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MARINE BIODIVERSITY IN BRAZIL: THE CURRENT STATUS

BIODIVERSIDAD MARINA EN BRASIL: ESTADO ACTUAL DEL CONOCIMENTO

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ABSTRACT

Brazil has one of the highest biodiversities in the world, both in the terrestrial and the marine environment. Thanks to its extensive coastal line, Brazilian marine flora and fauna are composed of species from many different marine bioregions. The ecosystems on the south-eastern and southern coasts have received considerable attention but, due to the great impact of human activities such as tourism, over-exploitation of marine resources, physical alteration, oil related activities and pollution among others, this environment is under great risk and its biodiversity is threatened. The most representative ecosystems of this region include sandy beaches, rocky shores, sea grass beds, soft bottom communities and mangrove forests. On the northern coast where the Amazon reaches the ocean, there is a complex group of freshwater, estuarine and marine ecosystems; the habitats there are very diverse and poorly known. This paper summarizes the known, which is the information currently available in Brazil in various types of publications resulting from research in marine biodiversity and the different ecosystems. As the unknown, a research priority is proposed involving the completion of a list of species and an assessment of the state of health of the main ecosystems on a national scale. This new information will need to be integrated and summarized in countrywide Geographic Information System (GIS) databases, accessible to the scientific community as well as to the management agencies. In the long-term, a genetic inventory must be included in order to provide better knowledge of the biological resources. Possible future projects at the local (Brazil), regional (Atlantic, off South America) and global (the whole of South America) scale are envisaged.

KEYWORDS: Brazil, tropical, marine biodiversity, conservation.

RESUMEN

Brasil se encuentra entre los 10 países con mayor biodiversidad en el mundo, tanto en el ambiente terrestre como en el marino. Dada su larga línea costera, la flora y fauna marina brasileña está compuesta por especies de biorregiones muy distintas. En la costa sudeste y sur, los ecosistemas han recibido una atención considerable, sin embargo, debido al tremendo impacto de actividades humanas tales como el turismo, sobreexplotación de recursos marinos, alteración física, la industria petrolera y contaminación, entre otras, este ambiente se encuentra bajo un gran riesgo y su biodiversidad está altamente amenazada. Los ecosistemas más representativos de esta región incluyen las playas arenosas, litorales rocosos, praderas de fanerógamas marinas, comunidades de fondos blandos y bosques de manglar. En la costa norte el aporte Amazónico está constituido por un grupo muy complejo de ecosistemas marinos, estuarinos y dulceacuícolas, los habitats son muy diversos pero hay muy poca información disponible acerca de este sistema. En este trabajo resumimos lo conocido, lo cual es toda la información disponible en Brasil acerca de la investigación científica en biodiversidad, los diferentes ecosistemas y el grado de conocimiento que ha sido generado a través de diversos tipos de publicaciones. Igualmente, como lo desconocido, proponemos como prioridad de investigación la estimación de área, el listado completo de las especies y el estado de salud de los principales ecosistemas a una escala a nivel nacional. Esta nueva información debe ser integrada y resumida en bases de datos de Sistemas de Información Geográfica, accesible a la comunidad científica así como a las agencias encargadas de los planes de manejo. A largo plazo debería incluirse un inventario genético como una necesidad para establecer un mejor conocimiento de los recursos biológicos. Proponemos posibles proyectos a futuro en una escala local (Brasil), regional (América del Sur Atlántica) y global (América del Sur).

PALABRAS CLAVES: Brasil, tropical, biodiversidad marina, conservación.

INTRODUCTION

The concept of biodiversity is complex and may be studied at the genetic, specific and ecological level, each of them sharing particular characteristics and interrelationships (Crisci *et al*. 1996). The most studied are species and ecosystem diversity, genetic diversity being known partially for some species. The exploitation of biodiversity is currently considered to be one of the main tasks for biology (May 1988) because of the destructive influence of human activities on the biota. Political actions have highlighted a need for inventories and management of biodiversity and, now, many countries have their own biodiversity action plans. Brazil is no exception and documentation and legislation are in the process of being drawn up.

In terrestrial terms, Brazil is recognized as one of the countries with the greatest richness of species in the world; it also has very high levels of endemism. Indeed, Brazil has been identified as the world's "hottest hotspot", biologically speaking.

No attempt to assess the richness of marine life in Brazil in a similar manner and place it in a global context has, so far, been made. Extensive areas of the coast, the continental shelf and particularly of the deep sea remained to be surveyed. Although the evidence from theses and dissertations suggest that the variety of marine species (and endemism) is very high, the patchy nature of these studies has precluded an overall evaluation of the Brazilian marine domain and has, as a consequence, limited global comparisons.

The Brazilian coastline is about 7,400 km long, extending from Cape Orange to Chuí. A compilation of geological, geographical, climatic, hydrographic and sedimentological criteria used for classifying the coast was developed by Ekau & Knoppers (1999). Following this study, the Brazilian coast may be divided into five regions:

1) North: from the mouth of the Oiapoque River (4°16'N) to that of the Parnaíba River (3°S).

2) Northeast: from the Parnaíba River to Todos os Santos Bay (13°S).

3) East: from Todos os Santos Bay to Cape São Tomé (22°S), including the Abrolhos archipelago (17°55'S; 38°42'W).

4) Southeast: from Cape São Tomé to Cape Santa Marta Grande (28°40'S).

5) South: from Cape Santa Marta Grande to Chuí (34°45'S).

