Buck Island Reef National Monument – Changes in Modern Reef Community Structure Since 1976

John Bythell
Elizabeth Gladfelter
William Gladfelter
Kathleen French
Zandy Hillis

Converted to digital format by Thomas F. Barry (NOAA/RSMAS) in 2004. Copy available at the NOAA Miami Regional Library. Minor editorial changes may have been made.

Buck Island Reef National Monument - Changes in Modern Reef Community Structure Since 1976

John C. Bythell,[1] Elizabeth H. Gladfelter,[1] William B. Gladfelter,[1] Kathleen E. French,[1] and Zandy Hillis[2]

[1]West Indies Laboratory

[2]National Park Service, St. Croix

INTRODUCTION

Buck Island is noted for its spectacular bank-barrier reef development encompassing the east end of the island. The reef is constructed largely from impressive formations of elkhorn coral *Acropora palmata,* both broken and in place. Massive individual colonies with branches up to a half meter in diameter and several meters long are not uncommon and the east forereef represents one of the most dense stands on St. Croix. High population densities coupled with prolific growth rates for the species result in considerable levels of carbonate production (Gladfelter *et al.* 1978, Gladfelter and Gladfelter 1979). Adey (1975) has shown that rates of vertical growth of these shallow A. palmata-dominated windward reefs may be as high as 15 meters per 1000 years.

The island and adjacent reef system was established as a national monument in 1961 and is under the jurisdiction of the U.S. National Park Service (NPS). It has been the focus of several marine environmental studies carried out by researchers at West Indies Laboratory (WIL) since 1976. At present we are in the process of establishing permanently marked sites for long-term monitoring of reef community structure and function, part of a regional program initiated and funded by the NPS. Much of the data presented here is drawn from these ongoing studies.

GENERAL DESCRIPTION

Buck Island is located 2 km north of the east end of St. Croix on the shallow St. Croix shelf (10-15 m depth). An emergent bank-barrier reef girdles the island from the southeast to the northwest, enclosing a 200-300 m wide lagoon, 2-4 m deep.

Shallow-reef structure, composed predominantly of dead *Acropora palmata,* tends to be more continuous to the south and east, but breaks up into a series of contiguous patch reefs to the north and west. The north side is also characterized by the development of many isolated patch reefs, both within the lagoon and seaward of the bank-barrier reef. The seaward patch reefs, known locally as "haystacks", are present between the inner fringing reef around Buck Island and Buck Island Bar, a submerged bank-barrier reef approximately 500 m to the north.

The haystacks are presently composed of almost 100% dead *Acropora palmata* and it is believed that they originated in shallow water as lagoonal patch reefs behind a barrier reef in the vicinity of Buck Island Bar (Hubbard, 1979).

There are no non-carbonate submarine exposures other than a narrow zone of the volcaniclastic Caledonia formation that fringes much of the island. This extends up to a few meters offshore on the more exposed north shore and is exposed along the entire coastline except for the west end of the island (Whetten, 1968). There are Holocene(?) beachrock deposits also fringing much of the island.

Buck Island is a popular tourist venue. Boat access to the lagoon from sea is via a marked channel on the south side of the island at the west end of the bank barrier reef. Several mooring buoys are maintained by the NPS at an underwater snorkel trail at the east end of the lagoon. SCUBA diving is not allowed on the underwater trail, but two moorings are maintained in the lagoon north of Buck Island and these allow divers to exit the lagoon through breaks in the reef to visit forereef zones (Fig. 1).

MODERN REEF STRUCTURE AND COMMUNITY COMPOSITION

Previous Studies

In 1976 a benthic community type map was made from quantitative and qualitative ground truthing of aerial photographs (Gladfelter *et al.,* 1977). Five transect lines were also established on the eastern half of the island, radiating out seaward from shore and extending across the bank barrier reef system. The physical character (bottom type, bathymetry), benthic community composition and major zonation patterns were determined at that time. Anderson *et al.* (1986) resurveyed one of the original transects in 1985, and also produced an updated benthic community type map covering the National Park area from 1984 ground-truthed aerial photographs. Recently, all five of the original transects have been resurveyed in

