Caribbean Journal of Science, Vol. 41, No. 3, 367-373, 2005

Ecological Monitoring and Biodiversity Surveys at the Smithsonian Tropical Research Institute's Bocas del Toro Research Station

RACHEL COLLIN

Smithsonian Tropical Research Institute, Apartado Postal 0843-03092, Balboa, Ancon, Republic of Panama
e-mail: collinr@naos.si.edu

ABSTRACT.—The Bocas del Toro Archipelago, site of the Smithsonian Tropical Research Institute's new Bocas Research Station, is a complex area of islands, mangrove cays, peninsulas, fringing reefs and seagrass beds on the Caribbean coast of Panama. The state-of-the-art research station runs long-term monitoring of physical and biological aspects of the local environments, that includes water and air temperature, precipitation, and tidal height. Biological monitoring includes annual or biannual surveys of seagrass productivity, mangrove forests and coral cover at reef sites. In 2003 and 2004 the station hosted workshops focused on taxonomic surveys of the marine fauna in the vicinity of the station. Collections of most major phyla resulted in the discovery of several new species and produced numerous new records for the country and region. This peer-reviewed special issue of the Caribbean Journal of Science presents results of the ongoing monitoring and faunal surveys with the goal of providing a solid foundation and context for future research in the area.

INTRODUCTION

The objective of this issue is to begin documenting the marine environment and biodiversity in the Bocas del Toro Archipelago, Panama. As the site of the Smithsonian Tropical Research Institute's new Bocas Research Station, this region will likely become the focus of intensive future research efforts. In order to facilitate these studies and to provide a context for them, this issue brings together information on the physical characteristics, geologic history, major habitats, and faunal diversity of the archipelago.

The marine fauna of the southern Caribbean, and the continental marine fauna of the Caribbean in general, is not as well studied as the island faunas of the Bahamas and Antilles, the location of most Caribbean marine laboratories. Therefore, a series of marine invertebrate surveys was conducted to document the fauna of the Bocas del Toro Archipelago and to compare it to our current knowledge of the rest of the Caribbean. The preliminary results suggest the species composition of the region is similar to other areas of the Caribbean, but that the abundances of various groups reflect the high productivity of the area. For example: the sponge fauna is generally similar to the rest of the Caribbean, but the abundance and accessibility is much greater in Bocas del Toro than many other sites (C. Díaz, pers. comm.); the suspension-feeding brittlestar *Othiothrix suensonni* is also extraordinarily abundant and often covers the corals and sponges; and the diversity of soft sediments appears to be higher than they are in off-shore Caribbean islands. It is evident that more mature research projects will uncover other unique features of Bocas del Toro and additional differences between Bocas del Toro and the northern and eastern Caribbean.

The Bocas del Toro Archipelago

The Bocas del Toro Archipelago is located on Panama's Caribbean coast near the border with Costa Rica. It is composed of six major islands (Islas Colón, Bastimentos, Solarte, Cristóbal, Popa and Cayo Aqua, Fig. 1) that fall within and delimit two main bodies of water: The Bahía Almirante and the Laguna de Chiriquí. A complex network of islands and mainland peninsulas fringed by mangroves surrounds these two distinct bays (Fig. 1). Mangrove overwash islands, seagrass beds, and patch