The Brazilian continent lies directly in the pathway of the South Equatorial Current which reaches the Northeast Brazilian Shelf between 11 and 15°S. Part of the this current flows northward to continue as the North Brazil Current, and another part forms the southward flowing Brazil Current. The North Brazil Current is dominant on the outer Amazon Shelf. The Brazil Current impinges on the narrow Eastern Brazilian Shelf, besides being the main forcing mechanism for outer shelf flow southwards in all of the regions considered. The outflow of fresh Amazon River water and sediments onto the shelf extends for hundreds of kilometres across and northwestward along the shelf. The impact of the Brazil Current on the shelf system from Cape São Tomé to the south gradually diminishes in comparison to the east. The Southeast and South regions are subject to more intense shelf edge and wind-driven coastal upwelling from South Atlantic Central Water in the summer. High volumes of low-salinity water are also observed over the Southern Brazilian Shelf. These waters arrive on the shelf from the Patos Lagoon and the northward inner-shelf advection of brackish water, probably originating from the Plata River estuary (Castro & Miranda 1998; Ekau & Knoppers 1999).

The geomorphological configuration of the shelf is diverse. The broadest shelves occur in the North with widths of up to 320 km while, in the Southeast and South, they are up to 220 km wide. In contrast, the Northeastern and Eastern parts are narrow, varying between only 20 and 50 km wide. The exception is the Abrolhos Bank which extends up to 220 km off shore (Ekau & Knoppers 1999). The Brazilian coastline has a variety of estuaries, backwaters, coastal lagoons, sandy and rocky beaches and coral reefs. Along the coast, urban areas and industrial plants cause environmental problems. In the open sea, on the other hand, the oceanic islands cause most of the observed effects.

The greater part of the Brazilian coastline is situated in tropical waters and hosts a large variety of species with relatively low productivity as compared to cold water environments where a lower diversity

of species with high productivity is observed. Brazilian tidal ranges decrease southward from being strongly macrotidal, with amplitudes greater than 8 meters, in the north to mesotidal (range 0.2 to 2 m) in the south. Mean annual rainfall varies greatly along the coast with the highest values in the north of Amapá state (3,250 mm) and the lowest in the northeastern states where evapotranspiration and precipitation values tend to be similar. Most of these regions suffer from droughts and hypersalinity that cause seasonal environmental stress.

The aim of the present contribution is to compile and critically analyze the information currently available about the diversity of Brazilian marine life in order to identify the gaps in our knowledge and indicate future research targets.

For this purpose, data were collected from various types of publication. Acceptable sources were considered to be published papers, master and doctoral theses, graduate dissertations, abstracts of the proceedings of meetings and web databases-a list is available from the authors. The main sources were the REVIZEE program technical reports and review articles.

PLANKTON, NEKTON AND BENTHOS

PLANKTON

Gelatinous plankton – jellies or jellyfish- is an alternative name for these animals. They are similar in appearance with bodies that are 95% liquid and usually transparent. Gelatinous animals are present in at least five phyla-the ctenophores, cnidarians, molluscs, polychaete worms and tunicate chordates. Within the Cnidaria, the classes Hydrozoa, Scyphozoa and Cubozoa are combined in the subphylum Medusozoa because metagenesis may occur with an alternation between the polyp and the medusa (Barnes *et al*. 1993). There is a tradition, mainly among Hydrozoa experts, to adopt independent systematics for the polyp and medusa stages. It would, however, be better to establish the exact relationship between polyp and medusa in order to overcome the duplication of the systematic (Migotto *et al*. 1999). According to Bouillon (1985), out of about 4,000 known species of Hydrozoa, only 25 % of the life cycles are known. Bouillon & Boero (2000) calculated that, globally, some 1,086 species of hydromedusae have been described but at least 244 are in doubt. Live animals need to be studied in order to discover more about their life cycles. Another difficulty in studying planktonic cnidarians is that the samples are often in a bad condition when caught by means of standard techniques using plankton nets. Bouillon (1999) strongly recommended that hydromedusae should be sorted soon after being caught and studied while still alive. Pugh (1999) stated that the best results when studying siphonophores are obtained with animals sampled *in situ* by SCUBA divers or submersibles. Tronolone (2001) made the important point that, with planktonic hydrozoans, cultivating and observing the animals in the laboratory results in much better systematic knowledge for a limited area, such as the waters of the São Sebastião Channel on the north coast of São Paulo State, as compared with previous studies of preserved medusae which had been caught with plankton nets towed over large areas. This author recognized 32 species, very similar to the number of 39 identified by Navas-Pereira (1981) for the entire coast of Rio Grande do Sul State, besides discovering two new species for the entire coast of Brazil and providing further information about the development of another seven-something that is almost impossible to achieve studying preserved medusae even soon after sampling.

An updated checklist of all the published records of Cnidaria Medusozoa along the Brazilian coast (Migotto *et al.* 2002) listed 373 species - 347 Hydrozoa, 3 Cubozoa and 23 Scyphozoa, either as polyp or medusa, or both (except for the Siphonophorae). This did not include the recent work by Bouillon (1999) as it was impossible to be sure of the exact records for the Brazilian coast as well as for the broad western margin of the South Atlantic, which includes offshore species.

