meyerhoff & Hatten 1968).

The most important element in the area is the saline dome Turiganó and other small saltwater intrusions dating back from the Upper Jurassic, stretching NE-SE. The oceanic materials are represented by northern ophiolites and arc- volcanic rocks.

The greatest portion of the territorial surface of the province is comprised of rocks belonging to the second main structural level in which the geological model of Cuba is divided into, which occurred after the consolidation of the folded substrate from Upper Eocene to Recent. According to Iturralde-Vinent (1978), oscillatory vertical movements resulted in the formation of block structures distinctively elevated. Lesser deformations are found in these deposits; which cover sub-horizontally nearly all the folded substrate in different ways. (Iturralde-Vinent, 1988)

Three sedimentary cycles or palaeographic transformation phases can be identified in these sediments. The Oligocene and Upper Eocene stage is characterized by the presence of terrigenous and siliciclastic facies, resulting from the erosion of pre-existing rocks. Carbonate sediments accumulated in this terrigenous formation; predominating towards the upper portion. Another phase from Lower to Upper Miocene develops with more uniform stratigraphic characteristics displaying a predominance of carbonate facies. The sediments typical of the third sedimentation phase in Cuban Neo-autochthonous occurred between Pliocene and Recent. This evidences a strong terrigenous character, constituted by detrital limestones, calcarenites, biocalcarenites and biolytic (Figure 2).

The geology of the investigated area is not complex, both from the lithological and tectonic point of view. Lithologically, the area is mainly composed of calcarenite, massive biodetritic with a creamy to white color, generally karsified and sometimes cracked, from "Dry" Mid Upper Pleistocene. It outcrops at the channel bottom where the current prevents the accumulation of friable sediments. The prevailing sedimentation areas are beach, post-reef and limitedly reef facies. This formation is probably more than 10 meters thick. Much younger sediments from Late Holocene make up superficial layers and are distributed at the bottom of inland bays, channels and some coastal sectors. They are made of peaty, clayey sands, mud, sandy mud and sand. These sediments are composed mainly of Halimeda species remains, with high content of fossils as bivalves, mollusk and reefs occasionally. The prevailing depositional environments are beach lacustris lakeside and trowel palustres and lacustres. (Empresa Geocuba, 2002).

There is a predominance of sand, muddy sand and white-cream colored mud, with varied grain size and thicknesses ranging from 0.50 to 4 meters in depth towards central areas and ends of some channels where the current is not very strong as well as in some occasionally flooded sectors. Peat deposits between 1 to 4 meters thick, prevail towards mangrove swamps. Tectonic events are not significant due to the predominance of quaternary sediments (tectonically passive period) and therefore, it covers the major events. However, it must be highlighted that the linearity of the coast suggests the existence of neotectonic ascent movements which are to be investigated in the future. The north-western insular platform; which the investigated area is part of, can be defined as a morphostructural unit, the result of the general tendency of neotectonic movements, the successive marine regressions and transgressions, the current level of the sea and development of climatic, biogenic and hydrodynamic processes (Empresa Geocuba 2002).

