



## Changes in benthic assemblages of the Gulf of Batabanó (Cuba) - results from cruises undertaken during 1981-85 and 2003-04

MILENA ARIAS-SCHREIBER<sup>1</sup>, MATTHIAS WOLFF<sup>1</sup>, MERCEDES CANO<sup>2</sup>, BEATRIZ MARTÍNEZ-DARANAS<sup>2</sup>, ZULEIKA MARCOS<sup>2</sup>, GEMA HIDALGO<sup>2</sup>, SUSEL CASTELLANOS<sup>2</sup>, ROSA DEL VALLE<sup>2</sup>, MERCEDES ABREU<sup>2</sup>, JUAN CARLOS MARTÍNEZ<sup>2</sup>, JHOANA DIAZ<sup>2</sup> & ARSENIO ARECES<sup>2</sup>

<sup>1</sup>Center for Tropical Marine Ecology, University of Bremen, Fahrenheitstrasse 6, 28359 Bremen, Germany.

E-mail: milena@zmt-bremen.de

<sup>2</sup>Instituto de Oceanología, Ave. Ira No 18406, e/184 y 186 Rpto. Flores, Ciudad de La Habana 11600, Cuba.

**Abstract.** Benthos samples in the Gulf of Batabanó (Cuba) were evaluated to explore if reported reduced lobster and finfish catches over the past two decades may be (at least partially) related to community changes and loss of benthic habitats of the gulf. Data was obtained from cruises carried out during the periods 1981-85 and 2003-04 covering the whole gulf area. Results suggest that adverse changes have occurred in the benthic assemblages in the areas of south of Pinar del Río and La Coloma with a great reduction in species diversity and seagrass coverage. Signs of disturbance of the benthic assemblage are also evident close to Peninsula Zapata and at the northeast of Isla de La Juventud. Further research in these four areas is strongly recommended to identify the sources of disturbances and to quantify impacts on the fishery.

**Key words:** Bottom community, habitat loss, lobster fishery.

**Resumen.** Cambios en las asambleas bénticas del Golfo de Batabanó (Cuba) - resultados de cruceros realizados durante 1981-85 y 2003-04. En este estudio se analizaron muestras de bentos obtenidas del Golfo de Batabanó con el fin de explorar si la reducción en las actuales capturas de langostas y peces del Golfo, durante las dos últimas décadas, estaría relacionada (al menos parcialmente) con cambios en la comunidad del bentos y pérdida de hábitat en el lugar. Los datos fueron obtenidos de cruceros, que abarcaron toda el área del Golfo, realizados durante los años 1981-85 y 2003-04. Los resultados muestran cambios drásticos en el bentos al sur de la zona denominada Pinar del Río y La Coloma con subsecuentes reducciones en la diversidad de especies y cobertura de pastos. Señales de disturbios en el bentos fueron también observadas en la Península de Zapata y al noreste de la Isla de La Juventud. Se recomienda intensificar los estudios en estas cuatro zonas del Golfo, con la finalidad de identificar las fuentes de disturbio y cuantificar los impactos a las pesquerías.

**Palavras chave:** Comunidades de fondo, pérdida de habitat, pesca de langosta.

### Introduction

Benthic organisms are the most common targets in biological assessments of environmental quality (Rosenberg and Resh 1993, Southerland and Stribling, 1995). These organisms provide a primary food source for fish, birds and marine mammals and affect sediment stability (Jumars & Nowell 1984) and geochemistry (Pfanckuche & Lochte 2000). They also possess appropriate attributes for use as

cost-effective indicators of environmental change and water quality (Bilyard 1987, Fabricius & McCorry 2006), such as limited motility, deposit feeding and relative long life cycles (Rosenberg & Resh 1993, Thompson & Lowe, 2004). Other characteristics that make these organisms suitable as indicators are their presence in a variety of habitats, a widely described response to stressors, the

existence of well-developed standardised protocols for sampling and the availability of background data in many cases.

In Cuba, the importance of benthic communities as sources of food and habitat for important economic marine species has been recognized since the decade of the 1970s. Research on benthos diversity, population dynamics and changes caused by natural or anthropogenic sources was considered essential to achieve an optimal resource management (Gomez *et al.* 1980, Alcolado 1990). Thus, considerable research effort was directed to the study of benthic communities of the Gulf of Batabanó during this period, being the gulf one of the most important fishing grounds in the country. At least 60% of the landings of the spiny lobster (*Panulirus argus* Latreille 1804) fishery are obtained from Batabanó (Baisre 1985, Alcolado 1990, Puga *et al.* 1996). However, catches of lobster and other important commercial fish species have shown a declining trend over the last two decades, with as yet no sign of recovery despite the enforcement of fishery management policies in the area (Claro *et al.* 2001, Valle 2005).

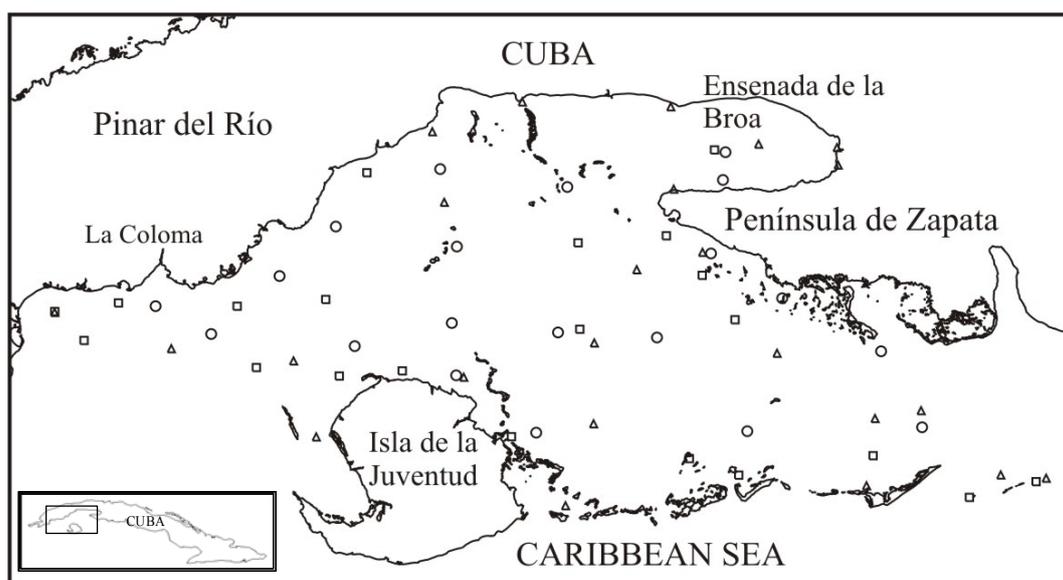
Changes in the nutrient input during the last two decades with subsequent changes in the hydrochemical cycle of the Gulf have been suggested as being responsible for the present lower productivity (Claro *et al.* 1994, Puga 2005). However, there are as yet no reports of deterioration or habitat loss for lobster and fish communities, which may also be playing an important role in the decrease of the fishery landings. Pollution due to urbanization, fishing gear damage to benthic biotopes and non-anthropogenic factors, such as the

loss of seagrass coverage due to higher frequency of hurricanes passing through the area, are also likely causes of habitat loss in the Gulf and subsequent changes in lobster landings (Hernandez and Puga 1995).

