HEALTH STATUS OF THE CORAL COMMUNITIES OF THE NORTHERN GALAPAGOS ISLANDS DARWIN, WOLF AND MARCHENA

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SUMMARY

Spatially reduced distributions of Galapagos corals and fragmented habitat, after recent strong El Niño Southern Oscillation events and greatly increased levels of human visitation, fisheries activities and dive tourism, raise important conservation questions as to the effects of compounding stress upon coral communities. A lack of knowledge concerning zooxanthellate coral disease in the Galapagos Marine Reserve, which could be used as an indicator of natural and/or anthropogenic stress prompted this characterisation of Galapagos coral health abnormalities. Colony condition was evaluated during research cruises conducted in September 2005, May 2006 and March 2007 at the northern islands of Wolf and Darwin, and in the north-central archipelago at Marchena. Observations of coral health and associated biota were taken for different coral species and sites, allowing characterisation of health anomalies that may indicate disease. Frequency of occurrence (FOC: the proportion of sites exhibiting a particular symptom) across sites and prevalence (the proportion of colonies presenting symptoms) were determined for six species-specific and three general anomalous health states. Over the eight coral reef communities sampled, the overall prevalence was 23.9 % (n = 973). The massive coral Porites lobata was found to be most affected, with 35 % showing symptoms of parasitism or illness. The most common health anomaly was identified as Porites trematodiasis, with 32 % overall prevalence within sites and found in all surveyed sites (FOC = 100 %).

RESUMEN

Estado de salud de las comunidades de corales de las islas del norte de Galápagos, Darwin, Wolf y Marchena. La reducción de la distribución espacial y la fragmentación de hábitats coralinos provocadas por los recientes eventos severos de El Niño-Oscilación Sur; conjuntamente con el enorme incremento de las visitas de turistas y las actividades de pesca comercial y buceo recreacional, plantean importantes preguntas de conservación tales como la identificación de los componentes de estrés sobre las comunidades existentes de corales. Una falta de conocimiento concerniente a enfermedades de corales zooxantelados en la Reserva Marina de Galápagos, que pueden servir como un indicador de stress natural y/o antropogénico, provocó esta caracterización de anomalías de salud en los corales de Galápagos. La condición de las colonias fue evaluada durante cruceros de investigación realizados en septiembre del 2005, mayo del 2006 y marzo del 2007 en las islas del norte Darwin y Wolf y en la parte del norte-central del archipiélago en Marchena. Observaciones de la salud de corales y la biota asociada entre especies de corales y sitios permitieron la caracterización de anomalías de salud que pueden indicar una posible enfermedad. La frecuencia de ocurrencia (FOC) (la proporción de sitios que muestran un síntoma en particular) a través de sitios y la prevalencia (proporción de colonias presentando síntomas) fueron determinadas para seis estados anormales de salud relacionados con especies en particular, y tres condiciones generales. La prevalencia total sobre las ocho comunidades de coral evaluadas fue de 23.9 % (n = 973). Porites lobata, un coral de crecimiento masivo, resultó ser el más afectado con 35 % de sus colonias mostrando síntomas de parasitismo o enfermedad. La anomalía de salud más común fue identificada como Porites trematodiasis, con un 32 % de prevalencia dentro de sitios y encontrada en todos los sitios evaluados (FOC = 100 %).

INTRODUCTION

Coral disease is an increasing concern across diverse reef communities worldwide. Incidence and distribution of diseases in species of zooxanthellate coral have greatly increased over the last decade (Green & Bruckner 2000; Porter et al. 2001, Sutherland et al. 2004, Weil 2004). Caribbean reef monitoring data from 1996–8 for example show a 200 % increase in the different diseases registered (Porter et al. 2001). Symptoms of illness observed in coral communities occur as a response to biotic stressors such as bacteria, fungi and viruses and/or abiotic stressors such as increases in water temperature, UV radiation, sedimentation or localized pollution. The onset of most diseases is a response to multiple factors (Peters 1997), where one type of stress can exacerbate and compound
The increase in occurrence has caused extensive mortality across coral reefs worldwide. In the Caribbean it is implicated as the principal cause of coral decline, resulting in an apparent shift towards algae-based communities (Hughes 1994, Aronson & Precht 2001, Porter et al. 2001, Sutherland et al. 2004).