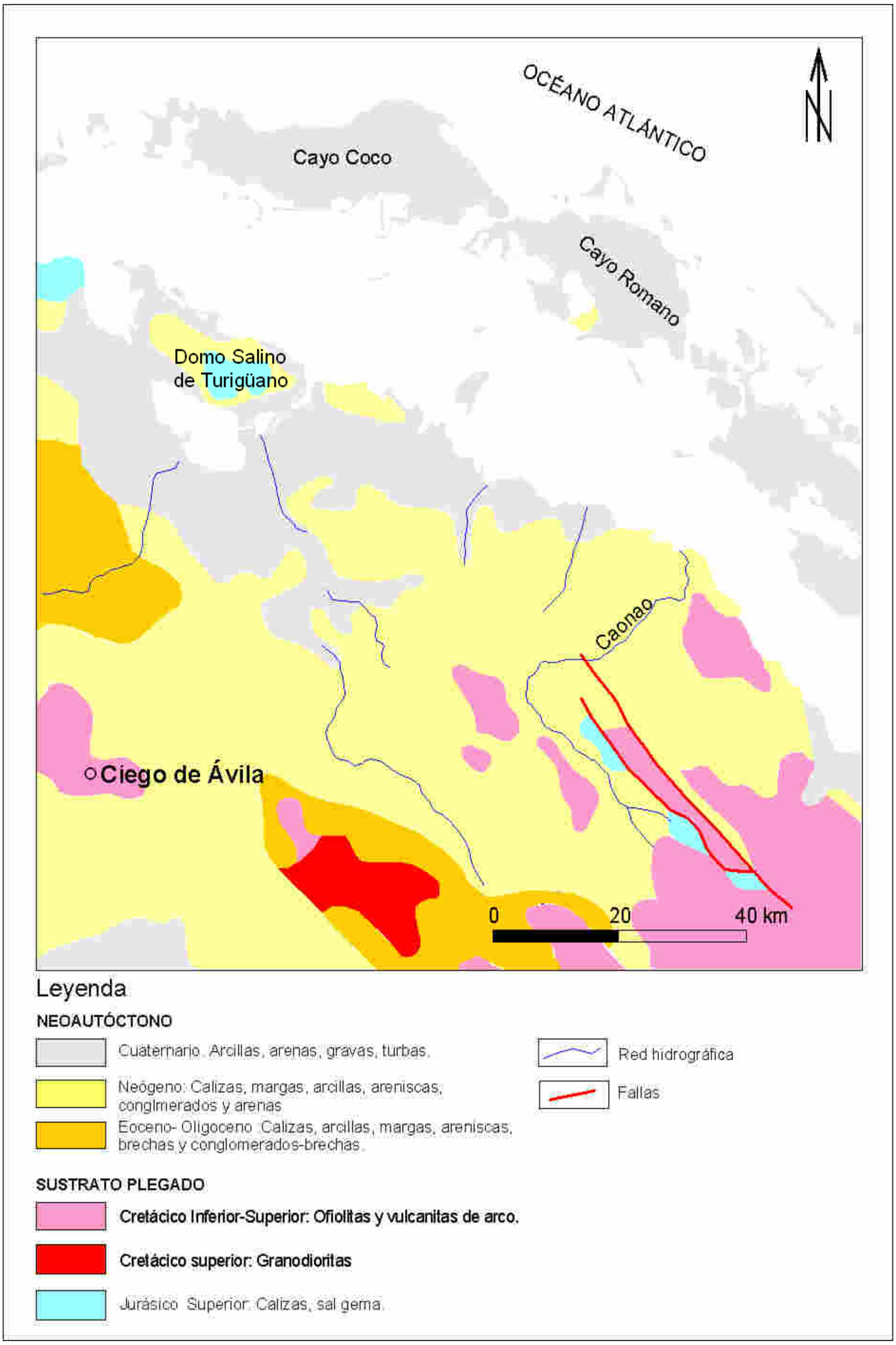

Figure 2. Regional geological map of the province of Ciego de Ávila (modified from the geological map of the Republic of Cuba, 1:1 500 000 (Atlas República de Cuba 1981).

The wetland develops in very flat areas, with little vertical relief (at less than 10 m mostly) and carsic uneven surfaces of small depth.

The wetland coastline is characterized by lagoons, swamps, marshes and other forms. In other sectors actions to build canalizations have been undertaken (pólderes de Turiguanó). The slopes are less than 0.8% along its entire length and 3% at the seabed (which is a part of the wetland) (Empresa Geocuba 2002).

From the geomorphological point of view, the wetland consists of an accumulative lacustrine-palustrine boggy plain, flat towards the south, continued by a marine bottom of abrasive-accumulative insular platform, interrupted farther north by the lagoonal-paludal plain of the 4 cays (in its southern portion) and ending at the north of the border of the cays again in the same abrasive- accumulative insular platform (Empresa Geocuba 2002).

The soils are hydromorphic swampy soils with muddy subtype, except in the highest parts of the interior (Turiguanó and Cayo Coco); which have typical humic calcimorphic soils.

The area constitutes a giant tourist attraction for its extensive beaches to the north of the cays, with Cayo Coco, Cayo Romano being the most important tourist resorts of international transcendence of Ciego de Ávila (Empresa Geocuba 2002)

2. MATERIALS AND METHODS

2.1 Sampling

The sampling stations in the bay were selected based on the circulation dynamics and the geographical features of the area. A total of 11 sampling stations (see Figure 1) were selected and three sampling campaigns were undertaken: the 2005 rainy season, less rainy periods between 2005 and 2006 and 2006 rainy season. The campaigns took place at the end of each annual season according to precipitations in the archipelago. Sampling was completed on a shallow draft boat on spring tides, starting in the morning regardless of the prevailing tide cycle at the time.

In each station, 3 samples of water were taken manually using a 2-liter Niskin-type bottle at a depth of 0.3 m from the surface, regard less of the thickness of the water layer in the investigated area of the GHN, which varied from 0.70 and 2.5 m. The samples were taken in each station starting from 8:00 am in the following order: 26, 30, 33, 32, 31, 28, 29, 27, 25, 24 and 23

2.2 Analytical methods

2.2.1 Salinity

Salinity is the content of dissolved solids in grams per kilogram of seawater. At present this parameter is measured based on the electrical conductivity (IOC-UNESCO 1983). Salinity was measured in situ by using a refractometer of ATAGO design with 1% accuracy.

2.2.2 Temperature

The temperature of the water was determined in situ by using a TM-4 thermometer with an accuracy of 0,1 ^{0}C. Measurements were completed in all sampling stations during rainy and less- rainy periods from 2005 through 2006.

2.2.3 Dissolved oxygen

Dissolved oxygen was also determined in situ by using a Hach digital oxygen meter with 0,01 mg/l accuracy.

2.2.4 Percentage of oxygen saturation

Saturation was determined through Weiss equation (IOC-UNESCO 1983) based on temperature (^{o}C), salinity (‰) and concentration of dissolved oxygen. The background percentage of oxygen saturation was 61, 08% based on 27 ^{o}C, 35 ‰ and 4 ml/l for temperature, salinity and average dissolved oxygen, respectively.

2.2.5 pH

The pH is a very important factor as certain chemical processes can only take place at a given pH. For example, chlorine reactions are only produced at pH 6, 5 and 8 . Buffer solutions with pH 4, 6, 8 and 9 were used. The procedure used was the calculation of in situ pH. (http://www.lenntech.com/español/feedback_esp.htm)

 ISSN 1993 8012

$pH_{in\ situ}$ is calculated applying the formula (IOC-UNESCO 1983):

$pH_{in\ situ} = pH_{medio} + 0,0118\ (t_2 - t_1)$

Where:

t_1- In situ temperature

t_2- Measurement temperature.

