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Black Band Disease upon the Reefs of Los Cayos Cochinos, Honduras

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Abstract. This study investigates Black Band Disease (BBD) incidence, distribution, and partial mortality effects upon scleractinian corals in the Marine National Monument, Cayos Cochinos (MNMCC). Searches for BBD used 80 m x 40 m plots at three different sites, chosen to represent a putative spectrum of site quality according to scleractinian coral species richness and percentage cover. The benthic community was analyzed using photo-quadrats, and BBD incidence figures were calculated. Colonies displaying BBD were tagged and photographed repeatedly to quantify the progression rate of disease. These same colonies were then re-photographed over the next two years to record colonization and succession data on the revealed skeletons. Incidence of BBD in MNMCC is low, with the impacted site showing only 0.1% of hosts infected. The healthiest site had an even lower incidence of BBD at 0.03%. The intermediate site had the highest incidence of BBD at 0.38%. BBD was found to follow linear and asymptotic patterns of progression rate. The Intermediate site, with the highest incidence was also found to have higher sediment flux than the other sites.

Key words: Black Band Disease, Honduras, Sediment, Coral Ecology.

Introduction

In the global degradation of coral reefs, coral diseases have been identified as one of the most important yet least understood causal factors (Harvell et al. 2004) For example it has been estimated that the disease, White Pox, has been responsible for reducing the population of the Elkhorn coral, *Acropora palmata*, by up to 87% in the Florida Keys during 1996 to 2002 (Sutherland et al. 2004). Black Band Disease (BBD) is unusual in being a microbial consortium upon the surface of a coral, rather than an internal infection (Carlton and Richardson 1995; Cooney et al. 2002; Frias-Lopez et al. 2002; Frias-Lopez et al. 2003). This microbial community is then responsible for creating a chemical environment that digests off and dissolves the coral tissue away from the skeleton (Richardson 1996). Unlike other coral diseases, BBD is often found in low incidences but persists within a reef for long periods, with the black band progressing over the surface of a coral at speeds of 3-10 mm per day (Antonius 1981; Edmunds 1991; Carlton and Richardson 1995). The distinctive patterning of healthy coral, black band and then recently killed white skeleton, makes BBD a distinctive infection on coral reefs. As such it is ideal for visual and ecological surveys, where laboratory analysis and microbiology techniques, such as Carbon Source Utilization Patterns, are not required to identify the pathogen. This facilitates the study of BBD in creating space on a reef for primary spatial competitors to corals, such as macroalgae and sponges. Sedimentation and elevated nutrients have been attributed as causal factors for increased disease prevalence on coral reefs (Bruckner et al. 1997; Kuta and Richardson 2002; Bruno et al. 2003; Nugues and Roberts 2003)

A study by the World Resources Institute, estimated that Honduran rivers provide 80% of all the sediment and over half of all the nutrients in the Mesoamerican Barrier Reef region (Burke and Sugg 2006). The Honduran Marine Protected Area, Marine National Monument Cayos Cochinos (MNMCC), is an archipelago consisting of two rocky islands and 13 smaller sandy cays. The archipelago is situated approximately 10 miles (16 km) off the coast of mainland Honduras and has been shown to be within reach of local river sediment plumes following the severe impacts of Hurricane Mitch in 1998 (Andrefouet et al. 2002). As such this area provides a unique opportunity to study BBD on reefs influenced by sedimentation and disturbance from local rivers (Paris and Cherubin 2008).

This investigation aimed to record BBD incidence at sites representing a spectrum of sediment impact and reef health. BBD progression rates and subsequent successional communities upon the corals were also recorded for inter-site comparison.

Material and Methods

Study site

Initially nine sites were surveyed with 100 m point transects to determine percentage cover of all benthic species. Additionally, scleractinian corals were identified to species level to form a gauge of reef health from percent cover and species richness (English et al. 1997; Hodgson 1999; Hill and Wilkinson 2004). Three sites were then selected out of the nine as putative healthy, impacted and intermediate sites (Fig.1.)

