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MARINE BIODIVERSITY IN COLOMBIA: ACHIEVEMENTS, STATUS OF KNOWLEDGE, AND CHALLENGES

BIODIVERSIDAD MARINA EN COLOMBIA: ESTADO ACTUAL DEL CONOCIMIENTO Y DESAFIOS FUTUROS

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ABSTRACT

Colombia is recognized as a megadiverse country on the basis of the number of terrestrial animal and plant species occurring within its boundaries. However, due to the circumstance that it possesses coasts on both the Caribbean Sea and the Pacific Ocean, each of them exhibiting distinct geological, oceanographic, and climatic features, Colombia is perhaps the country with the highest marine biological diversity in South America and one of the most biodiverse in the New World. Although scientific research concerning marine biodiversity of Colombia has a very short history, considerable knowledge has been achieved in the last 10 years, particularly in regard to species inventories and ecosystem characterizations, including thematic mapping. Relatively accurate estimates about the numbers of species of fishes, birds, mammals, reptiles, and some marine invertebrate groups occurring in Colombian waters are now available, as well as the location, extent, and structure of the major coastal-marine ecosystems, including coral reefs, mangroves, and seagrass meadows. According to their geologic, hydrographic, climatic, and biological features, the coastal and oceanic realms of Colombia have been subdivided into 18 natural ecoregions, nine in the Caribbean and nine in the Pacific. Considering the current scientific capacity of Colombia, including financial and logistic limitations, short and mid-term research plans and programs have been designed in order to orient marine biodiversity studies toward prioritary issues and geographic areas according to the responsibilities imposed by the Biodiversity Convention and the National Biodiversity Plan.

KEYWORDS: Marine biodiversity, Colombia, Caribbean, Eastern Pacific, Marine ecosystems.

RESUMEN

Colombia es reconocido como un país megadiverso con base en la cantidad de especies de plantas y animales terrestres que posee. Esto, debido, entre otras cosas, a que tiene costas sobre el mar Caribe y el océano Pacífico, con características geológicas, oceanográficas y climáticas muy contrastantes, Colombia es seguramente el país con mayor diversidad biológica marina de Sudamérica y uno de los más biodiversos del Nuevo Mundo. Aunque la investigación científica sobre la biodiversidad marina de Colombia tiene una historia muy corta y reciente, en los últimos 10 años se han realizado grandes avances en la generación de conocimiento, particularmente en cuanto a inventarios de especies y caracterización de ecosistemas, incluyendo mapas temáticos. Se dispone actualmente de estimativos relativamente confiables sobre la cantidad de especies de peces, aves, mamíferos, reptiles y de algunos grupos de invertebrados marinos que habitan en aguas colombianas, así como la localización, extensión y estructura de los principales ecosistemas, incluyendo arrecifes de coral, manglares y praderas de pastos marinos. De acuerdo con sus características geológicas, hidrográficas, climáticas y biológicas, las zonas costeras y espacios oceánicos de Colombia han sido subdivididos en 18 ecorregiones naturales, nueve en el Caribe y nueve en el Pacífico. Considerando las limitaciones en cuanto a la capacidad científica de Colombia, incluyendo las de índole presupuestal y logística, se han formulado planes y programas a corto y mediano plazo que buscan orientar las investigaciones en biodiversidad marina hacia temas y áreas geográficas prioritarias en conformidad con los compromisos que impone la Convención de Biodiversidad y el Plan Nacional de Biodiversidad.

PALABRAS CLAVES: Biodiversidad marina, Colombia, Caribe, Pacífico oriental, Ecosistemas marinos.

INTRODUCTION

Colombia, together with Indonesia, Brazil, and Mexico, share a privileged position at the top of the list of countries with the highest biodiversities of species in the world, the so called megadiverse countries (IAvH 1998a; IAvH 1998b). However, this reputation is based upon the relatively well documented diversity of terrestrial biota such as orchids, amphibians, birds, mammals, and butterflies (cf. Andrade *et al*. 1992).

Close to half of the continental territory covers the Amazonian River system and the Orinoco savannas. The Andes Mountains, which occupy part of the country, are separated into three ranges, and drainage from the Magdalena and Cauca River basins forms the wetlands of the Caribbean and feeds the tropical dry forest ecosystems. The watershed of the western Andes and the Pacific lowlands is an extremely rich region, isolated for many years, constituting the Chocó biodiversity hotspot. The Sierra Nevada de Santa Marta, the highest coastal mountain in the world, is an isolated mountain in the Caribbean, rising 5,500 m above the hot deserts of the Guajira Peninsula.

On the other hand, with nearly 1,000,000 km^2 of territorial waters, Colombia is close to being 50% maritime, and is the only South American country having coasts on both the tropical Pacific Ocean and the Caribbean Sea with a total shoreline of nearly 3,000 km. Because Colombia possesses oceanic islands located far offshore, wide sections of both the tropical eastern Pacific and the southern-central Caribbean are included within the boundaries of its Economic Exclusive Zone (Fig. 1).

FIGURE 1. Colombia and its continental and marine boundaries.

FIGURA 1. Colombia con sus límites continentales y marinos.