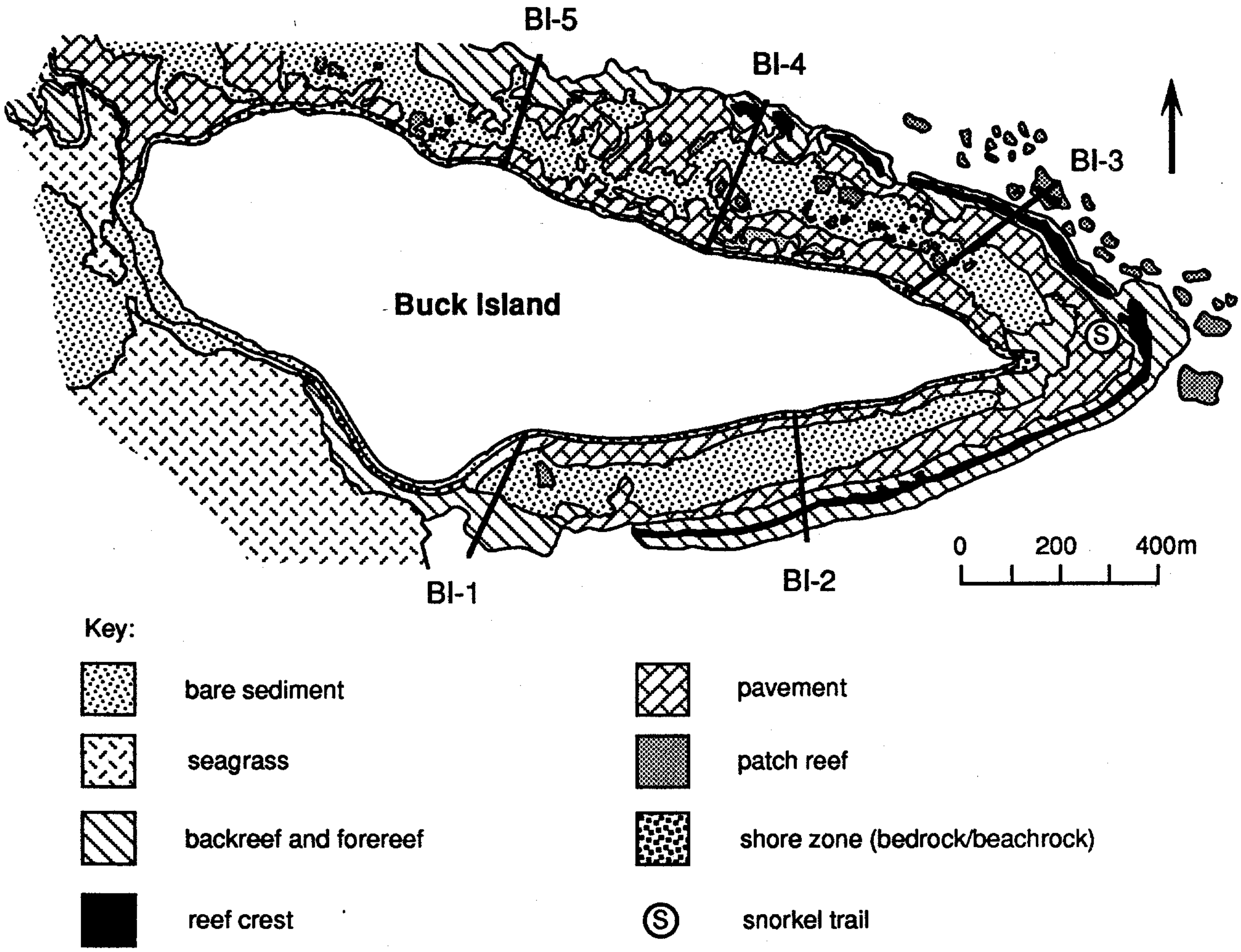

Figure 1. *Scale map of Buck Island, redrawn from Anderson et al. (1986), showing major benthic zonation patterns. Sites of the five cross-reef transects (BI-5) surveyed most recently in Fall, 1988 are indicated. Transect BI-3 crosses the east SCUBA mooring and a large, emergent "haystack" patch reef outside the bank-barrier reef. A second SCUBA mooring is sited near the break in the reef 200 m to the west.*

order to define the major changes in benthic community structure which have taken place over the last 13 years.

Methods

The major benthic zones along each transect were identified in accordance with the scheme of Anderson *et al.* (1986). Transects were relocated as closely as possible and benthic community composition was reassessed following the original census techniques (visual estimation of benthic cover from haphazardly placed 1 m^2 quadrats). Of the five transects, BI-3, the site of the 1985 resurvey, could be relocated most precisely due to the presence of several easily identifiable physical features along the length of the transect. Transects BI-4 and BI-5 were also believed to have been relocated to within a few meters of the original line. Transects BI-1 and BI-2 on the south reef crossed areas of more uniform reef structure and these transects may be several meters away from the original lines.

Within each subzone, ten or twenty haphazardly placed 1 m^2 quadrats were used to estimate percent coral cover, including *Millepora,* to species level. The number of replicates taken was determined somewhat subjectively, based on the subzone width and coral species richness. Total coral species number within each subzone was also assessed visually 3 meters either side of the transect line. Percent cover estimates were based on total surface area cover rather than planar or projected (2-dimensional) cover. Percent total bottom coverage was also estimated in the following categories: dead *Acropora palmata,* dead coral other than *A. palmata,* consolidated carbonate pavement, sediment (>1 cm depth), gorgonians, zoanthids and "other".

