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Pathologies Affecting Reef Corals at the Flower Garden Banks, Northwestern Gulf of Mexico

ERIC H. BORNEMAN AND GERARD M. WELLINGTON

The Flower Garden Banks are high-latitude reefs consisting of coral caps on the top of salt domes in the northwestern Gulf of Mexico. Limited studies to date report low incidence of coral disease on these reefs. Surveys were conducted to document the extent of coral diseases throughout the Flower Garden Banks, including types of disease present, species affected, percentage of recent colony mortality, cases of “false” disease, and descriptions of new pathologies. Very few of the known (or reported) Western Atlantic diseases were found, and they occurred at extremely low frequencies. Tissue-skeletal anomalies were common. Several conditions resembled known diseases, although their appearance was not wholly consistent with described pathologies and they may represent different conditions. Both “ridge-mortality disease” and “rapid wasting disease” were confirmed to be the result of fish biting activities. Several novel pathologic conditions that do not fit the description or known etiology of any currently described coral disease were discovered at relatively high prevalence rates. Because of an absence of standardized coral disease nomenclature and the unknown etiology of these novel syndromes, they are tentatively named pale ring, pale patch, and mottling syndromes on the basis of field characteristics.

The coral reefs of the Flower Garden Banks consist of coral caps that sit atop two large salt domes, comprising the East and West Flower Garden Banks. The reefs, at 18–36 m in depth, have a total area of approximately 350 acres and are a part of a larger nationally protected marine sanctuary established in 1992. The Flower Garden Banks are the most northerly and isolated coral reefs on the North American continental shelf, located approximately 110 nautical miles southeast of Galveston, TX, in the northwestern Gulf of Mexico. These reefs are among the least affected and healthy coral reef communities in the Caribbean and western Atlantic region, possessing very high (approximately 20–76%) scleractinian coral coverage (Dokken et al., 1999, 2001, 2003; Lang, 1999; Causey et al., 2000; Schmahl and Hickerson, 2000; Lang et al., 2001) but lacking the gorgonian communities that typify western Atlantic reefs. Largely unaffected by bleaching events and anthropogenic influences because of their depth, oceanic inputs, limited recreational use, and isolated location, coral coverage at the Flower Garden Banks has not significantly declined since monitoring began in the early 1970s (Lang, 1999; Pattengill-Semmens et al., 2000).

Increasing numbers and types of diseases of reef corals are being reported worldwide, but especially in the Caribbean basin (Bruckner, 2002). The most important hermatypic taxon, the *Montastraea annularis* spp. complex, is cur-

rently and primarily threatened by three diseases: black band disease, Caribbean yellow band (= yellow blotch) disease, and white plague. *Montastraea faveolata*, *M. franksi*, and *M. annularis* are the dominant coral species at the Flower Garden Banks ($\approx 57\%$), followed by *Diploria strigosa* ($\approx 17\%$), *M. cavernosa* ($\approx 7\%$), and *Porites astreoides* ($\approx 7\%$) (Dokken et al., 1999). Species of *Diploria* are also being affected heavily by both black band disease and white plague throughout the Caribbean and western Atlantic, and many of the other 20+ hermatypic (reef building) species present at the Flower Garden Banks are also susceptible to these pathologies.

The Flower Gardens Banks have historically had a low prevalence of coral disease reported. Coral mortality is primarily due to transient and seasonal increases in algae, parrotfish predation, damselfish “lawns,” and the corallivorous snail *Coralliophila abbreviata* (Gittings et al., 1993). The first reports of coral disease were described in the late 1970s and included “leprosy” of *M. cavernosa*, a “white flake” disease that affected numerous scleractinian species, and a “white gop” in *Montastraea* species (Bright and Rezak, 1978). Another early report of a coral disease on these reefs was white mat disease, also referred to as ridge disease, reported during monitoring activities from 1988 to 1991 (Deslarzes, 1992). Coral disease was also monitored as part of a long-term monitoring project cofunded by the National Oceanic

and Atmospheric Administration (NOAA) and the Minerals Management Service (MMS) from 1992 to present (MMS Publications 1996-0046, 1999-0005, 2001-101, and 2003-031) across 40 permanent 8-m² quadrats. In these studies, disease was found to be present at very low levels. Photo and video transects were also used in the long-term monitoring, and all survey techniques combined found an extremely low prevalence of disease level (0.006% of 3,700 colonies), resulting in approximately 0.03% of coral mortality on the reefs (Dokken et al., 1999). "Low" incidence of disease was reported during a joint AGRRA/REEF (Atlantic and Gulf Rapid Reef Assessment-Reef Environmental Education Foundation) survey from 15 to 20 Aug. 1999, although only 25 transects and a total of 295 colonies were examined (Pattengill-Semmens et al., 2000), and the figure represents prevalence and not incidence. Other studies report an incidence rate of coral disease at less than 2% (Gittings et al., 1993). At least one other team has recently performed preliminary investigations of coral disease at the Flower Gardens Banks (Oberding et al., in prep.).