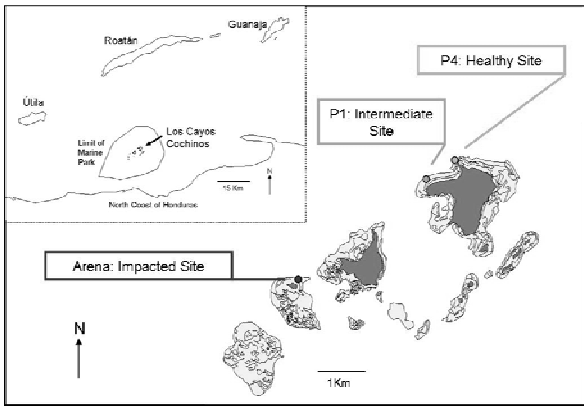

Figure 1: A map or the Marine National Monument Cayos Cochinos (MNMCC) and the three sample sites used in this investigation. Inset is a different scale map, showing the limits of the marine protected area and illustrating the relative close proximity of Los Cayos Cochinos to mainland Honduras. P1 is an abbreviation of Pelican 1 and likewise, P4 is Pelican 4.

At each site a 80 m x 40 m search area was created around permanent transect pins, which in turn had been used as a basis for the initial point transect surveys. The mid point of this 3200 m^2 search area was centered upon the reef crest at each site (6 m depth), thus encompassing both the reef slope and reef flat. 80 m x 40 m was chosen as it was the maximum search area that could be used within one dive, adhering to the local dive safety standards of 50 minutes per dive. Traditional belt transects and radial transects were tried (Kuta and Richardson 1996; Bruckner 2002), but did not cover a large enough area per dive to find incidences of Black band Disease (BDD). The ability to cover 3200 m^2 at each reef, on each dive, allowed daily comparisons of the three sites for new incidences of BDD, whilst monitoring existing infections. Between June and September 2005, colonies affected by Black Band Disease were identified and tagged using 3 mm diameter pins. These colonies were then photographed every day, and using Image Tool 3 software, progression rate and infection surface area were estimated. Colonies were then revisited in 2006 and 2007 for re-photographing and tracking of colony fate, in particular the colonization and succession of reef organisms on the post-BBD exposed skeleton. Other sources of mortality, such as bleaching, predation, burial by sediment or other diseases were also recorded with in the search area. Each 80 m x 40 m plot was then sub-sampled with photo quadrats to estimate the number of potential-host scleractinian colonies that could be infected by BBD according to the species list in Sutherland et al .(2004).

In order to compare site quality and any possible impacts from sedimentation, sediment traps were placed at each site, and suspended sediment sampled from the water column. Sediment traps were built from plastic tubing with a 9:1 optimum length to aperture internal diameter ratio (Bloesch and Burns 1980). This diameter was 7.4 cm and the trap length 67 cm. Baffles were fitted over the mouth to prevent large foreign objects falling into the traps, and to promote sediment capture and retention. Traps were placed on a 6 m isobath, in the center of each 80 m x 40 m plot. Traps were then recovered 7 days later, with the contents passed through pre-weighed Whatman Cellulose Filters (0.45µm) (Butler et al. 2008). Similarly, suspended sediment was determined by collecting one liter of water from near the traps during trap recovery, and then passed over similar pre-weighed filters. Comparison of filtrates allowed the calculation of sediment flux and inter-site comparison of sediment loads.

Results

Of the 14.2% hard coral cover found at the impacted site, Arena, approximately 50% (n=2133) of these corals were estimated to be potential host species for Black Band Disease (BBD). The overall incidence of BBD at this site was found to be 0.1% (n=2). At the healthy site, Pelican 4 (P4), hard coral cover was 15.4%, with around 30% (n=10664) of these corals estimated to be host species for BBD. BBD incidence at this site was the least at 0.03% (n=3). The intermediate site, Pelican 1(P1), had the highest incidence of BBD at 0.38% (n=15), but with lowest hard coral cover at only 5.5%, of which approximately 20% (n=4266) were estimated to be potential host species. The majority of infected corals (n=17 corals) were *Diploria strigosa*, with only 1 infection found upon a *Montastrea cavernosa* and 2 infections being upon *Diploria labyrinthiformis*. Infected corals were all found upon the reef flat at between 7 and 5 m depth.

