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# THE CARIBBEAN COASTAL MARINE PRODUCTIVITY PROGRAM (CARICOMP)

*CARICOMP*[§]

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ABSTRACT

CARICOMP is a regional scientific program to study land-sea interaction processes in the Caribbean coastal zone. It has been collecting data since 1992, when a Data Management Centre was established at the University of the West Indies in Jamaica. Initially it focuses on documenting the structure and productivity of major coastal communities (mangrove forests, seagrass meadows and coral reefs) at relatively undisturbed sites in diverse physical settings. Second, by regular recording of physical and biological parameters, it monitors for change, seeking to distinguish natural from anthropogenic disturbance. Third, it constitutes a regional network of observers, able to collaborate on studies of region-wide events. Examples are presented of the diverse data sets collected by the Program.

The shallow waters of the Caribbean Sea are typically clear and blue, devoid of nutrients and biologically unproductive. The productivity of island coastal waters depends largely upon primary productivity within mangrove forests, seagrass meadows and coral reefs, where nutrients, although to some extent conserved, are primarily derived from the land. Other major sources of nutrients for coastal productivity, especially near the continents, are upwellings and rivers. But Caribbean coastal zones occupy diverse geographic settings ranging from continental margins to low islands, far offshore, and ranging across many separate nations. Generally the three systems, mangroves, seagrasses and coral reefs, are studied by different sets of scientists, who work independently of one another. In 1982, UNESCO sponsored a multi-national workshop on interactions between the three systems in the Caribbean. This led to a workshop in 1985 on Caribbean coastal marine productivity, at which the idea of CARICOMP was born (CARICOMP, 1997a). It was to be a region-wide program to measure the productivity of the major ecosystems, across a diversity of locations, using identical methods, in order to understand regional variation in primary productivity, the basis for coastal fisheries. At the same time, it would develop studies on the ecological functions of the three systems, particularly their roles in modulating the impacts of land and sea upon each other.

For the next 4 yrs a Steering Committee met annually, with the support of UNESCO, trying to raise a large sum to operate the program, but without success. In 1989, it was

[§]This paper was edited for the CARICOMP Site Directors and members of the Steering Committee, who were responsible for the collection and interpretation of the data, by J. D. Woodley and D. M. Linton. It should be cited as CARICOMP (2001), and is based on data collected up to 1997.

Table 1. CARICOMP institutions and their monitoring sites.

| Country | Institution | Location | Date of 1st activity |
|---|---|---|---|
| Bahamas | Bahamian Field Station | San Salvador | 1994 |
| Barbados | Bellairs Research Institute | Bellairs | 1993 |
| Belize | University College of Belize | Turneffe Atoll | 1996 |
| | Smithsonian Institution | Carrie Bow Cay | 1993 |
| Bermuda | Bermuda Biological Station | North rim | 1992 |
| Bonaire | Bonaire Marine Park | Barcadera | 1994 |
| Cayman Is. | Dept. of Environment | Andes, Pinnacle | 1995 |
| Colombia | INVEMAR | Chengue Bay | 1993 |
| Cuba | Instituto de Oceanología | Cayo Coco | 1994 |
| Curaçao | Curaçao Underwater Park | Spanish Water | 1994 |
| Dominican Republic | U. Autónoma de Santo Domingo | Parque del Este | 1994 |
| Jamaica | Discovery Bay Marine Lab. | West Fore-reef | 1993 |
| Mexico | U. Nacional Autónoma de México | Puerto Morelos | 1993 |
| Nicaragua | MARENA | Great Corn Is. | 1993 |
| Puerto Rico | University of Puerto Rico | La Parguera | 1994 |
| Saba | Saba Marine Park | Ladder Bay | 1993 |
| Trinidad & Tobago | Institute of Marine Affairs | Buccoo | 1994 |
| Venezuela | Universidad Simón Bolívar | Morrocoy | 1994 |
| | EDIMAR | Margarita Is. | 1992 |
| New Sites (1998) | | | |
| Colombia | CORALINA | San Andrés Is. | 1998 |
| Costa Rica | Universidad de Costa Rica | Cahuita | 1999 |
| Honduras | Estación de Investigaciones | Cayos Cochinos | |
| Jamaica | CCAMF | Portland Bight | |
| | Montego Bay Marine Park | Montego Bay | |
| Panama | Smithsonian Institution | Bocas de Toro | 1999 |
| United States | Florida Institute of Oceanography | Florida Keys | |

