Assessing Representativeness of the Cuban Subsystem of Marine Protected Areas (SMPA). I. An overview.

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ABSTRACT. An evaluation of the Cuban SMPA was completed through a gap analysis using sites that were nominated, designated, or in the process of implementation. The analysis was based on information gathered through two main sources: in workshops by Delphic methods, or with a Geographical Information System (GIS) using data provided by nine agencies, scientific organizations, and governmental ministries. A program for the design of Marine Protected Areas (MPA) based on the automatic selection of planning units utilizing the information gathered in GIS, was used to evaluate three different conservation scenarios and to compare them with the SMPA (currently in the implementation stages). Selected sites by the scientific community according to their high natural, socio-economic, or cultural values, coincided with areas recognized in every of the conservation scenarios tested. This fact confirms the efficiency of the established procedure to determine site eligibility.

1. Introduction

Protected areas include those areas of any geographically defined region that have been selected or regulated and are administered to reach specific conservation goals. The need to establish protected areas in marine environments was not expressly proposed until the International Conference on Marine Parks and Protected Areas, promoted by the World Conservation Union and held in Tokyo in 1975 (Kenchington 1996). Currently, there are close to 1,300 MPA throughout more than 80 countries. These MPA range in area from just a few hundred square meters to up to 339,750 Km^2 in the Marine Park of Australia's Great Barrier Reef (Day & Roff, 2000). In the Great Caribbean (Caribbean basin and the Bahamas Archipelago), 55 areas of strict preservation have been identified. These areas are distributed throughout 21 countries with an average of 9,840 ha (Appeldoorn & Lindeman, 2003).

During the last 30 years, a great amount of information on MPA and concepts of use have been developed by the international community (Agardy, 1997; SEMARNAP, 1998; Day & Roff; 2000; Callum, 2000). This has been done within the framework of integrated coastal management (PNUMA, 1996; Rodríguez & Windevoxhel, 1998) and its effects on fishery resources. (Plan Development Team, 1990; Bohnsack, 1994; Callum, 1995; Rosenberg *et al*., 2000).

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Conservation goals for an MPA are focused on the preservation of natural communities and its exclusion from unsustainable exploitation, the protection of important fisheries, existing historic and cultural resources, and the establishment of parks for diving.

MPA are established as multi-use areas where resource exploitation and extraction are controlled and thereby not threatened in the long term. Among them, some areas are established as core zones or no-access areas, where natural resources extraction is prohibited and all human activities are restricted. Other areas are established as biosphere reserves where there are no-access zones within areas under partial regulation. These are generally for large areas and function as buffer zones when surrounded by transitional peripheral sites (Day & Roff, 2000).

The need to include an environmental scope in the sustainable exploitation of natural resources has granted great importance to the protected areas. The potential these areas provide for duplication, preservation, and the study of renewable and natural resources are unquestionable. Therefore, the design of current conservation policies is not possible without the creation of protected areas.

The objective of this research was centered on "making viable the implementation of the national SMPA in order to preserve ecological wealth of ecosystems on the Cuban continental shelf as well as contribute to the improvement of the quality of life of residents in coastal communities". Steps were taken to assess representation of the Cuban SMPA under development, based on various sources of information. Steps taken to evaluate the location and range of proposed areas are explained below.

1.1 National background

In Cuba, the legal system for protection and conservation of nature in ecosystems and habitats that are particularly fragile or diverse was established in December, 1999 under Decree-law No. 201 (GACETA NACIONAL DE CUBA, 1999). This legislation establishes regulations, control, and management of our system of protected areas.

Cuban marine or coastal protected areas are a sub-system within the National System of Protected Areas (SNAP). The development of these areas has been delayed compared to the land-based system (Estrada *et al*., 2003). SMPA was finally recognized as a subsystem in 1995, under the framework of the Second Workshop of Protected Areas, where 535 proposals were analyzed. The 18 fishery reserves proposed by the Institute of Oceanology of the Ministry of Science, Technology and the Environment, and the sites declared as 'Zones under a Special Rule for Use and Protection" by the Office of Fishery Regulations of the Ministry of the Fishing Industry served as the starting point for proposals for now-legally established MPA or those currently under the process of establishment (Estrada *et al*., 2003). The first group of MPA, including 18 areas, was formally established under Agreement 4262/2001 of the Executive Committee of the Council of Ministers (CECM). Three other MPA have been recognized in other legislation that was not committed to protected areas. There are also 23 sites with an important marine element that are currently in the final stages of approval by the CECM. Overall, 108 MPA have been proposed in Cuba, constituting 24.58% of the continental shelf. 48 of these (10.07 %) have national relevance and the remaining 59 areas have local significance (Estrada *et al*., 2003).