Unfortunately, many of the previous reports for the Flower Garden Banks National Marine Sanctuary (FGBNMS) have questionable coral disease identifications and reported disease levels, and disease nomenclature used for the Flower Garden Banks has been highly variable. For instance, Dokken et al. (1999, 2001, 2003) include disease descriptions as nonspecific tissue loss, the general term "bleaching" to indicate disease, and include "ridge disease" and an "algallike infection of *Montastraea* species." The algallike infection was not well described at the Flower Garden Banks and does not appear elsewhere in the literature. Ridge disease (Kaufman, 1977; Abbott, 1979), also called ridge-mortality disease in reports from the Flower Garden Banks (Zimmerman, 1994; Dokken et al., 1999; Oberding et al., 2002) and damselfish ridge-denuding syndrome (Williams and Bunkley-Williams, 2000), have been reported to be caused by damselfish predation (Bruckner, 2001). White mat disease, also referred to as ridge disease by Deslarzes (1992), is not a currently recognized condition or term by most coral disease researchers. Dokken et al. (1999) reported black band disease as common, affecting 4.17% of the total area surveyed, and also found Caribbean yellow band (= yellow blotch) affecting three species. Many investigators have erroneously attributed fish biting, snail predation, and bleaching events to coral disease (Bruckner, 2002; R. J. Bruckner

and A. W. Bruckner, 2004), and some question exists as to the accuracy of data presented in previous surveys because many signs of disease may be confused with predation, competition, and other conditions. In the majority of cases, gross examination of a specimen at one time point is inadequate to determine whether a disease is present and to identify that disease. Samples for histological examination and microbiological analyses must be taken and are critical in determining whether a disease is present.

Rigorous surveys were conducted at the FGBNMS between May 2003 and Aug. 2004, with the objective of establishing baseline data on the extent of coral diseases throughout the Flower Garden Banks. These surveys evaluated types of disease present, species affected, percentage of recent coral mortality, cases of "false" disease, and descriptions of any new pathologies. Three new pathologic conditions are reported in this study for the first time. Because of the lack of standardized nomenclature for coral diseases and an incomplete understanding of the etiology of these conditions, we tentatively call these syndromes pale ring, light patch, and mottling syndromes, on the basis of their field characteristics.

MATERIALS AND METHODS

In May and Aug. of 2003, eight haphazardly placed 1 × 25-m belt transects were examined while diving using Nitrox SCUBA at the East (n = 4) and West (n = 4) Flower Garden Banks. A modified AGRRA protocol was used to determine coral species abundance, size, and condition. Colony size and lesion size were measured using a meter stick divided into 1-cm increments and recorded to the nearest centimeter. Gross observations recorded included size, percent colony mortality as recent or old mortality, presence or absence of disease or bleaching, presence of corallivores, competition and overgrowth, and any other remarkable features. Diseases were identified on the basis of gross field signs as described in the literature, with tentative nomenclature presented for previously undescribed conditions. Overlapping quadrats approximately 1 m wide were photographed along the transect lines, using a Nikon CoolPix 990 digital camera and an underwater strobe.

In 2004, four 25-m transects were performed at each bank, although a point-intercept technique was used instead of the AGRRA approach. Each coral found under the transect line at 0.5 m increments was assessed individ-

TABLE 1. The population dynamics of reef-building corals (all colonies over 5 cm diameter) and condition at the Flower Garden Banks from May 2003 to Aug. 2004. All data are presented as a mean of all species examined on each reef. A total of 1,267 colonies were recorded during this study, representing 16 of 21+ species known to occur. The abundance of corals is represented as the number of colonies and as a percent representing the relative dominance of corals at the sites examined. Other data include the mean size^a (maximum diameter) and mean percent mortality (old and recent mortality). The cause of recent mortality includes the percentage of colonies with active coral disease, bleached colonies, overgrowth by cyanobacteria or algae, predation by snails or fishes, competition with other corals.