decided that the program should be started anyway, using whatever resources participating institutions could contribute. An affordable minimum set of physical and biological observations, was agreed upon at a workshop in 1990. Data collection began in 1992, after establishment of the CARICOMP Data Management Centre (now part of the Caribbean Coastal Data Centre) at the Centre for Marine Sciences, University of the West Indies, in Jamaica.

CARICOMP originally planned to collect information in 'pristine' locations in order to understand the natural systems and to provide baselines for the study of those that had suffered human disturbance. It was soon apparent that, while some locations had suffered less disturbance than others, nowhere was pristine. Indeed, there was concern everywhere about the degradation of natural habitats due to human activities. More understanding of natural variability will facilitate the recognition of anthropogenic changes. Therefore, another important role for the Program is the detection of changes by routine monitoring. Further, the network of institutions is able to carry out additional surveys, coordinated through the Data Management Centre, in response to region-wide events.

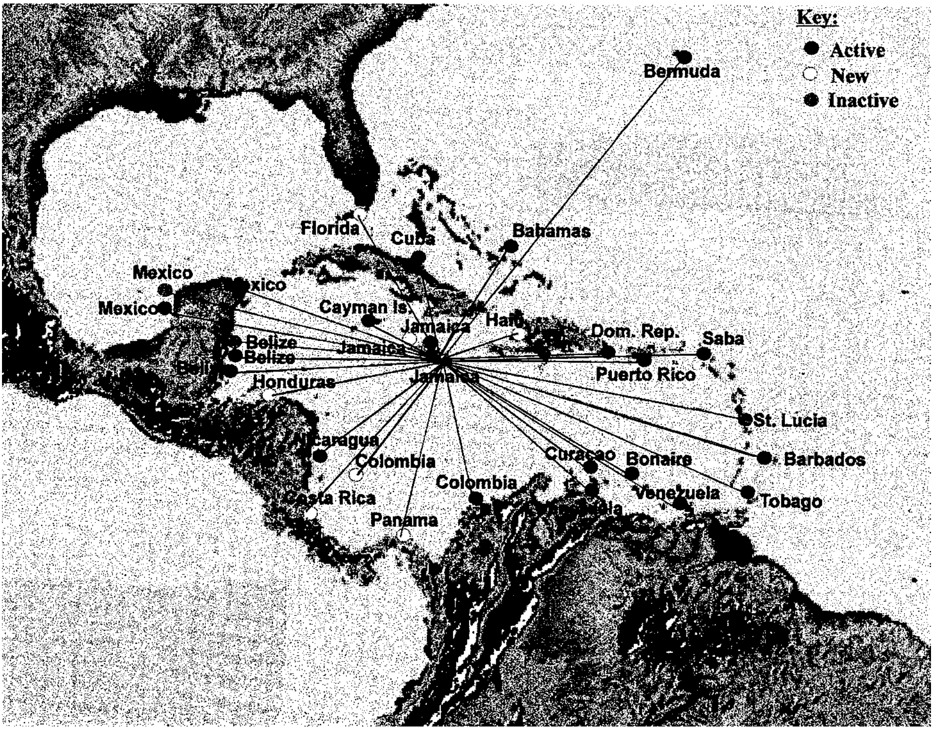


Figure 1. Map of the Caribbean showing CARICOMP monitoring sites.