There are remarkable differences between the two coasts in terms of climatic, geological, oceanographic, ecological, and biological features (for summarized descriptions, see and compare Botero & Alvarez León 2000 and Marrugo *et al*. 2000). Coastal morphology, climate, and physical oceanographic processes vary greatly along spatial gradients as well as seasonally within both the Caribbean and the Pacific realms.

In short, the great majority of tropical marine habitats are well represented in Colombia. Since most of these result from different and contrasting physical conditions and ecological processes, each habitat harbours its own particular biota. The total diversity of marine organisms in such a variety of environments is likely to be very high. Their study represents a huge challenge for future oceanographic and biological research.

In this paper, the history of marine scientific research in Colombia that led to the present status of knowledge is summarized and the major physical and ecological features of the Colombian marine realm (the "known") described. Research priorities (the "unknown") are then discussed in the framework of the national programs of research on biodiversity and the marine sciences. Finally, some other issues about marine life which might be considered unknowable are briefly considered.

The information presented here is derived, to some extent, from the authors' own knowledge of the antecedents, but to a greater degree from recent compilations, reviews, and diagnoses of current understanding of Colombia's biodiversity status, with which the authors were, to some extent, involved (cf. Arias 1998; IAvH 1998b; INVEMAR 2000, 2001; Díaz 2002; MMA 2002).

A BRIEF HISTORY OF MARINE RESEARCH IN COLOMBIA

Despite the large marine area over which it has jurisdiction, Colombia is, perhaps, one of the South American countries with sea coastlines having the poorest maritime tradition and vocation. This results not only in the minor contribution made by marine resources to the national economy and the generaly poor development of the coastal zone, but also in the overall low level of maritime culture of the population and the reduced availability of information about the oceanographic, geological, ecological and biological features of the marine environment.

Marine science in general, including inventories of marine organisms and ecology, is a very young discipline in Colombia. It has been developing very slowly for merely 35 years. The first papers published by Colombian marine scientists in international journals appeared late in the 1960s. All of the records of plant and animal species in Colombian marine waters existing before that time were gathered by foreign scientists usually on the basis of biological material collected by British, French, and American expeditions in Colombian waters. Outstanding were the oceanographic and biological cruises carried out by the research vessels 'Argo'(1875), 'Chazalie' (1886), 'Velero III' (1939), 'Pillsbury' (1966-67) and 'Oregon' (1969) in Caribbean waters; and the 'Albatross' (1887-88), 'Saint George' (1927) and 'Askoy' (1942), as well as the Allan Hancock Foundation Expeditions (1940-43) in Pacific waters.

The real starting point of marine research in Colombia is represented by the almost simultaneous establishment in the mid 1960s of the Colombian-German Institute of Scientific Research at Santa Marta (which later evolved into the present Institute of Marine and Coastal Research, INVEMAR), the Colombian Oceanographic Commission, the Colombian Science Foundation (COLCIENCIAS), and the Faculty of Marine Sciences at Bogotá.

Up to the end of the 1970s, the majority of the contributions to the knowledge of marine biodiversity in Colombia was made by visiting German and other foreign scientists and students working at INVEMAR. Several Colombian students began, at that time, to study the taxonomy of certain groups but only a couple of them continued in this field or gained further expertise in advanced academic programs. In the 1980s, taxonomic work and the compilation of inventories of organisms was somewhat disdained and it was very difficult to obtain funding to carry out this kind of work, something seen not only in developing countries but worldwide.

In 1998, a census of taxonomists in Colombia (ACH *et al.* 1999) showed that they were an endangered species. Only six trained professional taxonomists of marine organisms remained active in some way in Colombia at that time. Most of them were involved mainly with other fields, thus devoting only a small portion of their time to collecting and classifying biological material and publishing the results. The same census showed that knowledge of

the diversity of marine species was concentrated in a few groups such as sponges, corals, mollusc, decapod crustaceans, fish, and algae with very little information about other phyla. It has recently been suggested that the number of species belonging to the best known zoological groups in Colombia could be up to 50% higher than those so far reported (Lemaitre 2002).

Furthermore, until 1995, the research effort was largely devoted to shallow waters and mostly in locations in the vicinity of the research institutes. Almost 75% of the information published on Columbia`s marine biodiversity up to 1995 was based on material from areas close to Santa Marta and Cartagena in the Caribbean and Buenaventura on the Pacific coast. Extensive sections of the coast, the continental shelf, and particularly of the deep sea remained to be surveyed. On the Pacific coast, where many locations cannot be easily reached, the situation was even worse (INVEMAR 2000).

In 1990, the Science and Technology Law was passed and, in 1993, the Ministry of the Environment and the National Environmental System were created. Five research institutes were placed under the control of that Ministry including INVEMAR, the only one devoted exclusively to marine research. The Convention on Biodiversity (CBD) determined in the course of the 1990s, a new sphere of action in marine science targeted specifically at environmental issues concerning coastal zones and oceans. The supportive policy of COLCIENCIAS of forming research groups, as well as the CBD mandate that requires the setting up of biodiversity inventories, led to the rapid revival of taxonomy as an indispensable research tool. Species inventories for areas up to water depths of 600 m off the Caribbean coast, as well as interdisciplinary studies on coral reefs, seagrass beds, mangroves, and estuaries have produced an unprecedented amount of information in the last 5 years. This is reflected in the high number of recently published papers. Red books of endangered marine invertebrates and fish in Colombia have also been produced, recently. Cooperation between Colombian institutes and as with foreign specialists and laboratories has played an important role in this development. A consequence has been that the biological collections are undergoing an extraordinary expansion. The reference collection of marine organisms at INVEMAR, for instance, grew from about 6,200 items in 1997 (accumulated over a time span of nearly 24 years) to more than 15,500 in 2002, having acquired the official status of National Museum of Marine Natural History in 2001. INVEMAR is currently developing the National Biodiversity Information System in which distribution data at the species level, including descriptions with images of reference material and relevant literature, are being stored to produce an online, electronic atlas of Colombian marine organisms.