The main purpose of this study was to analyse benthic assemblages of the Gulf of Batabanó as recorded during the period 1981-1985, when lobster catches peaked at mean annual catches of c.a. 12000 t (Claro *et al.* 2001), with data from twenty-five years later. During the nineties, lobster catches dropped to levels around 5000t and have remained low ever since (Baisre 2000). The comparison of bottom communities during both periods, will allow us to test our working hypothesis according to which lobster and fish catches in the area were negatively affected by general environmental deterioration or habitat loss.

### Material and Methods

This research was carried out in the Gulf of Batabanó (21°N, 80°W), in southwest Cuba. The Gulf covers an area of c.a. 20,850 km<sup>2</sup> and has an average depth of 5-6 m. The area is fringed by mangrove stands along the northern and western shores and by coral reefs to the south, where it borders with the open ocean. During May 2003 and November 2004, two research cruises along the Gulf were carried out by the Cuban Oceanographic Institute (Instituto de Oceanología de Cuba) and benthic samples were taken from 24 and 21 sampling sites respectively (Figure 1). Samples were analysed and are presently preserved in the same research institute. For comparison, benthos data from the period 1981-1985 were obtained from the



**Figure 1.** Map of the study area, Gulf of Batabanó, showing sampling sites for cruises during 1981-1985 (circles), 2003 (triangles) and 2004 (squares).

literature (Alcolado 1990). These data correspond to 7 research cruises carried out in the Gulf (sampling sites are also shown in Figure 1). During both periods, sampling techniques were fully comparable and in some cases samples were taken and analysed by the same scientific personnel.

### Sampling

Sponges and echinoderms were collected using a 0.74 m long rake with a mesh size of 4 mm covered with a 2 cm mesh size net. At each sampling site, three hauls of 14 to 30 m were carried out and organisms were preserved in alcohol (70%).

At the same sampling sites, a corer with an internal diameter of 15 cm was used to collect seagrass and macroalgae. The corer was used four times at random (4 replicates) in an area of 10 m<sup>2</sup>. These samples were washed out with seawater and preserved with 5% formaldehyde neutralised with sodium tetraborate. To estimate foliar biomass, samples were identified to species level, washed with 5% chlorhydric acid to eliminate epiphytes and then rinsed with tap water. Samples were dried in an oven until constant weight and then weighed using an electronic scale with 0.1 g precision.

For the meiofauna samples, a cylinder with an effective sampling area of 5 cm<sup>2</sup> and volume of 50 cm<sup>3</sup> was employed using SCUBA diving. Samples were preserved in 4% formaldehyde neutralised with sodium tetraborate, and then sieved through a column with mesh sizes ranging from 500 to 45 micron using tap water. Macrozoobenthos was sampled using a frame-net-suction dredge system, collecting the sediment from an area of 0.1m<sup>2</sup>

submerged 10 cm into the substrate. The samples were subsequently preserved in neutralised 4% formaldehyde. Sediment was separated by decantation and organisms, which remain after using a sieve of 500 micron, were collected for identification.

### Data analysis

Data between both periods were compared using number of species, species composition, percentages of occurrence and average biomass per habitat. These variables were applied to different taxonomic groups. For analysis and spatial comparison purposes, we also divided the Gulf into four areas as shown in Figure 2. Area I covered the northern portion of the gulf bordered to the south by an imaginary line between the westernmost portions of Zapata Peninsula and Punta Capitana (north of La Coloma). Area II covered the portion between the trajectories of a straight line passing through the middle of Isla de la Juventud until reaching Area I in the north. Area III enclosed the area between the western portion of Zapata Peninsula in the north and Cayos del Rosario in the south, parallel to Area II; and Area IV the area between the eastern portion of Cayos Diego Pérez and the eastern border of Cayo Largo. Bottom characteristics in each of the areas covered a range of sediment features, seagrass coverage and habitat diversity; however this division helped us to compare sub-areas sampled in both periods and to identify regions with different levels of habitat loss.

For the purpose of characterizing areas of a common benthic species assemblage for both study



Figure 2. The Gulf of Batabanó divided in four study areas.

periods, species abundances vs. sampling sites matrixes were constructed for echinoderms, crustaceans and molluscs. These three taxonomic groups were the only ones for which raw abundance data were available for the period 1981-85. Matrix data were then subjected to a Multi Dimensional Scaling (MDS) ordination with the help of the software PRIMER v.5.2.9. We used the stress value to select the better MDS representation following the rule of thumb, in which any stress value under 0.1 is excellent and any over 0.15 is unacceptable.

## Results

Percentages of occurrence of seagrass in the Gulf of Batabanó for the periods 1981-85 and 2003-04 are presented in Table I. The turtle grass *Thalassia testudinum* (Banks and Soland. ex Koenig 1805) was the most widely distributed plant within the gulf in both periods. However the species was found in 69% of the sampling sites during 2003-04 compared to 91% during 1981-85. Average leaf biomass of turtle grass at the different sampling stations ranged from  $12 \pm 16$  to  $102 \pm 130$  g dw/m<sup>2</sup> in 2003-04 and from 21 to 100 g dw/m<sup>2</sup> for the 1981-85 period (Jiménez 1990).

Macroalgae were found at almost all sampling sites during 2003-4, with Chlorophyta being the most common group recorded (96% of occurrence) (Table 1). The most frequent genera identified were *Caulerpa*, *Halimeda*, *Penicillus*, *Udotea*, *Avrainvillea* and *Anadyomene*.

