EXECUTIVE SUMMARY

"We are studying arguably the most complicated ecosystem on the face of the Earth, and it is under serious threat…..We have an incredibly important message, if this ecosystem dies, if this ecosystem is otherwise perturbed to an extent that it cannot recover, not only does it spell potential disaster for this spaceship we call Earth, but there is no less than 80 emerging economies, nations that are entirely or nearly entirely dependent on coral reef ecosystems whether it be for the economy or for the subsistence." (Gary Ostrander, Vice Chancellor for Research at the University of Hawaii, opening remarks)

Shallow coral reefs in the IndoPacific contain the highest diversity of marine organisms in the world, with approximately 1500 described species of fish, over 500 species of scleractinian corals, and an estimated 1-10 million organisms yet to be characterized (Reaka-Kudla et al. 1994). These centers of marine biodiversity are facing significant, multiple threats to reef community and habitat structure and function, resulting in local to wide-scale regional damage. Wilkinson (2004) characterized the major pressures as including (1) global climate change, (2) diseases, plagues and invasive species, (3) direct human pressures, (4) poor governance and lack of political will, and (5) international action or inaction.

Signs that the natural plasticity of reef ecosystems has been exceeded in many areas from the effects of environmental (e.g., global climate change) and anthropogenic (e.g., land use, pollution) stressors is evidenced by the loss of 20% of the world's coral reefs (Wilkinson 2004). Predictions are that another 24% (Wilkinson 2006) are under imminent risk of collapse and an additional 26% are under a longer term threat from reduced fitness, disease outbreaks, and increased mortality. These predictions indicate that the current list of approximately 30-40 fatal diseases impacting corals will expand as will the frequency and extent of "coral bleaching" (Waddell 2005; Wilkinson 2004). Disease and corallivore outbreaks, in combination with multiple, concomitant human disturbances are compromising corals and coral reef communities to the point where their ability to rebound from natural disturbances is being lost.

Pacific reefs, in general, have been considered in good condition and most resource managers have no real concern about coral disease (regardless of whether the cause is an infectious agent or anthropogenic pollution); this 'good' condition status may only be a reflection of inadequate information for many areas. In fact, the U.S. state of coral reef ecosystems 2005 report (Waddell 2005) refutes this by showing an increase in disease reports throughout U.S. states, territories and freely associated states and documents a growing perception that coral disease may be a threat to Pacific reefs. Increased findings of coral disease from the World Bank Coral Disease Working Group (WBCDWG) and NOAA/USGS disease monitoring programs provide ample evidence that disease is present in Pacific reefs and may, in fact, be increasing. For example, in 2004, the WBCDWG recorded 12 syndromes at six survey sites; including four syndromes that had not been previously recorded (Waddell 2005). Some experts warn that Pacific coral reefs are on a trajectory of degradation similar to that experienced in the Caribbean Basin where coral reefs are decimated.

Though the proliferation of coral reef diseases is a sign of a sick ocean environment, this realization can also be used as an instrument of change. There is growing evidence that the increased severity and prevalence of these diseases is directly linked to human activities, such as pollution washing off the land, heat stress to corals, and through overfishing of organisms that can control macroalgae and pest species like corallivores. By developing an understanding of disease dynamics, causal links can be determined and factors driving these system failures can be identified. Developing such an understanding can move us toward the goal of *health management and preventative care* for coral reefs.

Recognizing the need for a strategic plan of action to combat and avert a possible health crisis for Pacific Reefs, the Coral Disease and Health Consortium (CDHC) convened a workshop to help organize and coordinate a U.S. scientific effort focused specifically on coral health issues in the Pacific. The goal was to develop an action plan that would enable regional scientific efforts to detect, identify, characterize, and manage coral diseases in the Pacific. This report documents the proceedings of this workshop: ***Coral Health and Disease in the Pacific: Vision for Action***. The goals of the workshop were to:

- Synthesize the state of knowledge of Pacific coral diseases;
- Discuss the concepts and principles of disease, their use in investigating causation and how this can be applied to corals;
- Characterize the difficulties in identifying, defining and managing disease in coral; and
- Develop a *Strategic Research Plan* that
  - identifies knowledge gaps that impede understanding coral disease mechanisms (i.e., pathology), and limit elucidation of causes, significance or control of coral disease (i.e., epidemiology);
  - recommends directed research and education to fill these knowledge gaps;
  - standardizes methods for investigating coral disease outbreaks considering both biotic and abiotic etiologies;
  - addresses issues relative to the management of coral reef resources; and
  - fosters collaboration among CDHC partners, stakeholders, key marine resource management agencies, and regional networks in the Pacific.