## CARICOMP Institutions

Initially, institutions participating in CARICOMP were all members of the Association of Marine Laboratories of the Caribbean, but now they include Marine Parks and NGOs (Table 1). Although external funds helped to establish and operate the network, there has been little money to support the fieldwork of the participating institutions. Therefore, the program has been maintained on a voluntary basis by the institutions themselves. Each institution signs a Memorandum of Understanding with CARICOMP in which it undertakes to complete the CARICOMP protocols to the best of its ability but, inevitably, they differ in the extent to which they have been able to do so. Meanwhile, CARICOMP funds have been used to convene annual workshops of participating scientists, for training and bilingual discussion of methods and results. Some lessons learned during the first 5 yrs operation of the program have been summarized by Woodley (1999).

## CARICOMP Sites

The study areas encompass high and low islands, upstream or downstream in the Caribbean Current; continental margins; windward and leeward exposures; high and low rainfall rates; high and low latitudes; differing frequencies of exposure to hurricanes, etc. (Fig. 1; Kjerfve, 1998). Each study site incorporates mangrove forests, seagrass beds and coral reefs, located along a land-sea transect to the extent that it is possible (CARICOMP

Table 2. The CARICOMP Level One monitoring methods.

PHYSICAL MEASUREMENTS

Daily lab measurements: Max/min temperatures, and rainfall
Weekly habitat measurements: Sea temperature, salinity, turbidity at mangrove, seagrass and coral reef sites. Temperature measurements are now also being made using automated submersible recorders.

MANGROVES

Red mangrove forest structure: tree location, diameter and height within three 10 × 10 m plots
Mangrove seedling/sapling biomass and productivity
Mangrove seedling and sapling biomass coefficient
Mangrove surface litter—initial
Mangrove litterfall—monthly
Mangrove interstitial water salinity—monthly

SEAGRASSES

Seagrass biomass measurements from core samples
*Thalassia* (turtlegrass) growth measurements
*Thalassia* leaf area index (LAI)

CORAL REEFS
(All surveys in mixed zone, c. 10 m depth)

Coral reef chain transects: 2 × 5, 10 m long
Coral reef gorgonian transects: 2 × 5, 10 m long
Coral reef urchin transects: 2 × 5, 10 × 1 m

Level Two, 1998

Visual census of coral reef fishes (using the AGRRA protocol)
Biomass of macroalgae on coral reef transects
Disease survey (back-reef and two fore-reef depths)

1997b). The initial aim is to collect base-line information: we recognize that nowhere is pristine, but CARICOMP sites are located in relatively undisturbed areas.

## CARICOMP Data

Because of limited resources, CARICOMP institutions agreed on a relatively small set of necessary but affordable monitoring protocols, known as Level One, so that each site is studied with identical methods, timing and units (Table 2). These protocols include measures of physical variables; of biomass and productivity of mangroves and seagrasses; but only the relative abundance of benthic organisms in coral reef communities. Details are given in the Methods Manual, which is available on the CARICOMP web site (http://www.uwimona.edu.jm/centres/cms/caricomp). Some further methods, known as Level Two, were introduced in 1998 (Table 2). Data are entered into spreadsheets and transmitted to the Data Management Centre. Annual summaries are distributed and published (UNESCO, 1998), and the coral reef data are sent to REEFBASE. In this way, the Program has initiated the Global Coral Reef Monitoring Network (GCRMN) in the Carib-