The exponentially increasing numbers of documents dealing in some way with marine biodiversity of Colombia in the course of the last six decades (Table I) clearly demonstrate the remarkable progress that has been made in the knowledge about these issues.

TABLE I. Number of documents concerning aspects of Colombian marine biodiversity, which appeared in the decades 1940 to 1990 (from a bibliographic database of INVEMAR).

TABLA I. Número de documentos relacionados con los aspectos de la biodiversidad marina en Colombia aparecidos entre las décadas de 1940 y 1990 (tomado de la base de datos bibliográfica de INVEMAR).

Decades	Total number of documents*	Published papers and books	Published papers and books in which Colombian authors were involved
1940 – 49	19	16	1
1950 – 59	13	12	0
1960 – 69	78	31	6
1970 – 79	421	108	57
1980 – 89	798	219	161
1990 – 99	1630	612	457

* Includes published books and papers, as well as unpublished “grey literature” (theses, technical reports and monographs).

According to a recent analysis (INVEMAR 2000), based on an exhaustive opinion poll and data provided by COLCIENCIAS, current research in Colombia about marine biodiversity issues involves fewer than 80 scientists devoting at least 25% of their time to research activities. Of these, about 30 have an M. Sc. or equivalent degree and 18 a Ph.D. degree. Furthermore, of the 744 research groups in Colombia recognized by COLCIENCIAS in 2000, only 13 are dealing in some way with marine biodiversity issues. (Table II).

The deficiency of manpower to cope with the challenges of current and future research becomes evident if, in general terms, scientists without postgraduate studies are able to solve scientific questions, those with a M. Sc. degree to analyze and solve them, and only those with a Ph.D. degree to generate ideas and to, analyze and solve the questions.

TABLE II. The 13 research groups working on marine biodiversity issues in Colombia, recognized by COLCIENCIAS in 2000 (from INVEMAR 2000).

TABLA II. Los 13 grupos de investigación, reconocidos por COLCIENCIAS en 2000, que trabajan en asuntos de biodiversidad marina en Colombia (del INVEMAR 2000).

Group name	Institution and location
Ecology of estuaries and mangrove swamps	Universidad del Valle, Cali
Coral reef ecology	Universidad del Valle, Cali
Natural products from marine organisms and fruits	Universidad Nacional de Colombia, Bogotá
Diversity and use of marine organisms	Universidad Nacional de Colombia, Santa Marta
Natural marine products	Universidad de Antioquia, Medellín
Tropical marine ecosystems	Universidad Jorge Tadeo Lozano, Bogotá
Mangrove ecology and restoration	INVEMAR, Santa Marta
Benthic communities	INVEMAR, Santa Marta
Coral reefs	INVEMAR, Santa Marta
Fisheries ecology	INVEMAR, Santa Marta
Integ rated coastal management	INVEMAR, Santa Marta
Marine pollution	INVEMAR, Santa Marta
Systematics, taxonomy, and inventories of marine organisms	INVEMAR, Santa Marta

MAJOR MARINE ECOSYSTEMS OF COLOMBIA

Before the final raising of the Central American isthmus during the late Tertiary period, the Pacific and Caribbean realms were connected and formed a unique biogeographical region. However, for the last $5x10^6$ years, the marine biota of these two regions have evolved independently, have undergone different extinction and speciation processes, and have been exposed to contrasting environmental

conditions, so that, at the present time, only a few elements of the biota are common to both regions.
The Pacific lowlands of Colombia are one of the rainiest regions in the world, resulting in large volumes of freshwater runoff and its associated sediments to the coastal zone. The region is occasionally subjected to El Niño disturbances, earthquakes, and tsunamis. The Caribbean coast is, on the other hand, less affected by natural phenomena and shows a greater variety of shallow marine environments which have a mosaic-like distribution along the mainland coast. Although it does not rain there so much, great quantities of freshwater and sediments are discharged into the Caribbean Sea by the Magdalena and other rivers which create important estuarine and lagoon systems. In addition, one of the most extensive coral reef systems of the Atlantic is the oceanic Archipelago of San Andrés and Providencia, about 700 km off the Colombian mainland. The tidal range in the Caribbean is less than 40 cm.
Such a variety of conditions leads to a great diversity of habitats and ecosystems, of which sandy and rocky shores, coastal lagoons, coral reefs, seagrass beds, mangrove forests, upwelling areas, the soft bottoms of the continental shelf, and the open ocean are the most noteworthy.