Species	Diameter (cm)	Abundance		Morbidity			Bleaching	Predation	Competi- tion	Algae
		#	%	Recent	Old	Disease				
<i>Montastraea franksi</i> ^a	197	374	29.5	1.1	1.3	0.2	0.6	0.6	0.0	0.7
<i>Porites astreoides</i>	39	265	21.0	1.6	1.9	0.0	0.6	0.6	0.3	1.9
<i>Montastraea faveolata</i> ^a	170	223	17.6	3.4	5.5	0.13	0.3	2.8	1.6	4.9
<i>Diploria strigosa</i>	134	170	13.4	5.6	2.4	3.24	0.6	2.5	0.8	0.5
<i>Montastraea cavernosa</i>	201	63	5.0	5.2	0.3	0.0	1.0	0.2	0.0	0.0
<i>Millepora alcornis</i>	70	44	3.5	6.7	0.0	0.0	2.1	0.0	0.0	0.0
<i>Colpophyllia natans</i>	93	42	3.3	0.75	0.0	0.3	0.1	0.4	0.0	0.0
<i>Stephanocoenia intersepta</i>	52	30	2.4	2.5	2.0	0.0	2.8	0.0	0.0	2.2
<i>Agaricia agaracites</i>	23	14	1.1	4.6	0.0	0.0	3.6	0.0	0.0	1.0
<i>Mussa angulosa</i>	9	12	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>Madracis decactis</i>	62	12	0.9	2.5	1.5	0.0	0.0	3.5	0.0	0.0
<i>Siderastrea siderea</i>	107	5	0.4	0.0	10.0	0.0	0.0	10.0	0.0	0.0
<i>Montastraea annularis</i> ^a	133	5	0.4	0.0	2.0	0.0	0.0	0.0	2.0	0.0
<i>Porites furcata</i>	35	5	0.4	5.0	2.0	0.0	0.0	3.0	2.0	2.0
<i>Scolymia</i> sp.	6	2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>Meandrina meandrites</i>	60	1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	1,391	1,267	100.1	38.95	28.9	3.87	11.7	23.6	6.7	13.2

^a Colony size was recorded only in 2003.

ually for condition. The transects were extended north, south, east, and west from mooring buoys #2 (East Bank) and #4 (West Bank). Each transect was archived using a housed Sony high-resolution digital camera fitted with a wide-angle lens.

Timed swims were performed in both Aug. 2003 and Aug. 2004 to assess specific disease conditions and increase the susceptible population size. After descending to the mooring anchor, a heading was taken continuing in a direction in line with the anchor rope. A slow swim speed of approximately 0.75 m/sec was continued for exactly 20 min, and all colonies within an approximately 1-m visual swath directly below the diver were observed for signs of the targeted disease and recorded on underwater paper.

RESULTS

The species that occurred on transects and their relative dominance of the total coral community are shown in Table 1. The dominant species were the *M. annularis* complex (47.5% of all colonies); *P. astreoides* (21.0%); *D. strigosa* (13.4%); *M. cavernosa* (5.0%); *M. alcornis* (3.5%); and *Colpophyllia natans* (3.3%).

All other species combined comprised 6.8% of the coral population. Colony density was approximately 2 colonies/m² with an average colony size of approximately 86.9 cm in diameter. The mean percent of partial mortality (old or new) was 4.2% of a colony. Recent tissue loss (partial mortality) averaging 2.4% existed on 10.9% of colonies, 93% (79 colonies) of which was due to fish bites. The remainder was due to coral-algal interactions (40 colonies), coral-coral competition (13 colonies), disease (four colonies), and unknown causes (three colonies). Old partial mortality was present on 35.5% (449 colonies) of corals and affected an average of 1.8% of a colony and was characterized by algal overgrowth of crustose coralline algae, *Lobophora* sp., various other species, and rarely *Dictyota* sp. (three colonies). Where possible to ascertain, reasons for old mortality were recorded as being due to fish bites and coral-coral competition.

Coral disease data for the surveys from 2003 to 2004 are shown in Table 2. A total of 1,267 colonies were observed for disease on transects, of which 66 showed signs of disease, although 62 of these did not have any tissue loss associated with the conditions. The prevalence of diseased colonies over the time periods ex-

TABLE 2. Diseases affecting corals at the Flower Garden Banks (May 2003–Aug. 2004). Susceptible colonies are the number of colonies occurring on transects that are known to be species susceptible to the given disease. Prevalence is the percentage of colonies of the surveyed population affected by a disease. Numbers in parentheses represent maximum point prevalence values for diseases with a temporal prevalence component.