So far, only four species of jellyfish have been recorded as stingers in Brazil. These are *Tamoya haplonema* and *Chiropsalmus quadrumanus* (Cubozoa), which are likely to be observed on most of the Brazilian coast and have been responsible for some severe accidents (Morandini & Marques 1997; Haddad Jr. 1999, 2000); the hydrozoan colony *Physalia physalis* that can cause severe injuries to bathers and fishermen (Freitas *et al*. 1995; Haddad Jr. 2000); and the hydrozoan medusa *Olindias sambaquiensis* that provokes mild accidents on the Southeastern coast (Haddad Jr. 2000).

Although studies of the ichthyoplankton of the

Brazilian coast are regarded as important, they have mostly been undertaken only on the south-southeast continental shelf, with only a limited amount of work on the north-northeast continental shelf and coastal areas in general.
An important atlas showing the composition of the zooplankton of the South Atlantic with contributions from many authors (Ed.: Boltovskoy 1999) provides information on many animal groups that can be regarded as gelatinous plankton based on extensive literature surveys. None of the chapters on gelatinous animals contained contributions from Brazilian scientists, however.

Nekton

The ichthyofauna of the Brazilian continental shelf is made up of tropical and temperate water species from both the northern and southern hemispheres, and some endemic species. The northern coast is part of the Caribbean marine zoogeographical province (Palacio 1977) while the southern coast is in the Argentinean province which extends from 22° to 42° S (Figueiredo 1981). More than 900 species of fish have been recorded in Brazilian marine waters, of which 56 are endemic (Carvalho Filho 1999).
There are several species lists and some reports about the composition and variation of the icthyofauna. Data on the ecology of fish are scarce and mainly limited to studies of commercially important species. Most of the studies were conducted off the southern coast where the demersal ichthyofauna is quite well known, in contrast to the northeastern coast. The Abrolhos archipelago (18°S), located in this region, is one of the most visited Brazilian marine parks. Despite being known for its high biodiversity, the region is still poorly studied. Fishing around the protected area and excessive tourism are potential risks for the conservation of the bank.
The Elasmobranchii, the least studied group of fish in Brazil, is at risk due to fishing and habitat destruction. At least 17 species are already considered to be in danger of extinction (MMA/SBF, 2002).
The Brazilian coast also hosts a high diversity of species from the other groups which make up the nekton. Five out of the seven marine *Chelonia* species of the world occur here, using the littoral areas and oceanic islands for reproduction. The "Projeto Tamar" develops studies of the life cycles of these species and programs aiming at their conservation (Marcovaldi & Dei-Marcovaldi 1999).
The marine mammal fauna are composed of Cetacea, Pinnipedia and Sirenia. Two of the four Sirenia species in the world occur here, *Trichechus manatus* and *Trichechus inunguis* (MMA/SBF 2002). Both are endangered species. Among the Cetacea, 38 species have been identified in Brazilian waters, corresponding to 49% of the species around the world. The humpback whale *Megaptera novaeangliae* comes to the Brazilian coast for reproduction. Only seven species the Pinnipedia have been reported, mainly from southern waters (MMA/SBF, 2002). There have been very few studies of the biology of these two groups.
Slightly more than 100 species of birds are considered to be coastal or marine in Brazil (MMA/SBF 2002). In the north region, the occurrence and reproduction of endangered species were observed. There are many nesting sites along the coast which is also visited by migratory species.

Benthos

Although fungi and especially bacteria are extremely abundant on the surfaces of marine bottoms, principally in soft sediments such as mud, studies of them along the Brazilian coastline are very scarce. Only a few papers on this theme, relating to the Patos Lagoon in the extreme south of Brazil, are available. Several different groups of benthic microalgae are recognized including diatoms, dinoflagellates, filamentous green and cyanobacteria. Among these, the diatoms are usually the most numerous ones with pennate forms, such as *Navicula* and *Nitzschia*, predominating. The taxonomic and ecological aspects of microalgae in Brazilian marine systems have been little studied though some work on the south-eastern coast, principally São Paulo state, has been carried out.
Macroalgae exhibit high endemism in Brazilian marine waters. According to Figueiredo (in press), they have been thoroughly studied in the South and Southeast, but extensive gaps in the North and Northeast regions remain. Brazilian marine macroalgae include around 642 infrageneric taxa and are considered to be less diverse than in many other tropical regions (Norton *et al*. 1996). The

Rhodophyta is the richest algal group followed by the Chlorophyta and the Phaeophyta. The Brazilian northern tropical region has smaller proportions of the total macroalgal taxa than the southern warm temperate region. In the north and north-eastern areas, biogenic reef systems seem to contribute to a higher level of species richness as do the rocky shores in the southeast and south, due to greater habitat heterogeneity. Mangroves and estuaries have fewer species. Macroalgae surveys have, in general, been carried out only in limited areas of Brazil rather than over large geographical regions (see Oliveira Filho 1977). Most floristic studies which describe species distributions give little information about their habitats. Descriptions of macroalgal flora may include species from different ecosystems, such as reef systems, seagrass beds or mangroves, in the northeast, lumped together for one geographical area. The same is found for southern regions where rocky shores, sandy beaches, and estuaries are contiguous. Because of this, the contribution of each habitat to total species richness remains unknown.

Benthic microfauna include all the heterotrophic Protista. Normally, foraminifera and ciliates are the most numerous. On the Brazilian coast, foraminifera, because of their importance in petroleum prospecting, have been studied more intensively. Unfortunately, other groups have not received equal attention. Meiofaunal groups are poorly studied components of the Brazilian marine benthos. Few specialists work on this subject. Most groups of organisms have been identified only at the phylum level. The composition, structure and ecological role of the meiofauna remain unclear.