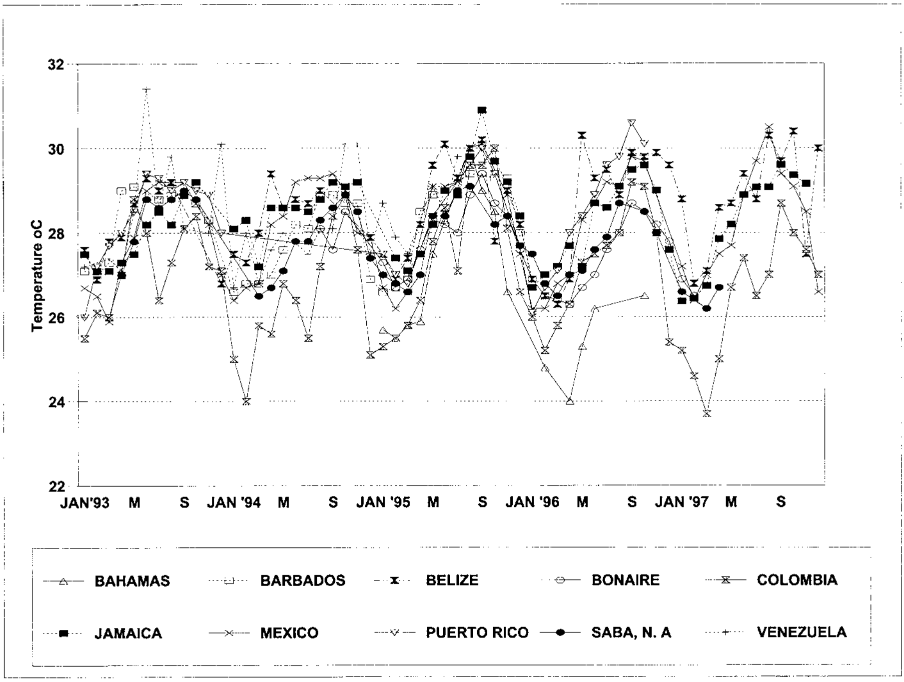


Figure 2. Monthly means of weekly seawater temperature at coral reef sites.

bean. The whole data set is maintained in a relational database (Microsoft Access) which will be accessible for queries on the web site. Papers based on the first 3 yrs of data were published in the Proceedings of the 8th International Coral Reef Symposium, held in Panama in 1996 (CARICOMP 1997a–g; Nagelkerken et al., 1997). Other publications that use CARICOMP data, or have been facilitated by CARICOMP, are listed at the end of this article. Here we present some illustrative examples of local or regional data sets obtained by CARICOMP.

Sea Surface Temperatures 1993–1997.—Sea temperature data were collected from each of the three main habitats both manually (once per week, Table 2) and by automatic data loggers. Weekly data from coral reefs are plotted here as monthly averages (Fig. 2). In 1995, late summer temperatures were generally higher than in previous years (CARICOMP, 1997d), and coral bleaching was reported from most Caribbean reefs (CARICOMP, 1997g).

Coral Reef Community Composition at CARICOMP Sites, 1993–1997.—Coral reef community composition was measured at two sets of five permanent 10 m transects (on fore-reefs at about 10 m depth), by a chain method (CARICOMP, 1997c). Presented here are data from all sites that have made at least one repeat survey (Fig. 3). They are arranged in order of highest initial coral cover. Permanent repeated chain transects have fairly high precision: sampling was shown (for Bermuda) to reliably detect about 4% change (Green and Smith, 1997). Many Caribbean coral reefs had suffered declines in coral abundance before CARICOMP monitoring began, due to coral diseases, hurricane