In addition to the method of haphazardly placed or "random" quadrats, a more intensive linear-quadrat method was also employed to survey transect BI-3. In this method, 1 m^2 quadrats were placed every consecutive meter on either side of the transect line and assessed

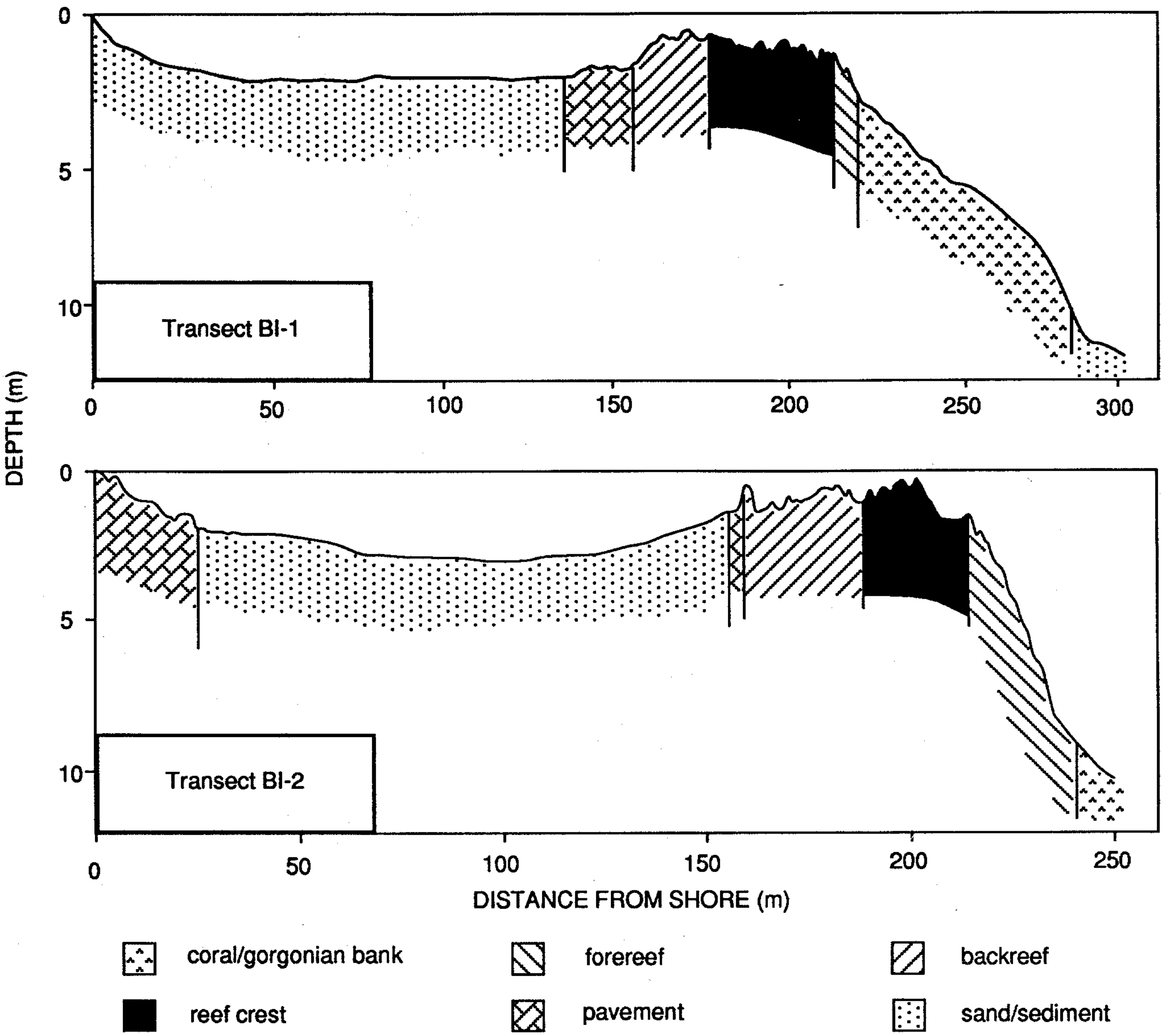

Figure 2. *Depth profiles and major benthic zonation patterns along transects BI-1 and BI-2. See Figure 1 for the locations of transects.*

visually as above. A comparison of the two methods showed no significant difference in percent coral cover estimates in 10 out of 11 subzones studied (from 95% confidence intervals on the mean after arcsin transformation; see Sokal and Rohlf,1981).

Present-day Community Structure

The major zonation patterns of the Buck Island bank-barrier reef and lagoon are presented in Figure 1, redrawn from the map of Anderson *et al.* (1986). Figures 2 and 3 show depth profiles for the five cross-reef transects (BI- to 5) surveyed most recently in Fall, 1988.