Coral communities in Galapagos constitute one of the key sensitive habitats subject to impact from not only natural disease, but also a complex interplay between climate change and anthropogenic activity. The Galapagos ecosystem, in comparison to other marine regions, is often cited as being in a near-pristine natural condition. Recently however, natural patterns of climatic stress are thought to have been exacerbated by resource over-exploitation, illegal fishing and increased dive tourism. Corals have persisted in Galapagos despite extreme archipelago-wide mortalities during El Niño Southern Oscillation (ENSO) warm events. In the 1982–3 event, coral mortality was higher in the Galapagos compared to other affected eastern Pacific study sites. Glynn et al. (1988) estimated a 95–99% mortality of branching and massive coral species, and the coral mortality in the 1997–8 event was a further 26.2% of remaining corals. Despite being of similar magnitude and duration, the coral responses during the two disturbance events were distinct (Glynn et al. 2001), having different spatial patterns of elevated sea temperature stress.

One might hypothesize that stress to corals through increased water temperatures would be exacerbated by resource over-exploitation, illegal fishing and increased dive tourism (e.g. during El Niño heavy rainfall), making coral more susceptible to disease. This may not be a driving factor in Galapagos, where pollution is still relatively localized around the three main urbanized ports and tourism anchorage zones. However, rain run-off from natural volcanic island deposits is rich in many minerals and may affect productive processes in low circulation coastal bays and lagoons. The causal factors behind the majority of the diseases observed for corals in Galapagos, as with many other sites in the Eastern Tropical Pacific (ETP), have yet to be elucidated, and work is needed to correctly identify them. It is strongly suspected that the change in coral habitat-forming species in Galapagos through ENSO stress has greatly altered marine ecosystem interactions over the last decades, although local observations are sparse, and largely anecdotal before 1982 (Robinson 1985, Glynn 1994). Coral populations once recorded across the archipelago are greatly reduced (Glynn 1994). Diseases are more likely to be a threat to such reduced fragmented populations.

The condition of a sample of zooxanthellate coral colonies across the range of native species present was recorded by diver survey along the coasts of Wolf, Darwin and Marchena Islands. The prevalence and significance of coral disease in Galapagos is an important indicator of their resilience to other stressors. This has local management implications for coral reefs and their associated subtidal communities. In providing a reference point against which to measure future stress, health and conditioning of Galapagos coral species it should also be possible to compare Galapagos observations with other global and ETP regional studies. To that end, prevalence and frequency of occurrence (FOC) of possible symptoms as well as tissue anomalies were documented along with associated epibiota.

**METHODS**

**Study area**

Sites were selected based upon areas of known coral coverage from previous surveys, which included a range of zooxanthellate coral assemblages and associated biota (Danulat & Edgar 2002). Nine sites were surveyed, on the coastlines of Wolf, Darwin and Marchena. At Darwin, two sites (North Anchorage 1.68095°N, 92.001°W and 92.001°W and...
South Anchorage 1.68074°N, 91.9995°W) lay in the northeast and one in the rarely visited “Hidden Reef” (1.67683°N, 92.00752°W) to the west (Fig. 1). At Wolf, two sites (North Corals 1.38696°N, 91.8164°W and South Corals 1.387°N, 91.8166°W) were in Bahía Tiburón, the protected coral bay to the east, and one (the Anchorage 1.37867°N, 91.81940°W) to the west (Fig. 1). In Marchena, the three sites were next to Roca Espejo, separated from each other by c. 50 m (0.31283°N, 90.40129°W; Fig. 1). Surveyed sites correspond to habitat largely exposed to oceanic swell and current, with the exception of the more protected coral bay in eastern Wolf Island.