3. RESULTS AND DISCUSSION

3.1 Spatial- temporal behaviour of temperature

According to location and physical and geographical characteristics of the investigated area, the temperature of the water in the GHN in Ciego de Ávila depends on various parameters:

1. Bottom depth
2. Level of exchange with waters more connected to the ocean.
3. Rainfalls favouring lower water superficial temperatures.

According to the map of distribution of water temperatures during 2005 rainy season (Figure 3) in GHN in Ciego de Ávila, the highest temperatures of 29,2; 29,2 and 28,6 ^{o}C were reported to the north of the Jiguey Bay around stations 24, 25 and 27; respectively while the temperatures are lower to the west of Los Perros Bay, reaching a minimum of 26,4 ^{o}C in station 28 where there is a direct exchange with ocean water. The average temperature during this season is 27,85 ^{0}C.

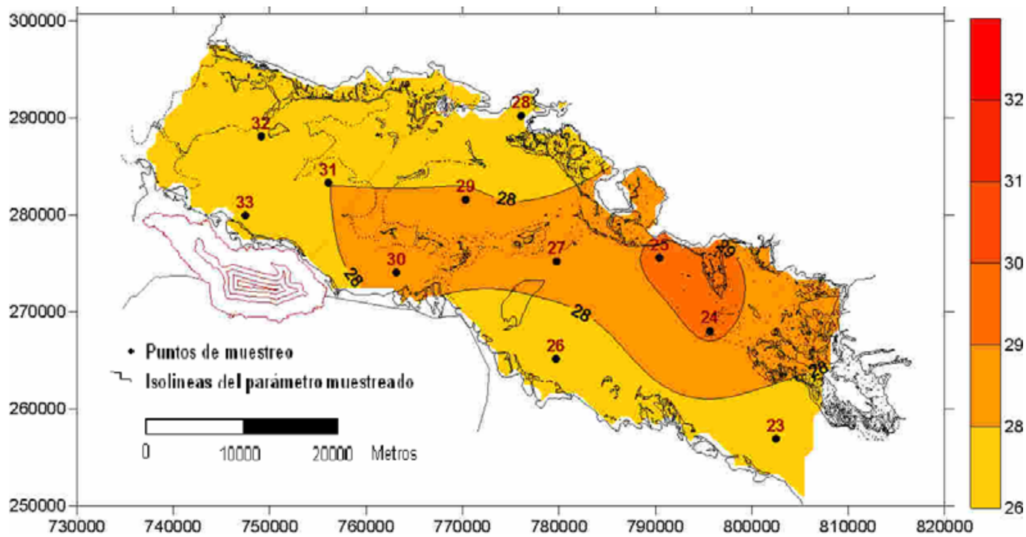

Figure 3. Spatial-temporal behaviour of temperature during 2005 rainy season.

During the less-rainy periods in 2005 and 2006 the temperature of the water increased by two degrees compared to the 2005 rainy season. It reached 28.2 ^{0}C in the western end of Los Perros Bay and up to 31,8 ^{0}C to the north of the Jiguey Bay, mainly in stations 24 and 25. This spatial –temporal behavior of temperature is attributable to higher temperatures of the water superficial layer during this period, favored by shallow aquatic bottom.

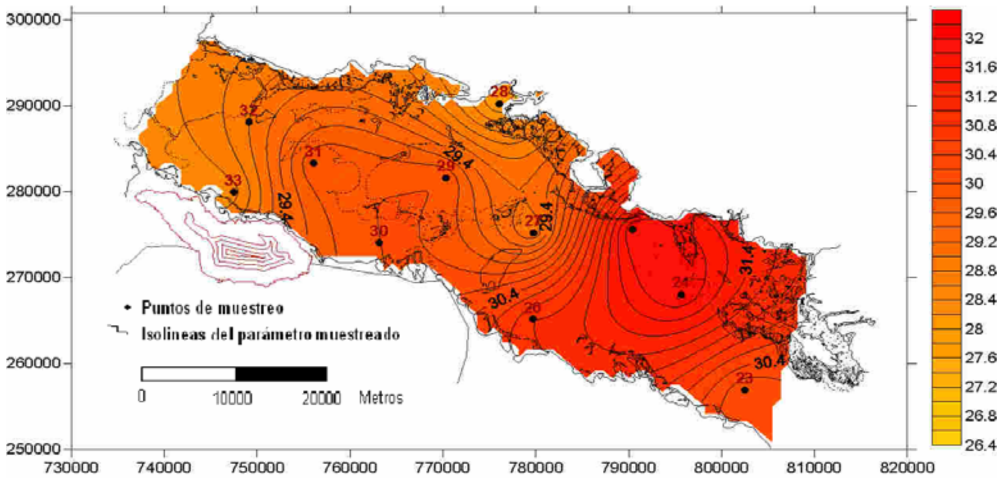

Figure 4. Behavior of temperature during the less-rainy periods 2005-2006.

During the 2006rainy periods (Figure 5) the spatial-temporal behavior of temperature was more homogeneous. The average value was 28.59 ^{0}C, which is one degree higher than that in the same rainy period in 2005. This was owed to the fact that the 2006 rainy season was drier than 2005´s.