The macrofauna are usually much larger and easier to study than the meiofauna and much more is known about their taxonomy and ecological function in Brazilian coastal systems-though deep-water forms remain practically unknown. Taxonomically speaking, the best known groups of the macrofauna are cnidarians, polychaete worms, crustaceans (except small groups such Tanaidacea, Cumacea and others), molluscs (principally bivalves and gastropods) and echinoderms. Other invertebrate groups are very poorly identified (Lana *et al*. 1996). Benthic fish, too, have been little studied. In general terms, research has been restricted to the shallow waters off most of the Brazilian coast and concentrated in the south-southeast region.

CURRENT KNOWLEDGE AND EXPERTISE IN BRAZIL

Of the approximately 30 free-living metazoan marine phyla world-wide, only 18 have been reported from Brazil. In other words, our understanding of diversity at the phylum level in Brazil is poor. In mitigation, perhaps, the missing phyla are all relatively small, have been poorly collected or newly described and, generally, have few devotees.

For those taxa of which Brazil has representatives, the known diversity is generally high. This is not surprising given its geographical position and the prevailing patterns of oceanic circulation since planktonic and motile organisms and highly mobile creatures, such as cetaceans, turtles and birds are common. However, it is equally clear that richness is also high among some of the large benthic taxa, such as gastropod molluscs and decapods crustaceans. This can be attributed to the wide range of ecosystems in the region which straddles several marine biogeographical provinces.

Endemism is also considered to be at a high level. Caution should be exercised in accepting this, however, because estimates of endemism may be influenced by the intensity of local or international studies. A taxon that has been well documented in Brazil may be poorly investigated in other countries and this could exaggerate the level of Brazilian marine endemism. On the other hand, the data may, in fact, underestimate actual endemism, owing to the generally poor coverage of Brazilian marine ecosystems.

In some cases (such as octacorals and molluscs, for example), endemism can be very high. Not surprisingly, it is less marked in pelagic and migratory or motile taxa than it is among benthic taxa, especially those without a planktonic larval phase.

Towards the end of the last century, the scientific community of São Paulo State working in the recently created BIOTA/FAPESP updated, with the support of the local Fundação de Amparo à Pesquisa do Estado de São Paulo (the Foundation for the Development of Research in São Paulo State), its information about the composition of the biota with the publication of a set of books, in seven volumes, entitled "Biodiversidade do Estado de São Paulo, Brasil: síntese do conhecimento ao final do século XX" (The Biodiversity of São Paulo State, Brazil: synthesis of the knowledge at the end of the XX century) (Editors: C. A. Joly & C. E. de M. Bicudo).

BRAZILIAN COASTAL ECOSYSTEMS

ESTUARIES AND COASTAL LAGOONS

Little is known about estuarine and coastal lagoon fish species. Fewer than 10% of over 100 Brazilian estuaries have so far been studied, with the number of species cited ranging from 21 to 118 (Vazzoller *et al.* 1999). The two more important systems are the estuary of the Amazon River (0 - 3°S) and the Patos coastal lagoon (32°S).

Only one study of the fish population of the Amazon River estuary and the continental shelf off its mouth has been made (Barthem 1985) even though there are important fisheries catching both freshwater and marine species, mainly from the Pimelodidae, Ariidae, Sciaenidae, and Mugilidae families.

The Patos lagoon is the biggest coastal lagoon in Brazil with an area of 10,360 km^2. It has been consistently studied and there is information about its faunal composition (Chao *et al*. 1985) and the biology of the most important fish species (Haimovici 1997). The estuary of the lagoon supports a large fishery, mainly of shrimps, Sciaenidae and Mugilidae species.

MANGROVES

According to earlier estimates, mangrove forests cover around 1,012,376 ha (Hertz 1991). This corresponds to 0.12 % of the total area of Brazil. This is probably an overestimate, however. Mangroves are found from the mouth of Oiapoque River (04^{o}30'N) to Laguna (28^{o}30'S) under a wide range of environmental conditions. This is reflected in the variable tree forms, the spatial distribution of species and their structural characteristics. The Brazilian mangrove species are: *Rhizophora harrisonii, R. racemosa, R. mangle, Avicennia germinans, A. schaueriana, Laguncularia racemosa* and *Conocarpus erectus*. This apparently low number of species is deceptive since they are extraordinarily adaptable to their environment.

Mangrove forests on the Brazilian coast have a great importance for the local fisheries. Only 20% of the species of shrimps of economic importance have no links with mangroves. The others spend 3 or 4 months in the estuaries covered by mangroves or at river mouths where mangrove organic debris is abundant. The major commercial species are all reliant on mangroves. Mangrove fauna also include crabs, oysters, clams and shrimps, all of which are important resources and support significant fisheries.

Studies of mangroves have concentrated on the general ecology of a few large sites, and on the spatial and temporal distribution of economically important species, particularly crabs, shrimps and oysters. A few lists of species and some reports on the biology of the ichthyofauna are also available.

Three species of vertebrates that occur in the Brazilian mangrove areas are in danger of extinction: the mangrove monkey (*Chipotes satanas*), the manatee (*Trichechus manatus*) and the red bird (*Eudocinus ruber*).