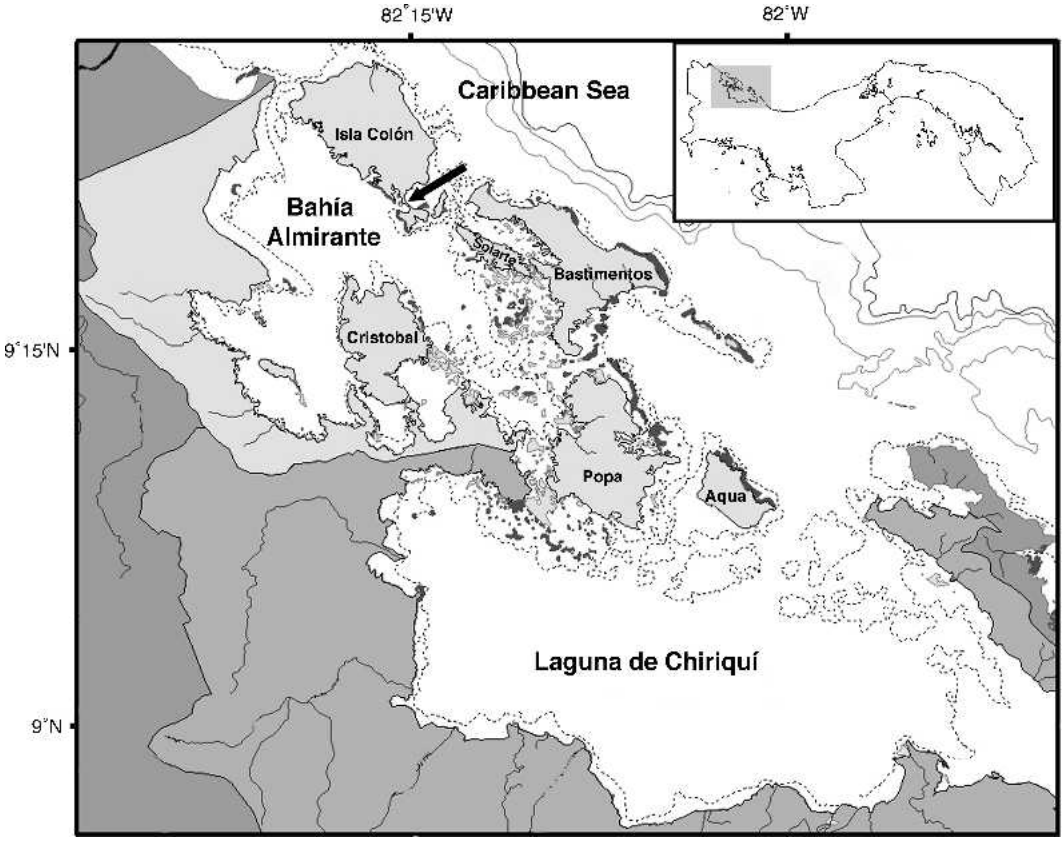

FIG. 1. Map of the Bocas del Toro Archipelago. The site of STRI's Bocas Research Station is indicated with an arrow.

reefs occur in both the Bahía Almirante and the Laguna de Chiriquí. Reefs and seagrasses are most well-developed in the Bahía Almirante, while mangroves predominate in the Laguna de Chiriquí, which receives most of the terrestrial run-off from several large rivers. The region receives about 3-5 m of rainfall annually and the temperatures and rainfall do not show the pronounced seasonal patterns typical of the Pacific coast of Panama (Kauffman and Thompson this issue).

The mainland is covered by montane and lowland humid tropical forest and banana plantations, and there are large expanses of peat-swamp forest along the coast of the Bahía Almirante. Deforestation is common in the lowlands and the larger islands in the archipelago are primarily covered with secondary forest, pasture lands and teak plantations. However, some old-growth forest still remains on Islas Colón and Bastimentos. Bocas del Toro holds vast fossil deposits and fossil reefs and other outcrops are common throughout the area. Terrestrial research in the region has focused on the geological history of the rise of the isthmus (e.g., Coates et al. 2003; Coates et al. this issue), the evolution and mate choice of dart poison frogs (Summers et al. 2003; 2004; Saporito et al. 2004), and mammalian taxonomy (Kalko and Handley 1994; Anderson and Handley 2002).