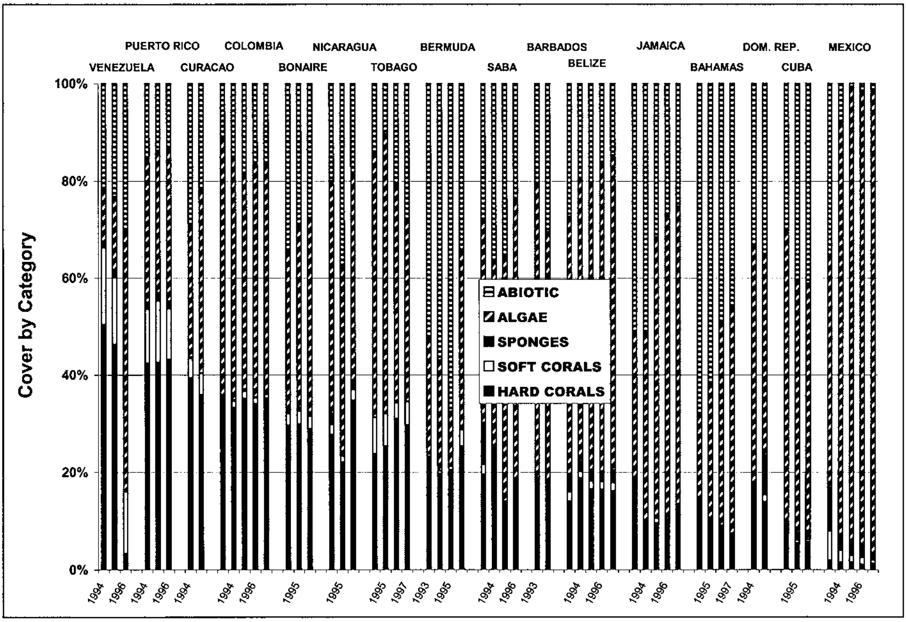


Figure 3. Percent cover by category on coral reefs at CARICOMP sites, 1993–1997.

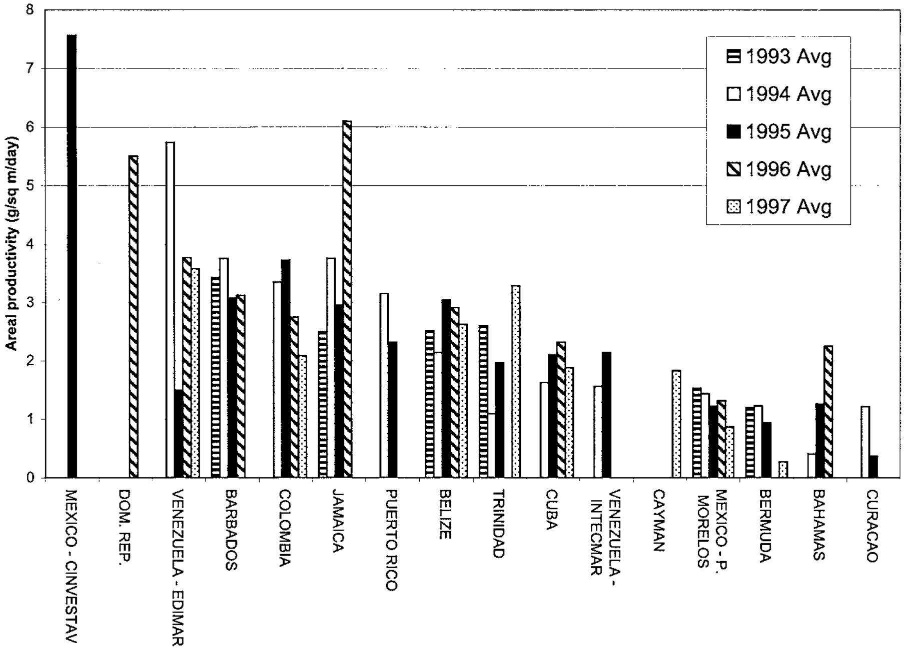


Figure 4. Areal productivity of seagrass at CARICOMP sites, 1993–1997.