Recent advances in mangrove research show the necessity to quantify how the economic value of these ecosystems depends upon their physical, chemical and biological integrity. The main activities in most mangrove forests are artisanal fisheries, salt and firewood extraction, clam and crab harvesting, shrimp culture, and tourism. The rapidly expanding tourism industry has had a major impact on mangroves because of their coastal location. Many mangroves sites have been lost or reduced in size as a result of resort expansion, the construction of airports and marinas and the filling-in of mangrove swamps in order to reduce troublesome insect populations. Industrial development has created serious problems of contamination, especially for oyster culture. Natural oyster banks have disappeared in areas where waste waters, of urban, industrial or agricultural origin, are released. Mangrove forests have important ecological functions and the optimization of the state of the ecosystem depends on the preservation of the water and habitat qualities. Preserving mangrove areas as nursery grounds and food sources for fish and crustaceans, for example, and protecting the coastline will improve habitat quality and sustain fisheries (Vannucci 1999).

SEAGRASSES AND THEIR HABITATS

The southern Brazilian coast is a transitional zone between the tropical mangroves and the warm temperate saltmarshes. The latter, formed principally of grasses such as *Spartina alterniflora, S. densiflora* and sedges, have traditionally been consid-

ered as structural and functional components of mangroves in the tropics and sub-tropics. However, extensive studies of the structure and temporal variability of benthic macrofauna do not support this viewpoint (P. Lana *et al*. unpublished work). Submerged macrophytes, in general, and seagrass beds in particular are ecologically recognized as very important habitats of the coastal zone (Larkum *et al*. 1989; Den Hartog & Phillips 2000) and they contribute to the biodiversity of soft sediment environments. Three genera of seagrasses, *Halodule*, *Halophyla* and *Ruppia*, are recognized though their taxonomy and diversity are still being examined. In this context, up to seven species have been reported to occur on the Brazilian coast. This represents ca. 9 % of the global number of species. Brazilian seagrass flora is not numerous though *Halodule emarginata* and, possibly *H. brasiliensis*, are endemic (Creed 2000). However, the seagrasses of Brazil show a high degree of morphological variability and the isolation of the beds has led to subspeciation.

In Brazil, *Halodule* and *Halophyla* species are usually associated with sandy or muddy beaches, and near rocky shores, beach rock reefs, coral reefs and coralline sand. *Ruppia* (not a true seagrass but ecologically equivalent) has been found in the vicinity of mangroves, in estuaries, in hyper- and hyposaline coastal lagoons and in fish ponds (Creed 2000).

About 540 animal taxa (to genus or species level) are associated with Brazilian seagrasses. The groups which contribute most to this richness are polychaetes, fish (mainly larval and juveniles stages), crustaceans (amphipods and decapods), molluscs, foraminifera, macroalgae and diatoms. In the north and northeast of Brazil, the giant green turtle (*Chelonia mydas*) and the manatee (*Trichechus manatus*) feed on *Halodule*. Economically important species found in Brazilian seagrass beds include fish, shrimps, crabs, swimming crabs, lobsters, molluscs, corals and seaweeds.

According to Creed (2000), Brazilian seagrasses remain largely unstudied. Little is known about the effects of pollution and other impacts upon them. Only two Brazilian Marine National Parks have *Halodule* and *Halophyla* beds in their protected areas. Future investigations will continue to increase our understanding of the biodiversity of these communities. The trophic structure of communities, interactions between seagrass and other habitats, habitat diversity and the genetic variability of seagrass populations have yet to be investigated.

SANDY SHORES

Although most of the Brazilian coastline is sandy, the first reports in the scientific literature on the ecology of sandy beaches appeared only in the 1980s. Brazilian sandy beaches exhibit great variability in morphodynamic characteristics which, besides other factors such as wave energy and grain size, are apparently also controlled by long term trends in shoreline configuration.

There are very few data on temporal variations in the macro-and meiofaunal communities of Brazilian sandy beaches. Macrofaunal composition, zonation, aspects of community structure and population dynamic studies were made for the sandy beaches in a few areas. Mole crabs (genus *Emerita*), coquine clams (genus *Donax*), and spionids polychaetes are the dominant organisms. Preliminary results suggest that these communities are regulated mainly by physical factors.

Information about beaches as nursery areas for fish larvae is practically non-existent. Studies of the ichthyofauna are also scarce and concentrated in the south-southeast region.

CORAL REEFS AND OTHER REEF SYSTEMS

The marine reef systems of Brazil are shallow hard substrata near to or at some distance from the coast, including the oceanic islands. There are still large gaps in the knowledge of the geology as well as of the composition of the biota established on reef tops. For some areas, reef studies are still pending, the logistical difficulty of getting them, being the main reason. Vilaça (2002) recognizes three main types of reef structures-sedimentary rock ("beach rocks"), bioorganic, and deep crust rock. The sedimentary and bioorganic reefs seem to be unique structures along the Brazilian coast and may possibly be related to the last major changes in sea level (Laborel 1969/70). The deep crust rock reefs are often observed along the southeast and south coast of Brazil from Rio de Janeiro State to the north coast of Rio Grande do Sul, and on many oceanic islands both close to the mainland and far offshore. The sedimentary rock reefs are mainly the long, straight, beach rock lines that emerge during low tides and