The mangrove forests of Bocas del Toro are estimated to cover about 28 km^2 (D'Croz 1993), comprising both forests that fringe the mainland and larger islands, and overwash islands within the Laguna de Chiriquí. They are dominated by red mangroves (*Rhizophora mangle*), while black and white mangroves (*Avicennia germinans* and *Laguncularia racemosa*) occur on the main-

land but are uncommon and patchy on the islands. Much of the forest is composed of dwarf trees and scrub. The low stature of these mangroves may be due in part to nutrient limitation (Lovelock et al. 2004) or relatively high pore water salinity (Lovelock et al. this issue).

Vast seagrass beds cover large areas in the shallow waters surrounding the islands and along the mainland coast. Four species *Thalassia testudinum*, *Syringodium filiforme*, *Halodule wrightii* and *Halophila decipiens* are found but *Thalassia testudinum* is the most abundant. The seagrasses in many areas of the archipelago are heavily epiphytized, which may be due to high nutrient levels caused by heavy terrestrial runoff (D'Croz et al. this issue; Barnes et al. this volume). The algal communities on hard bottoms are also diverse (Wysor and Kooistra 2003; Wysor and DeClerck 2003).

The structure and species composition of reefs in Bocas del Toro archipelago have previously been described in detail (Guzmán and Guevara 1998a, 1998b, 1999, 2001). In the Bahía Almirante reefs are well developed to a depth of 23 m. *Porites furcata* dominates the reefs at depths less than 2 meters and can produce as much as 90% cover. Below the *Porites* zone, to a depth of 6 meters, there is a zone dominated by *Agaricia tenuifolia* and below this a mixed assemblage of *A. tenuifolia*, *Madracis mirabilis* and *Sierastrea siderea* extending to the bottom of the reef. There are few reefs along the mainland coast of the Laguna de Chiriquí (Guzmán and Guevara 1998), but the southern coasts of Isla Popa and Cayo Agua, the channel between the two, and the eastern end of Isla Batimentos encompass biodiversity hotspot for corals, sponges and gorgonians (Guzmán and Guevara 1999). There are still considerable patches of *Acropora cervicornis* and *A. plamata* in more exposed sites in the archipelago despite the occurrence of white spot and white band disease in the area. Cores show that during the last several thousand

TABLE 1. List of sampling sites visited during the 2003 marine invertebrate taxonomy workshop.

Site	Locality	Latitude	Longitude
1	Isla Bastimentos, Crawl Cay	9° 15′ N	82° 9′ 30″ W
2	Isla Solarte, South side	9° 19′ N	82° 13′ W
3	Isla Bastimentos, Wild Cane Cay	9° 20′ 40″ N	82° 10′ 20″ W
4	Isla Solarte	9° 17′ 30″ N	82° 10′ 20″ W
5	Isla Solarte, South side	9° 17′ N	82° 11′ 40″ W
6	Isla Cristobal, Punta Coco	9° 17.345′ N	82° 15.249′ W
7	Isla Bastimentos, Crawl Cay Canal	9° 15.050′ N	82° 07.631′ W
8	Isla Colon, Punta Caracol	9° 22.627′ N	82° 18.117′ W
9	Isla Solarte, South side	9° 17.987′ N	82° 12.404′ W
10	Swan's Key	9° 27.198′ N	82° 18.024′ W
11	Isla Colon, Boca del Drago	9° 24.73′ N	82° 19.90′ W
12	Isla Cristobal, entrance to Bocatorito Bay	9° 14.28′ N	82° 13.85′ W
13	Isla Colon, Mangrove Inn	9° 19.870′ N	82° 15.286′ W
14	Isla Colon, Punta Caracol	9° 22.627′ N	82° 18.117′ W
15	Cayo Agua, Southeast side	9° 08.070′ N	82° 00.972′ W
16	Cayo Agua, Northwest side	9° 10.659′ N	82° 03.254′ W
17	Swan's Cay	9° 27.198′ N	82° 18.024′ W
18	Isla Pastores, North side	9° 14.332′ N	82° 19.968′ W
19	Isla Solarte	9° 17.929′ N	82° 11.672′ W
20	Isla Bastimentos, Crawl Key	9º 15.050′ N	82º 07.631′ W
21	Isla Colon, Matumbal Bay	9º 21′ 4.3″ N	82º 15′ 25.6″ W
22	Isla Colon, STRI Point	9° 21.08′ N	82° 15.85′ W
23	Isla Bastimentos, Punta Vieja	9° 17.45′ N	82° 05.38′ W
24	Cerro Brujo, entrance to Bocatorito Bay	9° 13.375′ N	82° 12.555′ W
25	Cerro Brujo, entrance Bocatorito Bay	9° 12.663′ N	82° 12.616′ W
26	Isla Cristobal, inside Bocatorito Bay	9° 12.641′ N	82° 14.940′ W