Disease	Susceptible colonies	Affected colonies	Prevalence (mean %)	Notes
Cyanobacterial mat disease (black band or red band disease)	1,260	0	0.00	Only putative cases observed
White plague (type II)	1,220	1	0.08	Only putative cases observed
Caribbean yellow band (=blotch)	1,141	0	0.00	Only putative cases observed
Tissue–skeletal anomalies (corallite gigantism, chaotic polyp development)	875	19	2.17	92% occur on <i>Diploria strigosa</i>
Dark spots syndromes	874	0	0.00	Only putative cases observed
Mottling syndrome ^a	291	37	12.7 (16.0)	Affects only <i>Colpophyllia natans</i> . Data include transects and timed swims
Light patch syndrome	115	1	0.87	Affects only <i>D. strigosa</i>
Pale ring syndrome	1,141	67	5.87 (19.2)	Affects numerous species (see text). Data include transects and timed swims
Patchy bleaching	265	1	0.37	Affects only <i>Porites astreoides</i>

amined showed a strong temporal effect. Point prevalence for colonies in May was 1.7% and 1.4% for 2003 and 2004, respectively. In August, point prevalence was 12.2% and 3.7% for 2003 and 2004, respectively. A mean disease prevalence of 4.75% exists for colonies at the Flower Gardens over the 2-yr period. The mean prevalence rate for the nine diseases observed (including novel conditions described below) is 2.45%.

Previously unreported conditions.—Mottling syndrome: Mottling syndrome affects the brain coral, *C. natans*, and occurs predominantly at the West Bank (Fig. 1). The condition presents initial signs of a focal lesion, often near a margin or depression of a colony, with tissue appearing mottled as a result of partial bleaching. Total to near-total bleaching is present at what appears to be the earliest focus of the lesion, with spotty bleaching occurring in a wide band that grades toward apparently healthy tissue. Tissue loss is not initially present, and there are no growth anomalies associated with lesions. The mucus tends to be heavy and gel-like on affected tissues. As the lesion increases in size, tissue loss occurs at the original focus and spreads outward. The severity of bleaching is always greatest near the oldest part of the lesion, with spotty bleaching farther away from the origin. Severely affected colonies may have

signs of this mottled appearance on nearly 100% of their tissue with up to 15% partial mortality at the original lesion site.

Mottling syndrome was not present during surveys in May 2003, but was first observed on transects in Aug. 2003. Sixteen (10.4%) and 13 (16.0%) *C. natans* colonies were affected by mottling syndrome as counted by a 20-min timed swim from mooring buoy #4 on the West Bank in Aug. of 2003 and 2004, respectively. In 2004, several affected colonies were seen with juvenile *Stegastes planifrons* present near the lesions. This factor is addressed in the discussion section below.

Pale ring syndrome: Pale ring syndrome was found to affect nine species at the Flower Garden Banks, but was most common on *M. favosolata*, *M. cavernosa*, *C. natans*, and *D. strigosa* at the Flower Garden Banks. The condition occurred at both East and West Flower Garden Banks but was most prevalent at the West Bank. Pale ring condition is characterized by a variably wide ring that occurs singly or in multiples on the corallum surface (Fig. 2). The rings may also appear as splotches or solid circles. There is no mortality, tissue loss, or growth anomaly associated with the condition. The pale areas do not appear to be bleached but rather result from an opaque white material within or attached to the surface of the tissue.

Figure 1–4. **Figure 1.** Mottling syndrome in *Colpophyllia natans* characterized by mottled bleached tissue and tissue loss occurring at the focus of the lesion.

Figure 2. Pale ring syndrome on *Colpophyllia natans* (left) and *Montastraea franksi* (right).

Figure 3. Pale patch syndromes on *Diploria strigosa*.

Figure 4. Tissue-skeletal anomalies with pale ring condition also present on *Diploria strigosa* (left) and corallite gigantism on *Colpophyllia natans* (right).

In Aug. 2004, four *Diploria* colonies were found outside of transect areas, with a very fine speckled pattern uniformly dispersed over the colony, which appeared, on close examination, to be the same opaque material but distributed differently on the affected colonies.

Forty-one colonies on transects showed signs of a pale ring at the West Bank near mooring buoy #4 in Aug. 2003, but only three affected colonies were seen during surveys earlier in the year in May. In Aug. 2003, approximately 20% of all susceptible coral species were affected by the condition as counted during a 20 min timed swim, although not all colonies had well-developed rings. This number decreased to less than 1% for all colonies in Aug. 2004 but still affected 11.7% of *C. natans* colonies.

Light patch syndrome: One of the more consistent conditions that occurs year round at the Flower Garden Banks appears to affect only *D. strigosa*. The condition is characterized by variably sized, solid patches of uniformly contrasting paler tissue on normally pigmented colonies (Fig. 3). No tissue loss is associated with the condition, but changes in the meander pattern of the corallum are present in some cases. The affected areas do not appear to increase in size faster than the colony growth as a whole, and in some cases, the pigment change of the patch area precisely follows the top corallite wall of the colony meanders. The prevalence for this conspicuous condition is less than 1% of *D. strigosa* colonies. Similar patch-like areas also have been occasionally observed in *M. faveolata*, but it is not known whether this is a similar or a different phenomenon.