Current trends in the zoning process of Cuban SMPA are based on relatively large areas with different management categories where "no-take" and other regulated conservation zones may be established. Such a strategy would allow representation of 15% of the continental shelf, 25% of reef areas and 25% of wetland subtypes in every region with coastal wetlands. (Estrada *et al*., 2003).

2. Materials and Methods

2.1 Planning the work

Two different sources of information were combined in order to validate the Cuban SMPA. The first was obtained through Delphic methods by analysis made by *ad hoc* expert groups. The second source provided multi-sectoral information from various domestic organizations and ministries. This approach allowed a comparison between official proposals, assessments based on personal or team experience and objective evidence based on data transcription to GIS maps. This analysis also included correspondence between the gathered information and the location and range of MPA proposed or already under designation. The entire process was completed between January 2002 and June 2003. Advisory and funds were kindly supported by the NGOs WWF-Canada and Environmental Defense, USA.

The analysis completed by the *ad hoc* expert team had two different levels: within the framework of small teams of specialists with some experience in GIS, and in national workshops with the comprehensive participation of the scientific community involved in bio-ecology, taxonomic studies, or fishery dynamics. In this case, decision makers and representatives of various state organizations were invited.

The first of the two national workshops held helped developed the common conceptual grounds, which would allow the integration of the scientific community's assessment on the distribution of natural or socio-cultural value in the continental shelf. It was based on eco-regionalization and classification of marine habitats on the continental shelf. This workshop was the first action taken towards certification. It was held at the National Aquarium on May 20 – 23, 2002. Objectives and some of the expected results are included in Table 1.

Table 1. Objectives and expected results from the workshop on eco-regionalization and shallow marine habitat classification

OBJECTIVES	**RESULTS**
1. Standardization of the terminology and selection of a classification system more suitable for our conditions.	- Conceptual and semantic work basis - Distribution of eco-regions - Classification of benthic habitats of the continental shelf

2. Define conservation priorities.	- Locate the most important habitats, focusing on elements of representation and uniqueness. - Identify habitats where conservation is essential to protect fishing activities
3. Define conservation goals for the continental shelf	- Locate those sites that require maximum priority for conservation

Recommendations of several authors were followed in identifying and selecting significant ecological spaces based on their representation or uniqueness (Scott & Sullivan, 2000; Day & Roff 2000; Roff & Evans, submitted; Evans, 2002). Once the workshop was concluded, all the relevant information was included in three topic-based sheets in a GIS.

The gap analysis to assess representativeness of the representation of the Cuban SMPA was performed during the second workshop. It would become the basis of the authentication process that determined efficiency of the Cuban SMPA under implementation in order to ensure preservation of recognized natural resources. The workshop was held one year after the first at Neptune Hotel, Havana, on June 24–25, 2003. In both workshops the analyses were completed using management techniques and the help of facilitators. Specialists from more than 20 institutions and national agencies participated in the debates and consensus was reached on almost all agreements.

Generally, gap analyses are achieved using geographic information systems (GIS). In order to facilitate the preparation of the GIS that would be used for gap analysis, a management committee was established. This committee consisted of representatives and decision-makers from institutions that would be able to contribute the most significant information. Under this management committee, institutions accepted various commitments (Table 2) and preparation of information was summarized. All the information gathered on the distribution of eco-regions and coastal ecosystems, geology, bathymetry, distribution of charismatic and endemic species, nesting areas, distribution of benthic habitats, and the location of spawning sites of commercial fish species, spiny lobster, and pink shrimp was translated into subject maps.

Table 2. Institution that provided information for gap analysis

Information	**Type**	**Institution**
Location of priority conservation sites	Thematic sheet in GIS	IDO
Distribution of representative, unique or distinct habitats	Subject sheet in GIS	IDO
Spawning areas of commercial fish	Subject sheet in GIS	IDO
Health condition of reefs	Subject sheet in GIS	IDO
Features of fish communities	Subject sheet in GIS	IDO
Geology of the continental shelf	Subject sheet in GIS	IDO
Activities at port	Subject sheet in GIS	CIMAB & IDO
Lobster recruitment areas	Subject sheet in GIS	CIP
Shrimp recruitment areas	Subject sheet in GIS	CIP
Distribution of fishing effort on lobster	Subject sheet in GIS	CIP
Distribution of fishing effort on finfish	Subject sheet in GIS	CIP
Distribution of fishing effort on shrimp	Subject sheet in GIS	CIP
Turtle nesting areas	Subject sheet in GIS	CIP & ENPFF
Dolphin capture areas	Primary data	AN