Rhodophyta from the genera *Laurencia*, *Hypnea* and *Bryothamnion* occurred in 33% and Phaeophyta in only 11% of the sampling sites. Jiménez (1990), who registered 54 species of Chlorophyta, 15 of Rhodophyta and 11 of Phaeophyta for the period 1981-85, reported the same pattern for the presence of macroalgae in the gulf, with percentages of occurrence in sampling sites of 93%, 73% and 7% for these three algae groups respectively (Table I). The most frequent genera were again *Penicillus*, *Halimeda*, *Udotea*, *Avrainvillea* and high biomass values of *Anadyomene* at the northwest of Isla de La Juventud and south of Zapata Peninsula (59.65 in 1981-85 and 31.2 g/m<sup>2</sup> in 2004). The genus *Rhipocephalus*, which was registered in 51% of the sampling sites in 1981-85, was not registered in 2004. In both periods, Phaeophyta were found associated with oceanic waters.

Thirteen species of sponges were found during the sampling in 2004 in comparison with seventy-two species during 1981-85. Among the sponges, *Aplysina fistularis* (Pallas 1766) and *Chondrilla nucula* (Schmidt 1862) were the most

frequent species in both periods. Some common species found during 1981-85 were absent during our surveys (Table I). Sponge's average biomass was also considerable lower for the 2003-04 surveys except in the case of sandy bottoms (Table II).

For the Mollusca, a total number of 51 species were registered in 21 sampling sites in 2004 compared to 188 species at 170 sampling sites in 1981. Filter feeders accounted for 61% of the species, herbivores 23% and carnivores 16% in 2004 and 59%, 23% and 4% respectively in 1981; the remaining species were detritivores (10%) and omnivores (4%). Average biomass was slightly lower during 2003-04, except at the substrate with medium dense vegetation (Table II). Maximum biomass registered was 7.72 g dw/m<sup>2</sup> during 2004 compared with 20 g dw/m<sup>2</sup> during 1981. Maximum densities were very similar with 11.16 ind/m<sup>2</sup> in 2004 and 7-10 ind/m<sup>2</sup> in 1981.

Echinoderm's group composition between 1981-1985 and 2004 is shown in Figure 3. The presence of Asteroidea and Echinoidea was almost identical while some Ophiuroidea were apparently replaced by species of the Holoturoidea group in 2004. The green urchin *Lytechinus variegatus* (Lamarck 1816) was the most conspicuous species for both periods with around 50% of occurrence at sampling sites. Echinoderms showed a maximum biomass of 10 g dw/m<sup>2</sup> during 2004 and 14.2 g dw/m<sup>2</sup> in November 1981; maximum densities were also much lower in 2004 (0.9 ind/m<sup>2</sup>) compared with 7.5 ind/m<sup>2</sup> in 1981.

Considerable differences were registered in the composition of the most important groups within the macroinfauna between the two periods. Sandy bottoms showed a lower representation of major taxa compared with 1981; the substrate was mainly dominated by polychaetes (85%) and there was a total absence of crustaceans (Figure 4). Lower quantities of different phyla were also registered in muddy substrates, with predominance of molluscs during 2003 and absence of nematodes during both periods. In the mixed and the sandy substrates with vegetation a slightly decrease in the number of echinoderms was recorded, apparently replaced by crustaceans (Figure 4).

Macrozoobenthos showed lower number of individuals per square meter in three of the four substrates sampled in 2003 and slightly higher densities of the sand and mud with vegetation substrate compared with 1981 (Figure 4). Only the sandy bottom substrate presented a similar number of individuals during both periods. Within the polychaeta, a higher number of species (86) was registered during May 2003 compared with May

**Table I.** Percentages of occurrence of seagrass, macroalgae and sponges in the Gulf of Batabanó.

Species	Period 1981-1985 (15 sampling sites)	Period 2003-2004 (44 sampling sites)
<b>SEAGRASS</b>		
<i>Thalassia testudinum</i>	91	69
<i>Halodule beaudetii (wrigthii)</i>	50	54
<i>Syringodium filiforme</i>	31	12
<i>Halophila decipiens</i>	9	6
<b>MACROALGAE</b>		
Chlorophyta	93	96
Rodophyta	73	33
Phaeophyta	7	11
<b>SPONGES</b>		
<i>Aplysina fistularis</i>	46	38
<i>Amphimedon viridis</i>	10-15	30
<i>Chondrilla nucula</i>	38	30
<i>Cliona vesparia</i>	40	23
<i>Haliclona implexiformis</i>	no data	23
<i>Halichondria melanodocia</i>	< 10	23
<i>Suberites aurantiaca</i>	no data	23
<i>Geodia gibberosa</i>	10-15	15.4
<i>Hyrtios violacea</i>	32	15.4
<i>Cliona varians</i>	40	7.7
<i>Haliclona molitba</i>	no data	7.7
<i>Ircinia felix</i>	18	7.7
<i>Tedania ignis</i>	27	0
<i>Hyrtios proteus</i>	22	0
<i>Clathria schoenus</i>	22	0
<i>Ulosa ruetzleri</i>	18	0

1981 (62 species); the most important species according to their frequency of occurrence were entirely different between both periods but with similar trophic components (Table III). During 2003-04, macrofauna biomass reached values close to 3 g dw/m<sup>2</sup> while during 1981 the highest biomass value corresponded to 6.4 g dw/m<sup>2</sup>.

Meiofauna samples showed lower density values during 2004 (1-3 ind/10cm<sup>2</sup>) in comparison with 1981-85 (18-80 ind/cm<sup>2</sup>). Nematodes, polychaeta and copepods were the most frequent groups during both periods.