Revisiting sites found dead portions of coral colonies were dominated by cyanophyta turfs within a month, then within 12 months succeeded by a an approximate 80% covering of *Dictyota* spp. macroalgae. However within 24 months post-BBD

mortality, the *Dictyota* coverage had been reduced, with *Porolithon* spp. covering the majority of the colony as clearly shown in Figure.2. Revision of the plots in 2006 found only 2 new incidences of BBD at Peli 4, 5 at Peli 1 and only 1 new incidence at Arena. In 2007 only 3 new incidences were found at Peli 1 and 1 incidence at Peli 4. No new incidences were found at Arena.

Analysis of BBD band progression rates found that not all infections progress at the same rate (Fig. 3.). Disease bands accelerate across a colony in linear fashions, but also progress in an asymptotic or sigmoid fashion, sometimes slowing down and dissipating altogether to leave patches of colonies alive in partial mortality events.

Sediment flux was found to be highest at Pelican 1, at 11.17 mg/m^2/d, with Arena having the lowest flux at 3.19 mg/m^2/d. Suspended sediment (Suspended Particulate Matter (SPM) was similar at all sites, ranging from 5.35 to 5.42 mg/L.

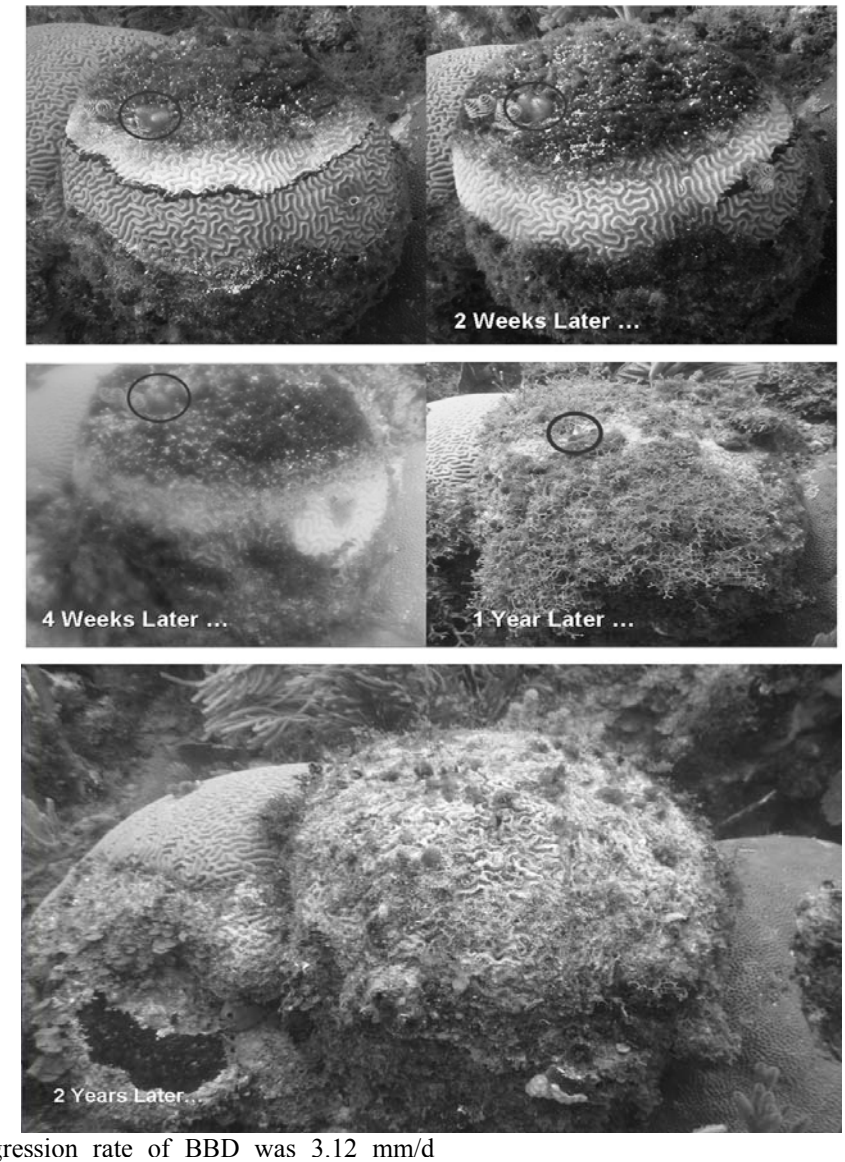

Figure 2: Succession of Black Band Disease and subsequent colonizers on a *Diploria strigosa* colony. Note rapid primary colonization by cyanophyta, then *Dictyota* spp., followed by succession to primarily *Porolithon pachydermum* cover. Circles highlight the same Christmas Tree worm cast as a point of reference

Mean progression rate of BBD was 3.12 mm/d (SE=2.65) at A and 1.45 mm/d

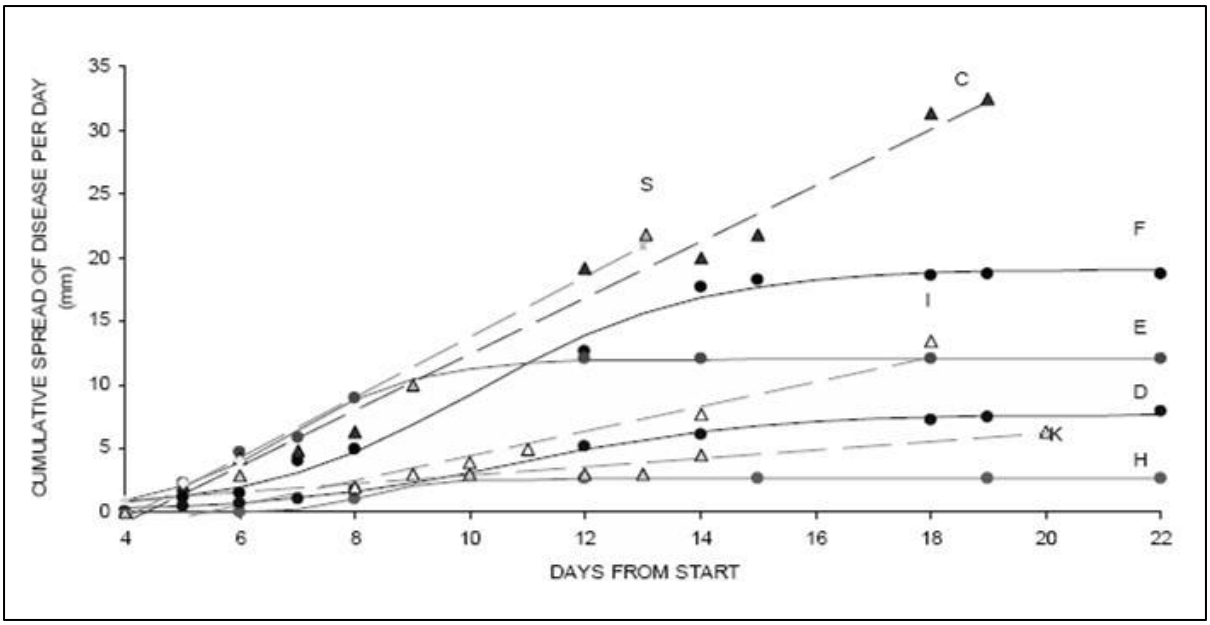

Figure 3: Cumulative spread of Black Band Disease upon 8 *Diploria* spp. colonies with linear response in triangles and dashed lines, and cessation of spread and asymptotic response after 7-14 days in circles and bold lines. Caps identify different colonies.