Dolphin observation areas	Primary data	AN
Crocodile distribution	Subject sheet in GIS	CNAP & ENPFF
Distribution of endemic or threatened species	Subject sheet in GIS	IES
Bird nesting zones	Subject sheet in GIS	IES
Location of protected areas	Subject sheet in GIS	CNAP
Distribution of coastal ecosystems	Subject sheet in GIS	CNAP
Marines and water sports	Primary data	MINTUR
Areas proposed for ecotourism	Primary data	MINTUR
Mineral resources	Subject sheet in GIS	ONRM
Oil surveying	Subject sheet in GIS	ONRM

IDO, Institute de Oceanology , Ministry of Science, Technology and the Environment; IES, Institute of Ecology and Systematic, Ministry of Science, Technology and the Environment; CNAP, National Center of Protected Areas, Ministry of Science, Technology and the Environment; AN, National Aquarium, Ministry of Science, Technology and the Environment; CIP, Center of Fishery Research, Ministry of the Fishing Industry; CIMAB, Center of Research and Environmental Management of Coastal Areas and Bays, Ministry of Transportation; ENPFF, National Enterprise for the Protection of Flora and Fauna, Ministry of Agriculture; ONRM, National Office of Mineral Resources, Ministry of the Basic Industry; MINTUR, Ministry of Tourism Industry.

Combining factographic databases with geo-referenced geometric elements, GIS facilities allows a manual selection of cartographic elements associated with different layers or, for instance, assess their similarities and differences by overlapping and comparing them. In this case, the information analysis was not manually developed as is typical; rather a software known as MARXAN was used for the automated selection of planning units.

The preparation of subject sheets was completed in between workshops. In addition, two meetings of experts complemented this process to determine objectives and conservation goals for Cuban SMPA (March 5-7, 2003) and run the MARXAN program (June 9-14/2003). A small number of specialists skilled in GIS took part in both meetings.

2.2 Methods used

Subject sheets in GIS were produced on a scale of 1:250000 using digitalized cartographic bases of GEOCUBA. Geodetic datum employed was NAD 27 for longitude/latitude. Professional MapInfo version 6.5 for PC was used. This system has a user friendly interface and has been widely used in Cuba. Therefore, it allows access of already developed information and easy data or image exchange between different agencies or Cuban institutions. Once the selected information was translated into subject maps, it was splitted within the 3,347 planning units (PUs) formed by cells of 25 km^2 on a grid measuring from 100m inland from the shoreline up to an isobath of 200m. The information contained in every unit was entered into the MARXAN software version 1.8.2 (Ball and Possingham, 2000), created for the design of marine protected areas.

MARXAN version 1.8.2 automatically selects all PUs that meets previously set requirements according to the pre-established conservation sites. Unlike other algorithms used for the same result, those used by MARXAN, version 1.8.2 make it possible to rely on several optimized solutions for the distribution of PUs, using the criteria of minimum

penalty. The algorithms used also make it possible to define the level of aggregation among the units or differentiate those which must appear in every solution, regardless of the various reasons.

The edge coefficient or aggregation was set up at 0.1 based on rough calculation during running, with values set between 0 and 1. This induced moderate grouping of PUs, thus preventing their dispersion. In order to generate the corresponding background, a survey was circulated throughout the Cuban scientific community linked to bio-ecological and fishery dynamics research.

Using three defined conservationist goals for our national SMPA and a set of performance criteria for implementation of those goals, this community was requested to establish purposes and performance criteria, and propose conservation targets in accordance with three different scenarios. The survey result, including almost 25% of all it members, served to define goals in the situation of minimum, medium, and maximum conservation requirements. Once the program was underway, distribution of PUs associated with each situation was used to determine, within the gap analysis, the connection between environmental protection levels, implementation of SMPA, and sites of conservation interest proposed by expert groups.

3. Results

The following tables show the distribution of ecoregions, sites with habitats that are representative, distinct, or unique, and priority conservation sites that were proposed for the Cuban continental shelf during the workshop on benthic habitat classification. Nine eco-regions were identified (Table 3, Fig. 1); within this group 66 regions or sub-regions were selected. With habitats that are representative, distinct, or unique 118 sites were distinguished (Table 4, Fig. 2.), and 26 sites of maximum conservation priority were established, six of which have national significance (Table 5, Figs. 3)

Table. 3. Regionalization of the Cuban continental shelf

ECOREGIONS (clockwise starting from the SE end of Cuba):