#### *Spatial analysis*

##### Seagrass

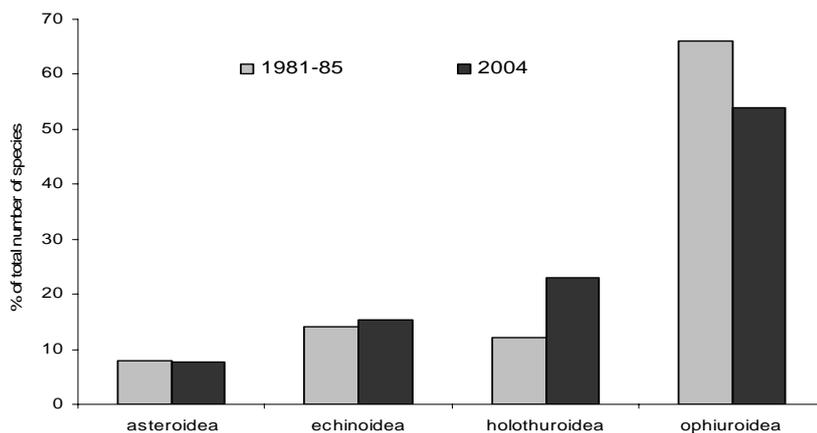
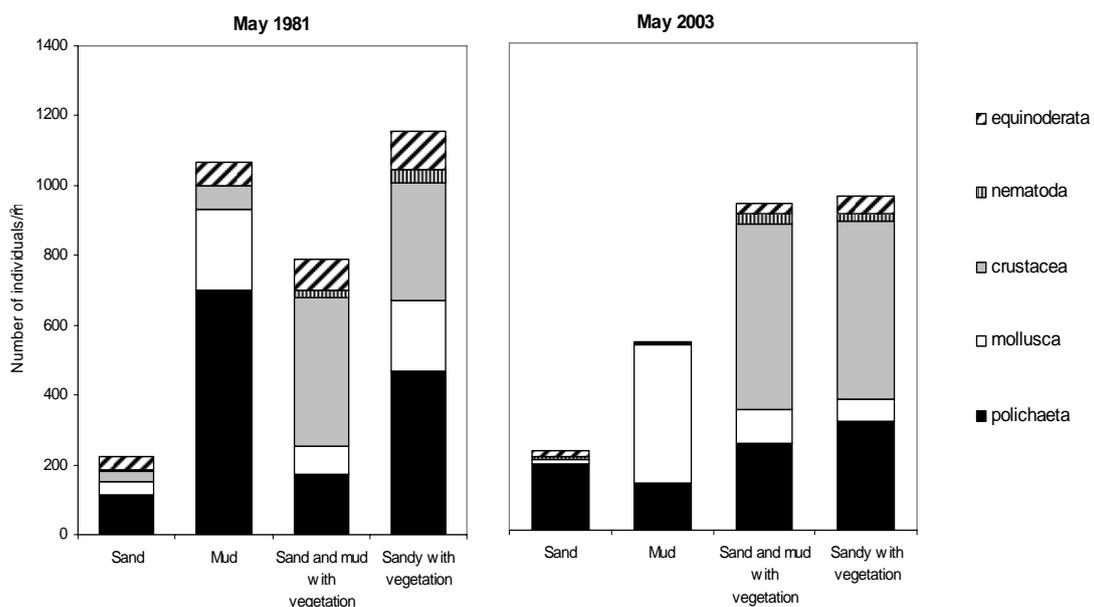
Area I embracing, Ensenada de la Broa, the adjacent waters of Guanímar and Batabanó and eastern portion south of Pinar del Río, showed three different distribution patterns of marine angiosperms biomass in 1981-85 (Figure 5). In this area,

Ensenada de la Broa presented a total absence of seagrass except from the coastal portion north of Zapata Peninsula, where a rocky bottom with some turtle grass patches was recorded (0-80 g/m<sup>2</sup>). Around Guanímar and Batabanó, there was very light seagrass coverage, in contrast to the southern part of Area I and the portion south of Pinar del Río, where high densities of turtle grass were registered in 1981-85. During 2003-04, Ensenada de la Broa showed the same distribution of angiosperms, with total absence of seagrass coverage except at the north coast of Zapata Peninsula. The same pattern of seagrass cover was also recorded for the areas adjacent to Guanímar, Batabanó and the southern portion of Area I, though the segment of Pinar del Río showed absence of seagrass coverage towards the southwest border of Area I.

Area II showed medium to high seagrass biomass on a strip parallel to the coast between south of Pinar del Río and La Coloma and around

**Table II.** Average biomass of different taxonomic groups (g dw/m<sup>2</sup>) in the Gulf of Batabanó at different bottom substrates.

Substrate	Period 1981-1985	Period 2003-2004
<b>SPONGES</b>		
Sandy bottom	4.8	4.4
Muddy bottom	6.4	1.8
Medium dense seagrass cover	12.4	2.0
High dense seagrass cover	4.3	0.8
<b>MOLLUSCA</b>		
Sandy bottom	0.8	0.6
Muddy bottom	1.6	1.0
Medium dense seagrass cover	2.0	3.9
High dense seagrass cover	no data	2.3
<b>MACROINFAUNA</b>		
Sandy bottom	1.5	0.5
Muddy bottom	2.1	0.4
Medium dense seagrass cover	2.1	0.8
High dense seagrass cover	3.5	0.7

**Figure 3.** Echinoderms composition in the Gulf of Batabanó during 1981-85 and 2004.**Figure 4.** Macrozoobenthos composition in the Gulf of Batabanó for four different bottom types.

**Table III.** Percentages of occurrence of polychaeta species in the Gulf of Batabanó.

May 1981		May 2003	
Species	%	Species	%
<i>Eupolyornia crassicornis</i>	57	<i>Syllis mexicana</i>	65
<i>Notomastus hemipodus</i>	57	<i>Axiothella mucosa</i>	57
<i>Paraprionospio sp.</i>	50	<i>Exogone sp.</i>	48
<i>Lumbrineris latreilli</i>	43	<i>Nereis riseii</i>	44
<i>Ehlersia mexicana</i>	43	<i>Prionospio cirrobranchiata</i>	39
<i>Exogone dispar</i>	43	<i>Armandia maculata</i>	39

