Coral Reef Targeted Research & Capacity Building for Management

Over one-half of the world's population lives within **100 kilometres of the sea.**





## Coral Disease Working Group

# Causes, origins and impacts of coral disease worldwide

### Management Implications

Coral diseases potentially impact both well-managed and unmanaged reefs indiscriminately. However, strategies for dealing with disease outbreaks are currently nonexistent. The increasing frequency with which diseases influence and alter reef communities (Aronson and Precht 1998; Harvell et al., 1999, 2002; Weil et al. in press) necessitates their consideration and incorporation in management plans. The proposed study addresses this need by providing the scientific background to formulate recommendations for managers and policy makers. For instance, correlations between water quality and disease prevalence are of growing concern but evidence of direct links and synergistic effects are limited (Kuta and Richardson 2002; Porter et al., 2001). In addition, the role of coral community structure and diversity in maintaining productive fish and invertebrate populations is well documented, but links between these aspects and coral diseases are generally unstudied. As many MPAs are established specifically with the goal of protecting the fishery in mind, diseases that alter a reefs' ability to support a diverse fish population is of concern. Understanding the specific ways in which coral diseases can alter reef function will allow better predictive power for conditions under which outbreaks may occur, and the rationale to apply pressure to policy makers and local government to improve waste water treatment, solid waste disposal and land use practices.

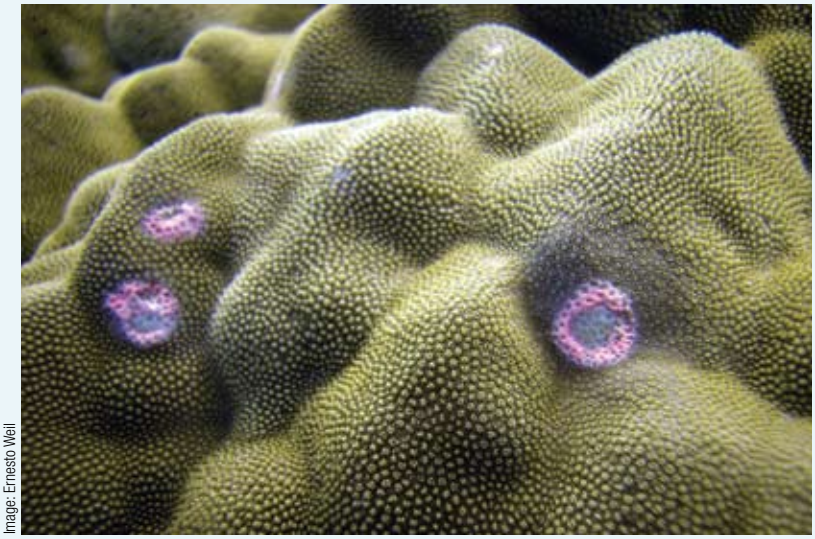

Image: Ernesto Weil

### Background

Over the last 20 years, coral reefs have been under increasing stress from natural and anthropogenic causes, including climate warming, poor water quality and over-fishing (Bryant, el al., 1998). Coral cover has declined significantly, particularly in the Caribbean (Green & Bruckner 2000, Richardson & Aronson 2003). Over this same period, an unprecedented increases in coral disease has contributed significantly to the loss of coral (Richardson 1998a; Porter, et al., 2001). Disease outbreaks cause not only coral loss, but they can result in significant changes in community structure, species diversity and abundance of reef-associated organisms. While diseased-related damage of coral reefs has been well documented in the Caribbean (Rodriguez-Martinez, et al. 2001) the status of disease throughout the Indo-Pacific is largely unknown. Preliminary surveys in Australia (and Lipscomb 2001, Dinsdale, 2003), the Philippines (Raymundo, et al., in press), and E. Africa reveal significant and damaging new diseases in all locations surveyed. The recent observations of disease in these regions is potentially a harbinger for increasing outbreaks and impacts associated with increased climate warming.

Current research supports a connection between climate warming and increased incidence of disease on both land and the ocean (Harvell et al. 2002; Harvell et al., 2001). Disease outbreaks are threshold phenomena associated with warming environments in many ecosystems, but coral reefs are among the most susceptible due to a very narrow thermal threshold for coral health (Harvell et al., 2002). The coral bleaching observed worldwide following the 1998 El Nino was the most massive

The Coral Reef Targeted Research and Capacity Building for Management Program (CRTR) is a leading international coral reef research initiative that provides a coordinated approach to credible, factual and scientifically-proven knowledge for improved coral reef management.

The CRTR Program is a proactive research and capacity building partnership that aims to lay the foundation in filling crucial knowledge gaps in the core research areas of Coral Bleaching, Connectivity, Coral Diseases, Coral Restoration and Remediation, Remote Sensing and Modeling and Decision Support

Each of these research areas are facilitated by Working Groups underpinned by the skills of many of the world's leading coral reef researchers. The CRTR also supports four Centers of Excellence in priority regions, serving as important regional centers for building confidence and skills in research, training and capacity building.