	Limits
• I S-East	From Punta Quemado, Maisi to Cabo Cruz
• II S-Central (Jardines de la Reina)	From Cabo Cruz to Punta María Aguilar
• III S-Central (S-Guamuhaya)	From Punta María Aguilar to Punta Perdiz, Bahia de Cochinos
• IV S-West (Los Canarreos)	From Punta Perdiz to Punta del Coco, Ensenada de Cortés
• V S-West (Guanahacabibes)	From Punta del Coco to Punta Morros de Piedra, P. of Guanahacabibes
• VI N-West (Los Colorados)	From Punta Morros de Piedra to Punta Morrillo, Bahía Honda

• VII N-West (Habana-Matanzas)	From Punta Morrillo to Punta de Morlas, Península de Hicacos
• VIII N-Central (Sabana-Camagüey)	From Punta de Morlas to Punta Prácticos, in Bahía de Nuevita
• IX N-East (North of Oriente)	From Punta Prácticos to Punta Quemados, Maisi

DIFFERENCIATED REGIONS IN EVERY ECOREGION

1. S-East

- Coastal sector Cabo Cruz - Ocujal del Turquino
- Coastal sector Ocujal del Turquino – Chivirico
- Coastal sector Chivirico - Bahía de Santiago de Cuba
- Bay of Santiago de Cuba
- Coastal sector between the bays of Santiago and Guantánamo
- Bay of Guantánamo
- Coastal sector between the Bay of Guantánamo and Punta Quemados, Maisí

2. Jardines de la Reina

- Estuarine zone between Ancón and Río Agabama
- Gulf of Ana María (interior)
- Gulf of Ana María (exterior)
- Médano de la Vela
- Keys Jardines de la Reina W
- Keys Jardines de la Reina E
- Zona del Pingüe between the Gufs of Ana María and Guacanayabo
- Gulf of Guacanayabo (interior)
- Banco de Buena Esperanza
- Gulf of Guacanayabo (exterior)

3. S-Guamuhaya

- Shore between the Bay of Pigs and the Bay of Cienfuegos
- Bay of Cienfuegos
- Shore between the Bay of Cienfuegos and Punta María Aguilar
- Exterior banks (Jagua, Silver Town, and Paz)

4. Los Canarreos

- Bay of Pigs
- Gulf of Cazones and reefs and keys of Diego Pérez

- Oolitic sandy bottoms of the Gulf of Batabanó
- Keys from Punta del Este to Cayo Guano del Este
- Keys around the Island of Youth (E, N and W)
- Siguanea Cove
- Los Indios Keys
- San Felipe Keys
- Center of the Gulf of Batabanó
- Cove of La Broa up to Las Cayamas
- Coastal zone from Cortés up to the W limit of the cove of La Broa, in front of Las Cayamas keys
- Coastal sector between Punta Francés - Punta del Este, Isle of Youth.

5. Guanahacabibes
(still undefined)

6. Los Colorados

- San Antonio Knoll Bank
- Sector between Punta Morros de Piedra to Punta Tabaco
- Sector between Punta Tabaco and Punta Morrillo, Bahía Honda
- Bahía Honda

7. Habana-Matanzas

- Bay of Cabañas
- Bay of Mariel
- Bay of Habana
- Shore between Jaimanitas and El Morro

8. Sabana-Camagüey

- Bay of Cárdenas
- Reefs of Varadero and Cayo Mono basin
- Bay of Santa Clara (exterior)
- Bay of Santa Clara (interior)
- E of Bay of Santa Clara
- Outer reefs from Punta Hicacos up to Santa Clara Bay
- Bay of Carahatas
- Isabela de Sagua Zone
- Novillo Bay
- Sagua la Chica Zone
- San Juan de los Remedios Zone
- Bay of Buenavista
- Keys to the W of Buenavista Bay

- Outer reefs with large terraces (up to Cayo Confites)
- Perros Bays
- Jigüey Bay
- La Gloria Bay, subregion W
- La Gloria Bay, subregion *E*
- Cove of Sabinal
- Bay of Nuevitas

9. Northeastern coast of Cuba

- Sector between Punta Prácticos-Bay of Banes
- Sub-region of Santa Lucía
- Sector between the Bay of Banes and Punta Quemados, Maisí
- Cayo Moa sub-region
- Sub-region in the mouth of Toa river

Table 4. Location of sites with representative, unique or distinct habitat, or of fishing or socio-cultural importance within the Cuban continental shelf.

