

Abundance of black-band disease on corals from one location on the Great Barrier Reef: a comparison with abundance in the Caribbean region.

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Abstract Black-band disease (BBD) occurs on the Great Barrier Reef, Australia, with at least 21 species in five families being affected. Surveys of reef crest corals at Lizard Island found 2.8% of 4569 coral colonies were affected with BBD. Acroporidae, in particular *Acropora hyacinthus*, *Acropora intermedia* and *Acropora millepora*, were susceptible to BBD, compared with the Caribbean where acroporid corals are resistant to BBD. Pocilloporidae, including *Pocillopora damicornis*, *Pocillopora verrucosa* and *Stylophora pistillata*, were identified as important host species. The abundance of BBD varied between sites, ranging from 1.3% to 4.9% of colonies affected. The percentage of BBD-affected colonies varied between coral families. The percent of colonies affected with BBD were: 6.0% for the Pocilloporidae, 3.6% for the Acroporidae, 3.0% for the Faviidae and 2.1% for the Poritidae. The level of BBD-affected colonies on the GBR was within the range of affected colonies reported in the Caribbean.

Keywords Black-band disease, Great Barrier Reef, Coral disease.

Introduction

Black-band disease (BBD) affects scleractinian and gorgonian corals from the Caribbean and Red Sea (Antonius 1981a, 1988a; Garret and Ducklow 1975; Feingold 1988; Peters 1993). Over half of the 34 species of scleractinian corals that have been reported as susceptible to BBD occur in the Caribbean region (Rützler et al. 1983; Antonius 1988b; Edmunds 1991; Green and Bruckner 2000). BBD in the Caribbean region has caused partial mortality of individual colonies and led to reduced coral cover on some reefs (Santavy and Peters 1997; Kuta and Richardson 1996; Bruckner and Bruckner 1997; Bruckner et al. 1997). In contrast, there are few reports of BBD affecting corals in the Pacific region. Antonius (1985) found two susceptible coral species, *Goniastrea pectinata* and *Platygyra lamellina*, in the Philippines. BBD has been observed but not quantified on reefs of the Great Barrier Reef (GBR) and Fiji (Miller 1996; Littler and Littler 1996). As noted by Green and Bruckner (2000), there is a "relative scarcity" of records of coral diseases in the Pacific region compared with the Caribbean. The lack of reports of BBD from the GBR

could be related to a lack of studies specifically focused on BBD or to a genuine lack of BBD on these reefs. In this paper, I quantify for the first time the prevalence of BBD at one location within the GBR.

Researchers have quantified BBD by describing the prevalence of the disease within coral communities and identifying susceptible coral species. Prevalence "refers to the number of cases of disease that exist, in a defined population, at some point in time" (Christie et al. 1997). The prevalence of BBD has been found to vary spatially and temporally. Surveys have recorded a range of 1% to 10% BBD-affected colonies within a population (Green and Bruckner 2000). Edmunds (1991) found that BBD prevalence in individual coral species at 7 locations in the Virgin Islands varied from 0% to 5.5%, with a mean of 0.25%. Dustan (1993) surveyed 19 reefs in the Florida Keys and found 6.2% of all colonies affected with BBD. The prevalence of BBD fluctuated from 0% to 3.2% on three different reefs in the Key Largo region (Kuta and Richardson 1996). The prevalence of BBD varies seasonally, with higher levels of BBD-affected colonies occurring during summer (Edmunds 1991).

Coral taxa appear to have different susceptibility to BBD (Peters 1993). In the Caribbean region, coral species from the family Faviidae are most often affected with BBD (Santavy and Peters 1997). Faviidae are important framework corals and have the highest diversity in Caribbean reefs (Walton-Smith 1971). *Diploria strigosa* and *Montastraea annularis* are most often affected with BBD, with lower levels of infections in closely related species, *Montastraea cavernosa*, *Diploria labyrinthiformis* and *Diploria clivosa* (Antonius 1981b; Rützler et al. 1983). Non-faviid corals are also susceptible to BBD (Green and Bruckner 2000). *Siderastrea siderea* was thought to be resistant to BBD (Antonius 1981a). However, infections on this species were recorded in 1992 on reefs of Jamaica and this species is now frequently recorded with BBD (Bruckner et al. 1997). Natural infections of BBD have not been recorded on corals in the families Acroporidae and Pocilloporidae in the Caribbean region. Experimental inoculations conducted on acroporids from the Caribbean suggest they are able to resist the BBD pathogens (Antonius 1981b, 1985; Rützler et al. 1983). However, in aquarium studies in the Red Sea, BBD was transferred