Discussion

Overall, Black Band Disease (BBD) incidence levels were found to be relatively low at the sample sites in Cayos Cochinos in 2005 (n=20), and continued to decrease in incidence through 2006 (n=8) to 2007 (n=4). This may be due to the period of increased water temperatures in 2005 (Rowlands et al. 2008). Increased temperatures could increase photosynthetic activity in the BBD consortium (Richardson and Kuta 2003) and in turn BBD virulence, or increased temperatures could abnormally stress corals, making them more susceptible to infection. The putative intermediate site in our study, Peli 1, had the highest incidence of BBD (0.38%). A possible explanation is that coral cover and potential host numbers are too low at Arena, the putative impacted site. In contrast the high coral cover and high species richness of the reef community at Peli 4 may be an indication that this putative healthy site is too 'healthy' for high BBD incidence. The sediment traps revealed the putative intermediate site, Peli 1, as having the highest sediment flux (11.17 mg/m^2/d). This higher sediment load than the other sites maybe directly causing BBD, acting as a substrate for cyanophyta mat formation or acting as a source of stress for corals, leaving colonies more susceptible to infection Dissolved nutrients have been found at only trace levels at all sites (Shrives 2007), but a future study could use Nitrogen and Carbon Isotope data or coral cores to better understand the nutrient regime at these sites.

BBD was found to play a part in patch dynamics upon the reef flats of Cayos Cochinos. The progression rate data (Fig.3.) illustrates that not all mortality from BBD resulted in entire colony death, leaving some patches of coral alive. Not all corals suffered from terminal *Dictyota* spp. domination, and often there was a succession to *Porolithon* spp. cover, suggesting that there is either still a reasonably good population of herbivores nearby, or that *Dictyota* spp. are dying back during the winter months. BBD was also observed to be an indirect source of mortality for the Christmas Tree worm, *Spirobranchus giganteus*, often abundant on the *Diploria* spp. colonies photographed and tagged within this study. Post BBD colonies supporting *Spirobranchus giganteus* became obscured by the growth of *Dictyota* spp. and died. In turn, the vacated *S. giganteus* tubes were observed and photographed as a new source of habitat and refuge for Blenniidae.

In conclusion, although found at relatively low incidence levels in Cayos Cochinos, Black Band Disease was found to contribute to the creation of primary space upon these reefs, playing a role in patch dynamics. Incidence levels and progression rates did not correlate as expected with the initial site classification for reef health using hard coral cover and species richness. BBD was also observed to have indirect effects upon the ecology of other fauna around the reef. Although sediment flux was found to

be highest at the study site with highest incidence of BBD, increased site replication and further studies are required to attribute any direct causal factors to disease outbreaks upon the reefs of the Honduran Marine National Monument, Cayos Cochinos.

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References

Andrefouet, Mumby, McField, Hu and Muller-Karger (2002). "Revisiting coral reef connectivity." Coral Reefs **21**(1): 43-48.

Antonius, A. (1981). "The 'band' diseases in coral reefs." Proc 4th Int Coral Reef Symp Philippines **2:**: 7–14.

Bloesch, J. and N. Burns (1980). "A critical review of sedimentation trap technique." Aquatic Sciences - Research Across Boundaries **42**(1): 15-55.

Bruckner, A. W. (2002). "Priorities for Effective Management of Coral Diseases." U.S. Department of Commerce. National Oceanic and Atmospheric Administration. National Marine Fisheries Service: pp57.

Bruckner, A. W., R. J. Bruckner and E. H. Williams (1997). "Spread of Black-band disease epizootic through the coral reef system in St. Ann's bay, Jamaica." Bulletin of Marine Science **61:**((3)): 919-928.

Bruno, J. F., L. E. Petes, C. Drew Harvell and A. Hettinger (2003). "Nutrient enrichment can increase the severity of coral diseases." Ecology Letters **6**(12): 1056-1061.

Burke, L. and Z. Sugg (2006). "Hydrologic Modeling of Watersheds Discharging Adjacent to the Mesoamerican Reef Analysis Summary - December 1, 2006." World Resources Institute.