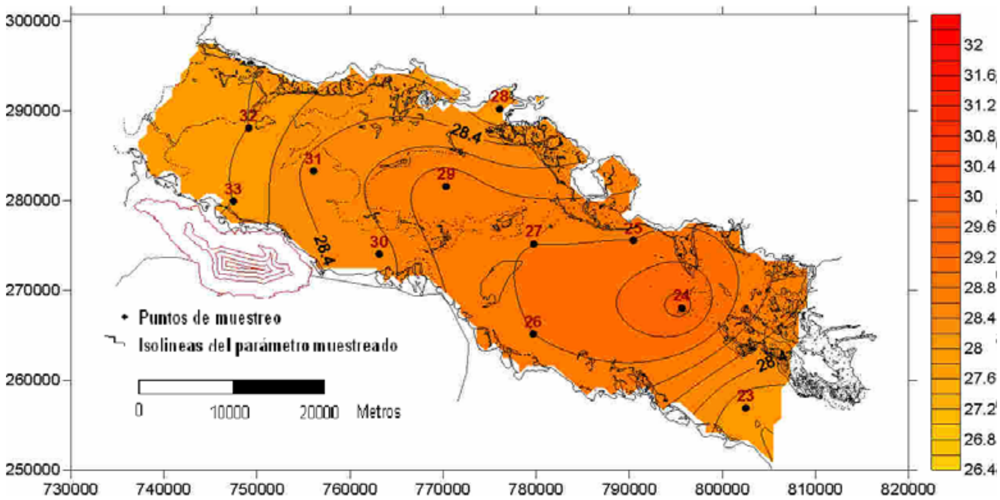

Figure 5. Spatial-temporal behavior of the temperature during the 2006 rainy season.

The spatial-temporal distribution of the temperature during the rainy and less-rainy seasons was consistent with the physiographic features and climatic conditions of the investigated area. The average temperatures during the three investigated seasons were 27,85 ^{o}C (2005); 29,95 ^{o}C (2005-2006) and,59 ^{o}C (2006). In general, it is observed that temperature decreased towards the western and northern zones of Los Perros Bay; which was more or less similar during the 3 seasons, caused mainly by the exchange of its water with that of the Buenavista Bay; which has lower thermal values as it comes from deeper zones and with acceptable exchange with ocean waters. In the exchange zones, temperatures are generally low, regardless of the depth of the inland bay´s bottom. For this reason, temperatures are generally much lower, in spite of the rainy season, in the western areas where the exchange with water from the ocean is permanent, than in the eastern areas, except in those deeper areas.

One can conclude that the spatial temporal behaviour of the water temperature in the Los Perros and Jigüey inland bays depends on factors such as the existing exchange with water from the ocean, the depth of the sea floor and rainfalls. The first of them is perfectly controlled by men by opening interconnecting channels with the ocean and a better connection with Buenavista Bay, to the northwest of Los Perros Bay, which directly communicates with the ocean.

3.2 The spatial-temporal variability of salinity

Water salinity is a chemical parameter that depends on the concentration of dissolved salts and temperature; which in turn, depends on the depth of the sea bottom. Its behaviour is also influenced by precipitation, surface and underground runoff and the exchange with water with haline nearly oceanic parameters. The average ocean salinity is approximately 35, increased to 40 ‰ in the Red Sea and Persian Gulf (Masson 1966. According to Clarke (1972), the rain water carries at about 27,35 x 10^{14} of dissolved substances, providing an average salinity of approximately 100%

for river water. However, the analysis of river water shows salinity values ranging from 13 and 9 185 ‰ although it is less frequent to observe values above 1 000. Conway (1942) indicates that the waters having a salinity above 50% come from zones mainly composed of eruptive and metamorphic rocks. Values above 50% are indicative of a large scale human contamination or drainage from arid regions where saline soils are predominant.

The behavior of water salinity of the marine area in GHN, Ciego de Ávila is similar to that of temperature. During the rainy periods (Figure 6) in 2005, water salinity ranges from 50 and 70 ‰. The spatial variation indicates that the highest values are distributed in less deep areas with no water exchange.

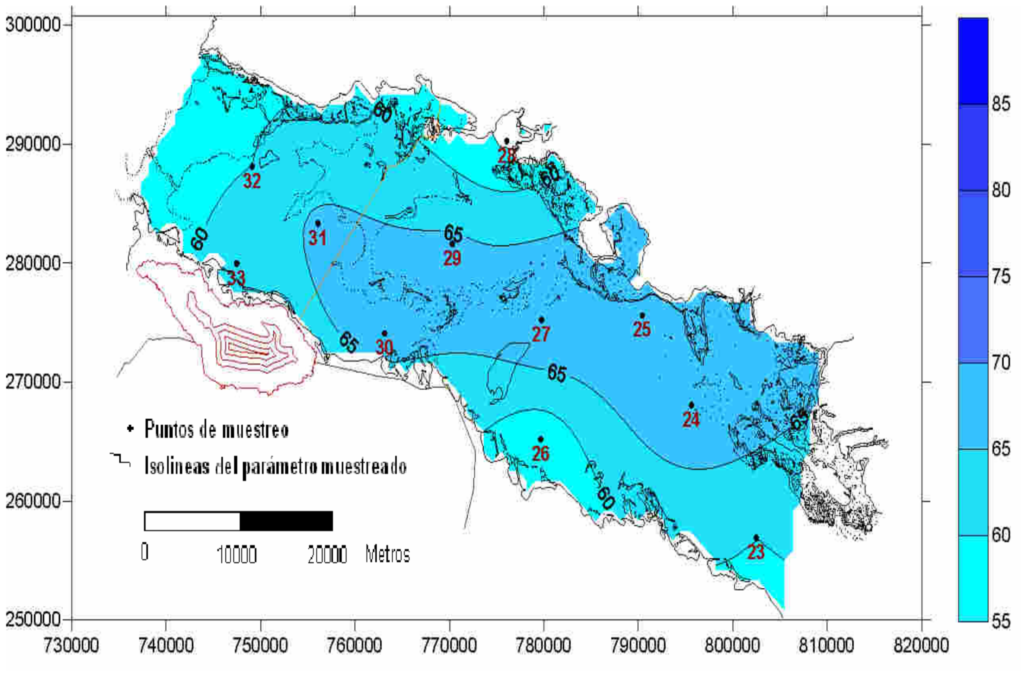

Figure 6. Behavior of salinity, 2005 wet season.