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successfully to Acroporidae and Pocilloporidae after colonies were injured, suggesting that these species may be susceptible to the disease when stressed or injured (Antonius 1988b). If some species are susceptible to disease while others are not, there is a possibility for susceptible species to be lost from the community and be replaced by non-susceptible species. The different levels of affected colonies within certain taxa could indicate that these species are more susceptible to BBD.

Four major coral diseases; black-band disease, white-band disease type II, white plague type II and *Aspergillosis*, have been described (Santavy and Peters 1997; Richardson 1998; Green and Bruckner 2000). The effects of diseases on coral communities have ranged from partial mortality of a few individuals to community-level changes (Edmunds 1991; Aronson and Precht 1997). White-band disease has caused profound effects on coral communities in the Caribbean region. *Acropora palmata* stands in the US Virgin Islands have been decimated by a combination of white-band disease (Gladfelter 1982) and hurricane damage (Bythell et al. 1993). *D. strigosa* and *Porites* species were the major corals recruiting after these events (Bythell et al. 1993), suggesting a community shift mediated by disease and disturbance. Aronson and Precht (1997) described a disease-induced replacement of the dominant shallow water coral *Acropora cervicornis* by the less dominant *Agaricia* species in Channel Cay, Belize.

The aims of my study were to identify species of corals from the Great Barrier Reef that are susceptible to BBD and to determine the prevalence of BBD-affected colonies. I investigated whether the characteristics of BBD on the GBR are similar to those in the Caribbean region. The important characteristic of different levels of BBD-affected colonies between individual taxa was investigated by quantifying the prevalence of BBD in major coral families. Different susceptibility of coral species to BBD was investigated by comparing the number of individuals within a species to show signs of BBD when experimentally placed in direct contact with necrotic tissue.

Methods

Corals on four reefs around Lizard Island (14°40'S, 145°28'E), Australia were surveyed for the presence of BBD during summer (January – February), 1994. Replicate belt transects (10 x 1m) were surveyed on the reef crest of the four sites in 1 to 3m water depth. Seven to ten transects were laid haphazardly parallel to the shoreline, at South Island, Lizard Head, Osprey Island and Patch Reef. Within each transect, benthos in the categories Scleractinia, Alcyonacea, Gorgonia and Hydrozoa were counted. Coral colonies displaying signs of BBD were recorded and identified to species, when possible.

For disease studies, the number of colonies in an area is usually recorded (Edmunds 1991; Kuta and Richardson 1996). A colony was defined as any autonomous coral skeleton with living tissue. BBD was identified in the field using these gross

morphological characteristics: a black band of necrotic tissue abutting relative healthy tissue on one side and bare white skeleton on the other (Fig. 1). I quantified the number of BBD-affected colonies and the numbers of non-affected colonies in each transect.

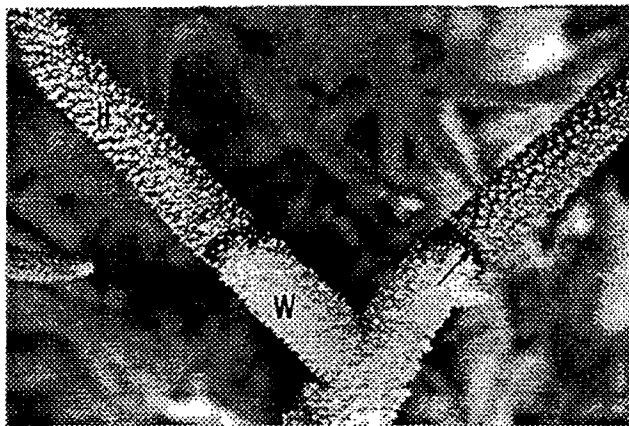


Fig. 1 *Acropora intermedia* from Lizard Island affected with black-band disease, illustrating the typical gross morphological features of the disease. Apparently healthy tissue (H) is abutted by a black band of necrotic tissue (arrow), with white (W) skeleton denuded of tissue posterior to the necrotic band.