Surveys were undertaken at 6 m and 15 m depth, with the exception of Marchena where the platform extends at a uniform depth of 12 m. Details by research cruise and survey are summarised in Table 1. The data for 15 m (12 m at Marchena) are used in the present analysis due to low abundance at 6 m and occasional sampling problems in high surge. A deeper survey, at 20 m, was also performed at North Anchorage, Darwin, parallel to the other surveys there.

**Study of coral illness**

Coral illness was first documented in the Galapagos by Glynn (1983). The data presented here represent the most comprehensive revision to date, and complement efforts to map, monitor and mitigate impacts upon corals. Information presented was collected over three years during research cruises in September 2005, May 2006 and February–March 2007.

At each of the nine sites, monitoring was undertaken by diver pairs installing a 50 x 4 m permanent plot (marked by short iron bars installed every 5–10 m), at 15 m and 6 m depths (12 m at Marchena). Each permanent plot contained three parallel 50-m transects separated by 2 m, centred on each of the 15 m and 6 m isobaths. Transects were denominated A (towards the coast), B (central) and C (towards open water). Because of trade-offs between diver experience and sampling coverage, sampling effort was divided between diver pairs recording just coral species composition and morphology and diver pairs collecting that same information, plus the more detailed health data presented here.

Along each transect (A, B and C), three 10-m segments (0–10 m, 20–30 m, 40–50 m) were surveyed, leaving unsurveyed 10-m intervals between each segment, resulting in 30 linear m per transect. Hence 90 linear m in total were surveyed at each depth at each of the nine plots. Detailed coral health data were collected on each cruise (total transect lengths evaluated for coral anomalies are given by site and cruise in Table 1).

A subset of these permanent plots may be used for future comparisons of coral cover and diversity, algal cover, macro-invertebrates and fish. We suggest that Darwin North Anchorage FN1 and FN2, Wolf North and South Corals CN and CS, and Roca Espejo RE1 be prioritised for such monitoring. Time-series community level...
data for fish, algae and macro-invertebrates collected since 2000 exist for these sites as part of a wider GMR evaluation.

Coral community structure was recorded by point intercept methods adapted from those used by the Atlantic Gulf Rapid Reef Assessment (AGRRA) in the Atlantic and Caribbean. Each diver recorded a set of measurements and observations for every coral colony falling under the transect line. These measures were: colony height from base (cm), maximum colony diameter (cm), % mortality (recent and old), % bleaching, associated fauna, % algae overgrowth, evidence of corallivory or grazing of algae, and the coral health observations presented here. In order to encourage robust comparable data we designated a pair of dedicated coral health inspectors who compared results after dives to check consistency. We also followed a consistent methodology between field trips, used a standard template for recording and used a shipside data coordinator and data format that facilitated rapid entry of information immediately after dive work. For each colony falling under the transect, all signs of illness were characterised, and photographed where possible, along with collection of morphometric measures for later comparison. Measurements of coral abnormalities used are based upon those applied in baseline studies of coral disease in the northwestern Hawaiian Islands (Aeby 2006).

Statistical analysis
Prevalence (or % incidence) of coral illness or infection was taken as the percentage of affected colonies among the total colonies sampled per transect. This was calculated grouping by condition, depth, and site and across all sites by dominant coral genera and species (Pavona chiriquiensis, Pavona clavus, Pavona gigantea, Pavona varians, Pocillopora effusus, Pocillopora damicornis and Porites lobata). Frequency of Occurrence (FOC) was calculated as the percentage of sites showing colonies with a particular infection among the total number of sites that harbour the coral genera affected by the condition.

FOC was used for descriptive comparisons between sites only. For Prevalence, a non-parametric Kruskal-Wallis test was performed across all sites and sampling visits between islands. Difference in overall Prevalence of disease between coral genera was tested with a $\chi^2$ test for equality of distributions. We complemented this with an orthogonal one-way analysis of variance between islands for the three sites that were monitored at each of the three orthogonal one-way analysis of variance between islands. We complemented this with an orthogonal one-way analysis of variance between islands and sites within islands (Table 2). Wolf and Darwin have a coastal margin dominated by large massive hermatypic coral colonies such as *Porites lobata* and, in lower pro-portion, *Pavona clavus* and *Pavona gigantea*, with greater net abundance at 15 m depth than at 6 m. A detailed coral inventory is presented separately (Banks et al. 2009).