Ecorregión I S-East

1. Shore to the west of the Bay of Santiago
2. Dama Key
3. Baconao Lagoon
4. South of Cabo Cruz
5. Coastal sector Pilón- Marea del Portillo
6. Guantánamo Bay
7. Granma Key
8. Playitas de Cajobabo

Ecoregion II S-Central (Jardines de la Reina)

1. Delta of the Agabama river
2. Tunas de Zaza
3. Médano de la Vela
4. Keys of the Gulf of Ana María
5. Corona de Cayo Bretón
6. Lagoon of Cayo Bretón
7. Las Auras
8. Channel near E of Caballones Key
9. Caballones Key
10. Grouper plateau

11. S of Cabeza del Este
12. Region of the large keys of Jardines de la Reina.
13. Punta Antón and Azuagas Key
14. Carapacho Key
15. Anclitas Key
16. Buena Esperanza Bank
17. Cauto River delta
18. Boca Grande Channel

Ecoregion III S-Central (S-Guamuhaya)

1. Jagua Bank
2. Bay of Cienfuegos
3. Guanaroca Lagoon
4. Casilda Bay
5. Ancón Peninsula

Ecoregion IV S-West (Los Canarreos)

1. Bay of Pigs
2. Cazones Gulf
3. Diego Pérez – Flamenco (keys south of Zapata Swamp)
4. Blue Hole of Diego Pérez Key and Flamenco Key
5. Oolitic sandy bottom of the Gulf of Batabanó
6. Guano del Este Key
7. Cayo Largo del Sur Key
8. Key Hicacos reefs
9. Herradura de Campos Key
10. Bocas de Alonso keys
11. Los Barcos Point
12. East Point
13. Los Cayuelos keys
14. Beaches from Guanal to Playa Larga
15. Pedernales Point
16. Los Indios keys
17. San Felipe keys
18. Shoal of Cayos de Dios keys
19. Coastal sector of Punta Loca - La Coloma
20. Las Cayamas and Los Guzmanes keys
21. Matahambre
22. Mouth of Hatiguanico river
23. Coastal sector from Surgidero de Batabanó to the mouth of Hatiguanico river
24. SW of La Broa Cove

Ecorregión V S-Occidental (Guanahacabibes)

1. María la Gorda
2. Beaches to the W of Guanahacabibes (Antonio, Jaimanitas, Las Cañas, Gutiérrez, Perjuicio, La Barca, Las Morlas)
3. Caleta Larga

Ecoregion VI N-East (Los Colorados)

1. Knoll Bank
2. La Leña keys
3. Pinalillo Point
4. Rapado key
5. El Diamante (in front of Puerto Esperanza)
6. Puerto Esperanza
7. Corona de San Carlos
8. Levisa Key
9. Gobernadora Point
10. Bahía Honda Bay

Ecorregion VII N-West (Havana-Matanzas)

1. La Ortigosa Bay
2. Cabañas Bay
3. Gobernadora Point to Santa Fe village
4. Santa Fe-Morro Lighthouse
5. Bay of Havana
6. Cojímar River
7. Beachs to the east of Havana City
8. Rincón de Guanabo
9. Bacunayagua
10. Hicacos Peninsula

Ecorregión VIII N-Central (Sabana-Camagüey)

1. W of Gorda Point
2. Elguea
3. Cádiz Bay key
4. Ojo del Mégano
5. N and S of Blanquizal Key
6. E of Santa Clara Bay
7. Sotavento Key
8. Filipinas Key
9. Las Picúas- Cayo Pelón Keys
10. Reefs from Mégano Chiquito to Cayo Cristo
11. Jutía Key-Pajonal Key
12. W of San Juan de los Remedios- La Vaca Cove
13. Fragoso Key

14. E of Fragoso Key
15. N of Francés Key
16. E of San Juan de los Remedios
17. Caguanes- Cayo Piedra
18. Las Loras
19. Borrachos Key
20. Buenavista Bay
21. Francés Key Cove
22. Los Caimanes- Cayo Felipe to Sotavento Reef
23. Playa Pilar Dunes
24. Loma del Puerto Dunes
25. Reference stations of CARICOM for mangroves, reefs and seagrass
26. Paredón Grande Beaches
27. SE of Cayo Cruz
28. Confites Key
29. Mangrove Point – Inglés Point
30. Mangrove Point - Cayo Montañés Key
31. Mouth of Máximo River
32. Nuevitas Bay

Ecoregion IX N - East (North of Oriente)

1. Nuevas Grandes Bay
2. Taco Bay
3. Managuana Beach
4. Toa and Duaba rivers deltas
5. Bariay
6. Nipe Bay (Saetía Key)
7. Guardavaca, Corintia and Levisa beaches
8. Coastal sector between Gibara and Boca de Samá

Table 5. Priority conservation sites in the Cuban continental shelf

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Ecoregions VI (Los Colorados) and VII (Havana-Matanzas)