Sandy beaches

Nearly 25% of the 1,300 km of the Pacific coast and about 60% of the 1,650 km of that of the Caribbean consists of sandy beaches. Studies of these have focused mainly on the zonation patterns of the faunal communities at a few sites. In the Caribbean, beaches with coarse sand exposed to wave action, which occur largely in the northern half of the coast, exhibit a more diverse community dominated by bivalves of the genus *Donax* and "sand dollars", *Mellita* sp. Low energy beaches, with fine sediments, have lower biodiversity and the communities are mostly dominated by polychaetes and the bivalve *Heterodonax brasiliana* (Dexter 1974). Caribbean sandy beaches have recently been classified in terms of their previous and/or current status as nesting habitats for sea turtles (INVEMAR 2002). Many beaches of the southernmost Caribbean coast are endangered as habitats for a variety of organisms due to increased erosion seemingly caused by a rise in sea level combined with geological subsidence.
Due to the large tidal range, the extensive sand plains and beaches of the Pacific coast, which are usually adjacent to mangrove swamps, exhibit a very rich infaunal community with a characteristic zonation pattern (Cantera *et al.* 1992). A great variety of birds, both migratory and resident, feed on these beaches.

Rocky shores

Rocky beaches and cliffs in the Colombian Caribbean represent no more than 15% of the shoreline and are scattered along the coastline. The cliffs along the indented coast of the Santa Marta area, where the ridges of the northern ranges of the Sierra Nevada descend abruptly to the sea, are noteworthy as are those close to the Panamanian border and along the northwestern shores of the Guajira Peninsula. In the Cartagena area, ancient coral reefs have emerged to form a characteristic calcareous platform that fringes the shoreline. In contrast, nearly half of the Pacific coastline is dominated by mostly basaltic rocky shores. The islands of Malpelo and Gorgona are also surrounded by steep rocky cliffs.
Studies of rocky shores have focused mainly on the composition and zonation of algae (Bula-Meyer 1985; Bula-Meyer & Schnetter 1988) and invertebrates (Brattström 1980; Cantera *et al.* 1979) as well as bioeroding organisms (Cantera 1995).

Coral reefs

Coral reefs have been intensively studied in Colombia during the last 15 years; mapping, zonation, health status, and the associated fauna and flora have all been involved. The most relevant information resulting from these studies was recently compiled and published in the form of a comprehensive atlas (Díaz *et al.* 2000).
Coral reefs in Colombia occupy a total extent of nearly 1,000 km^2, of which more than 98% are situated in the Caribbean. Pacific reefs are small and patchy in distribution but are, nevertheless, important because they shelter a diverse eastern Pacific reef fauna. The main coral reef areas in the Pacific are Gorgona Island and Malpelo Island, both under the control of the National Parks authority. Pacific reefs are built up predominantly by corals of the genus *Pocillopora*, but 20 other species have also been recorded.

The coral reefs of Colombia in the Caribbean, on the other hand, have a much wider distribution, harbor a more diverse coral fauna (57 species), and are highly variable in both size and geomorphology. Two main reef areas can be distinguished: the mainland coast and the already mentioned oceanic Archipelago of San Andrés and Providencia. Those along the coast are mostly small fringing reefs and patch reefs, scattered in sheltered bays e.g. those in the inlets of the Santa Marta area. Offshore reefs on the continental shelf emerge several meters above the sea surface in some places (e.g. the Islas del Rosario and San Bernardo), southwest of Cartagena. These islands are surrounded by luxuriant recent coral reefs. The oceanic reefs of the Archipelago of San Andrés and Providencia are among the most extensive reef systems of the Atlantic, occupying about 760 km^2. They include two barrier reefs surrounding the major islands, five large atolls, and several other less well defined coral banks.

SEAGRASS BEDS

Seagrass beds are distinct and unique ecosystems with relatively high rates of primary production which support detritus-based food chains. In Colombia, they occur solely in the Caribbean. The seagrass ecosystems provide habitats for a wide variety of marine organisms, promote sediment stabilization, and maintain a dynamic environment for nutrient cycling. Seagrass beds and their associated communities were little studied in Colombia until very recently (cf. Botero & Alvarez-León 2000). Most previous studies were focused on determining seagrass density, biomass, and growth (e.g. Laverde-Castillo 1992a; Fresneda *et al.* 1994; CARICOMP 1997) and the composition and structure of the animal community (cf. Díaz & Götting 1986; Puentes & Campos 1992; Laverde-Castillo 1992b) on small local scales. However, a recent base-line study of seagrass beds in the Colombian Caribbean has provided information on their structure and distribution patterns over much broader spatial scales, including maps (Díaz *et al.* in press).

Of the 7 species of seagrasses known to occur in the tropical western Atlantic, five have been recorded in Colombian waters of which *Thalassia testudinum* and *Siryngodium filiforme* are the most abundant. The total seagrass coverage in the Colombian Caribbean is estimated to be 43,292 ha. Almost 80% of this is situated along the shore and in the shallow portion of the continental shelf off the Guajira Peninsula. There, seagrass beds provide an important feeding habitat for the green turtle (*Chelonia mydas*) (INVEMAR 2002). The beds also occur in nearshore waters along the central mainland coast and around the offshore islands on the continental shelf. Human activities, including discharges of large quantities of sediment and freshwater, dredging, contamination by polluted industrial and domestic waste waters, and accelerated coastal development have led to the loss of nearly 1,000 ha of seagrass in the course of the last 5 decades in the Cartagena Bay and neighboring areas (Díaz & Gómez in press). The distribution of seagrasses is far from continuous along the continental coast, probably because of low salinities, high turbidity, and/or high wave energy in shallow waters. A further 2,000 ha of seagrass beds occur around the oceanic islands of San Andrés and Providencia. More than 550 species of fish and invertebrates and about 35 species of macroalgae have been recorded in the seagrass beds of Colombia (Montoya *et al.* in prep.).