The largest and by inference oldest colonies were concentrated in the Hidden Reef of Darwin and the North and South Anchorages, Wolf. Coral assemblages at Punta Espejo, Marchena, were dominated by *Porites lobata* and distinguished from any other site by large fields of small free living *Psammocora stellata* colonies.

### Incidence of coral illness
Seven abnormal conditions were identified as possible coral malaise (Table 3). Other unclassified tissue anomalies were grouped into an additional class by coral genus (17.4 % of all disease observations). Examples of the characterised conditions are given in Fig. 2.

All sites showed tissue anomalies. Average Prevalence was 24.0 % across all colonies (n = 973) in all sites, with site mean of 22.6 % (n = 8, range 8.3–30.5 %). No relationship between host coral abundance and Prevalence was evident (Fig. 3).

Differences in Prevalence between islands were not statistically significant (Kruskal-Wallis, $\chi^2 = 0.27$, df = 2, $P = 0.8752$). Prevalence varied among sites (Table 4), but comparisons were not statistically significant (Kruskal-Wallis, $\chi^2 = 7.74$, df = 7, $P = 0.3561$). A one-way ANOVA (comparing pooled data from the three repeated sites over the three years) generated the same results: differences between islands were not significant (df = 2, $F = 0.141$, $P = 0.871$) and nor was between-site variation (df = 7, $F = 0.326$, $P = 0.898$).

### Table 2. Percentages of sampled coral colonies by genus (*Pavona, Pocillopora, Porites, Psammocora*) for each site and survey.

<table>
<thead>
<tr>
<th>Year</th>
<th>Island</th>
<th>Site</th>
<th>Pav</th>
<th>Poc</th>
<th>Por</th>
<th>Psam</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>Darwin</td>
<td>FN1</td>
<td>50.0</td>
<td>8.8</td>
<td>38.2</td>
<td>2.9</td>
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<tr>
<td></td>
<td>Wolf</td>
<td>CS</td>
<td>42.0</td>
<td>8.7</td>
<td>44.9</td>
<td>4.4</td>
</tr>
<tr>
<td></td>
<td>Marchena</td>
<td>RE</td>
<td>2.7</td>
<td>14.8</td>
<td>57.1</td>
<td>25.5</td>
</tr>
<tr>
<td>2006</td>
<td>Darwin</td>
<td>AE</td>
<td>18.6</td>
<td>7.0</td>
<td>74.4</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>FN1</td>
<td>76.3</td>
<td>1.7</td>
<td>22.0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>FS</td>
<td>0</td>
<td>3.5</td>
<td>96.5</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wolf</td>
<td>CN</td>
<td>81.2</td>
<td>4.4</td>
<td>11.6</td>
<td>2.9</td>
</tr>
<tr>
<td></td>
<td>CS</td>
<td>70.8</td>
<td>3.4</td>
<td>24.7</td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>WFP</td>
<td>71.1</td>
<td>6.0</td>
<td>9.6</td>
<td>13.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Marchena</td>
<td>RE</td>
<td>9.1</td>
<td>9.7</td>
<td>45.1</td>
<td>36.0</td>
</tr>
<tr>
<td>2007</td>
<td>Darwin</td>
<td>AE</td>
<td>12.3</td>
<td>3.1</td>
<td>84.6</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>FN1</td>
<td>70.7</td>
<td>1.7</td>
<td>25.9</td>
<td>1.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>FN2</td>
<td>56.5</td>
<td>2.2</td>
<td>34.8</td>
<td>6.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>FnP</td>
<td>58.3</td>
<td>8.3</td>
<td>33.3</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wolf</td>
<td>CN</td>
<td>72.5</td>
<td>5.8</td>
<td>15.9</td>
<td>5.8</td>
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<tr>
<td></td>
<td>CS</td>
<td>50.0</td>
<td>6.3</td>
<td>42.2</td>
<td>1.6</td>
<td></td>
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<tr>
<td></td>
<td>WFP</td>
<td>88.3</td>
<td>5.0</td>
<td>1.7</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Marchena</td>
<td>RE</td>
<td>1.1</td>
<td>7.3</td>
<td>40.2</td>
<td>51.4</td>
</tr>
</tbody>
</table>