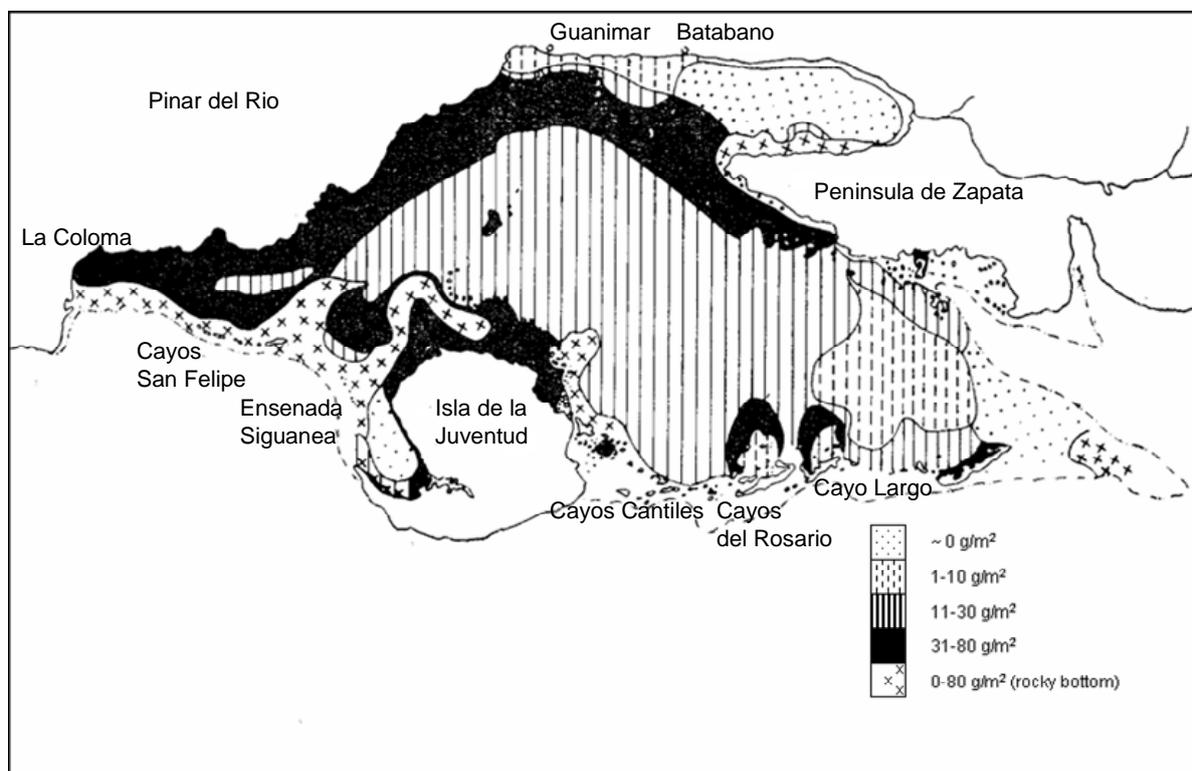
the north coast of Isla de la Juventud; rocky bottom poor seagrass abundances at the northeast border with Area I and no seagrass cover at Ensenada de Sigüanea in 1981-85 (Figure 5). During 2003-04, the same pattern was observed only around Cayos de San Felipe (west of Isla de la Juventud) and the north of the island, where medium to high marine angiosperms biomass was registered. As mentioned for Area I, in this period the sampling sites corresponding to south of Pinar del Río and La Coloma in Area II showed absence of seagrass coverage. Ensenada de Sigüanea was not sampled during 2003-04.

Area III and Area IV showed poor seagrass coverage except for the north and east central waters of Isla de la Juventud, south coast of Zapata Peninsula (Area III) and small patches north of Cayo Cantiles, del Rosario and Largo respectively in 1981-85 (Figure 5). For the period 2003-04, sampling sites at Area III around Isla de la Juventud

with seagrass patches to the west of the island and south of Zapata Peninsula showed a decrease in seagrass coverage with low biomass of angiosperms ( $0.8 \text{ g/m}^2$ ) and some patches of high densities were also found close to those Cayos.

#### Other groups

For the period 1981-85, high biomass of sponges ( $21\text{-}70 \text{ g/m}^2$ ) were also distributed inside the gulf in the central west part of areas III and IV and northwest of Isla de la Juventud. Low biomass of this group was associated with coastal areas with terrigenous affluence. These areas corresponded to a broad strip from the north west coast of the gulf at La Coloma, passing through south of Pinar del Río, Guanímar, Batabanó to Ensenada de la Broa in the east (Areas I and II), and the waters adjacent to Cayo Cantiles, del Rosario and Largo, northeast coasts of the island and Ensenada Sigüanea. During 2004, none of the sampling sites recorded sponge biomass



**Figure 5.** Seagrass biomass distribution (dry weight) for the period 1981-85 (taken from Jimenez 1990).

similar to the ones observed in the 1980s. A maximum biomass of only 8.2 g/m<sup>2</sup> was found at sampling site 25 south to Pinar del Río.

In 1981 (May and December) high values of polychaeta biomass (> 2g/m<sup>2</sup>) were registered only in only one small patch inside the gulf, one facing northwest to Isla de la Juventud and the other north of Cayo del Rosario. Polychaeta biomass in the remaining areas of the Gulf was 0.1 – 1.4 g/m<sup>2</sup>. Higher numbers of individuals (>2500 ind/m<sup>2</sup>) were observed north of Cayo Largo (Area IV). During 2003-04, sampling sites located to the right side of Area III (E4,E15,E6, E12 in 2004) and north of Cayo Largo, exhibited the highest densities (1000-2500 ind/m<sup>2</sup>).

Mollusc biomass was higher in the central and southern portion of Area III (66-200g/10m<sup>2</sup>), exhibiting lower biomass in other areas for the period 1981-85. Higher densities of molluscs were observed north of Cayo Largo (Area IV), at the northwest coast of Isla de la Juventud and the southwest corner of Area I at Pinar del Río. During 2004 sampling sites E11, E15 and E23 showed the maximum mollusc biomass, the areas corresponding to waters adjacent to Cayo El Rosario, central portion of Area III and La Coloma. The biomass values at these sites were similar to values in 1981-84 (<25g/m<sup>2</sup>), except for sampling site E15 where mollusc biomass has apparently considerably decreased. High mollusc densities were found south of Pinar del Río (7-10 ind/m<sup>2</sup>) during 1981-85 compared with a density of only 1.4 ind/m<sup>2</sup> (sampling site E 25) in 2004.

In the case of the echinoderms, the maximum biomass for the period 1981-85 was registered northwest to Isla de la Juventud in Area II (16 –35 g/m<sup>2</sup>). Area I was characterized by the lowest biomass of echinoderms (0.6 – 2 g/m<sup>2</sup>) and Areas III and IV presented medium biomass of this taxonomic group (2-16 g/m<sup>2</sup>). During 2004, maximum biomass of echinoderms did not reach past values and were registered at sampling sites E23 (10 g/m<sup>2</sup>) and E25 (9.9 g/m<sup>2</sup>) corresponding to La Coloma and the center of Area II. In contrast to the high values of echinoderms biomass northwest to Isla de la Juventud in 1981-85, a very low biomass was registered in this area in 2004 (2.06 g/m<sup>2</sup> at sampling site E17). For both periods biomass at Ensenada de la Broa showed the lowest values (<1g/m<sup>2</sup>).

Meiofauna presented the higher densities in the middle of Peninsula de La Broa, close to La Coloma, northwest and central east portions of Isla de la Juventud, north of Cayo Largo and close to Cayo Diego Pérez. The same pattern was observed

during 2004 except for the sites close to La Coloma.