The workshop incorporated diverse viewpoints from experts representing biomedicine, coral disease, toxicology, and resource management. The opening day focused on presentations from 14 position papers (Appendix VI), to provide context and concepts for the break-out group discussions. These presentations covered key topics that included:

- ***What do we currently know about coral diseases in the Pacific?***
- ***What lessons have we learned from Caribbean disease outbreaks?***
- ***Diagnostic methods, systems biology and leveraging post-genomic technologies***
- ***Emerging diseases, disease outbreak investigations and ecological epidemiology***
- ***How to integrate science with social, economic and political values?***

The participants were then assigned to one of four groups: (1) Coral Cellular Physiology & Pathology; (2) Coral Toxicology & Ecological Epidemiology; (3) Pathology of

Infectious Disease; and (4) Preventing and Responding to Coral Disease in the Pacific Region: Management Perspectives. Each team was charged with identifying key impediments and making recommendations for strategic research priorities that comprise this *Strategic Plan of Action*.

The opening presentation provided a context for the workshop, identifying and discussing the features that set U. S. Pacific reefs apart from those in the Caribbean and other parts of the world. The U. S. Pacific and Atlantic reef areas have similar political histories and both were exploited through plantation agriculture. Recently, the economies of both regions are shifting from agriculture to tourism, and to a lesser extent fisheries, mining and logging. All of these activities have an impact on the region's coral reefs. The Pacific coral reefs have the highest biodiversity with at least 200 genera and 580 recognized species of coral. The hub of this diversity is located in Southeast Asia around Indonesia and the Philippines in portions of the Indian and Pacific Oceans referred to as the **'coral triangle'**. This diversity then diminishes from one island to the next across the Pacific to the east. The eastern Pacific (e.g., Pacific coast off central and South America) has the lowest coral diversity in the Pacific, followed by Hawaii. However, Hawaii has the highest regional endemicity, with an estimated 25% endemic organisms that inhabit these coral reefs. The region is also distinguished by resource management practices that are shaped by traditional cultural knowledge and practices that remain active in many of the Pacific islands today. These customs and tribal governance are unique in that U. S. Pacific Islanders perceive their natural resources as valuable and an integral part of their lives. In areas where these practices occur, their influences have successfully guided community-based management practices that contrast "western" ideas and National and regional management practices. The most obvious difference between the Caribbean and Pacific is the sheer area of coral reef habitat, the number of islands and atolls that exist in the Pacific, and the amount of open ocean between these islands, all of which greatly exceed those found in the Atlantic. This in itself creates a degree of isolation for many of the Islanders. However, this vastness and high biological diversity creates logistical, biological and cultural challenges to research as the Pacific Islander population is spread over numerous islands often at great distances, resulting in diluted scientific resources and insufficient personnel to monitor and combat any potential disease crisis in their reefs.

Our most comprehensive records (1972-2005) of coral disease are compiled in the Global Coral Disease Database (WCMC Wcmc 2006) developed through a partnership between NOAA and UNEPs World Conservation Monitoring Centre (WCMC). Dr. Andy Bruckner presented a report on the global diversity and distribution of coral diseases (Appendix VI). To date, this effort has documented reports of over 40 coral diseases from the western Atlantic, 28 from the Indo-Pacific and 5 from the Red Sea, and covers 63 countries. Over 150 species representing 39 genera have been observed with disease. In the Caribbean, this translates to 80% of all taxa (41 species of scleractinian, 8 gorgonians, 2 hydrozoans) being afflicted with disease. In the Indo-Pacific 97 species (approximately 17%) from 34 genera have been identified with disease and this is on the rise. These numbers reflect a 25% increase in genera and 45% increase in species number since 1999, with 7 new genera in the Indo-Pacific observed with disease over the last 5

years. Recent surveys conducted in strategic locations across the Indo-Pacific (Australia, the Philippines, American Samoa, Northwest Hawaiian Islands (NWHI) and elsewhere) illustrate the widespread, global distribution of coral diseases with prevalence varying from a low of 0.14% in American Samoa to 0.5% in the NWHI and highs of 10% along the Great Barrier Reef (GBR) to 14% in the Philippines (see white papers in Appendix VI of this report by Willis, Aeby and Work). In these areas, over the last five years, regions previously unaffected are reporting disease, while in other locations (i.e., GBR) the percentage of reefs affected by disease has increased, and several new disease manifestations have been reported since 2002 (Willis et al. 2004). Based on this and other information, it is reasonable to conclude that diseases in the Indo-Pacific are undergoing a rapid expansion in range and types of disease and ***now*** is the time to recognize the signs of a pending problem and take action.