### RESULTS

#### Coral community structure
Relative abundance of coral taxa varied between islands and sites within islands (Table 2). Wolf and Darwin have a coastal margin dominated by large
Figure 2. Corals showing some of the abnormal conditions recorded: 1, 2 Porites discoloration tissue thinning syndrome; 3, 4 Porites trematodiasis; 5 Porites uncharacterized disease; 6 Porites abnormal overgrowth; 7 Pocillopora white band; 8 Pavona white spot.
Prevalence differed almost significantly between coral species ($\chi^2 = 18.32$, df = 6, $P = 0.055$) with *Porites lobata* having the highest Prevalence and *Pavona varians* the lowest (Fig. 4).

Darwin South Anchorage presented the greatest FOC and Darwin North Anchorage the least. Between islands, study sites in Darwin presented greater Prevalence of affected corals and Wolf the least (Fig. 5).

Table 3 shows the distribution of the different abnormal colony conditions that could be differentiated (including possible infections, parasitism and tumours). Trematodiases in *Porites lobata* (Cheng & Wong 1974, Aeby 1998a) was observed at all sites with the exception of Darwin North Anchorage at 20 m. *Porites* trematodiases was by far the most common condition, affecting over 30% of all *P. lobata* colonies, while undescribed conditions in *Pavona* spp. accounted for <15% of health problems (Fig. 6). The other characterised conditions were far less common (<10% of colonies presenting the other seven health

<table>
<thead>
<tr>
<th>Possible disease</th>
<th>Characteristics</th>
<th>Sites</th>
<th>FOC (%)</th>
<th>Host species</th>
</tr>
</thead>
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<tr>
<td><em>Porites</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Porites</em> trematodiases</td>
<td>Pink to pale, swollen nodules on coral colony. Nodules can be clustered or widely distributed on colony.</td>
<td>AE, FN, FS, RE, CS, CN, WF</td>
<td>100</td>
<td><em>P. lobata</em></td>
</tr>
<tr>
<td><em>Porites</em> discoloration tissue thinning syndrome.</td>
<td>Areas of tissue thinning and discoloration that are poorly defined from surrounding healthy tissue. Polyps reduced or absent.</td>
<td>AE, CS, WF, FN</td>
<td>57.1</td>
<td></td>
</tr>
<tr>
<td><em>Porites</em> abnormal overgrowth</td>
<td>Abnormal skeletal growth.</td>
<td>CS, FN</td>
<td>33.3</td>
<td></td>
</tr>
<tr>
<td><em>Porites</em> mucus</td>
<td>Colonies show excessive mucus secretion.</td>
<td>AF, FN</td>
<td>28.6</td>
<td></td>
</tr>
<tr>
<td><em>Porites</em> yellow spot</td>
<td>Irregular yellow spots on colony.</td>
<td>CS</td>
<td>14.3</td>
<td></td>
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<tr>
<td><em>Porites</em> uncharacterized disease</td>
<td>Uncharacterized abnormal conditions.</td>
<td>CS, RE</td>
<td>25.0</td>
<td></td>
</tr>
<tr>
<td><em>Pavona</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Pavona</em> WRBS</td>
<td>Rings, bands and white spots of dead tissue in the coral colony.</td>
<td>CS, CN, FN, FNp, WF</td>
<td>83.3</td>
<td><em>P. clavus</em>, <em>P. gigantea</em></td>
</tr>
<tr>
<td><em>Pavona</em> abnormal growth</td>
<td>Present abnormal skeletal growth.</td>
<td>CS, FN</td>
<td>33.3</td>
<td><em>P. clavus</em></td>
</tr>
<tr>
<td><em>Pavona</em> mucus</td>
<td>Colonies show excessive mucus secretion.</td>
<td>FN</td>
<td>16.7</td>
<td><em>P. chiriquiensis</em></td>
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<tr>
<td><em>Pavona</em> yellow spot</td>
<td>Irregular yellow spots on colony.</td>
<td>CS</td>
<td>16.7</td>
<td><em>P. gigantea</em></td>
</tr>
<tr>
<td><em>Pavona</em> uncharacterized disease</td>
<td>Uncharacterized abnormal conditions.</td>
<td>AE, WF, CN, CS, FN</td>
<td>83.3</td>
<td><em>P. clavus</em>, <em>P. gigantea</em>, <em>P. varians</em></td>
</tr>
<tr>
<td><em>Pocillopora</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Pocillopora</em> white band</td>
<td>White bands present on the coral branches.</td>
<td>WF</td>
<td>50.0</td>
<td><em>P. damicornis</em></td>
</tr>
<tr>
<td><em>Pocillopora</em> uncharacterized disease</td>
<td>Uncharacterized abnormal conditions.</td>
<td>CS</td>
<td>50.0</td>
<td><em>P. effusus</em></td>
</tr>
</tbody>
</table>