MANGROVE FORESTS

Mangroves are amongst the biologically most productive ecosystems in the world and play an important role in the sustainability of fisheries, protect the shoreline against erosion, and provide an important resource of wood. In 1981, Colombia was placed tenth on the list of countries with mangrove forests, with around 4,440 km^2 (Alvarez-León 1993) but, as the result of intensive and uncontrolled destruction and exploitation during the last two decades, only approximately 3,790 km^2 were left by the year 2000, 86% of which is considered to be threatened (Marrugo-González *et al.* 2000).

Mangrove forests grow on both of the Colombian coastlines (Zambrano & Rubiano 1997). Approximately 863 km^2 of the Colombian Caribbean coast are covered by mangroves, comprised mainly of *Rhizophora mangle*, *Avicennia germinans*, and *Laguncularia racemosa*, although 2 other species are also present. Tree-height in the Caribbean rarely exceeds 15 m due to the arid conditions and strong winds. The largest mangrove wetlands are found in the deltas of the Atrato, Sinú, and Magdalena rivers while smaller forests are found in the northern bays of La Guajira Peninsula, certain inlets of the Tayrona National Park near Santa Marta, and the offshore islands of San Bernardo, El Rosario, San Andrés and Providencia.

Eight mangrove species occur on the Colombian Pacific coast where the forests extend up to 30 km inland in certain areas, especially in the southern half of the coast between Buenaventura and Tumaco. Tree-height usually attains over 20 m. Occupying about 2,927 km^2, mangroves represent about 7.5% of the total Colombian Pacific exploitable forest (Marrugo-González *et al.* 2000). On the southern half of the Pacific coast, the extensive mangrove forests are mainly associated with the complex system of rivers that drains the lowlands, whereas, on the mountainous northern coast, the forests are smaller and fringe intertidal flats at the mouths of major rivers.

Upwelling Systems

A large part of the northeastern Colombian Caribbean, off the Guajira Peninsula, is characterized by coastal upwelling of deep (150-200 m) subtropical water during the dry season (January – May) when the trade winds blow at average speeds of over 10 m s^{-1} (Alvarez-León *et al.* 1995). Phytoplankton productivity in this upwelling system has been found to be lower than in other upwelling areas but it is significantly higher than that observed in normal Caribbean waters (Corredor 1979). Nearly 50% of the activity of the industrial shrimp fleet in the Colombian Caribbean takes place in this area. This seasonal upwelling also creates special conditions that favor the growth of certain species of algae and invertebrates not usually occuring in tropical waters, so that this area has been considered to be a particular zoogeographical subprovince in the southern Caribbean (cf. Bula-Meyer 1977, 1985; Díaz 1995).

Seasonal cold-water upwelling also occurs regularly in the waters off the northern Pacific coast of Colombia and most of the Pacific coast of Panamá. However, information about the physical and biological characteristics of this system is still scarce.

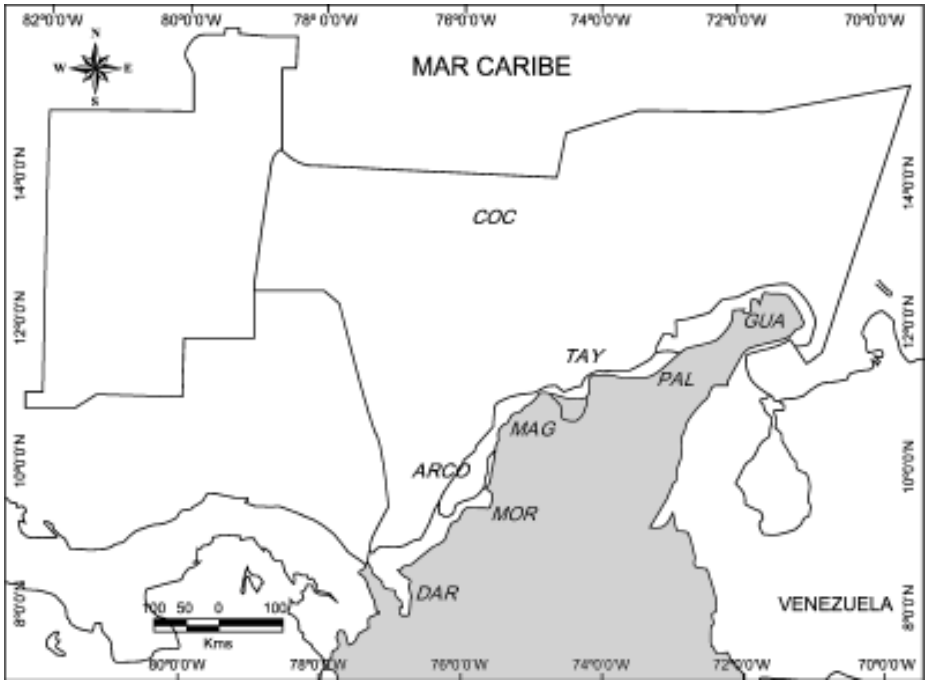

Figure 2. Marine and coastal natural ecoregions of the Colombian Caribbean: GUA (Guajira), PAL (Palomino), TAY (Tayrona), MAG (Magdalena), MOR (Morrosquillo), ARCO (Coralline Archipelagos), DAR (Darién), SAN (San Andrés and Providencia Archipelago), CAO (Oceanic Caribbean).