The CRTR Program is a partnership between the Global Environment Facility, the World Bank, The University of Queensland (Australia), the United States National Oceanic and Atmospheric Administration (NOAA) and approximately 40 research institutes & other third parties around the world.

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and devastating ever recorded (Hoegh-Guldberg 1999). It appears that the death of some of the coral was accelerated by opportunistic pathogens.

Deteriorating environmental conditions could influence disease by altering host/pathogen interactions. For example, ocean warming could affect basic biological and physiological properties of coral, thus influencing the balances between opportunistic pathogens and the coral's ability to fight them (Harvell et al. 2002; Rosenberg & Ben-Haim, 2002). Environmental factors could also alter the surface mucous layers (SML) of coral organisms. These mucous layers harbor a normal microbial flora that protects the coral against pathogen invasion. Other stresses include nutrient loading, which could enhance pathogen growth, and sedimentation, which could decrease coral resistance.

The etiological agents of most coral diseases are unknown. Reservoirs have only been identified for 2 diseases: black band disease (Cooney et al. 2002) and aspergilliosis (Shinn et al. 2000), and the only coral disease vector to be identified is the fireworm, (Hermodice carunculata) which harbors a bacterium that induces bleaching (Sussman et al. 2003).

Key objectives must be met to better manage reef ecosystems under newly intensified disease pressure. Exploring even basic questions is hampered by 1) lack of resources, 2) the global nature of the problem and 3) lack of expertise and technology in developing countries where many reefs are located.

This cooperative research effort is being guided by a team of internationally known microbiologists, ecologists and physiologists We will test specific hypotheses about climate and anthropogenic changes threatening coral reef sustainability. By building the capacity to manage these ecosystems, we hope to enhance reef resilience and recovery, worldwide.

WORKING GROUP GOAL

To fill critical information gaps about coral reef disease, build capacity internationally, and develop solutions for managing and conserving reef ecosystems.

## Major Areas of Research

### 1. Global Impact of Coral Disease

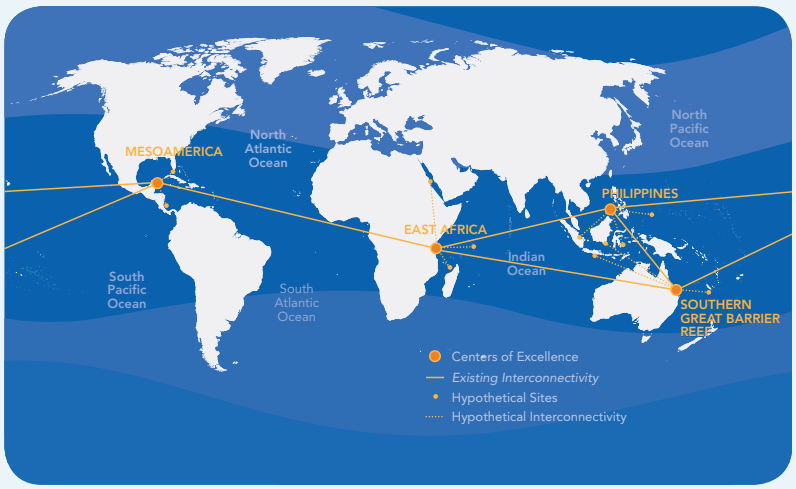
Coral disease stands out as a primary factor in the deterioration of many Caribbean coral reefs. (Weil et al. in press). While the incidence and impact of disease on coral reefs in the Pacific remains unknown, our preliminary surveys in Australia and the Philippines reveal significant new diseases (Willis et al. 2003, Raymundo et al., in press). Baird (2000) recently detected white spot I and II on the Great Barrier Reef, and Dinsdale (in press) reported black band disease and white syndrome on the Great Barrier Reef. These widespread, intensive outbreaks may alter the composition, structure, and dynamics of coral populations and communities at local and geographic scales (Richardson 1998). Recent results show that surviving coral of some species affected by disease are non-reproductive, adding urgency to documenting direct impacts (Petes et al, in prep).

- Hypothesis 1: Disease is changing the structure and composition of coral assemblages in all reef regions
- Hypothesis 2: Disease is changing coral reef biodiversity
- Hypothesis 3: Disease changes reproductive output, as well as, the dynamics of coral populations

Research strategies: We propose an annual census at approximately 24 sites globally. At each location (e.g. Philippines, Central Visayas, Palau, Hawaii, Australia, Caribbean)

Image: B Willis

we will measure disease impact and prevalence to catalogue existing diseases and investigate impact of disease. We will work at 9 GIS registered sites per locale with both high and low water quality. Surveys are underway; team members have already collected initial data in the Caribbean and Australia.




## 2. Global Warming & Anthropogenic Inputs

The Global Assessment is designed to catalogue disease syndromes worldwide for the first time and reveal whether disease outbreaks are correlated with climate warming anomalies. There is evidence for this in the mass mortality of the gorgonian coral Briareum asbestinium following the 1998 El Nino event (Harvell et al. 2001). An increase in disease following warming events may be because corals are less able to fight disease while under temperature stress, or because bacteria are more virulent (Alker et al. 2001; Ben-Haim et al. in press). In at least three cases, (Aspergillus sydowii, Vibrio shiloi, and Vibrio corallilyticus) pathogen growth and/or virulence factors increase to an optimal temperature (Isrealy-Tomar et al. 2001; Banin, et al. 2000).