During the less rainy periods in 2006-2006 (Figure 6), salinity reached 55 and 81 ‰, higher than that recorded during the preceding rainy period, with a similar distribution pattern because the factors influencing salinity are the same. During the 2006 rainy season (Figure 8), salinity decreased between 52 and 67 ‰.

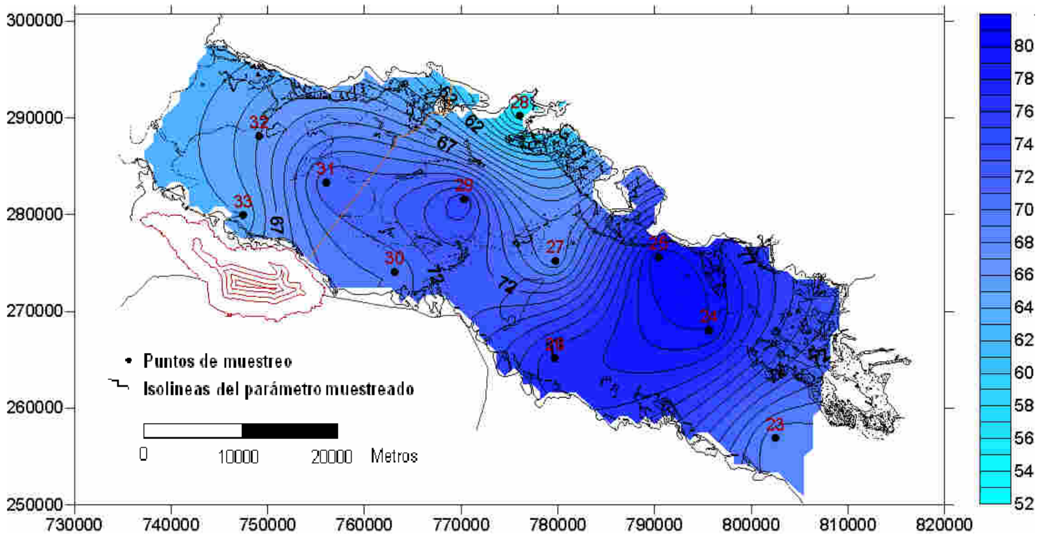

Figure 7. Behaviour of salinity, 2005 less rainy periods.

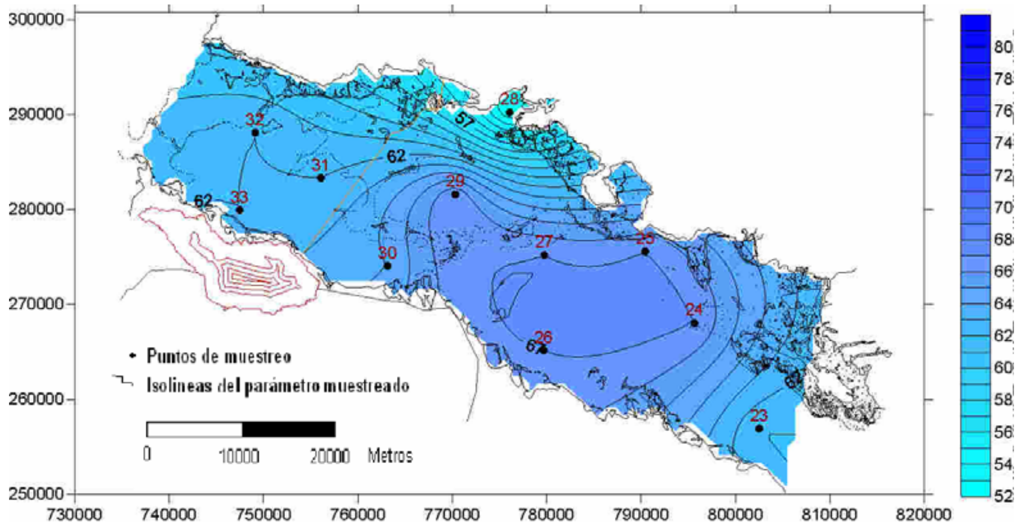

Figure 8. Salinity behavior, 2006 wet season.

During the rainy and less- rainy seasons, 2005-2006, it is observed that the salinity of the water decreases towards the W and NW of Los Perros Bay due to the exchange with the Buenavista bay waters and less influenced by precipitation during the less rainy season. On the other hand, it has to be pointed out that depth appears to significantly influence the salinity concentration in this zone as this is a region of moderate temperatures for this time of the year.

Salinity increases towards the NE of the bays caused by waters with temperatures above 28°C, the presence of the bottom at depths lower than 0.30 m and little or no exchange with ocean-like water.

 ISSN 1993 8012

Underground water influences the behaviour of water in wetlands (Buil-Gutierrez & Fernández-Escalante 2002) so it is ruled out that underground waters coming into contact with the Tariguanó saline dome enter the inland bays, mainly Los Perros, and increase its salinity.