Figura 2. Las ecoregiones naturales marinas y costeras del Caribe colombiano: AGUA (Guajira), PAL (Palomino), TAY (Tayrona), MAG (Magdalena), MOR (Morrosquillo), ARCO (archipiélagos Coralline), DAR (Darién), SAN (archipiélagos San Andrés y Providencia), CAO (Caribe oceánico).

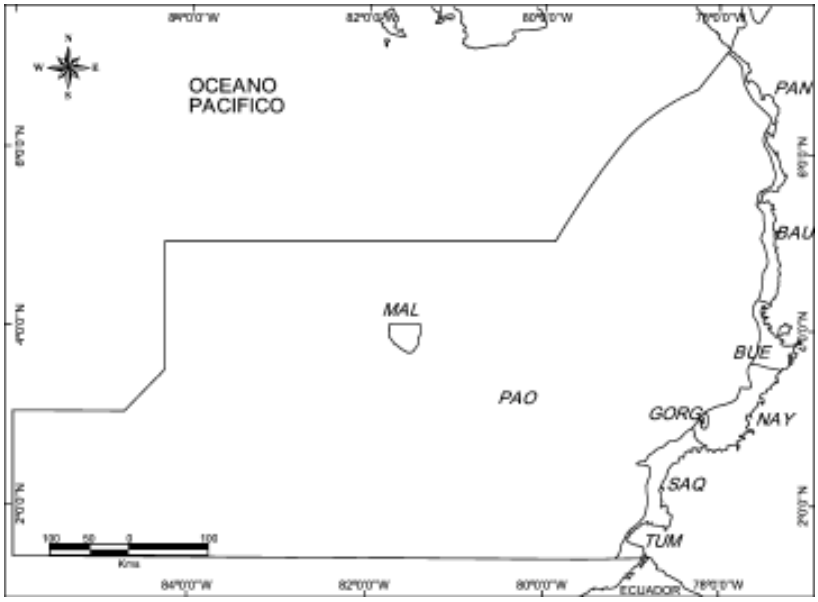

FIGURE 3. Marine and coastal natural ecoregions of the Colombian Pacific: PAN (northern Pacific), BAU (Baudó), BUE (Buenaventura), NAY (Naya), SAQ (Sanquianga), TUM (Tumaco), GOR (Gorgona Island), MAL (Malpelo Island), PAO (Oceanic Pacific).

FIGURA 3. Las ecorregiones naturales marinas y costeras, del Pacífico colombiano: PAN (Pacífico norte), BAU (Baudó), BUE (Buenaventura), NAY (Naya), SAQ (Sanquianga), TUM (Tumaco), GOR (isla Gorgona), MAL (isla Malpelo), PAO (Pacífico oceánico).

MARINE AND COASTAL ECOREGIONS

Taking into account the distribution of the main marine ecosystems on the coasts of Colombia, the topography and width of the continental shelf, the geomorphological features of the coast, and the influence of terrestrial drainage through major rivers, the marine and coastal territories of Colombia have recently been classified into 9 Caribbean and 9 Pacific ecoregions (Figs. 2 and 3). (INVEMAR 2000). Brief descriptions of these follow.

THE CARIBBEAN

Guajira Ecoregion (GUA): The Guajira Peninsula, from the Venezuelan-Colombian boundary to the mouth of the Ranchería River. The coastal zone is desert, mainly sandy beaches and salt marshes. The wide continental shelf is covered with extensive seagrass and algal beds in the shallower parts. Other features: seasonal upwelling, high primary and secondary production, scattered fringing mangrove forests; several endemic components of the marine biota have been identified.

Palomino Ecoregion (PAL): Situated between the mouths of the Ranchería and Piedras rivers; highly exposed coast dominated by coarse sand beaches; several streams and small rivers that drain the northern ranges of the Sierra Nevada de Santa Marta form freshwater swamps and small coastal lagoons behind the sand bars; an important nesting area for sea turtles.

Tayrona Ecoregion (TAY): Extends from the mouth of the Piedras to Punta Gloria (near Santa Marta); hilly and mountainous coastal morphology which descends to the sea forming a series of small bays and inlets with pocket beaches, scattered seagrass beds, and coral

reefs; rocky shores predominate; very narrow continental shelf; 80% of this ecoregion is protected (Tayrona National Park); it is the best studied area with regard to marine biodiversity in Colombia.