are observed from Natal (approximately 6° S) to the mouth of the São Francisco River (approximately 10° S) (Castro & Pires 2001). Additional beach rock systems are observed along the north coast of Espírito Santo (Longo 1997) and Bahia State (personal observations). The bioorganic reefs include coral reefs and coralline algal reefs (Vilaça 2002). Probably, the best known algal reef in Brazil is that of the oceanic Rocas Atoll, around 266 km off the northeast coast of Brazil. This is the only atoll known in the South Atlantic. The coralline algae *Porolithon* spp. form the main recent structure, with vermetid molluscs, encrusting foraminiferans, stony corals and tubes of polychaetes worms also incorporated. This involvement of coralline algae with the development of reefs, both on their crests and along large areas, appears to be widespread in the coral reefs in Brazil – e.g. those in the Abrolhos reef area. Castro & Pires (2001) reviewed the status of knowledge of Brazilian reefs with emphasis on the coralline type. Large coral reef communities were recorded from near the Equator (at 00° 53'S) to as far south as Cape Frio (23°S), but the southernmost true reefs are in the Abrolhos area (18°S). Fifteen scleractinian species (5 endemic) have been described. The hydrozoans milleporids play an important role on some reef crests and are believed to be the ecological equivalents of the shallow water stony corals, e.g. *Acropora* spp., which forms reefs in other areas (Table I). Knowledge of the rich assemblage of stony corals and milleporids in Maranhão State was obtained a few years ago and is restricted to the submerged reefs, at depths of 20 or more meters, of the Parcel do Manuel Luiz area. The most unexplored area is that between Parcel do Manuel Luiz and the Cape of São Roque which extends for more than 1,000 km along the north coast of Brazil. A part of the northeast coast of Brazil, from Natal to the mouth of the São Francisco River, has been called "The Reef Coast". This section is some 600 km long and there are reports of still unmapped submerged banks, probably on top of sunken beach rock. Three different types of carbonate structures - algal crusts, coral-algal communities and coral reefs - were identified in the northern part of Bahia State (Kelmo & Attrill 2001).

Leão (1996) reviewed the morphology and distribution of the reefs over some 900 km of shoreline from the mouth of the São Francisco River to the south of Bahia State-the Abrolhos region. Most of the submerged reefs in the area are still poorly known. The Abrolhos area is located on a widening section of the continental shelf (up to 200 km wide). It is the largest and richest coral reef area in the South Atlantic Ocean. There are several reef structures including fringing reefs, isolated columns (the unique chapeirões), and offshore bank reefs. Coral covers of up to 39% were detected in some of the Abrolhos reefs with an average of about 15% for the area. The region from Abrolhos south to Santa Catarina State in southern Brazil represents the southern limit of coral reefs (Table I).

Coastal and oceanic islands

Brazilian oceanic islands are all the result of volcanic eruptions with the exception of the Rocas Atoll which has a volcanic base and an organic top made of coral, incrustant macroalgae and limestone. Their distance from the mainland has allowed the adaptation, differentiation and appearance of endemic species, both aquatic and terrestrial. Large colonies of seabirds breed on the islands or pause there during trans-continental migrations.

The island of Trindade is about eight km by two km with a maximum altitude of 610 m above sea level. It lies 600 nautical miles off the Brazilian coast, at the latitude of Vitória in Espírito Santo State and is an important nesting site for giant green turtles, *Chelonia midas* which lay their eggs on the island's sandy beaches at night.

The Martin Vaz group of islands is made up of a main and several smaller islets located 35 miles from Trindade. Even the main island is extremely small. Several species of seabirds breed on the islands including giant boobies (*Sula dactylatra*), fairy terns (*Gygis alba*), and frigatebirds (*Fregata ariel* and *F. minor* and an endemic sub-species, the greater frigatebird, *F. ariel trinitatis*). Their breeding season is from July to August and again in December. Another species breeding on the island is the herald petrel, *Pterodroma arminjoniana*, the only member of the Porcellariidae family to breed on Brazilian territory.

The Rocas Attol has the shape of a hoof print when seen from the air. It is 144 miles from the South American mainland (Rio Grande do Norte state), and has a total area of 36,000 hectares, including the surrounding waters out to a depth of 1,000 m. Around 148,000 seabirds live amongst its scrub veg-

TABLE I. Species list and distribution of stony corals (Scleractinia, A - P) and hydrocorals (Milleporidae, Q - U) along the Brazilian coast (abbreviations of coastal State names from north to south are in the left hand column). (A) *Madracis decactis* (B) *Stephanocoenia michelinii* (= S. *intersepta*) (C) *Agaricia agaricites* (D) *Agaricia fragilis* (E) *Siderastrea stellata* (F) *Porites branneri* (G) *Porites astreoides* (H) *Favia gravida* (I) *Favia leptophylla* (J) *Montastraea cavernosa* (L) *Meandrina braziliensis* (M) *Mussismilia harttii* (N) *Mussismilia hispida* (O) *Mussismilia braziliensis* (P) *Scolymia wellsi* (Q) *Millepora alcicornis* (R) *Millepora nitida* (S) *Millepora braziliensis* (T) *Millepora squarrosa* (U) *Millepora* sp.

Notes: [1]Endemic species, but restricted to the coast of Bahia State and to a depth of 20 m. [2]Endemic species on the Brazilian coast.

TABLA I: Listado de especies y distribución de corales rocosos (Scleractinia, A-P) y de hidrocrales (Milleporidae, Q - U) a lo largo de la costa Brasileña (Las abreviaciones de los nombres de los estados costeros de Norte a Sur están en la columna del lado izquierdo). (A) *Madracis decactis* (B) *Stephanocoenia michelinii* (= S. *intersepta*) (C) *Agaricia agaricites* (D) *Agaricia fragilis* (E) *Siderastrea stellata* (F) *Porites branneri* (G) *Porites astreoides* (H) *Favia gravida* (I) *Favia leptoph ylla* (J) *Montastraea cavernosa* (L) *Meandrina braziliensis* (M) *Mussismilia harttii* (N) *Mussismilia hispida* (O) *Mussismilia braziliensis* (P) *Scolymia wellsi* (Q) *Millepora alcicornis* (R) *Millepora nitida* (S) *Millepora braziliensis* (T) *Millepora squarrosa* (U) *Millepora* sp.