Salinity to SE of the bays, NE coast of Ciego de Ávila, where stations 23 and 26 are located, is low as a result of greater depths and precipitations typical of the wet season. However, haline levels in station 26 during the 2006 rainy season seemed not to be influenced by run-off, which is probably because of the limited input reported by precipitation during this time. The same happens with the exchange with ocean waters as these are closed areas. The highest salinity values were registered in the centre of the bay as this is a low zone, less than 0.30 m deep; temperatures and lack of exchange with ocean waters influenced significantly.

Based on the above, it is concluded that salinity in the GHN from Ciego de Ávila is high, with an enrichment factor of approximately 2. This means that it is higher than that for the sea bottom water (35 ‰). These inland bays are considered to be hypersaline (Alcolado et a.l 2010). The temperature and poor exchange with sea water are the main factors causing salinity of the area to increase, a subsequent strong evaporation with the resulting increase in the concentration of salts. The existing fauna in this wetland is threatened by such living conditions, which can be suitable for euryhalines only. A possible influence of saline domes on the behavior of the aquatic salinity is not ruled out.

3.4 Spatio-temporal variability of oxygen saturation

In Figure 9 it can be observed that the area occupied by stations 24, 25 and 27 has the lowest percentage of oxygen saturation ranging from 67,82 to 68,43%. This is approximately the saturation of the bottom and thus is typical of this season. It is somewhat higher in the rest of the wetland, ranging between 70, 26 and 71,80%.

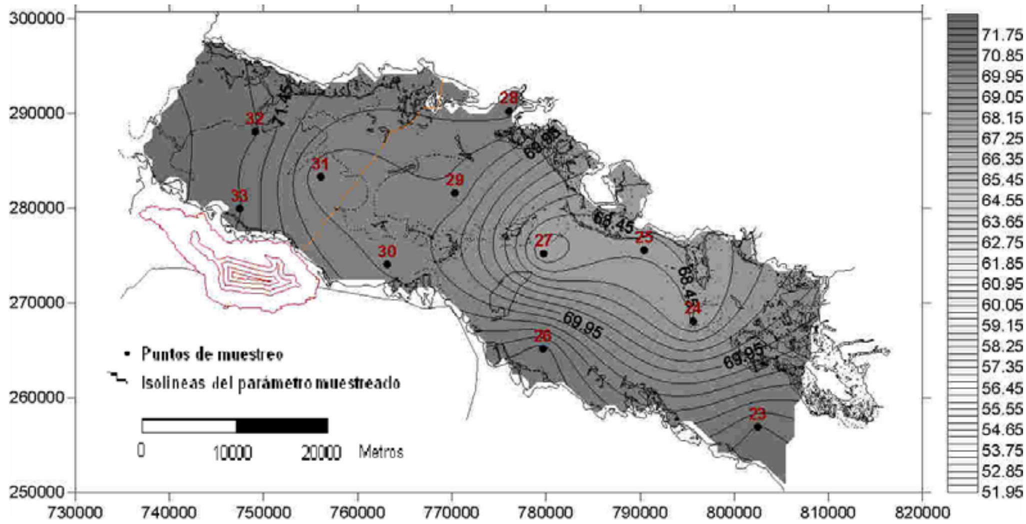

Figure 9. Variability of the percentage of oxygen saturation, 2005 rainy season.

In the distribution map for the percentage of oxygen saturation, during the less rainy periods in 2005-2006 (Figure 10), it is observed that it decreased by 4% with relation to the 2005 rainy period.

It is observed that the values during the dry season are below average due to a higher concentration of dissolved salts. This occurs in interior areas where there is no exchange with ocean water. The highest values are found in the NW where there is a permanent exchange with ocean water. The distribution of the percentage of oxygen saturation during the 2006 rainy season (Figure 11) is very similar to the 2005 rainy season.

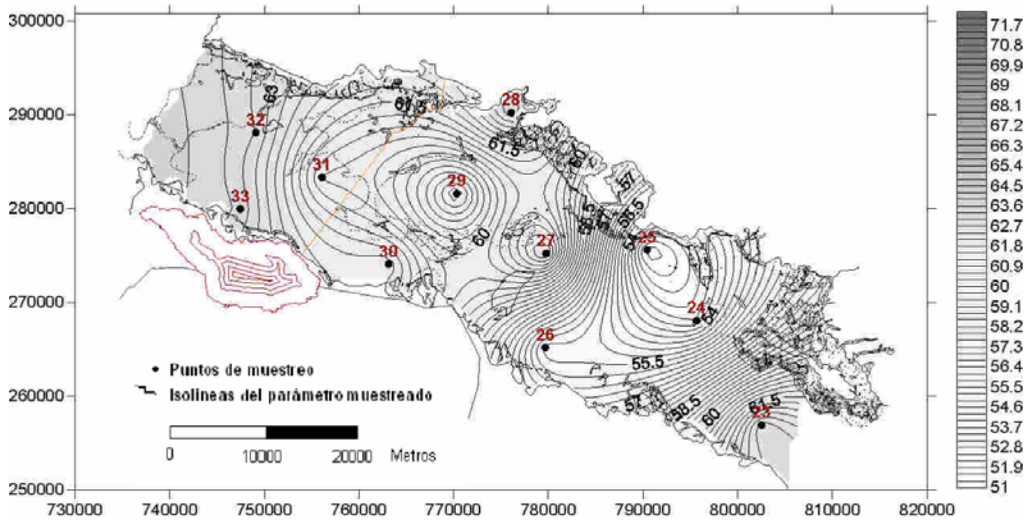

Figure 10. Variability of the percentage of oxygen saturation, less rainy season 2005-2006.