**Figure 3.** Total relative abundance of corals vs. disease prevalence across three sites in Darwin, three sites in Wolf and one in Marchena (at 12–15 m depth).
condition categories). Of all characterised conditions, that termed “yellow spot” was the least common.

Aside from having a greater proportion of affected colonies compared to other species, *Porites lobata* demonstrated symptoms of all observed conditions, while *Pavona varians* had both a lower relative abundance of colonies and the lowest Prevalence of health anomalies. Wolf South Corals, although showing relatively fewer affected colonies, presented all observed anomalies.

**Occurrence of associated biota**
Records of species associated with each colony (fish, mobile macro-invertebrates, sessile macro-invertebrates and algae) were collected to help evaluate the state of health of coral communities and improve understanding of species interdependence (Fig. 7).

Predation, as evidenced by the percentage of colonies with fish bite marks, was higher in Wolf than Darwin. Sessile bivalve and bio-eroder *Lithophaga* spp. were also more abundant around coral at Wolf. The mollusc corallivore *Coralliophillia violacea* was more abundant at Marchena than at the other two islands. Cryptic crabs were more abundant at Marchena. The crabs (e.g. *Trapezia* spp.) are typically beneficial endosymbionts and denote coral health, rather than disease (J. Feingold pers. comm.). The widespread bio-eroder pencil urchin *Eucidaris galapagensis* was most evident associated with coral colonies in Darwin and less abundant on colonies in Wolf.

**DISCUSSION**
An average 23.95% of all evaluated zooxanthellate coral colonies showed tissue anomalies. This value is higher than found in other regions. In Colombia long-term coral reef monitoring programmes have been running since 1998 at San Andrés (five stations) and Providencia Islands.
Figure 6. Mean Prevalence of all characterized coral symptoms, calculated as the % of affected colonies by species and genus. *Porites lobata*: TRM = Trematodiasis; DTTS = Discoloration tissue thinning syndrome; UD = Uncharacterized disease; GA = Growth anomaly; YS = Yellow spot; MUC = Mucus. *Pavona* spp.: WS = White spot; UD = Uncharacterized disease; GA = Growth anomaly; MUC = Mucus; YS = Yellow spot. *Pocillopora* spp.: WB = White band; UD = Uncharacterized disease.

- Porites lobata:
  - TRM
  - DTTS
  - UD
  - GA
  - MUC
  - YS

- Pavona spp.:
  - UD
  - WB

- Pocillopora spp.:
  - UD
  - WB

Figure 7. Mean occurrence of associated colony biota; evidence of fish predation, algae overgrowth, sessile and mobile macro invertebrates across the monitored sites.
(four stations) in the Caribbean. Coral condition was monitored from 1998–2003, and Prevalence of illness recorded at 5%, with peaks in 1999 and 2001 in San Andrés of 9.1% and 6.3% respectively (Garzón-Ferreira et al. 2000). Santavy et al. (2001) surveyed coral disease across 32 stations in the Florida Keys, finding an average Prevalence of 9.6%. Approximately 0.5% of corals were reported to have signs of infection in the Hawaiian Islands across 73 sample sites (Aeby 2006), whereas Weil (2004) found an overall Prevalence of 5.3% over 28 sites across islands in the Caribbean.