Summary data for total benthic cover are presented for each subzone along each transect in Figure 4. Data represent mean percent cover of each category within the subzone. Transects cross similar subzones in several areas (Fig. 1) and aspects of community structure of each of these features are described below:

Lagoon pavement - A shallow (1-2 m) limestone pavement with scattered live coral heads fringes the east coast and is best developed on the more exposed northeast shore. A particularly rich pavement/fringing reef exists at the east point. On the south shore, this zone is narrower and less consolidated, in places consisting of rubble and sand patches. Although overall live coral cover on the inshore pavement is low (2-6%), individual coral heads often attain very large sizes (Fig. 5a). In particular, *Diploria strigosa* heads 2-3 m in diameter can be seen on the northeast shore. From maximal shallow-water growth rates (Huston, 1985), we estimate some of these live coral heads to be at least 50 years old. The dominant coral species in this inshore zone are head corals; *D. strigosa,*

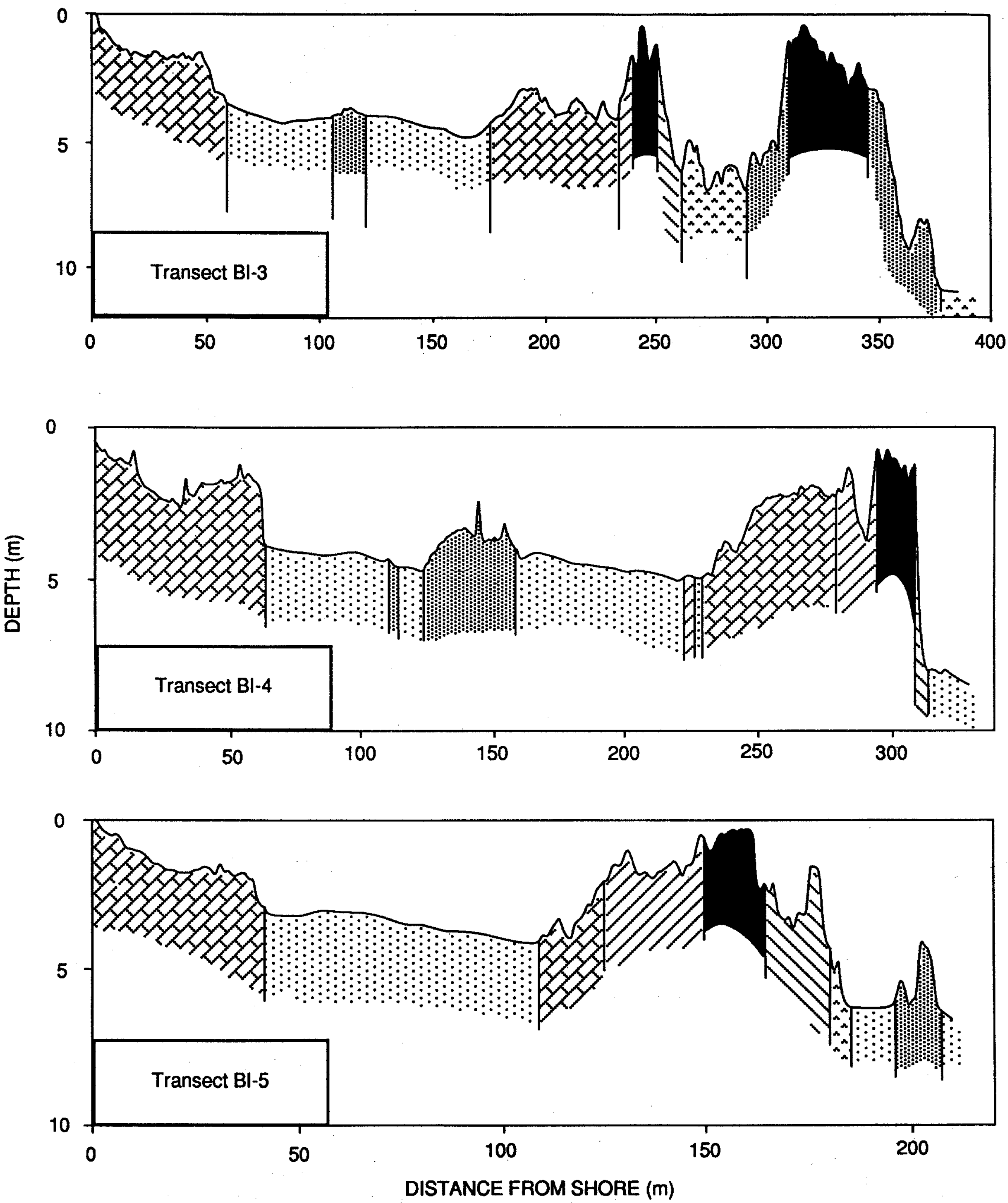

Figure 3. *Depth profiles and major benthic zonation patterns along transects BI-3, BI-4 and BI-S. See Figure 1 for the locations of transects and Figure 2 for a key to other zonation-pattern definitions.*