To analyze the distribution of BBD between the four sites at Lizard Island, the percentages of BBD-affected colonies were compared using a one-way analysis of variance (anova). A post hoc Tukey's test was used to analyze if sites within habitats displayed similar prevalence of BBD (Underwood 1997). Due to the lack of normality in the data, an arc-sin square root transformation was performed prior to the analysis and homogeneity of variance was tested using the Levene statistic. Alpha level was set at $P < 0.05$.

To analyze whether BBD-affected colonies were spread evenly between taxa, a Pearson chi-square test (Zar 1999) was conducted. Data were pooled for all sites, since there were no obvious groupings of sites from the Tukey's test. To meet the assumptions of a chi-square test, it is necessary to minimize the number of cells with frequencies of less than five. Therefore, coral species were grouped into five categories; Acroporidae, Faviidae, Pocilloporidae, Poritidae and other Cnidaria (composed of the remaining scleractinian families, alcyonaceans, gorgonians and hydrozoans). A subdivided chi-square analysis with Yates' continuity correction was performed to identify which coral family was causing the variation in levels of BBD prevalence (Zar 1999).

To examine whether the different levels of affected colonies within a species were due to differences in susceptibility of that species, I compared the rate of infection of BBD on five individuals in each of eight coral species. It would be predicted that if a species was highly susceptible, all individuals would become affected with BBD. BBD was transferred by attaching a piece of BBD-affected *A. hyacinthus* to the experimental colony in the field. The necrotic area was placed in direct contact with a healthy colony, and fixed using plastic coated wire. Although care was taken not to injure the experimental corals, two control groups were established. In the first control group, five individuals from each species had a piece of healthy *A. hyacinthus* attached using plastic coated wire, to control for the

effects of contact between corals. The second control group was a tagging control, where five individuals in each species were tagged and handled. The experimental group and two control groups were collected after 48 h and presence or absence of BBD was noted. The time period was chosen due to the rapid movement recorded for BBD (Rützler et al. 1983). Coral species used during the trial were, *A. hyacinthus*, and *A. cuneata* in the family Acroporidae; *P. damicornis*, and *Seriatopora hystrix* in the family Pocilloporidae; *Hydnophora ridiga*, and *Platygyra daedalea* in the family Faviidae; *Symphylia recta* in the family Mussidae; and *Porites lichen* in the family Poritidae. Colonies used in this experiment were located 1 to 3 m deep within a 30 m² area on a reef in the Lizard Island lagoon. The rates of transmission and levels of BBD-affected colonies recorded during the survey were compared to identify if differences in susceptibility between species were apparent.

Results

Seventeen species of corals in five families (Pocilloporidae, Acroporidae, Faviidae, Poritidae and Mussidae) were affected by BBD in transects surveyed at Lizard Island (Table 1). Corals in the family Acroporidae and Pocilloporidae had 69 and 33 colonies affected with BBD. The species affected with BBD varied between sites. *A. hyacinthus*, *A. millepora* and *P. damicornis* were affected with BBD at all sites. *A. intermedia* was affected at Osprey Island and Patch Reef and *Goniastrea retiformis*, *P. verrucosa* and *Acropora gemmifera* were affected with BBD at South Island and Lizard Head. Four additional species, *Goniopora stokesi*, *Acropora*

polystoma, *Acropora divaricata* and *Montipora tuberculosa*, were recorded with BBD off-transect.

Based on a sample size of 4569 corals, 2.8% of all colonies surveyed at Lizard Island were affected with BBD. The percentage BBD-affected colonies was variable between sites and ranged from 4.9% at South Island to 1.3% at Patch Reef (one-way anova $MS=2.52 \times 10^{-2}$, $df = 3$, $F = 4.6$, $P < 0.001$). However, a Tukey's test did not distinguish any patterns in BBD abundance between the sites.

The prevalence of BBD was not spread evenly between the five coral families affected with BBD (chi-square test $X^2 = 54.266$, $df = 4$, $P < 0.001$). Pocilloporidae had the highest level of affected colonies with 6.0% affected (Table 2). The subdivided chi-square analysis showed that Pocilloporidae colonies were affected at a higher rate than corals in the families Acroporidae, Poritidae and Faviidae ($X^2 = 6.546$, $df = 1$, $P < 0.05$). The percentage of BBD-affected colonies was spread evenly between the Acroporidae, Poritidae and Faviidae ($X^2 = 2.125$, $df = 2$, $P = 0.346$). This suggests that pocilloporid corals may be more susceptible to BBD than corals in other families. Apart from one BBD-affected colony in the family Mussidae on Lizard Head, other Cnidaria, such as alcyonaceans, gorgonians and hydrozoans, were not identified with BBD during this survey.