years intermediate depths have been dominated by *Porites* sp. and that the shift to *Agaricia* sp. has occurred only in the last few decades (Aronson et al. 2004).

History of the Smithsonian's Bocas Research Station

Scientists from the Smithsonian Institution first began conducting research in Bocas del Toro in the 1970s and 1980s when Dr. C. Handley from the National Museum of Natural History mounted a number of expeditions to survey the mammal fauna of the region. Much of the initial demand for a permanent research station in the area came in the 1990s from paleoecologists interested in the fossil history of the Caribbean and Pacific. In 2001, a dormitory building was completed on a six-hectare plot on Isla Colón. The large, state-of-the-art laboratory building was completed and inaugurated in October, 2003. The main laboratory building has 8000 square feet of internal floor area and an additional 7000 square feet of exterior work areas and walkways. The interior space includes laboratories, a classroom, library, and computer room. A building-integrated photovoltaic system provides power to all areas of the building and the roof also functions as a rainwater collector. In 2004 the running seawater system was completed, and construction and development of additional buildings continue.

Physical and Biological Monitoring

Weekly and daily measurements of rainfall and air and sea temperature are taken

TABLE 2. List of sampling sites visited during the 2004 marine invertebrate taxonomy workshop.

Site	Locality	Latitude	Longitude
1, 10, 12, 24	Isla Colon, STRI Lab Dock	9° 21′ 04.3″ N	82° 15′ 25.6″ W
2, 9	Isla Bastimentos, Hospital Point	9° 20′ 0.7″ N	82° 13′ 6.8″ W
3, 25, 30	Isla Colon, Mangrove Inn	9° 19.870′ N	82° 15.286′ W
4, 15	Isla Colon, North Coast	9° 21.112′ N	82° 15.328′ W
5, 14	Pilings near Almirante	9° 16.218′ N	82° 23.382′ W
6	Rio Oeste near Almirante,	9° 15.822′ N	82° 23.442′ W
7	Isla Pastores, west coast	9° 14.588′ N	82° 20.690′ W
8	Pond Sock Reef	9° 17′ 17.9″ N	82° 19′ 39.9″ W
9	Isla Solarte, North coast	9° 18′ 45.5″ N	82° 12′ 46.8″ W
13	Isla Solarte	9° 18′ 45.3″ N	82° 12′ 46.6″ W
16	Isla Colon, Playa Drago (?Graco)	9° 25′ 36.6″ N	82° 19′ 30.1″ W
17	Isla Colon, Punta Caracol	9° 22.627′ N	82° 18.117′ W
18, 45	Isla Colon, near Punta Caracol	9° 21.573′ N	82° 16.587′ W
19	Isla Colon , Matumbal Point	9° 27′ 12.3″ N	82° 18′ 1.7″ W
20	Islas Zapatillas	9° 15.564′ N	82° 02.750′ W
21	Crawl Cay	9° 15.261′ N	82° 07.787′ W
22	Islas Zapatillas	9° 15′ 53.5″ N	82° 03′ 27.6″ W
23	Crawl Cay	9° 14′ 37.8″ N	82° 08′ 25.0″ W
26, 27, 32	Sand Fly Beach, Isla Colon	9° 21.911′ N	82° 14.293′ W
28	Bocatorito Bay	9° 12.641′ N	82° 14.940′ W
29	Swan's Cay	9° 27′ 12.2″ N	82° 18′ 01.8″ W
31	Isla Colon, STRI point	9° 21′ 03.2″ N	82° 15′ 26.1″ W
33, 40	Isla Colon, Pilings in Bocas Town	9° 20.319′ N	82° 14.388′ W
34	Isla Bastimentos	9° 20.898′ N	82° 9.959′ W
35	Isla Bastimentos, North Side	9° 21′ 5.2″ N	82° 15′ 34.0″ W
36	Cayo Adriana	9° 14.456′ N	82° 10.413′ W
37, 42, 43	Isla Colon, Boca del Drago	9° 24.73′ N	82° 19.90′ W
38, 41	Isla Colon , Emilio's beach	9° 22.027′ N	82° 14.336′ W
39	Isla Colon, Ancon Expeditions pilings	9° 20.558′ N	82° 14.444′ W
44	Red Frog Point, Isla Bastimentos	9° 20.354′ N	82° 10.932′ W