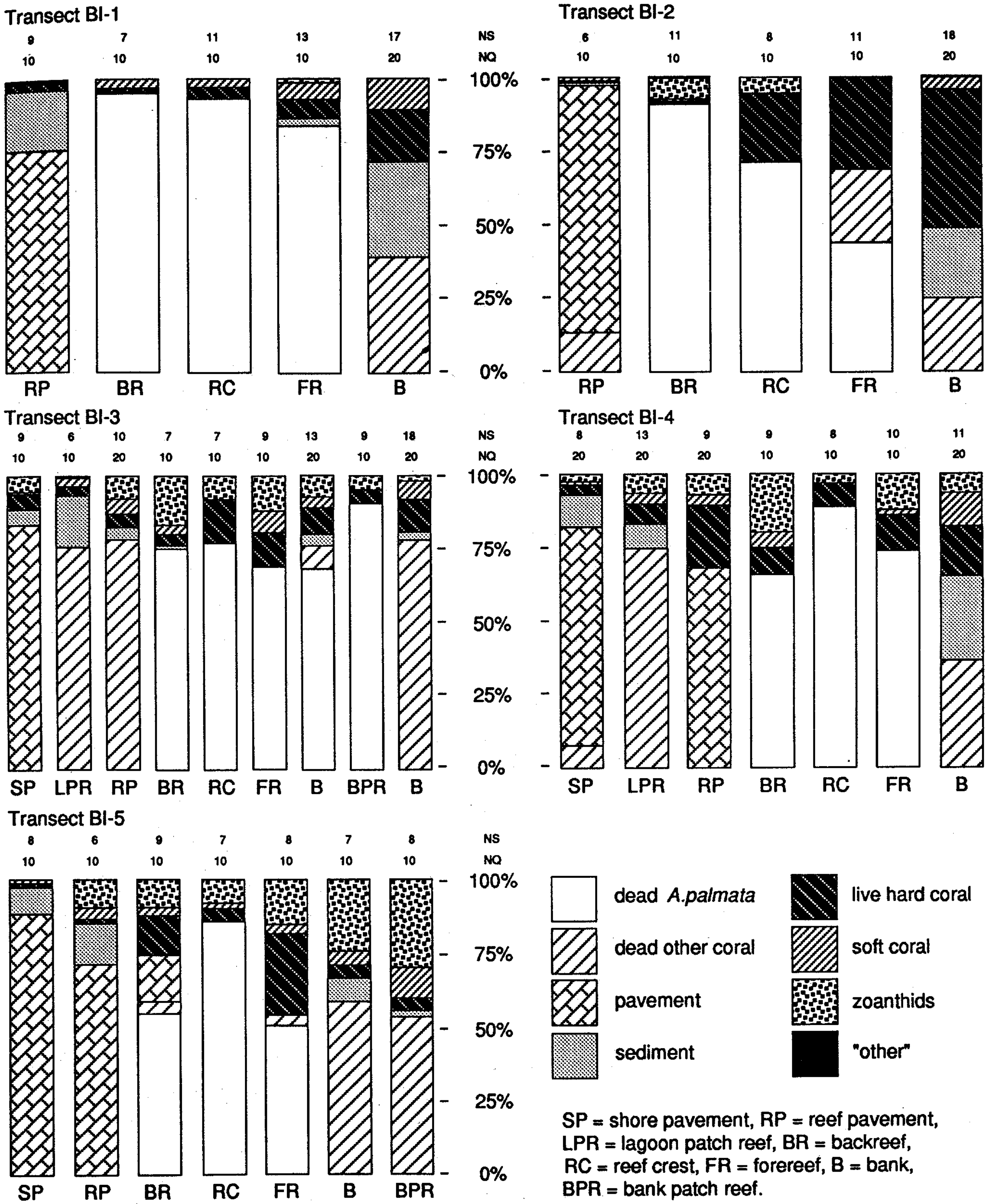

Figure 4. Percent benthic cover data for each zone (excluding sand) along transects BI-1 to BI-5. Data represent mean percent cover for each category. NS = number of hard coral species (including Millepora *spp.) recorded from visual surveys of each zone, 3 m either side of the transect line. NQ = number of 1-m*^{2} *quadrats used within each zone.*

Figure 5. ***A****. Large colony of* Diploria *strigosa in the nearshore pavement zone on the north side of Buck Island.* ***B****. Large stands of* Montastrea annularis *on the lagoon pavement near the backreef of transect BI-3.* ***C****. Dense patch of mainly dead Acropora* prolifera *in the seaward lagoon pavement zone near transect BI-3.* ***D****. The steep shallow forereef zone, consisting almost entirely of dead Acropora* palmata, *on the north side of Buck Island.* ***E****. A colony of A.* Palmata *infected with White Band Disease.* ***F****. Colony of* D. *strigosa with Black Band Disease.*