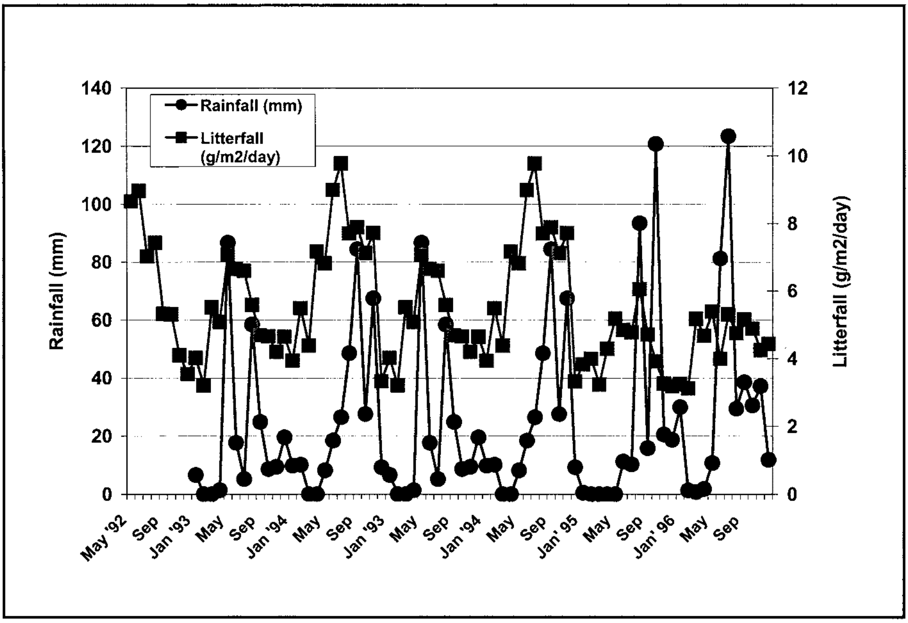


Figure 5. Rainfall, and red mangrove litterfall, Margarita Is., Venezuela (1992–1996).

damage, and algal overgrowth following the mass mortality of *Diadema* in 1983. A few reefs have shown declines since then, but most show little change.

Seagrass Productivity.—The areas selected for study of seagrasses were those where turtle grass (*Thalassia testudinum*) was best developed. Its productivity was measured by punching holes through the shoots with a hypodermic needle, and measuring leaf growth after 10–14 d (CARICOMP, 1997e). Productivity per unit area (Fig. 4) shows a wide range, highest in the Celestun Lagoon, Mexico. Among the other sites, there is a tendency for higher rates to be found adjacent to high islands or continents, lower rates near low islands.

Productivity of the Red Mangrove (*Rhizophora mangle*).—The weight of fallen leaves, captured on a monthly basis, is the primary measure of mangrove productivity (CARICOMP 1997f). Detritus derived from leaf litter is the main route by which mangroves contribute to downstream habitats. There is a marked seasonal cycle in production, here illustrated with data from Isla Margarita, Venezuela (Fig. 5), which may be related to both temperature and rainfall.

Unusual Events Captured by Routine Monitoring.—Routine monitoring provides a baseline reference for changes, some of which may be large and unexpected. One example is the mass mortality of corals at Playa Caimán, Morrocoy, Venezuela early in 1996 (Fig. 6). This was due to an upwelling of nutrient-rich water during a period of calm weather (Laboy-Nieves et al., in prep.). Another example is the increase in abundance of the sea-urchins *Echinometra viridis* and *Tripneustes ventricosus* on the fore-reef at Discovery Bay, Jamaica, in 1997 (Fig. 7; Woodley et al., 1999).

Monitoring of Regional Events.—The CARICOMP network is able to collaborate in monitoring region-wide events and reported on two of them in the Panama Symposium.