Magdalena Ecoregion (MAG): Extends from Punta Gloria southwest to Cartagena; highly influenced by the discharges of the Magdalena River with heavy sediment loads; very heterogeneous and dynamic coastal morphology, with sand bars across the entrances of coastal lagoons (surrounded by mangroves), sand dunes, beaches, very exposed to wind and wave action and vulnerable to erosion; turbid waters; continental shelf is 5 to 30 km wide, made of terrigenous sands and silts.

Gulf of Morrosquillo Ecoregion (MOR): Extends from Cartagena (Punta Barú) to the delta of the Sinú River out to the 40 m depth contour; influenced by continental discharges through the Canal del Dique and the Sinú River; low water transparency; coastal morphology dominated by quaternary deposits and deltaic systems; low exposure to wind and wave action; seagrass beds; deltaic and estuarine systems with mangrove forests; biodiversity relatively well known.

Coralline Archipelagos Ecoregion (ARCO): Encompasses the islands, shallow carbonate platforms, and coral shoals located off the mainland coast between Islas del Rosario and Isla Fuerte as well as the continental shelf between the 40 and 130 m depth contours; clear waters; high species and habitat diversity with coral reefs, seagrass beds, bioclastic sand flats, and fringing mangroves in some islands; deep bottoms made of bioclastic and terrigenous mud; biodiversity relatively well known.

Darién Ecoregion (DAR): Extends from the mouth of the Sinú River south to the Panamanian-Colombian border; wide continental shelf, mainly terrigenous muds; high influence of continental discharges; predominantly turbid waters; coastal morphology can be divided into three subregions: in the northern part, lithological and made up of lodolites and turbidites that are subject to high rates of marine erosion; the southern coast of the Gulf of Urabá defined by alluvial plains with mangrove forests and a rapidly extending delta of the Atrato River; the gulf may be regarded as an estuary; by contrast, the northwestern shore of the gulf is constituted of tertiary volcanic rocks forming discontinuous cliffs alternating with alluvial valleys; scattered coral reefs and seagrass beds along this mountainous coast; biodiversity poorly studied.

San Andrés and Providencia Archipelago Ecoregion (SAN): Includes the oceanic islands of San Andrés and Providencia, 5 atolls and several less well defined coral shoals in the southwestern Caribbean; very clear, oceanic waters; extensive and very diverse coral formations; seagrass beds around the 2 major islands; frequently affected by storms and hurricanes; composition, structure, and origin of coral reefs intensively studied in recent years; this ecoregion was declared a Biosphere Reserve by UNESCO in 2000.

Caribbean Oceanic Ecoregion (CAO): The territorial and Economic Exclusive Zone oceanic waters ranging from 130 to more than 3,000 m in depth; biodiversity very poorly known; some areas of moderately high pelagic productivity due to upwelling and eddies.

THE PACIFIC

Northern Pacific Ecoregion (PAN): Extends from the Panamanian border to Cap Corrientes; very narrow continental shelf; high tectonic activity; coastal morphology defined by mountains with a dense canopy of rain forest; steep rocky (volcanic) cliffs alternating with pocket beaches; very rainy; rather clear waters; seasonally affected by upwelling; scattered mangrove forests and coral formations.

Baudó Ecoregion (BAU): Extends from Cap Corrientes to the northernmost mouth of the San Juan River; coastal morphology defined by a large alluvial plain with extensive sandy beaches and intertidal sand flats; rather narrow continental shelf; marine waters moderately influenced by terrestrial runoff; biodiversity poorly known.

Buenaventura Ecoregion (BUE): Extends from the mouth of the San Juan River south to the mouth of Raposo River, including the San

Juan Delta and the bays of Málaga and Buenaventura; coastal morphology heterogeneous, combining alluvial and deltaic plains with mangroves, intertidal mud plains, sandy beaches, and littoral terraces of soft rocks with steep cliffs subject to marine erosion; turbid waters; narrow continental shelf.

Naya Ecoregion (NAY): Between the mouths of the Raposo and Guapi rivers; coastal morphology defined by an ample alluvial plain drained by many rivers and littoral barrier islands that form a highly dynamic estuarine system; well developed mangrove forests behind the barrier islands; turbid waters; rather wide continental shelf; biodiversity poorly known.

Sanquianga Ecoregion (SAQ): Extends from the mouth of the Guapi River to Isla del Gallo, within the Tumaco Inlet; it is a large deltaic system formed by several meandering rivers which form a complex system of estuaries, channels, and open lagoons; extensive mangrove forests and intertidal sand plains (nesting habitat for sea turtles); wide continental shelf; turbid waters; nearly 50% of the ecoregion is a protected area (Sanquianga National Park).

Tumaco Ecoregion (TUM): Encompasses the Tumaco Inlet and the delta of the Mira River south to the Ecuadorian border; alluvial plains; scattered rocky cliffs within the Tumaco Inlet; fringing mangrove forests; turbid waters; narrow continental shelf.

Gorgona Island Ecoregion (GOR): Gorgona Island and surrounding waters out to a depth of 50 m (Gorgona National Park); mountainous island covered by rain forest; rocky and sandy shores, fringing coral carpets and reefs, submerged rocky and soft bottoms; relatively clear waters; biodiversity relatively well known; this is the main breeding area of the humpback whale (*Megaptera novangliae*) in the South American Pacific.