D. clivosa and *Porites astreoides,* with *Montastrea annularis* being locally abundant.

There is also an extensive pavement zone on the inshore side of the bank-barrier reef. The zone is widest (175 m) at the east end and narrowest (5-10 m) along the more sheltered south reef. Gladfelter et *al.* (1977) classified this the 'head coral zone' due to the predominant growth form in these areas. The zone is mainly composed of small to medium-sized coral heads, with locally abundant gorgonians. Near the backreef zone in particular, there are several areas with large colonies of *Montastrea annularis* (Fig. 5b) and *Diploria strigosa* and also some well-developed stands of *Acropora palmata.*

Of particular interest on the pavement zone near the back reef of transect BI-3, is an extensive thicket of mainly dead *Acropora prolifera* (Fig. 5c). In 1976 this area had approximately 60% cover of live A. *prolifera,* perhaps the best-developed stand of this species on St. Croix. Recent surveys show that *Diploria clivosa* and D. *strigosa* are now the dominant coral species, contributing to a total percent coral cover of only approximately 5%.

Lagoon - The lagoon is deepest (3-5 m) on the north side and shallower (2-3 m) on the south. The bottom is largely unvegetated sediment in the fine sand to silt range, with little seagrass development. Sediments are extensively reworked by the burrowing shrimp, *Callianassa* spp., whose mounds are evident throughout the lagoon.

Lagoon patch reefs - Patch-reef development is extensive in the north lagoon. Structure of the patch reefs is generally similar to the reef pavement zones, with depths of approximately 2-3 m. However, there are occasional rich stands of *Montastrea annularis, Acropora palmata* and individual large heads of *Diploria strigosa,* and some of the patch reefs are emergent at low tide. Generally, live coral cover is poor. Only two lagoon patch reefs were included in recent surveys (transects BI-3 and BI-4), with 4% and 7% cover respectively.

Bank barrier reef - The reef is formed almost exclusively of dense stands of dead *Acropora palmata* and can be divided into at least three distinct ecological zones; the landward backreef, the reef crest and the seaward forereef. Being comprised of massive-branching A. *palmata,* the whole reef is highly porous with many cuts, channels, larger holes and caves. This porous structure is particularly evident on the north reef, with the south reef being wider, more uniform and more consolidated in structure. Both the forereef and backreef slopes are steeper on the north reef, being vertical or undercut in many areas. To the south of Buck Island, the steeply inclined shallow forereef grades into a deeper forereef or bank region which slopes gradually to a sand/seagrass bottom in 10-12 m depth. The steep northern forereef (Fig. 5d) drops abruptly to a coral/gorgonian bank, with some large sand patches, at shallower (6-10 m) depths.

In addition to A. *palmata,* the hydrocoral *Millepora complanata* is abundant on the shallow (0-0.5 m) reef crest in most areas, with the zoanthid *Palythoa caribbea* forming extensive sheets or "caps" in many areas. Head corals, *Diploria strigosa* and Porites *astreoides,* are also abundant on the reef crest, although generally these species are restricted to pockets or cuts in the crest of the more-exposed northern reef. Highest live-coral cover was found on the south reef crest of transect BI-2 (24%), with *D. strigosa* the dominant species.

The backreef generally has the lowest coral cover and species richness of all zones studied; 1-2% live cover on the south reef and 4-6% on the north. The exception to this was a rich stand of *Acropora palmata* on the backreef of transect BI-5, contributing to total live coral cover of 13%.

Coral cover is high on the shallow forereef (6-30%), with *Acropora palmata,* Porites *astreoides, P. porites* and *Agaricia agaricites* being the dominant live corals. On the two southern transects, the deeper forereef slope showed very high coral cover (20% and 48%) and number of species (17 and 18 species). Species composition is similar to the coral/gorgonian bank on the north and east (see below), with *Montastrea annularis, Porites porites* and *Siderastrea siderea* being the most abundant species.

Mixed coral/gorgonian *bank* - Outside the reef is the more or less flat bank region, part of the St. Croix shelf. On the north and eastern sides of Buck Island this consists of carbonate pavement with live coral and gorgonian cover, together with some large sand patches. This region is also characterized by tall, conical bank patch reefs or "haystacks". To the south, the bank is mainly sand and seagrass, with some isolated patch reefs of low relief. Coral cover on the north bank region was generally high (9-17%) with *Montastrea annularis* dominant in most areas. Gorgonians are locally abundant, with mean cover of 3-11%.