Occurrence of previously described diseases and other conditions.—Tissue-skeletal anomalies: Tissue-skeletal anomalies (Peters et al., 1986; Peters, 2004) resulting in corallite gigantism (also known as areas of abnormal accelerated growth or hyperplasia) and chaotic polyp development are common at the Flower Garden Banks and affect numerous species (see Table 2). They are most common in *Diploria* spp. (Fig. 4). Ninety-two percent of the growth anomalies were corallite gigantisms that occurred on *D. strigosa*, with a single case of chaotic polyp development occurring on a *M. franksi* colony. Approximately 15% of *Diploria* colonies were affected by these abnormal growths but less than 1% of other species. Other forms of growth anomalies, such as neoplasia (calicoblastic epithelioma), were not seen.

Damselfish ridge denudation: Conspicuous areas of denuded tissue along the tops of corallite walls of colony meanders were present on 8.9% of *D. strigosa* colonies and 8.5% of *C. natans* colonies, as counted during timed swims (Fig. 5). The exposed skeleton follows the meanders for variable distances (1–45 cm), originating from larger focal lesions usually near colony margins. The larger lesions bear areas of recently denuded tissue, older exposed skeleton, and patches of filamentous algae.

Forty-three colonies of *D. strigosa* were monitored for several minutes for the presence of *S. planifrons*. In 95% of cases, *S. planifrons* were found near to or defending the lesion area. In 34% of colonies with *S. planifrons* present, active nipping was observed at the distal end of the ridge lesions into healthy tissue. Two colonies in relatively exposed locations did not have *S. planifrons* present, and both colonies' ridge lesions were already becoming covered with epilithic growth with no freshly exposed skeleton or well-developed algal turf patches present.

Other diseases: Black band disease was not observed during surveys, although several cyanobacterial mats had developed at the interface of competing corals that appeared to be consistent in appearance with the well-organized band of the black band microbial consortium. A single colony of *P. astreoides* exhibited a dark band line that may have been a cyanobacterial band disease (Fig. 6), although tissue grazing, filamentous algae, and an unusual appearance may indicate a different condition or a tissue reaction by the colony. The band material was strongly attached to nearby filamentous algae but loosely associated with tissue.

A colony of *M. cavernosa* outside transect areas was observed at 35 m depth in Aug. 2003, with signs that resembled a rapid white plague type II (Fig. 7). A single colony of *D. strigosa* with signs that resembled an incipient white plague type-II infection occurred on a West Bank transect in Aug. 2004.

Caribbean yellow band (= yellow blotch) disease was not observed during these surveys. Colonies of *M. faveolata* and *M. cavernosa* (n = 8) outside transect areas were observed with abnormal coloration, including yellowish lesions that are consistent in gross appearance with the early lesions of Caribbean yellow band (= yellow blotch) disease. However, no colonies were found with the larger lesions forming wide characteristic bands, with tissue loss from the foci that characterize the ongoing disease process.

Figure 5–9. **Figure 5.** Damselfish ridge denudation produced by *Stegastes planifrons* on *Diploria strigosa*. This pattern has been erroneously referred to as “ridge mortality disease.”

Figure 6. A band-like lesion on *Porites astreoides* with cyanobacterial margins that does not resemble typical cyanobacterial mat diseases like black band and red band diseases.

Figure 7. A white syndrome with signs of rapid tissue loss consistent with white plague type III on *Montastraea cavernosa* was observed in deep water in August 2003.

Figure 8. Small, darkened lesions are occasionally found on *Montastraea faveolata* that resemble conditions described as a “dark spots syndrome” by Weil (2004).

Figure 9. A patchy occurrence of bleaching was observed in colonies of *Porites astreoides* in cool water during May 2003.

No cases of dark spots disease were found on any transects. In 2004, a single colony of *Siderastrea siderea* was found with a darker tissue margin surrounding several lesions on the corallum surface, but appeared to be a tissue reaction to old injury or fish bites. Three colo-

nies of *M. faveolata* between 2003 and 2004 were observed outside transect areas, with signs of multifocal, noncoalescing, dark pigmented spots present within light patches or on normally pigmented colonies (Fig. 8). These differ in their pattern and distribution

on the corallum from the more characteristic signs of dark spots disease usually affecting *Siderastrea* species elsewhere in the greater tropical Atlantic and Caribbean. No spots were associated with depressions in the corallum surface nor did they appear to be causing depressions. A highly unusual dark pattern was found on an *M. cavernosa* colony on the West Bank in Aug. 2004 that appeared as though a dark liquid was poured onto the colony. Unusual mixing of coloration patterns seems to be relatively common at the Flower Gardens but is generally not grossly associated with loss of colony function or integrity.