Malpelo Island Ecoregion (MAL): The oceanic island of Malpelo and its surrounding waters out to 1,000 m depth; steep basaltic cliffs; absent insular shelf; predominantly rocky bottoms; scattered coral carpets; together with Cocos and Clipperton islands, it represents a "step stone" for tropical shallow water fish and invertebrates migrating from the Indo-West Pacific to the Eastern Pacific; it is also an important breeding area for oceanic birds.

Oceanic Pacific Ecoregion (PAO): The territorial and Economic Exclusive Zone oceanic waters ranging from 200 to more than 3,000 m in depth; biodiversity very poorly known; moderately high pelagic productivity due to the effects of nutrient enrichment from terrestrial runoff; as part of the Panama Bight, it is one of the most important commercial tuna fishing areas in the American Pacific.

RESEARCH PRIORITIES IN MARINE BIODIVERSITY

Although the total number of species of most marine animal groups and plants in Colombia is, as yet, far from well known (INVEMAR 2000; Lemaitre 2002), it seems clear that in addition to its terrestrial biota, Colombia also has a megadiversity of marine biota, surpassed, amongst the neotropical countries, perhaps only by Mexico (cf. INVEMAR 2000). That coral reefs in the Colombian Caribbean occupy nearly 1,090 km^2 and in the Pacific only 1.5 km^2 (Díaz *et al.* 2000), that there are 863 km^2 of mangroves in the Caribbean and less than 3,000 km^2 in the Pacific (Sánchez-Páez *et al*. 2000), and that seagrass beds, which occur only in the Caribbean, cover 421 km^2 (Díaz *et al.* in press) are all very precise facts that pertain to Colombian marine biodiversity. The nearly 2,500 species of molluscs, 120 of sponges, 144 of corals, 2,000 of marine fish, seven of marine reptiles, and eight of marine mammals that are known to occur in Colombian waters are also numbers that might not be far from the expected totals. However, the species inventories of other marine groups such as worms, bryozoans, echinoderms, and crustaceans are still very incomplete. It has even been suggested that the numbers of species in these groups recorded to date represents only 50 % of the likely totals that can be expected for Colombia, a tropical country with extensive coasts and marine territories in both the Caribbean and the Pacific (Arias 1998; Lemaitre 2002). Furthermore, our knowledge about the functional dimension of biodiversity is very fragmentary and scarce. A comprehensive view, on the ap-

propriate scale, of the environmental complexity of the coastal, marine, and oceanic Colombian territories, as well as of the spatial and temporal processes involved, is still very.

Marine scientific research has become, and should be, the *sine qua non* requisite for sustainable use and protection of the sea. It is obvious that people whose decisions affect marine life and their uses need to understand what species and ecosystem processes occur in their coastal waters, where an ocean current comes from, what a fish species feeds on, how the breeding biology of any species affects or directs its distribution, and how pollutants affect organisms. On the other hand, the quality of the science, which determines how effectively researchers can provide needed information to decision makers, depends greatly on the training of the scientists, the facilities and funding available to them, and their status and recognition in society. In regard to this, despite the institutional efforts made in the last years, and even though the Colombian Government has recognized the importance of availability and ready access to scientific knowledge in order to make informed choices among options for environmental management (MMA 2002), scientific knowledge about Colombian marine biodiversity is still seriously lacking.

The reduced budget available for marine research, which mostly requires highly sophisticated equipment and specially trained personnel and makes it, in general, much more expensive than terrestrial investigations, necessitates thematic and geographical research priorities addressing problems of regional or national relevance. With this in mind, the National Marine Biodiversity Research Program (NMBRP), launched by the Ministry of the Environment in 2000, contemplates a 10 year action plan. To start with, a series of consultations and workshops involving biodiversity experts and managers was organized (INVEMAR 2000). The discussions began with an exhaustive analysis of the existing information about Colombian marine resources and biodiversity according to 12 main issues which included the 5 thematic areas of the Jakarta Mandate (Decision 10 of the II Conference of the Parties of the CDB toward conservation and sustainable use of marine biodiversity) and the complementary measures recommended for the implementation of the CDB in the marine environment (Fontaubert *et al.* 1996). The 12 issues are: Ecosystems characterization, species characterization, endangered species, marine protected areas, bioprospection, information systems, impact assessment by extractive techniques, ecosystems monitoring, species monitoring, traditional knowledge, prevention and reduction of marine pollution from terrestrial sources, and introduced species. The exercise greatly contributed to gaining an accurate insight into what is really known and finally led to identifying major information gaps and future research projects to address particular problems of local, regional, or national relevance. According to their urgency, pertinence, and current capacity, 53 major priority goals or projects were identified and arranged in short (1-4 years), medium (5-10 years), and long (>10 years) term categories (INVEMAR 2000). Of these goals, 14 are at the national or macroregional scale and 39 at the regional or local scale. Among the most important in the first category are some focused on the organization of biological collections and data bases, the strengthening of species inventories and publication of species catalogues, implementation of monitoring programs in strategic ecosystems, and the assessment of the vulnerability of biodiversity to climatic change (ENSO, sea level rise). At the regional level, the most important goals to be achieved deal with the characterization of the upwelling systems, the assessment of genetic links between coral reef areas in the Caribbean, and the investigation of the impacts of commercial fisheries on the shelf bottom communities in areas of intensive bottom trawling activity.

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