The spatial analysis of macroinfauna during 1981, showed higher biomass at the north and northwest of La Isla de la Juventud (Area III) and north of Punta Capitana (Area II), with values higher than 4 and close to 7 g/m<sup>2</sup>. In the remaining areas of the Gulf, biomass values ranged from 0.3-3.7 g/m<sup>2</sup>. When considering number of individuals, patches of high densities (>4000 ind/m<sup>2</sup>) were registered in Area IV and the north section of Area III. In 2003-04, lower biomass values between 0.1 and 1.3 ind./m<sup>2</sup> were found close to Isla de La Juventud and north of Punta Capitana. Similarly density spatial distribution values decreased from a range of 4000 to 4700 ind/m<sup>2</sup> to 1500-3600 ind/m<sup>2</sup> north of Area III and IV.

#### *Multivariate analysis*

The multidimensional scaling plot for the year 1981 showed differences in the benthic assemblages at the south portion of Peninsula Zapata, the eastern border of the Gulf and northwest of Isla de la Juventud (sampling sites 5 and 7, 13). Figure 6a shows that the benthic communities presented similar assemblages of echinoderms, crustacean and mollusks at all the other sampling sites. During 2004, additional differences in benthic assemblages were added to the results of 1981 (Figure 6b). E29 and E24, corresponding to South of Pinar del Río and close to La Coloma present different benthic characteristics compared to other areas of the Gulf, Ensenada de la Broa and Zapata Peninsula show also differences in benthic structure.

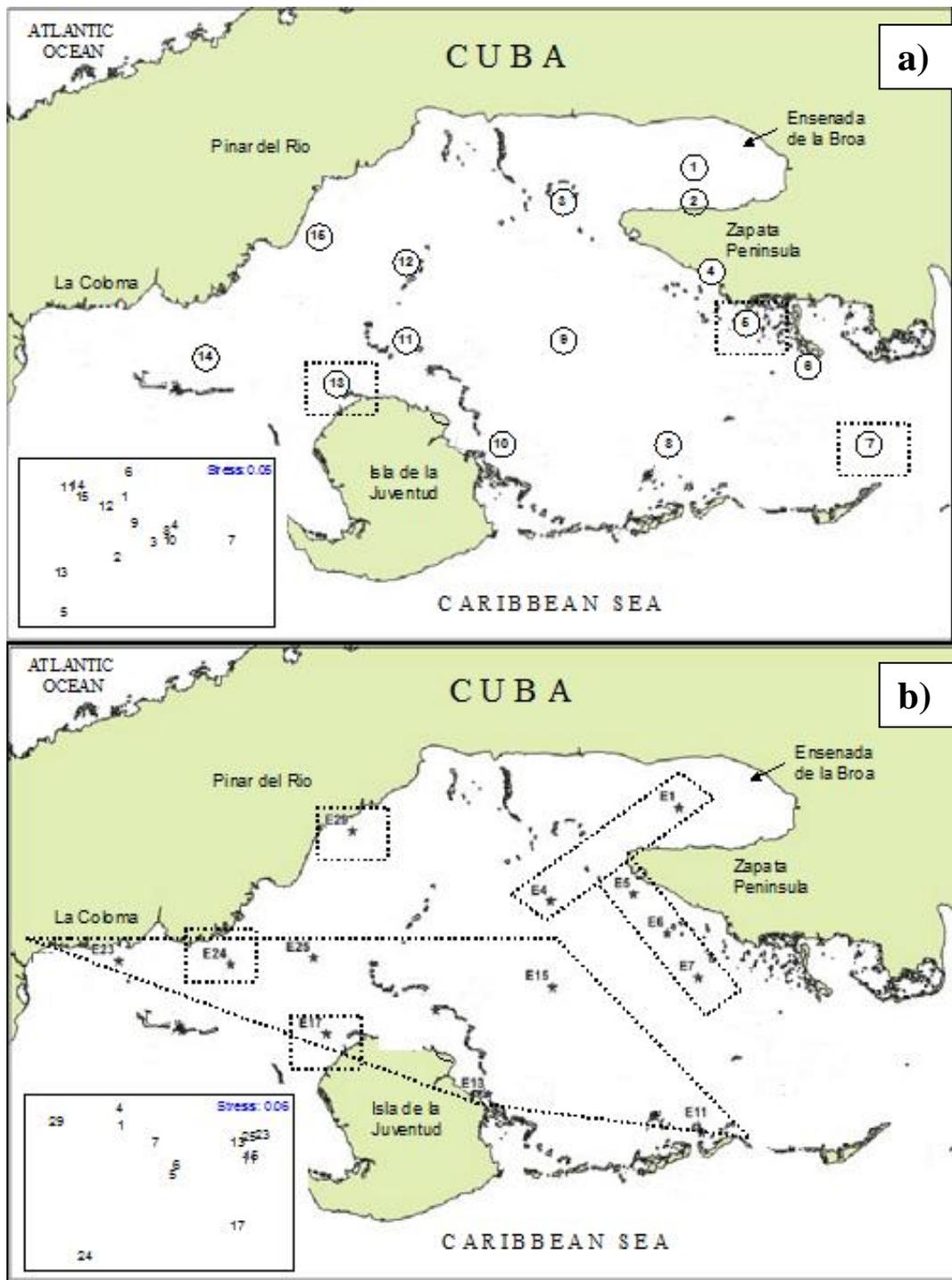
#### **Discussion**

Marine species diversity is recognized as one of the most widely used indicators to assess environmental changes. Case studies of the effects of human activities around the United Kingdom coastline, suggest that the number of species and the Shannon-Wiener diversity index were most suited to identifying impacts on the benthic macrofauna in the vicinity of known anthropogenic disturbance (Rees *et al.* 2003). The present study uses number, densities and biomass of species as indices to compare and analyse the biological quality of the Gulf of Batabanó within a 25-year period. Long-term comparisons of benthic communities have been carried out in temperate and tropical areas (Pearson *et al.* 1986, Pearson & Bannet 1987, Service & Feller 1992, Molina Lara & Zamora 1995, Laine *et al.* 1997, Fromentin *et al.* 1997, Laine *et al.* 1997, Davoult *et al.* 1998, Gremare *et al.* 1998, Frid *et al.* 1999, Currie & Parry 1999, Raut *et al.* 2005). A major problem arising from this kind of comparisons

is that methodological factors like different sampling gears and effort, as well as natural factors like seasonality, succession processes, changes in hydrological regimes, long term climatic cycles; or the combination of several of these factors, may also significantly impact the benthos communities and subsequently the study results. However we expect those factors to impact the entire study area and therefore a spatial analysis is presented here to

corroborate and support our deductions. We assumed in this study that long-term comparisons between sub-areas of the Gulf will allow us to identify sections with apparent habitat degradation due to anthropogenic activities. We also assumed communities, which seems to be the case for tropical aquatic ecosystems (Yule & Pearson 1996).