NOTA: [1]Especies endémicas, pero restringidas a la costa del Estado de Bahia y a una profundidad de 20 m. [2] Especies endémicas de la costa Brasileña.
(Modified and updated from Bélem *et al*)

	A	B	C	D	E[2]	F	G	H	I[2]	J	L	M[2]	N[2]	O[1]	P	Q	R[1]	S[2]	T	U[2]
MA	X		X	X	X	X	X	X	X	X	X		X		X	X		X		X
PI		X			X			X				X				X		X		
CE		X			X			X				X				X		X		
Rocas F.Nor.	X		X	X	X	X	X	X		X	X	X	X		X	X	X	X		
RN		X	X		X	X	X	X		X	X	X	X		X	X		X		
PB		X	X		X	X	X	X		X	X	X	X		X	X		X		
PE		X	X		X	X	X	X		X	X	X	X		X	X		X	X	
AL		X	X		X	X	X	X		X	X	X	X		X	X		X		
SESÃO FRANCISCO RIVER BARRIER																				
BA	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
Abrolhos	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
ES	X		X		X	X		X		X	X	X	X			X		X		
RJ	X				X	X					X		X			X				
SP	X												X							
PR	X																			
SC	X						X													

etation. Thousands more visit the island at different times of the year whilst migrating.
In these habitats, several species of fish are endemic such as those that are found only in Fernando de Noronha, the Rocas Attol and around the St. Peter and St. Paul Rocks-*Stegastes rocasensis* and *Thalassoma noronhanum*. Some animals there are in threat of extinction, e.g. the humpback whale (*Megaptera novaeangliae*), sea turtles (the giant green turtle, *Chelonia* midas; the hawksbill turtle, *Eretomochelys imbricata*; the loggerhead turtle, *Caretta caretta* and the leatherback turtle, *Dermochelys coriacea*), the sea manatee, *Trichechus manatus* and some species of fire coral, *Millepora nitida* and *M. braziliensis*.
Brazilian islands and their biota have been little studied considering their number and importance as reserves of marine biodiversity. Nevertheless, some species, because of being threatened with extinction or due to specific behavioural traits, have been the subject of research and even protection, resulting in their guaranteed survival as well as in a deeper understanding of their habitats.

Deep sea habitats

Few taxonomists work on marine organisms in Brazil. In particular, the deep sea areas are very poorly studied and articles on this zone are scarce. This dearth of information is being corrected with the first of a series of reports on the fish fauna between 100 m and 1,500 m deep as a part of the REVIZEE project (Figueiredo *et al.* 2002). At the moment, no cold seeps or hydrothermal vents have been located, but there is growing interest amongst Brazilian scientists to develop research programs to map and study these environmental features and their associated biological communities (Ramírez-Llodra *et al.* 2002).

Coastal and pelagic resources management

Total marine fishery catches increased from 630,000 to 970,000 tones between 1975 and 1994 (IBAMA, in Dias Neto & Dornelles 1996). The Southeast region is responsible for 41 % of this followed by the South region with 32 %. The most important resources are shrimps, sardine, tunas, lobster, pargo, demersal species, and piramutaba (Dias Neto & Dornelles 1996; Paiva 1997). The estuary and the continental shelf off the mouth of the Amazon River supports major fisheries, exploiting both freshwater and marine species, mainly of the families Pimelodidae, Ariidae, Sciaenidae, and Mugilidae. The "piramutaba", *Brachyplatystoma vaillantii*, is the second most important fishery marine resource of the North region, shrimps being the first (Dias Neto & Dornelles 1996).
Shrimp catches are very important along the Brazilian coast, with the species varying between the regions: *Farfantapenaeus subtilis* in the North, *Litopenaeus schimitti* and *Xiphopenaeus kroyeri* in the Northeast, *F. brasiliensis, F. paulensis, Artemisia longinaris* and *X. kroyeri* in the Southeast and South. All of these are heavily exploited and require strict management. Incidental catches of other species are one of the most serious problems associated with shrimp trawling.
Lobsters, mainly *Panulirus argus* and *P. laevicauda*, are an important resource in the Northeastern and Eastern regions, with exports earning US$ 50 – 70 million per annum (IBAMA, in Dias Neto & Dornelles 1996). The snapper, *Lutjanus purpureus*, is also exploited in these regions and exported. In the North and Northeastern regions, the "uçá", *Ucides cordatus*, is one of the most abundant mangrove crabs and the main animal resource for the fishing community there (Dias Neto & Dornelles 1996).
In the Southeast and South regions, the most important demersal fish resources are Sciaenidae species. Almost all of the stocks are overexploited (Haimovici 1997). The estuary of the Patos Lagoon supports a heavy fishery, mainly of shrimps, Sciaenidae, and Mugilidae species (Reis *et al.* 1994).
Pelagic resources are composed mainly of Clupeidae, Engraulidae, Carangidae and Scombridae. *Sardinella brasiliensis*, an endemic species, and *Engraulis anchoita* are the two most common coastal pelagic resources. Apparently, the stocks of *S. brasiliensis* are overfished (Cergole 1995), in contrast to *E. anchoita* (Acuña & Castello 1986).
Offshore, in the waters of the Brazil Current, Scombridae migratory species are important resources, mainly *Thunnus albacares* in the southern region, and *T. alalunga* in the northern region (Zavala-Camin & Antero da Silva 1991).