Table 1. Seventeen species were identified with black-band disease (BBD) on Lizard Island, suggesting multiple host species are a feature of BBD. The numbers of BBD-affected colonies compared with the numbers of unaffected colonies (in parentheses) are given for each site. The total number BBD-affected and unaffected colonies for each family are listed. Only BBD-affected colonies that were identified to species are listed. (NQ, species not quantified)

Family	Species	South Island	Lizard Head	Osprey Island	Patch Reef	Total
Pocilloporidae		13(105)	16(203)	3(111)	1(79)	33(549)
	<i>Pocillopora damicornis</i>	3 (82)	4 (111)	2 (77)	1 (41)	10 (311)
	<i>Pocillopora verrucosa</i>	5 (48)	6 (53)	0 (0)	0 (1)	11 (102)
	<i>Stylophora pistillata</i>	5 (20)	6 (33)	1 (17)	0 (9)	12 (79)
Acroporidae		18(459)	20(766)	20(421)	11(259)	69(1905)
	<i>Acropora hyacinthus</i>	4 (114)	5 (121)	5 (47)	3 (27)	18 (339)
	<i>Acropora intermedia</i>	0 (11)	0 (3)	4 (121)	6 (45)	10 (180)
	<i>Acropora gemmifera</i>	5 (58)	3 (154)	0 (7)	0 (5)	8 (224)
	<i>Acropora millepora</i>	1 (29)	1 (17)	2 (32)	2 (16)	4 (94)
	<i>Acropora microclados</i>	3 (3)	0 (5)	0 (3)	0 (4)	3 (15)
	<i>Acropora monticulosa</i>	0 (16)	2 (118)	0 (0)	0 (0)	2 (134)
	<i>Acropora florida</i>	0 (1)	1 (4)	1 (23)	0 (2)	2 (35)
	<i>Acropora microphthalma</i>	0 (0)	0 (0)	2 (12)	0 (7)	2 (19)
	<i>Acropora robusta</i>	0 (0)	0 (5)	2 (12)	0 (0)	2 (17)
	<i>Acropora humilis</i>	0 (10)	1 (17)	0 (3)	0 (13)	1 (43)
	<i>Acropora palifera</i>	0 (0)	0 (0)	1 (2)	0 (18)	1 (20)
	<i>Acropora sarmentosa</i>	1 (7)	0 (0)	0 (10)	0 (4)	1 (21)
Faviidae		9(79)	6(115)	0(167)	0(90)	15(496)
	<i>Goniastrea retiformis</i>	4 (12)	3 (23)	0 (18)	0 (54)	7 (97)
	<i>Favia matthaii</i>	1 (NQ)	NQ	NQ	NQ	1 (NQ)
Poritidae		3(38)	4(155)	0(72)	0(71)	7(336)
Mussidae		0(2)	1(7)	0(18)	0(20)	1(47)

The percentage of BBD-affected colonies in each family varied with site (Table 2). High levels of affected colonies were found in the Pocilloporidae, Faviidae and Poritidae at South Island with lower levels at Lizard Head. The percentage of affected Pocilloporidae colonies was lower at Osprey Island and Patch Reef, and no affected colonies were found for the Faviidae or Poritidae. Similar percentages of BBD-affected colonies in the family Acroporidae were found at all sites (Table 2).

Table 2. Percentage of black-band disease affected colonies in each family at each site.

Family	South Island	Lizard Head	Osprey Island	Patch Reef	Total
Pocilloporidae	8.3	7.9	2.7	1.3	6.0
Acroporidae	3.9	2.6	4.5	4.2	3.6
Faviidae	11.4	6.3	0	0	3.0
Poritidae	7.9	2.6	0	0	2.0
Other Cnidaria	0	0.4	0	0	0.1
Total	4.9	3.3	1.9	1.3	2.8

BBD transferred to all nine species in the transmission experiment after a 48-hr period. Of the five colonies tested for each species, *A. hyacinthus* had four individuals affected with BBD, while *P. damicornis*, *S. hystrix* and *H. ridgia* each had three individuals that were affected. In the other five species, BBD only transferred to two individuals in each species. None of the individuals in the two control groups showed any signs of BBD. Only four control colonies showed the presence of white tissue areas and small patches of denuded skeleton, suggesting handling stresses were low.