1. Fringe reefs of Los Colorados
2. From Levisa Key to Paraíso Key
3. Bahía Honda
4. Cabañas Bay
5. Ortigosa Bay
6. Shore of Havana from Santa Fe village up to Morro Lighthouse

Ecoregion IV (Los Canarreos)

1. S of Guanahacabibes
2. Lobster and fish recruitment area in the Gulf of Batabanó
3. Keys between East Point and Cayo Largo del Sur Key
4. Cazones Gulf
5. Keys to the S of Zapata Swamp

Ecoregions I (S-East), II (Jardines de la Reina) and III (S-Guamuhaya)

1. Jagua Bank
2. Jardines de la Reina Keys
3. Buena Esperanza Bank
4. Agabama and Cauto Rivers deltas
5. Cabo Cruz

Ecoregions VIII (Sabana-Camaguey) and IX (North of Oriente)

1. Borracho-Madruguilla Key
2. Máximo River mouth
3. Sta. María-Guillermo-Los Caimanes Keys
4. Toa and Duaba river mouths
5. Fragoso Key
6. CARICOM Stations
7. Hicacos Peninsula (Varicacos-Galindo)
8. Cádiz Bay reefs
9. Francés Key
10. Verde-El Cristo Keys

MAXIMUM PRIORITY CONSERVATION SITES UNDER CONSERVATION PROCEDURES

- Jardines de la Reina Keys
- Los Canarreos Archipelago
- Region Cazones – South of Zapata Peninsula
- Fish spawning zones and lobster and finfish recruitment sites in the continental shelf.
- Santa María-Guillermo-Los Caimanes Keys
- Cauto River Delta

With a few exceptions, the scientific community involved in biology and marine ecology research confirmed conservationist goals and its performance criteria as proposed. The community's perception for the most convenient conservation goals for the protection of the continental shelf is shown in Table 6.

Table 6. Proposed conservation goals for the protection of the continental shelf.

SURVEY

CONSERVATION GOALS OF THE NATIONAL SMPA

1. *Contribution to sustainability of fisheries*

GOALS (%)

CRITERIA	V(min)	V(max)	Median	Mode	Modal Class
Spawning sites	5	100	25-35-100	50-20-100	3rd
Juvenile fish rearing sites	5	100	50-35-100	50-75-100	2nd
Critical sites in migratory routes of spawning commercial fish	10	100	40-37.5-80	75-15/50-100	2nd
Shrimp: spawning sites	5	100	50-50-100	50-75-100	3rd
Shrimp: juvenile growth areas	5	100	50-75-100	50-75-100	3rd
Lobster: spawning sites	5	100	7.5-30-75	5-15-100	2nd/3rd
Lobster: breading areas	5	100	50-70-100	5-70-100	
Lobster: feeding sites	75	100			

2. *The protection of representative marine-coastal biodiversity.*

GOALS (%)

CRITERIA	V(min)	V(max)	Median	Mode	Modal Class
Habitat heterogeneity	40	100	55-50-100	...-...-100	2nd/3rd
Representation:					
Reefs	15	100	50-75-75	50-75-100	3rd
Rocky bottoms	5	70	10-25-50	10-25-50	2nd
Muddy bottoms	5	75	10-25-50	10-25-50	1st/2nd/3rd
Sandy bottoms	5	70	10-25-50	10-25-50	2nd
Low density sea grass	5	80	15-20-30	15-25-30	1st/2nd/3rd
Dense sea grass	5	100	75-75-100	75-75-100	1sr/3rd
Vertical gradient:					
0-2m.	5	100	10-17.5-20	10-15-20	2nd
2-10m	5	75	10-15-20	10-15-20	2nd
10-30m	10	55	10-15-20	10-15-20	2nd
30-90m	10	20	...-20-...	...-20-...	2nd
90-150m	5	25	10-15-20	15-15-20	2nd
>150m	5	25	10-15-20	10-15-20	2nd
Degree of habitat conservation	5	100	42.5-55-100	...-....-100	3rd*
Critical sites for migratory birds	10	100	20-25-75	…-25-100	3rd
Nesting sites of	5	100	25-25-100	.-25-100	3rd

aquatic birds					
High density sites of turtle nests	10	100	50-75-100	50-75-100	3rd
Areas of threatened and endangered species	5	100	50-60-100	…-…-100	3rd
Areas of endemic species	10	100	…-30-100	…-…-100	3rd*
Eco-region representation	5	100	32.5-25-100	50-…-100	3rd*
Species Type Location	….	100			
Sites of high species diversity	….	100			

3. Representation of traits and scenarios (geographic and historic)

TARGETS(%)

CRITERIA	V(min)	V(max)	Medians	Modes	Modal Class
Relevant geomorphologic elements	10	100	50-30-100	…-…-100	3rd•
Dive sites	5	100	50-25-100	….-25-100	3rd
Unique marine landscapes	5	100	40-50-100	….-...-100	3rd•
Archeological sites	5	100	…-…-100	…-…-100	3rd*
Sunken ships	5	100	50-45-100	…-…-100	3rd*
Stone art	5	100	50-…-100	…-….-100	3rd*

4. Educate and raise awareness of national and international visitors
5. Develop nature tourism (including ecotourism)

Note: • Significantly larger than the others.
Additional goals and criteria proposed by some of those surveyed are in red.