BRAZILIAN PRIORITIES IN MARINE BIODIVERSITY

In developing countries like Brazil and most of the others in South America, urban, industrial and tourism projects with a large potential for ecosystem perturbation are often installed in pristine habitats before any baseline data about the composition of the biota and the structure and function of the ecosystem can been obtained. A capacity for rapid proactive action in order to gather the necessary reference information seems to be required.

The economic evaluation of the ecological functions of different marine systems and of their resources of economic importance is a complex area of research. On tropical and subtropical coasts, it is an urgent necessity in view of the intensive, unplanned development of these coastlines and the pressure to exploit their natural resources. Despite the economic importance of these ecosystems, they are gradually being destroyed in Brazil. Legislation for their preservation is still of little effect and, in general, is not a priority.

An economic analysis needs an adequate identification of the relevant ecological functions and of the products (or resources) generated. This evaluation may be most important for assessing the importance for sustainable economic activities in a given area of not only commercial developments but those, such as amenity "value", which are difficult to quantify. Getting the correct balance between these represents the difference between destruction and conservation, between irreversible environmental impact and sustainable development.

The conservation of Brazilian marine environments began only recently, in the 1980s, with the setting up of various marine conservation units, including the Biological Reserve of the Rocas Attol (Rio Grande do Norte state), the National Marine Park of Abrolhos (Bahia state), the Reserve of Comboios (Espírito Santo state), and the Biological Reserve of Santa Isabel (Sergipe state). Projects to protect certain threatened species, including marine turtles, manatees, and "jubarte" whales, were also begun.

Another factor bearing directly on the preservation of the marine environment is the changeover from traditional methods of subsistence fishing to modern, industrial scale techniques. Artisanal methods of fishing, once predominant along the Brazilian coast, are disappearing. Coastal communities, always dependent on the resources of the sea, have recently observed the disappearance of various fish species and, faced with competition from industrial methods, are gradually losing interest in fishing. The decline in fish stocks, accelerated by increasing coastal pollution, has occurred even before these have been properly studied. It has also taken employment away from families who were dependent on fishing.

Efforts to guarantee a healthy and balanced marine environment continue, however. Various additional marine conservation units have been created at the federal, state and municipal level, many of them located on islands, reef systems and in pristine areas along the coastline. Accompanying an increasing interest in conservation in Brazil, these projects are aimed at species preservation and a return to the traditional activities of the coastal communities.

Present studies of Brazilian marine diversity are not coordinated and are mostly reported in academic theses. In general, Brazilian marine systems remain largely unstudied. The genetic variability of populations, their trophic structure, and interactions between different systems have yet to be investigated.

The Brazilian exclusive economic zone (EEZ) encompasses about 820,000 km². Sampling of this has been patchy though several important articles and monographs have been published. The larger and more conspicuous organisms of the rocky intertidal and mangrove areas have been well sampled at a national level, as have the shallow subtidal waters of the southern and south-eastern coasts. Unfortunately, the same cannot be said for the shallow-water flora and fauna of the north and north-eastern coasts, or for the biota other than fish and the megafauna in shelf waters. The fauna of the deep waters around the country are completely unknown. Up to now, the total number of species reported for the marine waters of Brazil is around 8,100.

Despite its presumed high marine biodiversity, Brazil has few full-time taxonomists working on marine taxa, and these concentrate on macrocrustaceans and fish. Furthermore, they are scattered around the country in a few state and national museums. These institutions are mainly in the southeastern and southern regions. One large museum is located in the northern region but its marine collections are very limited. Northeastern collections of flora and

fauna are kept in laboratories whose futures are uncertain.

This lack of professional expertise within the country is serious and imposes significant problems for our ongoing understanding of biodiversity as it will inevitably lead to an under assessment of the actual pool of species. This problem is not new, nor unique to Brazil (UNESCO 1988; Gaston & May 1992). It is depressing that the number of taxonomists is decreasing at a time when our appreciation of the importance of marine biological diversity has just started to develop (Ormond *et al.* 1997) and our need to mitigate human disturbance is greatest. If this essentially economic problem cannot be solved, it will be all but impossible to compile a reliable database of extant organisms and have the basic knowledge necessary to support their exploitation, to monitor their future and to prevent their extinction.

The requirements for future marine research in Brazil, following the recommendations of the workshop on Brazilian Marine Biodiversity held at Ilhéus, Brazil, in April 2002, are:

1) Taxonomic training, seen as a topmost priority. Taxonomists could be trained relatively quickly (in two–five years), either in Brazil or in cooperation with other countries. For most taxa, identification guides and manuals are lacking or deal with only part of the marine biota.

2) The improvement of museum collections. There is an urgent need to create conditions for maintaining these biological collections, not always easy in institutions lacking long-term stability.

3) The integration of historical biological and oceanographic data, collected on the Brazilian Continental Shelf, into a systematic geographical database.

4) Deep water taxonomic and functional studies lasting well over 10 years. A similar program for the oceanic islands of Rocas Atoll, Fernando de Noronha Archipelago and Trinidad (studies to be accomplished within 10 years).

5) Reef system studies, to be accomplished within 10 years.

6) Long term studies, well over 10 years due to their large number and geographical dispersion along the Brazilian coast, of estuaries and their associated ecosystems.

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