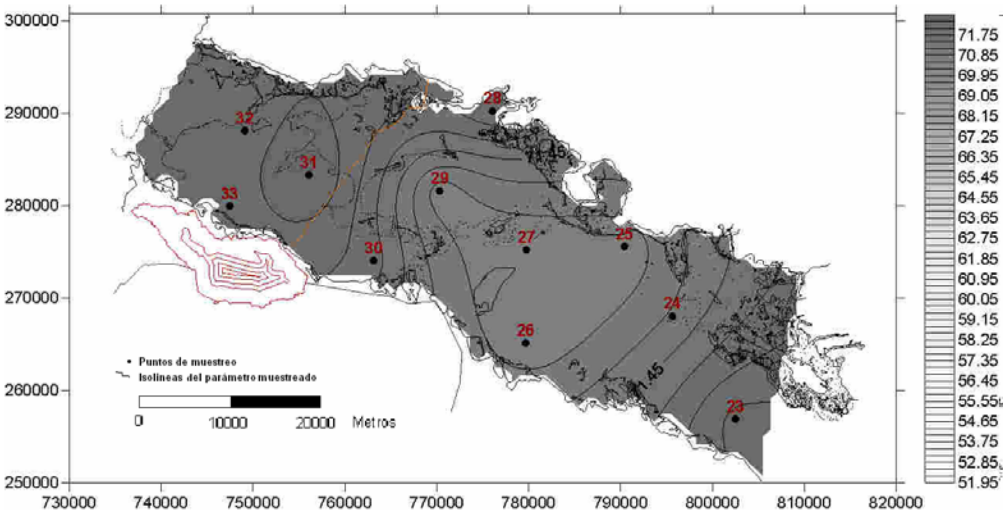

Figure 11. Distribution of the percentafe of oxygen saturation, 2006 rainy season.

The distribution of the percentage of oxygen saturation during the three seasons analyzed shows that the highest values were distributed in the coldest and therefore less saline areas; which are located to the W and NW of the GHN. It can be concluded that this parameter is influenced by water temperature and the salinity.

3.5 Spatio-temporal variability of pH

The pH is homogenously distributed along the entire aquatic area in the wetland during the 2005 rainy season, except for the area occupied by stations 24, 25 and 27 where it decreases to 7,791. pH remains above 8, slightly alkaline, in the rest of the area.

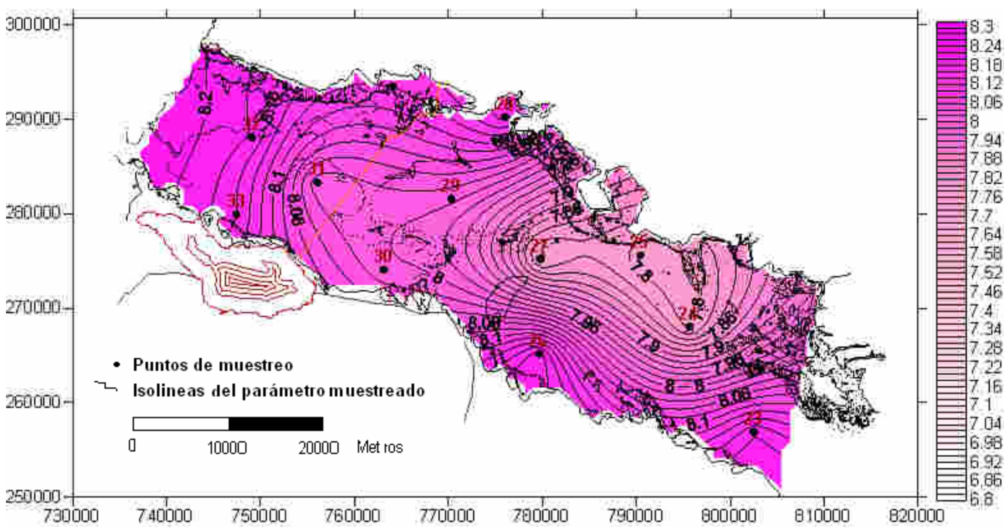

Figure 12. Distribution of pH during the 2005 rainy season.

The pH distribution in the GHN during the less rainy seasons between 2005-2006 is very irregular (Figure 13). The lowest pH between 6,96 and 7,18 towards the eastern areas form an aligned strip in the direction of stations 24, 25 and 26; i.e, water is neutral. A similar situation occurs in station 29 where pH is 7,46. Towards the W and NW, the wetland water comes into contact with the ocean waters and pH remains above 8 in spite of the fact that it is a less rainy period. The pH distribution during the 2006 rainy season (Figure 14) is fairly homogeneous along the entire wetland, with values ranging from 8,0 and 8,2