Our results suggest that the overall seagrass that seasonal changes do not have a significant



**Figure 6.** Multidimensional scaling analysis for the sampling sites in 1981 (a) and 2004 (b).

impact on the overall structure of the benthos composition in the gulf is similar for both periods, except for a slightly general increase in the occurrence of the shoal grass *Halodule wrightii*. This species has been described as a pioneer colonizer of disturbed areas where other seagrass cannot grow, and can withstand the widest range of temperatures and salinities (Phillips & Meñez 1988, Gallegos 1994). Its higher occurrence during 2003-04, in addition to the lower occurrences for the other seagrass may thus be indicative for a certain level of disturbance in the Gulf. The picture becomes clearer when the spatial patterns of biomass distribution are analysed. Important extensions with high to medium seagrass coverage South of the Province of Pinar del Río and close to La Coloma in 1981-85, were absent in the recent surveys of 2003-04 and a reduction in the seagrass coverage was evident for at least some areas around Isla de la Juventud and Zapata Peninsula. The same pattern could be observed from the multidimensional scaling plots where sampling sites around Pinar del Río, La Coloma and Zapata Peninsula showed different benthic assemblages compared to the rest of the Gulf during 2004 (Figure 6b). These results agree with Lorenzo (2005), who reports muddy areas without vegetation based on satellite images all around the northern borders of the gulf and Perigó (2001) who classifies the waters around La Coloma as eutrophic waters, while Alcolado (1990) based on primary production data from 1968, describes the waters of the Gulf as mesotrophic waters (except NNW to Isla de la Juventud and probably Ensenada de la Broa).

As indicated by Alcolado *et al.* (2004) sponges diversity in Cuba is higher at coral reefs and decreases towards sandy-muddy bottoms, and mangrove roots. In contrast to the 1981-85 period, during 2004 only soft bottom areas were sampled, and the significance of the difference found in number of species remains doubtful. A general decrease in average biomass was observed in the results in the case of sponges, molluscs, crustacean and equinoderms, however the species composition of these groups stayed similar. For the polychaeta group the overall abundance decreased, a higher diversity was observed in 2003 and the species composition was different between 1981 and 2003. Polychaeta densities and also probably biomass decreased from one period to the other, however the higher species richness recorded in 2003 could be a result of an improvement in the identification and knowledge of the group. The diversity increment in this group could be also a response to organic

enrichment at moderately disturbed zones as reported by Samuelson (2001) for sub-arctic tidal flats. High densities of opportunistic species of polychaeta close to Zapata Peninsula support the idea of a disturbed zone around this area. Low biomass and number of individuals in the case of meio and macroinfauna particularly south of Pinar del Río considering the spatial analysis, agree with the results from the multidimensional scaling and the changes in the distribution of seagrass in this area between the two periods.

This study has demonstrated that benthos community assemblages have changed considerably in some areas of the Gulf of Batabanó, despite the problems of comparing surveys that were not designed specifically for this purpose. Benthic assemblages, unlike most pelagic fauna reflect local environmental conditions (Gray 1979) and the analysis of benthos data from the Gulf between both periods has result in the identification of disturbed zones and habitat loss South of Pinar del Río and La Coloma and moderately disturbed areas around Zapata Peninsula and the northeast portion of Isla de la Juventud. Further research on these four sectors is recommended in order to identify the sources of disturbance and their impacts to the fishery.

### Acknowledgments

We would like to acknowledge the Parliament of the City of Bremen in Germany to kindly provide the financial support to carry out the cruises on the Gulf of Batabanó during 2003 and 2004. This research was sponsored by the German-Cuban Cooperation in Marine Sciences between the Center for Tropical Marine Ecology (ZMT) from the University of Bremen and the Oceanographic Institute (IdeO) at La Habana, Cuba. We also thank two anonymous referees, whose comments were essential for the improvement of the manuscript.

### References

- Alcolado, P. (Ed.). 1990. **El bentos de la macrolaguna del Golfo de Batabanó**. Editorial Academia, La Habana, 161 p.
- Alcolado, P., Grovas, A. & Markos, Z. 2004. General comments on species inventory, fisheries, culture and some community features of the Porifera in Cuba. **Bolletino dei Musei e degli Istituti Biologici Dell'Università di Genova**, 68:15-186.
- Baisre, J. A. 2000. **Crónica de la pesca marítima en Cuba (1935-1995). Análisis de tendencias y del potencial pesquero**. FAO: Documento Técnico de Pesca 394, Roma.
- Baisre, J. A. 1985. Los recursos pesqueros marinos