at the research station. In 2002, an automated NOAA-type station began recording hourly values of oceanographic and meteorological data, including water level, rainfall, and solar and quantum radiation. Hourly sea temperature is also recorded at seven remote sites in the surrounding area. Results from this monitoring are presented by Kauffman and Thompson (this issue) and can be downloaded from the STRI web site (http://striweb.si.edu/esp/physical_monitoring/downloads_intro.htm).

The region around the STRI station has been the focus of considerable biological survey and monitoring effort. Seventy-one coral sites, 52 seagrass sites, and 5 mangrove sites have been surveyed and there are currently several permanent monitoring sites in each habitat. Since 1999, Bocas del Toro has been part of CARICOMP, a Caribbean-wide program to monitor the productivity of coral reefs, mangroves, and seagrass. We conduct standardized CARICOMP monitoring protocols for all three habitats. Standing crop, biomass, growth rate, and leaf area index are recorded for two sites within a *Thalassia* bed on the south side of Isla Colón twice a year. For mangrove sites, each tree is mapped and tree dimensions are recorded each year, seedling recruitment and litterfall are monitored regularly. Two permanently marked coral subsites at 8 to 12 meters are monitored for percent cover and species diversity. The site descriptions and initial data are presented by Guzmán et al. (this issue).

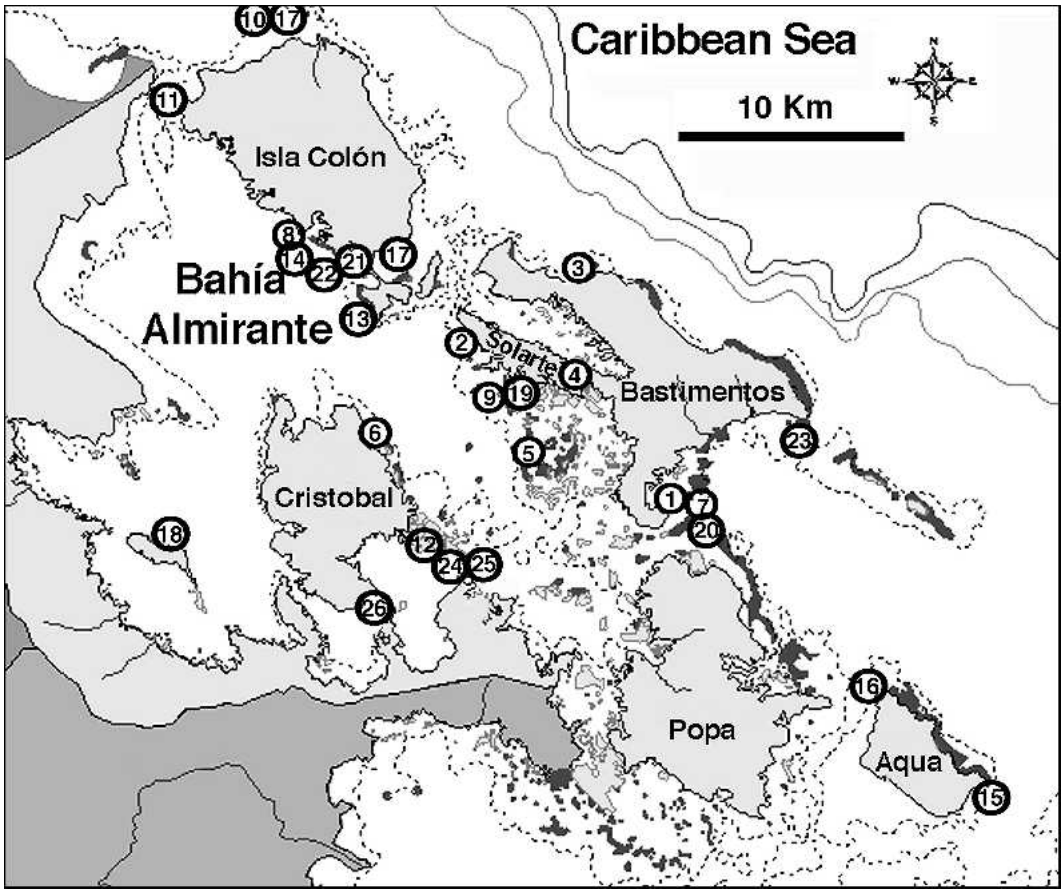