Discussion

I have recorded 129 coral colonies from five scleractinian families affected with black-band disease at one study location on the Great Barrier Reef, out of a total of 4569 colonies surveyed. This would suggest that BBD affects coral communities on the GBR, as well as in the Caribbean region. Corals from the family Acroporidae in the Caribbean region appear resistant to BBD (Rützler et al. 1983; Antonius 1988a). In contrast, Acroporidae from Lizard Island are susceptible to BBD, with 14 species affected. The family Pocilloporidae has eleven species that occur on the GBR; of the five species present on transects three were susceptible to BBD. The high percentage of Pocilloporidae colonies affected with BBD (6.0%) suggests this family may be an important host for BBD on the GBR.

A total of 2.8% of coral colonies were recorded with BBD during the survey at four sites around Lizard Island. The percent occurrence of BBD identified was more than the 0.25% of corals affected in US Virgin Island reefs (Edmunds 1991). However, other sites such as Floridian reefs (Dustan 1993) and Jamaican reefs (Bruckner and Bruckner 1997) had 6.2% and 6.1% of BBD affected

colonies respectively, higher than recorded for Lizard Island. Feingold (1988) reported that 13.8% of octocorals were affected over a two-year period on the Northern Florida Keys, which is substantially higher than the prevalence of BBD on Lizard Island. My study suggests BBD is evident within coral populations on Lizard Island and the percent of affected colonies is within the range of BBD reported in the Caribbean region.

BBD often occurs seasonally, with the highest prevalence during the summer months (Edmunds 1991). The Lizard Island survey was conducted during the summer and therefore, may represent a maximum prevalence of BBD. Further surveys would be required to determine if seasonal variation also occurs on the GBR.

BBD is characterized by affecting multiple species, and there is variation in the level of affected colonies within a species between reefs (Peters 1993; Bruckner et al. 1997; Green and Bruckner 2000). These trends of BBD were also evident during my study on Lizard Island. Pocilloporidae had high levels of affected colonies compared with Acroporidae, Faviidae and Poritidae. The level of affected colonies within families also varied between sites. Bruckner et al. (1997) found similar variation in levels of affected colonies, with *M. annularis* (morphotype I and II), *D. clivosa* and *D. strigosa* most frequently affected in sheltered habitats. Conversely, *M. cavernosa* and *S. siderea* were most frequently affected with BBD in fore-reef habitats.

BBD transferred to all eight species in the transmission experiment and was found on a large number of species in a range of families during this and other surveys, suggesting that many species are susceptible to BBD. The levels of BBD-affected colonies recorded during a survey may depend on how BBD is transferred, not on differences in susceptibility of the corals. Research directed at testing susceptibility of species in different environments is required to understand the variation in levels of BBD-affected colonies between species.

Substantial reduction in living coral tissue occurs with BBD (Bruckner and Bruckner 1997), and <5% to 30% of colonies affected with BBD will eventually die (Green and Bruckner 2000). Mortality can be estimated using the prevalence of BBD recorded during the surveys and the mortality range from the literature. Therefore, if 2.8% of colonies were affected with BBD around Lizard Island, it is estimated <0.14% to 0.84% of coral colonies could die due to the disease. Compared with catastrophic events like *Acanthaster planci* outbreaks (Moran 1986), hurricane damage (Woodley et al. 1981) or white-band disease (Gladfelter 1982), where 60% to 90% of coral colonies die, mortality due to BBD is probably low at Lizard Island. However, the time between catastrophic events may be greater than for BBD, suggesting BBD may be a chronic mortality agent.

In conclusion, the survey of Lizard Island corals demonstrated that BBD affects coral communities on the GBR. BBD has multiple host species, with the level of affected colonies within a species varying between sites, similar to BBD in the Caribbean region. Corals in the family Acroporidae and Pocilloporidae are important host species on the GBR, in contrast to Faviid corals being important host species in the Caribbean region. The abundance of BBD at four sites surrounding Lizard Island was within the range of BBD recorded in the Caribbean region.

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