Patchy bleaching was observed in 38 colonies of *P. astreoides* in two areas approximately 10 m² in size at the East Flower Garden Bank in early May 2003 (Fig. 9). The bleached areas also appeared to be spreading across and between colonies. The condition was not observed later in the year. In Aug. 2004, an estimated 30 colonies of *P. astreoides* were observed with variably extensive areas of bleached tissue, most of which were mainly confined to rings of bleached tissue around the outer margins of the colonies. The nature of the bleaching was patchy in distribution and was invariably associated with red cyanobacterial mats that intimately surrounded affected colonies.

A white mat-like covering was observed on a single colony of *Millepora alcornis*. Signs of this condition have been noted elsewhere in the Caribbean in several species (E. H. Borneman, pers. obs.), and this may be the condition referred to as white mat disease by Deslarzes (1992).

DISCUSSION

The Flower Garden Banks are unusual and exceptional reef formations in the northwestern Gulf of Mexico. They contain some of the healthiest fish and invertebrate communities in the Caribbean and boast very high coral coverage. They are also exceptional in their low prevalence of coral diseases that threaten colony integrity. Coral species coverage, abundance, distribution, and dominance found in this work are similar to previous efforts, although the five most common species seem slightly lower in percent composition (Dokken et al., 1999, 2001, 2003). This may be a reflection of transient population changes, different sampling sizes, variations between transect locations, a general decline in the primary reef-building species, or taxonomic misinterpretations.

To date, coral diseases have been associated

with conditions that cause variable rates of partial or total colony mortality. Mortality, however, is not a required characteristic of the disease process, and most diseases do not kill the affected organism. The majority of coral diseases reported here, for example, do not appear to cause colony mortality. Disease can be defined as an impairment of the normal state of the living animal or plant body or one of its parts that interrupts or modifies the performance of the vital functions and is a response to environmental factors (e.g., malnutrition, industrial hazards, or climate), specific infective agents (e.g., worms, bacteria, or viruses), inherent defects of the organism (as genetic anomalies), or combinations of these factors (Medline). Disease criteria include a recognized etiological agent, identifiable signs or symptoms, or consistent anatomic alterations. Some of the conditions reported here for the Flower Gardens occasionally consist of one or a few observations which, on the basis of the general appearance of many colonies of a species, bear alterations from what is the "normal condition or appearance," but which may not be consistent or identifiable because of the low number of observations. In the results of this study, disease was scored and perhaps arbitrarily defined as an abnormal appearance of a colony showing signs of growth anomalies, tissue loss, or change in the normal appearance of tissue in the absence of obvious nondisease related biotic or abiotic factors known to cause such an appearance (e.g., predation, abrasion, competition).

White plague, black band disease, and Caribbean yellow band (= yellow blotch) diseases are occurring at epizootic levels across various spatial and temporal scales in the Caribbean and tropical Western Atlantic. These diseases affect species that also occur at the Flower Garden Banks. Yet, corals at these remote banks do not show evidence of these pathologies to any degree, and of over 1,700 total colonies examined, no clear cases of these diseases were found.

During the course of these surveys, white plague (reported as white plaque in Dokken, 2003) appeared to be a rare disease at the Flower Gardens. The colony of *M. cavernosa* found off the transect areas at 35 m depth showed patterns of tissue loss similar to white plague, but the rate of tissue loss estimated by the amount of white skeleton exposed would suggest a much more rapid condition than white plague type II (Richardson et al., 1998). Other diseases mentioned in the literature that could result in such rapid tissue loss are shut-

down reaction (Antonius, 1981) and white plague type III (Richardson and Aronson, 2002). Only one putative case of white plague was found on transects, and similar signs have been observed only occasionally on isolated colonies during dives over the past 4 yr. However, this disease can suddenly appear on unaffected reefs and cause significant mortality to numerous taxa of Caribbean reef corals. Since the surveys conducted and described here, FGBNMS personnel have documented what appears to be a white plague type-II outbreak. Although diagnosis of the condition is yet to be conducted, surveys have resulted in the reports of at least 40 coral colonies exhibiting signs of a white syndrome and affecting seven coral species (Hickerson, pers. comm.).

Caribbean yellow band (= yellow blotch) disease has also been reported at the Flower Gardens (Oberding et al., in prep.), although no corals were clearly affected by this disease. Given the common occurrence of Caribbean yellow band (= yellow blotch) disease in *Montastraea* species in other locations and the dominance of *Montastraea* at the Flower Garden Banks, it was encouraging to not find clear cases of the disease present. The occasional colonies found with smaller lesions may represent incipient yellow band (= yellow blotch) disease that does not fully develop or they may represent other conditions or events. Other conditions characterized by pigmentation changes have been seen on isolated colonies at the Flower Garden Banks, including lesions that resemble those of variations of "dark spots" recently presented by Weil (2004), but the appearance may have been a tissue reaction to old injury or fish bites.