Bank patch reefs ("haystacks") - Only one haystack reef was included in current surveys, a large reef on transect BI-3. Community composition appears to be similar to that of the bank-barrier reef, with *Acropora palmata, Millepora complanata* and *Diploria strigosa* dominating the reef crest. Both the windward and leeward slopes have sparse coral cover (3-4%), consisting mainly of *Millepora squarrosa, A. palmata* and Agaricia sp.

MAJOR SHIFTS IN CORAL COMMUNITY STRUCTURE SINCE 1976

Between the 1976 and 1985 surveys (Gladfelter *et al.,* 1977; Anderson et *al.,* 1986), some major changes were noted in reef community composition and specific coral abundances. Present studies allow us to make a comparison using all five of the original transects rather than the single transect resurveyed in 1985.

The major changes that were noted in 1985 (Anderson et *al.,* 1986) have been confirmed by recent studies. In 1976, the reef crest on the north and south bank-barrier reefs and also on the northern forereef was composed of greater than 50% live *Acropora palmata.* At that time A. *palmata was* seen to dominate the forereef slope down to the bank at a depth of 10-15 meters in the north and east sections of the reef. In the south, this species was dominant down to 3-4 meters. The northern forereef slope had total coral coverage of 44% of which nearly three quarters was A. *palmata.* The 1985 survey showed that coverage of A. *palmata* was dramatically reduced in the region of transect BI-3, with the dead colonies encrusted with algae and gorgonians. In the forereef area, coverage by hard corals was reduced to 20%, although A. *palmata* was still dominant (>10% of coral coverage). Present results show that live coral coverage is now less than 12% with only approximately 3% A. *palmata* on the forereef in the vicinity of transect BI-3. Figures are similar for transect BI-4. In contrast, transect BI-5 shows an abundance of this species (27% live coral, with 72% *A. palmata* on the upper forereef), suggesting that this area was less affected by the mass mortality which devastated most of the reef. The higher coverage in this area cannot be solely due to recruitment or recovery of fragments, since many of the colonies present have a spread of several meters and, therefore, predate the 1976 survey. *A. palmata* still dominates the coral community in many shallow reef areas on the south side, but coverage is low. This species is now only rarely seen below a depth of 3-4 meters on any part of the reef.

Also noted in the 1985 study was a dramatic reduction in coverage by *Acropora prolifera,* which previously formed an extensive thicket (60% coral cover) on the lagoon pavement landward of the reef in the region of transect BI-3. Recent surveys show that this species has been reduced to approximately 10% of the live coral coverage which constitutes only about 5% of the total bottom cover. This area is now dominated *by Diploria clivosa* and *D. strigosa,* although a small percentage of healthy live colonies of A. *prolifera* are present. A. *prolifera* was not seen on any of the other four transects.

Further degradation in community structure has been noted during recent studies, and some of these changes appear to have occurred since 1985. *Acropora cervicornis* composed approximately 2% of the total coral cover of 27% in the rich bank area on the north side in 1976, and this species was seen to be still dominant in the bank region of transect BI-3 in 1985. *A. cervicornis* was not found at all on transect BI-3, or indeed in any of the northern transects during current surveys, even outside recorded quadrat areas. This species is still present on the southern reef, however, and may be locally abundant (2-3% of coral cover).

The mass mortality of *Acropora palmata* populations on St. Croix due to the effects of White Band Disease (Fig. 5e) was first noted by Gladfelter (1982) in 1976. This disease also affects A. *cervicornis* and *A. prolifera,* and is still relatively common at Buck Island, despite the low remaining population densities of acroporids. It is possible that the reduction of *Acropora* populations since 1976 may be largely attributed to this disease, although this cannot be determined with certainty, and the causes and effects of the disease are still poorly understood (Peters *et al.,* 1983; Peters, 1984). Several of the massive corals are also affected by Black Band Disease (Fig. 5f), a disease with similar etiology (Antonius, 1981).

The massive coral *Porites astreoides* does not appear to be affected by the band diseases and there is evidence from present surveys to suggest that this species has benefited from the reduction in A. *palmata* populations. This species is dominant in many reef crest and forereef areas. In 1976, it was particularly abundant on the reef crest on the south side and the forereef on the north side of Buck Island. Today, *P. astreoides* also dominates the northern reef crest (25% to 70% of coral cover), although populations appear to have remained more stable on the southern part of the reef (8% to 15% on the reef crest and 8% to 23% on the forereef). Data suggest that the increased dominance of P. *astreoides* on the north side is not due solely to the relative reduction of *A. palmata* populations, but is also a result of growth and increased coverage. On both the forereef and reef crest of transects BI-3 and BI-4, where *A. palmata* abundance is low (0 to 8% of coral cover), P. *astreoides* is dominant (35% to 70% of coral cover) and represents between 5% and 6% of the total bottom coverage. However, on transect BI-5, A. *palmata* is abundant and still the dominant species (51% on the crest and 72% on the forereef) and both abundance and total bottom cover of *P. astreoides* are lower (25% and 1% of coral cover on the crest and forereef respectively, representing only 1% and <1% total bottom cover).