Everyone surveyed agreed on the need to establish a minimum level of protection for the components implicit in each proposed criteria, at least 5% of the total number or area existing in the continental shelf. They also admitted that the minimum acceptable figure should be increased for those cases of high diversity sites (e.g. heterogeneous habitats and reefs). They also enhanced protection levels of pristine sites, unique marine landscapes, relevant geomorphologic elements, endemic species, and charismatic or threatened species. The survey did not indicate the type of protection actions which may be undertaken. The analysis of modal classes shows therefore, a trend towards conservation as the only protective action rather than use regulation by zoning and management plans. This is particularly true for dense sea grass, coral reefs and unique marine landscapes. Owing to this, perception about how much to protect is perhaps not completely objective because it potentiates user conflicts. Also, the survey strongly influenced the suggested conservation goals, particularly when it involved the protection of fishery resources.

For this reason, the goals considered when running the MARXAN program led to a readjustment of the survey's results (Table 7) so that the resulting figures are more objectives and can be accomplished, even in the highest conservation scenarios, in such a way that the application of these goals would not go much beyond a total area of 25% of the continental shelf. This value matches international standards as an appropriate conservation commitment to accomplish reasonable protection of marine environment under current conditions.

Table 7. Final values considered for conservation targets

	CONSERVATION TARGETS (%)		
ELEMENTS	Value(min)	Value(mean)	Value(max)
Eco-regions	10	15	20
Marine habitats			
Reef crests	10	25	50
Frontal reefs	10	25	50
Rocky bottoms	5	10	25
Muddy or muddy-sandy bottoms	5	10	25
Sandy or sandy-muddy bottoms	5	10	25
Average or high density seagrass beds	10	25	50
Low density seagrass beds	5	10	25
Coastal habitats			
Grass coverage or grass and shrub coverage	5	10	15
Lagoons	5	10	15
Mangroves	10	25	50
Salt marshes sites	5	10	15
Sandy coast vegetation	5	10	15
Rocky coast vegetation	5	10	15
Geological components			
Fine sand	5	10	15
Medium sand	5	10	15
Coarse sand	5	10	15
Clay	5	10	15
Limestone	5	10	15
Aleurolite	5	10	15
Gravel	5	10	15
Slime	5	10	15
Depth			
0-2m	5	10	15
>2-10m	5	10	15
>10-30m	10	20	30
>30-90m	10	15	20
>90-150m	10	15	20
>150m	10	15	20

Critical sites for migratory birds		50	75
Turtle nesting sites			
Beaches with high nest density	100	100	100
Beaches with low nest density	75	75	75
Keys with high nest density	100	100	100
Keys with mean nest density	75	75	75
Keys with low nest density	50	50	50
Spawning sites of red snapper and groupers	25	60	50
Sites with damaged species	100	100	100
Lobster spawning sites	8	25	50
Lobster rearing sites	10	25	50
Shrimp spawning sites	10	25	50
Shrimp rearing sites	10	25	50

Note: Due to their wide dispersion, six of the 18 endemic or damaged species included in the analysis were allocated values below 100%. The same value was allocated in similar cases for every scenario (50 or 75 % of sites where they are present).

The summary of MARXAN program running is shown in Table 8. Two aggregation levels were considered for PUs distribution: with no aggregation and with moderate grouping of PUs.

Table 8. Surface involved in each conservation scenario.

SCENARIO	No. PUs selected	**TOTAL SURFACE** (% of the shelf)
Minimum conservation *No aggregation* *Moderate grouping*	 **319** **326**	 **9.5** **9.7**
Mean conservation		

No aggregation	**473**	**14.1**
Moderate grouping	**478**	**14.2**
Top Conservation		
No aggregation	**900**	**26.8**
Moderate grouping	**910**	**27.1**

The table analysis evidences the little influence the aggregation level may have on the number of PUs selected, at least when this level is moderate. Obviously is will not either influence on the total surface involved. This does not mean that PUs distribution turns out similar, because the iteration process implemented by MARXAN looks for solutions that would reduce penalty as much as possible when selection is not based on conservation targets and the relative element importance. It is for this reason that aggregation must be always born in mind because it would influence on the final shape of the sites selected. The difference observed between the two first scenarios with that of top conservation, which almost doubled or tripled the number of PUs is remarkable.