Black band disease has been reported at the Flower Garden Banks and has been cited as a common disease (Oberding et al., in prep.). Results and observations from these surveys result in no clear evidence of black band disease at the FGBNMS. It must be noted that during hundreds of dives over decadal scales, not a single case of black band disease has been seen by FGBNMS personnel (E. L. Hickerson, G. P. Schmahl, S. R. Gittings, pers. comm.). I have seen only a single colony indicative of black band disease at the Flower Garden Banks during dives spanning 5 yr; however, this assessment was not confirmed through tissue analysis. Therefore, it should be emphasized that the results of Oberding et al. (in prep.) appear to be in error. Several cyanobacterial mats bearing a gross appearance to those occurring on active black band disease lesions were observed at the interfaces of competing corals,

and these may have the potential to move onto coral tissue and become active disease bands (Santavy and Bruckner, 2004). However, this was never observed. A second unusual lesion was found on a single colony of *P. astreoides*, where the lesion margins had a thin band of what appeared to be cyanobacteria. However, the large lesion was covered with fine filamentous algae, and the skeleton had evidence of previous grazing, likely caused by scarids. The role of the cyanobacteria and the progression of this band was unclear because the band did not appear to be moving into healthy tissue as evidenced by recently exposed skeleton, and it did not resemble the distinct appearances of either red or black band diseases.

Consistent at the Flower Garden Banks are hyperenzootic levels of corals with tissue-skeletal anomalies such as corallite gigantism. These have been erroneously reported as neoplasms by Oberding et al. (in prep.). Neoplasms are quite different and distinct in appearance and are only reported in *Acropora* spp. in the Caribbean (Peters et al., 1986; Peters, 2004). The condition that occurs at the Flower Garden Banks is frequently termed hyperplasia, although consensus now exists that hyperplasia requires histological exam to determine whether specific tissue characteristics implicit to a designation of hyperplasia are present (Peters, 2004).

"Ridge-mortality disease" has been confirmed to result from the nipping behavior of the adult three-spot damselfish, *S. planifrons*, mainly on *D. strigosa*, causing the characteristic pattern of tissue loss on the upper surface of the corallum meanders in brain corals. The damsels are seen in almost every case where the exposed meander ridge pattern is present. In the two cases where damselfish were not seen, the colony was in an exposed location that was not a seemingly ideal territory for the fish. In fact, the ridges were beginning to be covered by epilithic growth, suggesting that the coral colony had been abandoned by the damselfish. Similarly, the characteristic bite patterns of scarids forming large scars on colonies (Bruckner and Bruckner, 1998; Bruckner and Bruckner, 2004) were once reported as rapid wasting disease (Cervino et al., 1997) and later as Rapid Wasting Syndrome (Cervino et al., 1998). This behavior with resultant scarring is a common occurrence at the Flower Garden Banks. In this study, it is suggested that colony lesions with exposed meanders are no longer termed ridge disease or ridge-mortality disease but should be described using the term "damselfish ridge denudation."

The novel conditions described in this study are, with the exception of the pale ring condition, apparently found only at the Flower Garden Banks. Several colonies showed signs of two or more of these novel conditions concurrently. Pale ring condition has also been observed at Mona Island, PR, in 2001 and 2005 (E. H. Borneman and A. W. Bruckner, pers. obs.). No tissue mortality is associated with the affected areas, and it does not appear to be a threat to colony integrity. This condition may also have been reported as "false bleaching" (E. C. Peters, pers. comm.) and also resembles bacterial aggregates currently being investigated in Red Sea corals (Kushmaro and Kramarsky-Winter, 2004). Histology of a sample of *C. natans* within the pale ring area shows evidence of several layers of what appear to be bacteria attached to the epithelium but not invading the tissue. In Aug. 2003, areas of opacity occurred on many colonies in many species, not all of which formed clearly defined rings. In some cases, the covering resembled a film or formed a mottled pattern. The pale patch condition, while presenting clearly different signs, is also an abnormal condition that does not appear to threaten colony integrity. It is found consistently at the Flower Gardens year round.

The mottling condition in *C. natans* does affect colony integrity. This condition may have been previously reported as "coenosarc swelling" (D. L. Santavy, pers. comm.). Bleaching is present at and around the lesion, with tissue loss occurring over time. Spring surveys indicate no prevalence of the condition before the onset of warmer water in summer. A possible correlation with disease incidence and warmer water deserves further investigation, and this condition was seen in late summer during dives over the past 4 yr. Colonies have recently been tagged to follow the seasonal and annual progression of the disease. In Aug. 2004, however, juvenile *S. planifrons* were noticed near the lesions. On approaching the colony, the damselfish would hide unlike the active colony defense displayed by adults. It is conceivable that the condition is due to tissue nipping behavior to cultivate algal lawns, but the smaller size of juvenile damselfish and heavier tissue of *C. natans* may produce the signs of mottling condition, whereas the larger adult damselfish nipping results in the ridge pattern of exposed skeleton seen in *D. strigosa*.