- de Cuba: fundamento ecológico y estrategia para su utilización. **Revista de Investigaciones marinas**, 12(1-3): 117-124.
- Bilyard, G. 1987. The value of benthic infauna in marine pollution monitoring studies. **Marine Pollution Bulletin**, 18(11): 581-585.
- Claro, R., Baisre, J. & García-Arteaga, J. P. 1994. Evolución y manejo de los recursos pesqueros. Pp: 435-456. *In*: Claro. (Ed.). **Ecología de los peces marinos de Cuba**. Chetumal, Quintana Roo: Centro de Investigaciones de Quintana Roo (CIQRO), Mexico, 525 p.
- Claro, R., Baisre, J. A., Lindeman, K. C., & García-Arteaga, J. P. 2001. Cuban fisheries: historical trends and current status. Pp: 194-219. *In*: Claro, R., Lindeman, K.C. & Parenti, L.R. (Eds.). **Ecology of the marine fisheries of Cuba**. Smithsonian Institute Press, Washington D.C., 253 p.
- Currie, D. R. & Parry, G. D. 1999. Changes to benthic communities over 20 years in Port Phillip Bay, Victoria, Australia. **Marine Pollution Bulletin**, 38: 36-43.
- Davoult, D., Dewarumez, J. M. & Migné, A. 1998. Long term changes (1979-1994) in two coastal benthic communities (English Channel): analysis of structural developments. **Oceanologica Acta**, 21: 609-617.
- Fabricius, K. E., & McCorry, D. 2006. Changes in octocoral communities and benthic cover along a water quality gradient in the reefs of Hong Kong. **Marine Pollution Bulletin**, 52: 22-33.
- Frid, C. L. J., Buchanan, J. B. & Garwood, P. R. 1999. Variability and stability in benthos: twenty-two years of monitoring off Northumberland. **ICES Journal of Marine Sciences**, 53(6): 978-980.
- Fromentin, J. M., Ibañez, F., Dauvin, J. C., Dewarumez, J. M. & Elkaim, B. 1997. Long term changes of four macrobenthic assemblages from 1978 to 1992. **Journal of the Marine Biological Association of UK**, 77: 287-310.
- Gallegos, M.E. 1994. Growth patterns and demography of pioneer Caribbean seagrass *Halodule wrightii* and *Syringodium filiforme*. **Marine Ecology Progress Series**, 109: 99-104.
- Gómez, O., Ibarzábal, D. & Silva, A. 1980. Evaluación cuantitativa del bentos en la región suroccidental de Cuba. **Informes Científicos-Técnicos del Academia de Ciencias de Cuba**, 149: 1-25.
- Gray, J.S. 1979. Pollution-induced changes in populations. **Transactions of the Royal Philosophical Society of London (B)**, 286: 545-561.
- Grémare, A., Amouroux, J.M. & Vétion, G. 1998. Long-term comparison of macrobenthos within the soft bottoms of the Bay of Banyuls-sur-mer (northwestern Mediterranean Sea). **Journal of Sea Research**, 40: 281-302.
- Hernandez, B. & Puga, R. 1995. The influence of the El Niño phenomenon over the western region of Cuba and upon the lobster fishery (*Panulirus argus*) in the gulf of Batabanó. **Investigaciones marinas**, 23: 3-24.
- Ismael, A. A. & Morgham, M. M. 2003. Ecological indices as a tool for assessing pollution in El-Dekhaila Harbour (Alexandria, Egypt). **Oceanologia**, 45(1): 121-131.
- Jiménez, C. 1990. Macroalgas y fanerógamas marinas de la macrolaguna del Golfo de Batabanó. Pp. 14-17. *In*: Alcolado (Ed.). **El bentos de la macrolaguna del Golfo de Batabanó**. Editorial Academia, La Habana-Cuba, 161 p.
- Jiménez, C. y Alcolado, P. M. 1990. Características del macrofitobentos de la macrolaguna del Golfo de Batabanó. Pp. 8-12. *In*: Alcolado (Ed.). **El bentos de la macrolaguna del Golfo de Batabanó**. Editorial Academia, La Habana-Cuba, 161 p.
- Jumars, P. A. & Nowell, A. R. M. 1984. Fluid and sediment dynamic effects on benthic community structure. **American Zoology**, 24: 45-55.
- Laine, A. O., Sandler, H., Andersin, A. B. & Stigzelius, J. 1997. Long term changes of macrozoobenthos in the Eastern Gotland Basin and the Gulf of Finland (Baltic Sea) in relation to the hydrographical regime. **Journal of Sea Research**, 38: 135-159.
- Lorenzo, S., Cerdeira, S. Martinez, C. & Areces, A. 2005. Carta temática de la distribución de los tipos de fondo del Golfo de Batabanó, obtenida a partir del procesamiento digital de Imágenes Landsat-7. **Workshop on the Gulf of Batabanó**. Workshop report. La Habana, Cuba, 14-17 March.
- Molina Lara, O. A. & Vargas Zamora, J. A. 1995. Poliquetos (Annelidae: Polychaeta) del estero de Jaltepeque, El Salvador una comparación

- 1959-1991. **Revista Biología Tropical**, 43: 195-205.
- Pearson, T. H. & Barnett, P. R. O. 1987. Long term changes in benthic population in some west European coastal areas. **Estuaries**, 10: 220-226.
- Pearson, T. H., Duncan, G. & Nuttall, J. 1986. Long term changes in the benthic communities of Loch Linnhe & Loch Eil (Scotland). **Hydrobiologia**, 142: 121-127.
- Perigó, E. 2001. Evaluación de la calidad ambiental del Golfo de Batabanó. **Informe final**. Archivo Científico. Instituto de Oceanología.
- Pfannkuche, O. & Locote, K. 2000. The biogeochemistry of the deep Arabian Sea: overview. **Deep Sea Research**, 47(14): 2615-2628.
- Phillips, R. C. & Meñez, E. G. 1988. Seagrass. **Smithsonian Contributions to the Marine Sciences**, 34: 1-104.
- Puga, R. 2005. Variaciones de la abundancia de la langosta. Necesidades de investigación. **Workshop on the Gulf of Batabanó**. Workshop report. La Habana, Cuba, 14-17 March 2005.
- Puga, R., de León, M. E. & Cruz, R. 1996. Catchability for the main fishing methods in the Cuban fishery of spiny lobster *Panulirus argus* (Latreille, 1804), and implications for management (Decapoda, Palinuridea). **Crustaceana**, 69: 703-718.
- Raut, D., Ganesh, T., Murty, N. V. S. S. & Raman, A. V. 2005. Macrobenthos of Kakinada Bay in the Godavari delta, East coast of India: comparing decadal changes. **Estuarine Coastal and Shelf Science**, 62: 609-620.
- Rees, H. L., Sneddon, J. & Boyd, S. E. 2004. 4. Benthic Indicators: criteria for evaluating scientific and management effectiveness. **Indicators of Stress in the marine benthos – Book of abstracts**. Torregrande-Oristano, Italy, 8-9 October 2004.
- Rosenberg, D. M. & Resh, V. H. (Eds.). 1993. **Freshwater biomonitoring and benthic macroinvertebrates**. Chapman and Hall, New York, 488 p.
- Samuelson, G. M. 2001. Polychaetes as indicators of environmental disturbance on subarctic tidal flats, Iqaluit, Baffin Island, Nunavut Territory. **Marine Pollution Bulletin**, 42(9): 733-741.
- Southerland, M. T. & Stribling, J. B. 1995. Status of biological criteria development and implementation. Pp. 81-96. *In*: Davis, W. S. & Simon, T. P. (Eds.). **Biological Assessment and Criteria: tools for water resource planning and decision-making**. Lewis Publishers, Boca Raton, Florida, 415 p.
- Thompson, B. & Lowe, S. 2004. Assessment of macrobenthos response to sediment contamination in the San Francisco Estuary, California, USA. **Environmental toxicology and Chemistry**, 23(9): 2178-2187.
- Valle, S. 2005. Capturas de Peces en el Golfo de Batabanó. **Workshop on the Gulf of Batabanó**. Workshop report. La Habana, Cuba, 14-17 March 2005.
- Yule, C. M. & Pearson, R. G. 1996. Aseasonality of benthic invertebrates in a tropical stream on Bougainville Island, Papua New Guinea. **Archives of Hydrobiology**, 137 (1): 95-117.

Received May 2007

Accepted February 2008

Published online March 2008