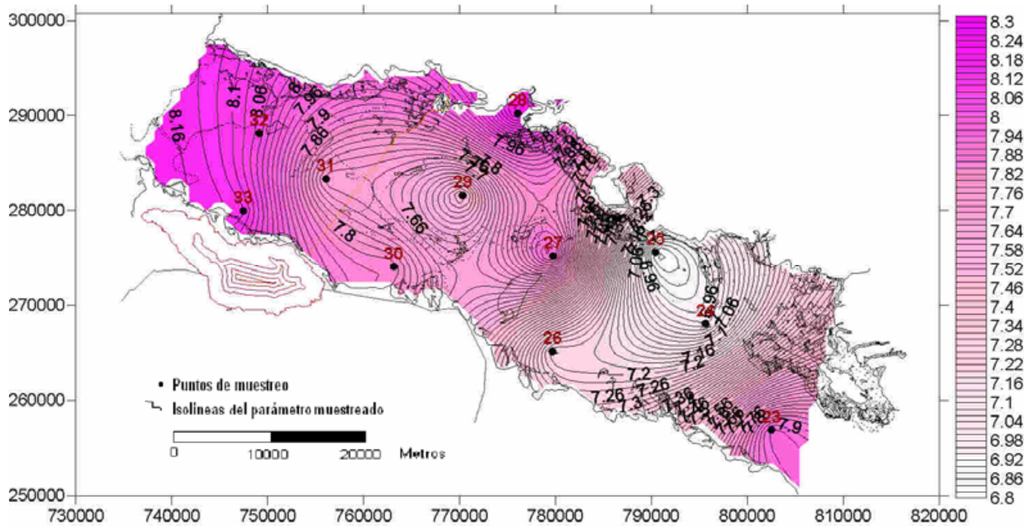

Figure 13. pH distribution, less rainy periods in 2005.

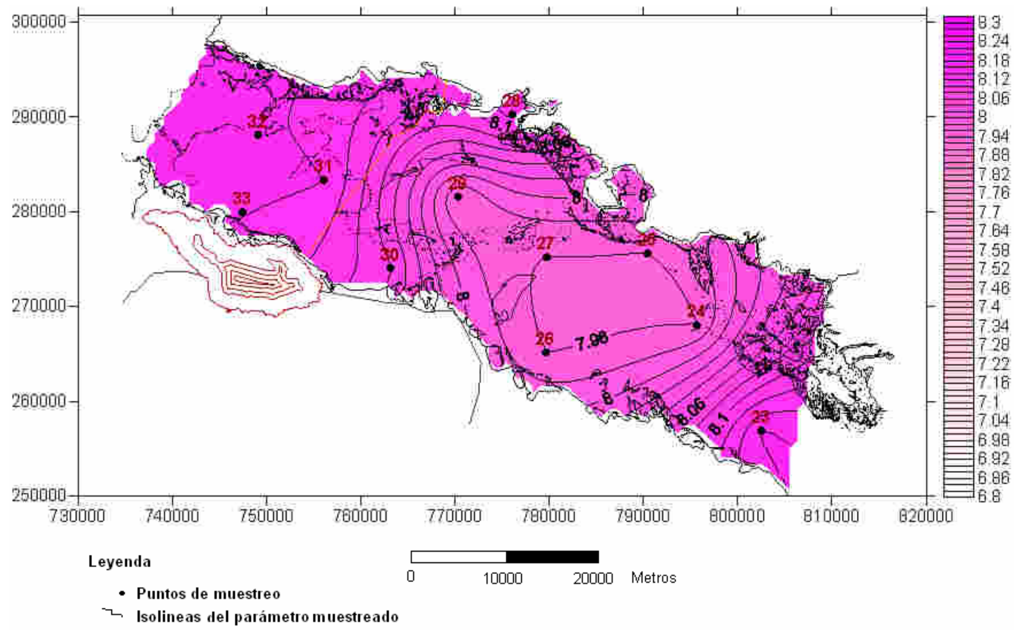

Figure 14. Behaviour of pH during the 2006 rainy season.

There was an increase in pH during the rainy and less rainy seasons in 2005 and 2006 towards the W and NW, with values between 8,6 and 8,2, undoubtedly influenced by a greater exchange with the oceanic waters coming from he Buenavista Bay, lower temperatures and salinity and higher percentage of oxygen saturation; resulting in favorable living conditions for phytoplankton.

The lowest pH values were reported to the NE of the bays, as this is an area of high temperatures and salinity and low percentage of oxygen saturation, caused by almost non-existent surface run off from Cayo Romano, no exchange with ocean waters and shallow bottoms, which significantly contributed to high temperatures and salinities limiting living conditions. Rainy seasons had little influence to improve living conditions. In the east of the wetland forming a strip in the NE-SW direction (stations 24, 25 and 26 Figure 16), pH values of at about 7 indicate the water is neutral. This is owed to a small exchange with oceanic water resulting in unfavorable living conditions.

Based on the above, it can be concluded that the changes in pH GHN in Ciego de Ávila are attributable to the exchange with the oceanic waters leading to an increase in relation to interior areas with less exchange, less deep and little superficial runoff.

4. CONCLUSIONS

The water of Los Perros and Jiguey inland bays are affected by hydrological and anthropic changes. The factors which influence the most the spatial-temporal behaviour of temperature, salinity, percentage of oxygen saturation and pH in the investigated bays are the exchange with the ocean water, the depth of the aquatic area and; to a lesser extent, superficial runoff. The influence of the Turiguanó saline dome on the behaviour of salinity is not ruled out. By controlling these factors in the GHN in Ciego de Ávila, corrective actions can be implemented to prepare and update a plan for the management of the hydric resources present in the protected areas of the wetland. In that sense, is then recommended to connect interior lakes with the waters from the ocean; which would result in reduced salinity, increased pH and more stable temperatures throughout the year.

5. ACKNOWLEDGEMENTS

The team of authors would like to express their gratitude to Eng. Rolando González Santana, Director de la Filial de Medioambiente de la UCT GEOCUBA Investigación y Consultoría Ciego de Ávila – Camagüey, and the rest of the specialists who works in this entity as well as to Unidad Científico Técnica GEOCUBA Investigación y Consultoría, Centro de Investigaciones Costeras, Cayo Coco (CIEC) and GEOCUBA, Ciego de Ávila.

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