While correlations between poor water quality (nutrient loading and sedimentation) and disease prevalence are of growing concern, evidence of direct links and synergistic effects are limited (Kuta and Richardson 2002; Porter et al., 2001; Kim et al, in prep). This survey will explore the interactions between anthropogenic stressors and disease load.

- Hypothesis 1: Coral disease prevalence correlates globally with warming trends
- Hypothesis 2: Coral disease prevalence correlates regionally with changes in climate and environmental quality.
- Hypothesis 3: Disease prevalence and changes in coral mucous communities correlate locally with point source inputs

**Research strategies:** At each site, we will measure nitrogen and sediment loading. We will use molecular and enzymatic assays to assess differences in the microbial communities in coral mucus, water and sediment between sites with different loadings and to assess changes in microbial communities between healthy and bleached corals. We will use multiple regression analysis to evaluate climate and anthropogenic influences on changes within microbial communities.

## 3. The Causes, Reservoirs & Vectors of Coral Disease

Current research on disease reservoirs and vectors is hampered by lack of knowledge of the pathogens causing the majority of coral diseases. To date, there are only 5 coral diseases for which the microbial cause is known: black band disease (Cooney et al. 2002); white plague type II (Richardson et al. 1998), aspergilliosis (Smith et al. 1998; Nagelkerken et al. 1997; Geiser et al. 1998), white pox (Patterson, et al. 2002) and bleaching of Oculina patagonica by Vibrio shilio (Kushamaro, et al., 1997). Disease reservoirs have only been identified for black band disease (biofilms in reef sediments, which contain non-pathogenic aggregates of the BBD; Carlton & Richardson, 1995) and possibly for aspergillosis (atmospheric African dust, which contains spores of the fungus, Aspergillus sydowii; Shinn et al., 2000). The only coral disease vector that has been identified is the fireworm, Hermodice carunculata, which has been found to harbor Vibrio shiloi (the pathogen inducing bacterial bleaching in a Mediterranean coral) in its guts (Sussman et al., 2003). Other good candidates include snails, parrot fish and damsel fish, which directly interact (predation, grazing, etc.) with coral colonies of the most important reef-building species.

Image: E Rosenberg

- Hypothesis 1: Specific coral predators and grazers act as vectors and/or reservoirs for coral diseases.
- Hypothesis 2: Reef sediments are major reservoirs of coral pathogens.

**Research strategies:** We will first develop a suite of techniques to facilitate the identification of pathogens in coral. Because only a small percentage of bacteria in nature are culturable, we will confirm the identity of and track the source of pathogens using various molecular fingerprinting techniques. The development of genetic probes and pathogen-specific antibodies will also help verify the presence of pathogens. These probes will then be utilized to trace the route of pathogen transmission and identify vectors and reservoirs of infectious agents. Eventually a micro-array chip of global coral disease will be developed.

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- RESEARCH UPDATE

## 4. Coral Resistance to Disease

The microbial communities associated with corals are very complex (Rohwer, et al. 2002), existing both inside the coral animal and in the surface mucous layers (SML). These normal communities, which may be specific to their host, protect the coral from disease. When the community structure changes, corals may become more susceptible to disease. Both bleaching and disease appear to change the microbial community profiles in the SML.

Mechanisms of inherent host resistance among corals are effectively a black box; we lack understanding of basic disease resistance mechanisms and their interaction with environmental stressors. While the first line of defense against pathogen invasion is probably the establishment of a healthy normal microbiota, some cellular defense mechanisms have been described. Both anti-bacterial and anti-fungal activities have been found in extracts from gorgonians (Jensen et al 1996; Kim et al. 2000a) and scleractinians (Koh and Sweatman, 2000) and in the case of sea fans, the response is inducible (Kim et al 2000b). Petes et al. (in prep) reports the production of chitinase, melanin and an inflammatory reaction in infected sea fans.

- **Hypothesis 1**: Environmental stress can cause changes in mucous microbial communities.
- **Hypothesis 2**: Changes in the mucous microbial community are correlated with disease.
- **Hypothesis 3**: Climate and anthropogenic stress compromises coral immunity and facilitates disease outbreaks.

Research strategies: Various molecular approaches will be employed to assess changes within the microbial mucous communities in stressed, diseased and healthy corals.

The goals of the immunological work, starting with gorgonian seafans as a study system, are to develop assays for prophenyloxidase (PPO), chitinase and general antimicrobial activity. Once resistance compounds are identified, they will be incorporated into a chip of biomarkers for stress (through collaboration with the CDHC). Field sampling will eventually allow us to estimate clonal variation in sea fan resistance, quantify the response of corals to different experimental treatments of enhanced nutrients and temperature, and map spatial variation in resistance in the field.

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