Butler, O. T., J. M. Cook, C. F. Harrington, S. J. Hill, J. Rieuwerts and D. L. Miles (2008). "Atomic spectrometry update. Environmental analysis." Journal of Analytical Atomic Spectrometry **23**(2): 249-286.

Carlton and Richardson (1995). "Oxygen and sulfide dynamics in a horizontally migrating cyanobacterial mat: Black band disease of corals." FEMS Microbiology Ecology 18 (1m> IS5--J62.

Cooney, R. P., O. Pantos, M. D. A. Le Tissier, M. R. Barer, A. G. O'Donnell and J. C. Bythell (2002). "Characterization of the bacterial consortium associated with black band disease in coral using molecular microbiological techniques." Environmental Microbiology **4**(7): 401-413.

Edmunds, P. J. (1991). "Extent and effect of Black Band Disease on a Caribbean reef." Coral Reefs **10**(3): 161-165.

English, S., C. Wilkinson and V. Baker (1997). Survey Manual for Tropical Marine Resources, Australian Institute of Marine Science.

Frias-Lopez, J., G. T. Bonheyo, Q. Jin and B. W. Fouke (2003). "Cyanobacteria associated with coral black band disease in Caribbean and Indo-Pacific Reefs." Appl. Environ. Microbiol. **69**(4): 2409-2413.

Frias-Lopez, J., A. L. Zerkle, G. T. Bonheyo and B. W. Fouke (2002). "Partitioning of Bacterial Communities between Seawater and Healthy, Black Band Diseased, and Dead Coral Surfaces." Appl. Environ. Microbiol. **68**(5): 2214-2228.

Harvell, D., R. Aronson, N. Baron, J. Connell, A. Dobson, S. Ellner, L. Gerber, K. Kim, A. Kuris, H. McCallum, K. Lafferty, B. McKay, J. Porter, M. Pascual, G. Smith, K. Sutherland and J. Ward (2004). "The rising tide of ocean diseases: unsolved problems and research priorities." Frontiers in Ecology and the Environment **2**(7): 375-382.

Hill, J. and C. Wilkinson (2004). Methods For Ecological Monitoring of Coral Reefs , Australian Institute of Marine Science.

Hodgson, G. (1999). "A global assessment of human effects on coral reefs." Marine Pollution Bulletin **38**(5): 345-355.

Kuta and Richardson (2002). "Ecological aspects of black band disease of corals: relationships between disease incidence and environmental factors." Coral Reefs **21**(4): 393-398.

Kuta, K. G. and L. L. Richardson (1996). "Abundance and distribution of black band disease on coral reefs in the northern Florida Keys." Coral Reefs **15**(4): 219-223.

Nugues, M. M. and C. M. Roberts (2003). "Coral mortality and interaction with algae in relation to sedimentation." Coral Reefs **22**(4): 507-516.

Paris, C. B. and L. M. Cherubin (2008). "River-reef connectivity in the Meso-American Region." Coral Reefs **27**(4): 773-781.

Richardson, L. L. (1996). "Horizontal and Vertical Migration Patterns of *Phormidium corallyticum* and *Beggiatoa* spp. Associated with Black-Band Disease of Corals." Microbial Ecology **32**(3): 323-335.

Richardson, L. L. and K. G. Kuta (2003). "Ecological physiology of the black band disease cyanobacterium Phormidium corallyticum." Fems Microbiology Ecology **43**(3): 287-298.

Rowlands, G. P., S. J. Purkis and B. M. Riegl (2008). "The 2005 coral-bleaching event Roatan (Honduras): Use of pseudo-invariant features (PIFs) in satellite assessments." Journal of Spatial Science **53**(1): 99-112.

Shrives, J. P. (2007). "Reef Benthic Ecology, Coral Disease and Nutrient Flow Pilot Project: A Combined Summary Report for Cayos Cochinos 2006." Operation Wallacea (Available for download at www.opwall.com).

Sutherland, K. P., J. W. Porter and C. Torres (2004). "Disease and immunity in Caribbean and Indo-Pacific zooxanthellate corals." Marine Ecology-Progress Series **266**: 273-302.