FIG. 2. Map of Bahía Almirante showing the sampling sites of the 2003 marine invertebrate taxonomy workshop. Each sampling site is indicated by number corresponding to Table 1.

Invertebrate Workshop

In both 2003 and 2004, ten taxonomists spent 11 days surveying the marine invertebrates in the vicinity of the Research Station, with the aim of increasing the working knowledge of the local fauna. In 2003, researchers visited 28 sites and in 2004 they visited 45 sites, representing a variety of habitats, mostly in the Bahía Almirante (Tables 1 and 2; Figs. 2 and 3).

Preliminary identifications of the material collected yielded 58 species of stony corals, 6 black corals, 54 soft corals, 168 polychaetes, 50 tunicates, 50 nemerteans, 62 echinoderms, 160 sponges, 212 molluscs, 141 crustaceans, 78 hydroids, 85 bryozoans, 15 sipunculans, 26 acoel flatworms, and 18 anemones. This doubles the number of marine invertebrate species recorded for the area. Details of the results for several groups are presented in this volume (Calder and Krikendale, Díaz, Rocha et. al., Schwartz and Norenburg, and Hendler) and species lists, localities, photographs and natural history information for these species are available at: http://striweb.si.edu/bocas_database/. A photographic field guide covering several of the major groups, at the end of this issue, also resulted from the activities during these workshops (Collin et al. this issue).

Although corals and reef sponges have previously been surveyed, the workshop resulted in adding 58 species to the known sponge fauna of the area. For other groups,