It can, therefore, be seen that there has been a substantial reduction in live coral coverage in almost all areas of the Buck Island reef system since surveys were originally carried out in 1976. This reduction is almost entirely due to the loss of *Acropora* species, the most rapidly growing species present. It appears that at least one species, *A. cervicornis,* has virtually disappeared from the north side and is significantly depleted on the south side (this decrease was not recorded in the 1985 survey). Although there are promising signs of recovery and recruitment to both *A. palmata* and *A. prolifera* populations (personal observations), coral abundance is still much reduced. There is some evidence to suggest that other species may have increased bottom cover in areas where *Acropora* species have been denuded, but this represents only a relatively small recovery in terms of total cover.

The geologic significance of these changes in community composition cannot be fully assessed until further data are available on rates of recruitment and recovery of the denuded populations. It is obvious though, that these changes could represent a 'switch off event in terms of reef accretion in the area. These changes appear to have occurred without any catastrophic storm damage or obvious changes in water quality. It is possible that similar biological phenomena, perhaps undetectable in the geologic record, may have caused the cessation of reef growth in the past. Continued long-term ecological monitoring, and a WIL/NPS coring investigation just starting at Buck Island, will hopefully address some of these questions. Certainly, processes of recovery barely detectable over a 13-year period do not appear to equal those of Pacific reefs devastated by Crown-of-Thorns starfish, some of which have shown replenished coral cover (if not community composition) within five years (Pearson, 1981; Done, 1985).

Whatever the outcome of these events at Buck Island, the dramatic change in benthic cover has served to raise two significant points. First, from a geological standpoint, there is a great danger in using zonation schemes derived from short-term studies of modern reefs to model their ancient counterparts. The community shifts at Buck Island have resulted in a very different reef from that which existed in 1976. Furthermore, these changes have occurred without the dramatic perturbations in oceanographic conditions typically invoked to explain such shifts in the fossil record. Second, from a biological and management standpoint, we are presently unable to separate community shifts due to regional or global-scale man-induced changes from those naturally occurring as part of a longer-term cycle. We must, therefore, have detailed long-term observations of community structure and environmental conditions before we can apply such terms as "typical" or "healthy" to modern reefs.

REFERENCES CITED

Adey, W.H., 1975, Algal ridges and coral reefs of St. Croix: their structure and Holocene development, Atoll Res. Bull. 187:1-67.

Anderson, M., Lund, H., Gladfelter, E.H., and Davies, M., 1986, Ecological community type maps and biological community descriptions for Buck Island Reef National Monument and proposed marine park sites in the British Virgin Islands. U.S. National Park Service and Virgin Islands Resource Management Cooperative Rep., 236p.

Antonius, A. 1981, The "band" diseases in coral reefs, Proc. Fourth Intl. Coral Reef Symp. 2:6-14.

Done, TJ., 1985, Effects of two *Acanthaster* outbreaks on coral community structure - the meaning of devastation, Proc. Fifth Intl. Coral Reef Symp. 5:315-320.

Gladfelter, W.B., Gladfelter, E.H., Monahan, R.K., Ogden, J.C., and Dill, R.F., 1977, Environmental studies of Buck Island Reef National Monument, U.S. National Park Service Rep., 144 p.

Gladfelter, W.B., 1982, White band disease in *Acropora palmata:* implications for the structure and function of shallow reefs, Bull. Mar. Sci. 32:639-643.

Gladfelter, W.B., and Gladfelter, E.H., 1979, Growth and total carbonate production by *Acropora palmata* on a windward reef, in Gladfelter, W.B., Gladfelter, E.H., Monahan, R.K., Ogden, J.C., and Dill, R.F., Environmental studies of Buck Island Reef National Monument, U.S. National Park Service Rep., p. to iii-8.

Hubbard, D.K., 1979, Reef development and sedimentary processes, in: Gladfelter, W.B., Gladfelter, E.H., Monahan, R.K., Ogden, J.C., and Dill, R.F., Environmental studies of Buck Island Reef National Monument, U.S. National Park Service Rep., p. ii-1 to ii-12.

Pearson, R.G., 1981, Recovery and recolonization of coral reefs, Mar. Ecol. Prog. Ser. 4:105-122.

Peters, E.C., Oprandy, J.J., and Yevich, P.P., 1983, Possible causal agent of "white band disease" in Caribbean acroporid corals, J. Invertebr. Pathol. 41:394-396.

Peters, E.C., 1984, A survey of cellular reactions to environmental stress and disease in Caribbean scleractinian corals. Helgoländer Meeresunters, 37:113-137.

Sokal, R.R., and Rohlf, F.J., 1981, Biometry, W.H. Freeman, San Francisco.