Unusual bleaching in *P. astreoides*, found in both cooler and warmer times of the year, was patchy in distribution and probably did not represent thermally induced events (Fitt et al., 2000). In the cool water event (2003), the con-

dition appeared to be spreading across and between colonies. Water temperatures were low (20–21 °C) but not unusually low for the time of year. Spreading bleaching is a possible characteristic of bacterial bleaching, such as the vibronic bleaching of *Oculina patagonica* and *Pocillopora damicornis* (Rosenberg, 2004; Rozenblat and Rosenberg, 2004). In the warm water event, bleached colonies were only found attached to substrate that was temporally covered with red cyanobacterial mats, and bleached tissues occurred almost entirely along colony margins. Cyanobacteria are known to produce toxins and also have negative effects on coral health (Santavy and Bruckner, 2004; Titlyanov et al., 2004).

Low to nonexistent levels of coral disease, the presence of only relatively minor or transient conditions found on isolated colonies, coupled with an apparent lack of colony mortality, that, at the most, only indicate predisease states or incipient infections that fail to become fully developed, are present on these reefs. The very early diseases reported by Bright and Rezak (1978), despite their careful descriptions and photos, have not been seen at the Flower Garden Banks by this author. However, deepwater corals with signs that are consistent with the description of white gap have been observed by submersible explorations in the area (G. P. Schmahl and E. L. Hickerson, pers. comm.). As such, the Flower Garden Banks may represent one of the last areas in the Caribbean and tropical Western Atlantic available to determine baseline levels of disease in healthy and relatively unaffected reefs. For most of the wider Caribbean, disease outbreaks have been reported to occur before accurate baseline data were obtained.

It is important to note that the majority of diseases found at the Flower Garden Banks do not appear to cause colony mortality. The overall disease prevalence was 4.75%, but this figure may be misleading for a number of reasons. A disproportionately large component of prevalence occurs because of tissue-skeletal anomalies and mottling syndrome, and a high rate of pale ring syndrome in 2003 further contributed to the disease prevalence. However, several conditions occurred in a patchy distribution and did not appear on transects, possibly resulting in underestimation of disease prevalence. Some conditions such as tissue-skeletal anomalies and light patch condition appear to be long-lasting enzootic diseases. The corallite gigantisms, in particular, could mask otherwise significant increases in the incidence of diseases causing colony mortality

from their contribution to total disease prevalence. If mottling condition is due to damselfish nipping, prevalence for all diseases would drop significantly because this is one of the most common conditions at the Flower Garden Banks during the summer.

To gain a better understanding of disease prevalence and incidence, given the generally low levels of coral disease requires analysis of greatly increased numbers of colonies and long-term monitoring of large permanent transects. For example, analysis of the belt transect data from May 2003 indicated that because of the large colony sizes and low abundance of *C. natans*, the timed swim would provide more meaningful prevalence rate data for mottling syndrome. It is important for any future efforts to consider each disease separately, on the basis of its own etiology and prevalence as well as the best practice methods to gather data for the condition. Other variables that must be addressed are the pronounced seasonal patterns observed for patchy bleaching, mottling condition, and pale ring condition. The temperature in May averages around 25 C, whereas Aug. has the warmest water temperatures averaging near 30 C (Dokken et al., 2003). If a correlation exists between disease prevalence and higher temperature, one would expect the August prevalence to be the near the maximum value for the year. Future work will address this potential factor.

Because of the isolation of the Flower Gardens Banks from land-based influences, gyre currents that nearly prevent genetic flow from other reef areas, low effect from other stresses, and a healthy baseline condition of the reefs, understanding coral disease at these sites can provide an extremely valuable model of study and is vital to the preservation of these and other coral reefs. Unfortunately, the far-off-shore location, unpredictable weather conditions, variability in site mooring locations per trip, and infrequent number of research cruises to the Flower Gardens hamper efforts to acquire data at these reefs. The large size of colonies, high coral coverage, and low diversity of hermatypic species, most of which are known to be susceptible to disease, however, make this community especially vulnerable in the event of a disease epizootic. Continued monitoring of the Flower Garden Banks, training or experience with the identification of coral disease, integration with existing programs and managers, and further histological, microbiological, and epizootiological investigations into the pathologies occurring here will help en-

sure that these reefs remain in excellent condition for future generations.

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