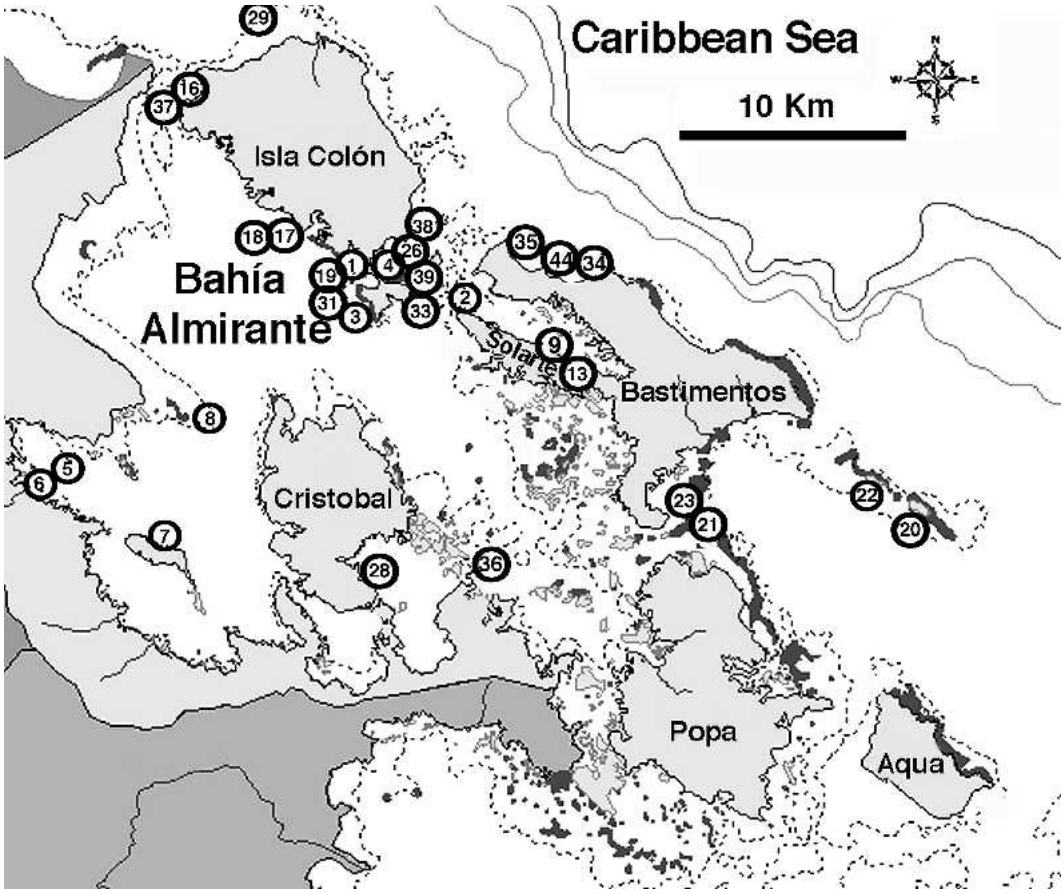

FIG. 3. Map of Bahía Almirante showing the sampling sites of the 2004 marine invertebrate taxonomy workshop. Each sampling site is indicated by number corresponding to Table 2.

like the tunicates and ribbon worms, this was the first survey of species from a continentally influenced site in the Caribbean. After only 10 days of sampling Bocas del Toro has become the site of the second-most diverse tunicate fauna in the Caribbean (Rocha et al. this issue) and the most diverse known site for nemerteans. Undescribed species were collected in each group (Schwartz and Norenburg, this issue; Hendler this issue) and several previously undescribed and unrecorded genera of polychaetes and ribbon worms were also discovered. Numerous species were first records for Panama. It is clear that additional surveys of each group are necessary before the marine biodiversity of the area is well-described.

ACKNOWLEDGMENTS.—The invertebrate taxonomy workshops would not have been possible without the support of the Smithsonian's Marine Science Network and the Smithsonian's Women's Committee, G. Jacomé, M. Salazar, M. Venegas, and the staff of the Bocas del Toro Research Station . Development of the station in Bocas del Toro and previous surveys and monitoring were conducted with the support of the Andrew W. Mellon Foundation, AEC Trust, the National Science Foundation, the Hunterton Endowment for Oceanography, Frank and Lisina Hoch, Katherine Medlinger and Ervin Himmelfarb, Max and Heidi Berry, the Upton Trust, and Dr. and Mrs. David A. Cofrin. We thank the Panamanian government, the Authoridad Marítima de Panama and ANAM for providing permission for scientists visiting the station to collect and export material for study.