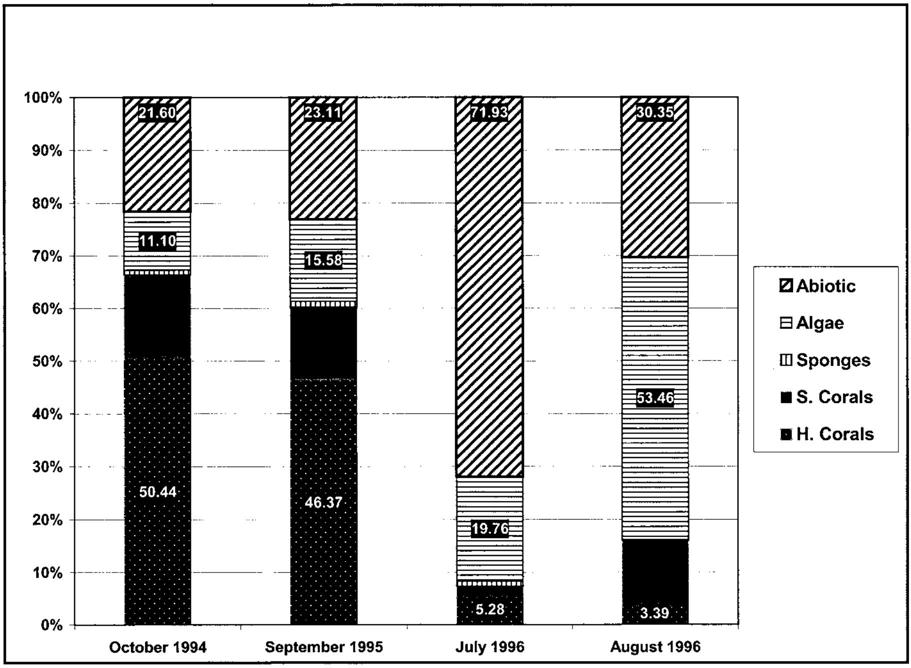


Figure 6. Changes in % cover by category on coral reefs at Playa Caimán, Morrocoy, Venezuela.

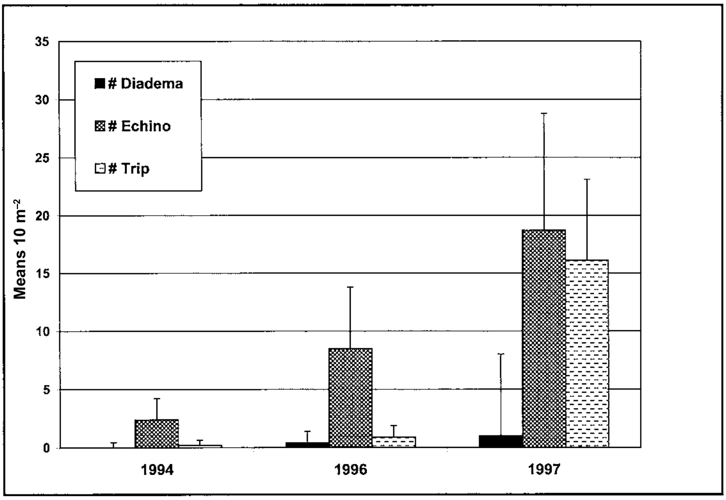


Figure 7. Abundance of sea urchins at 8 m depth on the fore-reef at Discovery, Jamaica.

Data were presented from 19 countries on the coral bleaching event of 1995–96, showing that it was most extensive in the center and west of the region, but only slight in the Lesser Antilles and Bermuda. Perhaps more important, the consequent mortality was estimated at eight sites. For *Montastraea annularis,* this ranged from 1.7 to 30%, 6 mo after the onset of bleaching (CARICOMP, 1997g). Also in 1995, data were collected from 24 locations on the health of the common seafans, *Gorgonia* spp. These documented the spread of recent mortality, due to infection by the terrestrial fungus *Aspergillus* sp., which was prevalent throughout the Caribbean, with the apparent exception of areas in Colombia and southern Central America where populations had not recovered from similar epidemics in the 1980s, and locations in the West where populations were still healthy. This pattern was consistent with the hypothesis of origin from riverine discharges and spread by prevailing currents (Nagelkerken et al., 1997).

Work with Coastal Human Communities.—CARICOMP has collected preliminary data on the use of coastal resources by people living near the study sites. At some sites (Discovery Bay and Portland Bight, Jamaica; La Parguera, Puerto Rico; Buccoo Reef, Trinidad & Tobago; Moroccoy, Venezuela), members are engaged in community development work, facilitating local management of coastal resources, especially fish stocks. These activities were described and discussed at a recent workshop (UNESCO, in prep.).

## Acknowledgments

CARICOMP has, since its conception in 1985, been a program of UNESCO: first in COMAR, now in CSI (Environment and Development in Coastal Regions and Small Islands). Funding for training workshops, equipment, the Data Management Centre and annual workshops has also been provided by the National Science Foundation; the MacArthur Foundation; and the Coral Reef Initiative of the U.S. Dept. of State. Monitoring work is maintained by all the participating institutions (Table 1). The program is administered by the Florida Institute of Oceanography, University of South Florida. To all, we are very grateful. This paper was edited for CARICOMP by J. D. Woodley and D. M. Linton (Centre for Marine Sciences, University of the West Indies).

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