4. Discussion

Modern planning of any MPA should make a dynamic combination of two actions. The first deals with design as regards shape and site extension, considering specific conservation targets and the need to incorporate the site because of its representativeness and connectivity as another functional element within the national or local network of protected areas. The second action is a whole process that would be used to check up nomination effectiveness, based on its compatibility with sectoral interests and the assessment of the scientific community and the local residents involved on its importance or value.

In Cuba, compatibility is made on duly established legal basis and essentially it is a transparent and participative process under any consult level. This favors rationality of decision as regards location and purpose of MPA. On the other hand, site design and categorization has been traditionally done using the criteria of specialists and assessments of organizations like CNAP and different ministries and scientific organizations, as the source of information.

Under the working scale used in the gap analysis, it was observed that generally there is a good correspondence between the location of sites identified for its habitats singularity or classified for priority or top priority conservation in a Delphic way, and the distribution of PUs selected more times by MARXAN according to any of the conservation scenarios involved (Fig.4). They gather the main sites proposed as priority sites for conservation actions (archipielagos of Los Canarreos, Jardines de la Reina, Los Colorados, Sabana Camagüey, keys Santa María-Guillermo-Los Caimanes, Juan García and San Felipe, Keys to the S of Zapata Swamp, S of Guanahacabibes, Cazones Gulf, Jagua Bank, Buena Esperanza Bank, Cauto River Delta, Cabo Cruz), and a large share of sites with

representative, singular or distinctive habitats. There are only two main sites identified by MARXAN as of high natural value, both in Cuban south shelf, that were not considered by the expert team as important elements for conservation actions. Neither the SW coast of Pinar del Río, nor the central region of the outer edge of the Gulf of Guacanayabo was included. In the SW coast of Pinar del Río only the presence of peculiar habitats was indicated in the site between Loca Point and La Coloma. May be this is so because of the presence in both sites of environmental gradient that causes habitat heterogeneousness, a fact that this software recognizes and selects with priority, or in the case of the S coast of Pinar del Río, because there are also recruitment sites.

It must be said that this agreement is partly the result of skipping program running costs although there was information with respect thereof. For the purpose of only contrasting correspondence between sites remarkable for its natural values or economic importance in different information sources, no information on nautical or harbor activity or on mining surveying or fishing in the shelf was used in this step. Among all these factors considered as expenses, fishing is the major human impact on the island's shelf, because of its magnitude and intensity. Due to its tropical nature, it is almost always done in sites with high biodiversity (e.g. crests and frontal reefs) or in important habitats for recruitment of numerous resources (i.e. seagrass beds). So, including fishing in MARXAN running as part of the expenses would have affected PUs selection just because of penalties imposed, and this would have affected the validation of the type of data used in a GIS-based approach for selecting in a less personalized way the sites more remarkable of our shelf, upon their correspondence with a subjective perception of were are they.

The analogy between design, extension and also gaps of Cuban SMPA under implementation and the sites identified by the use of MARXAN under different conservation scenarios considering costs are going to be shown in other paper. Though the large differences on information availability at ecoregion level detected during the exercise and, obviously, its impact on PUs nomination (gradient definition based on the PUs selection frequency was lower in the less studied narrow shelf ecoregions) is, nevertheless, possible to conclude that computer selection of PUs, through MARXAN, evidenced how powerful this kind of programs can be in the location of areas based on preestablished criteria.

5. Conclusions

- By consensus, in a Delphic way, nine ecoregions were identified; within this group, 66 regions or sub-regions were selected. Having representative, distinct, or unique habitats were distinguished 118 sites. Of maximum conservation priorities were established 26 sites, six of which have national significance.
- All the sites acknowledged as top priority sites for conservation actions were represented in the cells more selected in all scenarios using the MARXAN program.
- A significant number of habitats with representative, singular or distinctive habitats are also represented in the cells more selected derived from the application of MARXAN.

- Appropriate correspondence among locations and sites recognized by expert groups and those obtained with MARXAN, validates the design of the GIS implemented for MARXAN runs and demonstrates the feasibility of combine multisources data and consensual analysis in the process.

6. Recommendations

- To use MARXAN program for the automatic selection of PUs in coastal management.
- To increase working scale to run MARXAN in the Cuban shelf, with due consideration of specifics in every ecoregion.

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FIGURES