Including “uncharacterized”, eight anomalous conditions were observed across the monitored islands: six for Porites lobata, five for Pavona spp. and two for Pocillopora spp. These do not all correspond to conditions reported in other regions. In the Indo-Pacific a similar number of diseases have been reported. Six states of coral malaise were described from the Philippines (Raymundo et al. 2005) and eight described for the Great Barrier Reef of Australia (Willis et al. 2004). Coral disease research in the Caribbean has a 30-year history, whereas Indo-Pacific research began during the past few years, and it is likely that the number of diseases recorded will increase with improved sampling effort in the region.

There are notable differences in the nomenclature of signs of disease, predation or parasitism. The condition characterized by swollen pink spots, termed here Porites trematodiasis, is known as Porites trematodiasis in Hawaii, pink spot in Australia and pink block Porites in Okinawa. Aeby (2006) recommends that nomenclature be standardized in the future. However, similarity between signs of illness described from different localities does not necessarily imply the same etiology. Porites lobata is the dominant coral (in terms of bottom cover) over the communities evaluated, averaging 64.7% across the three transect plot sites that were monitored each cruise. For species-specific anomalies, Prevalence depends on the density distribution of the host. This explains in part the relative FOC of each condition. Porites trematodiasis, the most ubiquitous condition, is for example closely linked to sites where Porites coral is most abundant. This condition is caused by the encystment of the larval stage of a digenetic trematode worm (of or related to Digenea) within the host colony (Cheng & Wong 1974, Aeby 1998a). The life cycle of this parasite is facilitated by corallivore fish ingesting infected polyps and the adult worm residing in the gills of the fish (Aeby 1998b). We inferred this condition, based on observations of tissue anomalies consistent with descriptions of the disease. Future microscopic/histological analysis should be applied to confirm this. The encysted stage of the parasite within the host coral is viable for many months before the parasite develops (Aeby 1998a). The pink coloration and swelling of infected polyps attract fish that preferentially graze upon them (Aeby 1992, 2002). These two attributes, the ability to maintain viability for long periods before transmission and the altered appearance of the host coral, promote successful dispersal via the host fish. Faecal liberation by the fish as a vector for the parasite eggs into the environment facilitates dispersal over the coral community as a whole.

Symptoms similar to four of the eight anomalies described in this study have been reported from other areas in the Indo-Pacific. Porites trematodiasis has a wide distribution across the Indo-Pacific, reported in Australia (Willis et al. 2004), the principal Hawaiian Islands (Aeby 1998a) and Okinawa, Japan (Yamashiro 2004). The white band disease inferred in Pocillopora in Wolf Anchorage is apparently similar to that described from the Caribbean. Future analysis isolating disease agents from corals displaying symptoms would help distinguish between denuded skeleton that could have resulted from corallivory and the inferred disease (J. Feingold pers. comm.). The other abnormal conditions registered in Pavona corals do not seem to have been reported from other regions.

As a region under extreme temperature stress and greatly increased anthropogenic activity in the coastal zone since the 1980s, the last remaining Galapagos zooxanthellate corals can be considered on the threshold of their natural tolerance. Estimating coral health and incidence of disease is important for assessing stress response and helps elucidate the possible compounding effects between recovery from strong climatic regional events such as El Niño, anchor damage, local pollution, physical diver damage and global climate change over larger scales. Given the recent tendency towards more frequent warm-water and cold-shock bleaching events and consequent greater susceptibility to pathogens and parasites (Hughes et al. 2003) the emphasis needs to turn towards how best to protect and manage the remaining Galapagos coral resources.

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