LITERATURE CITED

Aronson, R. B., I. G. MacIntyre, C. M. Wapnick, and M. W. O'Neill. 2004. Phase shifts, alternative states, and the unprecedented convergence of two reef systems. *Ecology* 85(7):1876-1891.

Anderson, R. P., and C. O. Handley, Jr. 2002. Dwarfism in insular sloths: biogeography, selection, and evolutionary rate. *Evolution* 56:1045-1058.

Coates, A. G., M.-P. Aubry, W. A. Berggren, and L. S. Collins. 2003. Early Neogene history of the Central American arc from Bocas del Toro, western Panama. *Geol. Soc. Am. Bull.* 115(3):271-287.

D'Croz, L. 1993. Status and Uses of Mangroves in the Republic of Panama. Technical report of the project conservation and sustainable utilization of mangrove forests in Latin America and Africa. Part 1. Latin Amercia. Pp 115-127. International Society for Mangrove Ecosystems, Okinawa, Japan/ International Tropical Timber Organization, Tokyo, Japan.

Guzmán, H. M., and C. Guevara. 1998a. Arrecifes coralinos de Bocas del Toro, Panamá: I. Distribución, estructura y estado de conservación de los arrecifes continentales de la laguna de Chiriquí y la Bahía Almirante. *Rev. Biol. Trop.* 46:601-623.

Guzmán, H. M., and C. Guevara. 1998b. Arrecifes coralinos de Bocas del Toro, Panamá: II. Distribución, estructura y estado de conservación de los arrecifes de las islas Bastimentos, Solarte, Carenero y Colón. *Rev. Biol. Trop.* 46:893-916.

Guzmán, H. M., and C. Guevara. 1999. Arrecifes coralinos de Bocas del Toro, Panamá: III. Distribución, estructura y estado de conservación de los arrecifes de las islas Pastores, Cristobal, Popa y Cayo Agua. *Rev. Biol. Trop.* 47:659-675.

Guzmán, H. M., and C. Guevara. 2001. Arrecifes coralinos de Bocas del Toro, Panamá: IV. Distribución, estructura y estado de conservación de los arrecifes continentales de Península Valiente. *Rev. Biol. Trop.* 49:53-66.

Kalko, E. K. V., and C. O. Handley. 1994. Evolution, biogeography, and description of a new species of fruit-eating bat, genus *Artibeus* Leach (1821) from Panama. *Z. Saeugetierkd.* 59:257-273.

Lovelock, C. E., I. C. Feller, K. L. McKee, B. M. J. Engelbrecht, and M. C. Ball. 2004. The effect of nutrient enrichment on growth, photosynthesis and hydraulic conductance of dwarf mangroves in Panamá. *Funct. Ecol.* 18:25-33.

Saporito, R. A., H. M. Garraffo, M. A. Donnelly, A. L. Edwards, J. T. Longino, and J. W. Daly. 2004. Formicine ants: An arthropod source for the pumiliotoxin alkaloids of dendrobatid poison frogs. *Proc. Nat. Acad. Sci.* 101: 8045-8050.

Summers, K., T. W. Cronin, and T. Kennedy. 2004. Cross-breeding of distinct color morphs of the Strawberry Poison Frog (*Dendrobates pumilio*) from the Bocas del Toro Archipelago, Panama. *J. Herpetol.* 38(1):1-8.

Summers, K., T. M. Cronin, and T. Kennedy. 2003. Variation in spectral reflectance among populations of *Dendrobates pumilio*, the strawberry poison frog, in the Bocas del Toro Archipelago, Panama. *J. Biogeogr.* 30:35-53.

Wysor, B., and W. H. C. F. Kooistra. 2003. An annotated list of marine Chlorophyta from the Caribbean coast of the Republic of Panama. *Nova Hedwigia* 77:487523.

Wysor, B., and O. DeClerck. 2003. An updated and annotated list of marine brown algae (Phaeophyceae) of the Caribbean coast of the Republic of Panama. *Bot. Mar.* 46:151-160.