Our understanding of coral diseases and thus ability to combat the declining health of our reefs is limited by our lack of understanding of the basic biology and physiology of coral hosts, and their responses and tolerances to changes in their environment. We are at the cross-roads---we can remain in the dark ages of medicine, as our understanding of coral disease has been described, or we can take advantage of the established principles of wildlife veterinary medicine and the technologies of a post-genomics era, apply them to coral health, and accelerate the evolution of this field….not only to determine the cause, but how to manage disease in the reef environment. The approach undertaken by the CDHC and strategies recommended by the workshop participants can help move the coral disease field into the 21st century, through implementation of wildlife and human medical approaches and tools. This requires enhanced funding, improved training and capacity building efforts, education initiatives, and development of new tools and information resources.

Recommendations:

- **Provide Competitive-based Grant Opportunities to Fill Knowledge Gaps.** Our ability to understand coral disease pathology is hampered by a limited knowledge of molecular and cellular physiological functions of corals. An understanding of these critical features of coral biology could be rapidly advanced by tapping into a knowledge-base and skills that exist in the wider research community, is just beginning to be applied to corals. Funding is a key impediment to filling these gaps. Partnerships with funding agencies (NSF, EPA NIEHS) to offer directed grant opportunities can provide the impetus needed to engage a broader research community in developing a knowledge-base of coral cellular physiology.

- **Adopt Model Coral Species for Research.** Identify representative reef building coral species from the Atlantic and Pacific that could be used in research studies to better characterize normal coral physiology and biological stress responses, then support culture facilities to propagate these corals (i.e., living stock collection), and make specimens readily available to researchers.

- **Adopt an *Ecological Epidemiology* Approach to Identify Risk Factors and Assess their Contribution to Coral Reef Degradation.** The principles and methodologies of epidemiology can be used to identify and quantify risk factors that impact coral health (e.g., toxins and pollutants that make corals more susceptible to disease) and quantify the contribution of the various factors leading to adverse health effects. Implementation requires developing standardized methods and tools to detect and track biological responses of corals which can focus diagnostic efforts, and help direct and prioritize management and research actions toward risk reduction.

- **Develop a Systematic Approach to Investigate and Study Diseases in Corals.**
  - Identify and recommend standardized approaches to systematically investigate coral diseases, including a system of nomenclature and terminology to describe diseases, survey approaches and laboratory techniques to provide compatibility among data.
  - Develop a protocol for responding to coral disease outbreaks, train regional and local teams in disease investigative methodologies, including documenting case histories, assessing the area and extent of an outbreak using appropriate survey techniques, sampling techniques for specific laboratory analysis, and implementing systematic investigations in response to unusual coral disease outbreaks and mortality events.
  - Develop a bioinformatics system to track outbreaks, synthesize case data to identify drivers in outbreaks and provide data in a format easily accessible to researchers and resource managers.

- **Manage Coral Reefs to Reduce Stressors that may make Corals more Vulnerable to Disease.** Managers often discount the study of coral disease because conceptually they believe disease is part of nature or even if causes of disease are identified, nothing can be done so why bother. However, management of disease in animal populations cannot occur in absence of information. Indeed, several tools are available to manage disease in human and animal populations (including wildlife), and these tools were developed precisely because targeted research identified the key interactions between agent(s), host, and their interactions with their environment that drive the occurrence of disease. Similar concepts also apply to corals. The key to managing coral health and mitigating disease impacts is not through stereotypic routes of medication, vaccination, and treatments, but rather by identifying causes of coral diseases, pathogenesis and factors that may modulate the resulting pathologies, including interactions with manageable anthropogenic and environmental stressors. The most controllable environmental factors are those associated with land-based sources of stressors; understanding disease dynamics can identify control points in a disease cycle that can also be used in management strategies. This will require researchers working collaboratively with key marine resource management agencies and regional networks in the Pacific such as the U.S. All Islands Coral Reef Initiative Coordinating Committee.

- **Create and Support Advanced Educational Opportunities.** There is a critical need to build scientific capacity in the field of coral pathology and disease management skills in reef resource management. These programs should include development of advanced degree programs in coral pathology, cellular physiology, toxicology or epidemiology as well as continuing education in specialty topics (e.g., disease identification for resource managers; disease investigation methods; environmental forensics) for professionals (i.e., resource managers).

- **Develop Guidance for the Proper Handling and Containment of Corals in Infectious Disease Experiments.** Most experimental studies involving corals have occurred under conditions that, in a medical setting, would be unacceptable. Typically, corals are placed in water tables, exposed to a suspect agent, and monitored for development of gross lesions whereupon the conclusion is made that agent 'A' caused disease 'B'. Critical oversights in such experiments include lack of environmental controls (e.g. use of water tables with little monitoring of what microorganisms go in and out of the system), lack of morphologic follow-up to confirm that a gross lesion is indeed due to the putative infectious agent being investigated, and lack of knowledge regarding the normal physiology and biota of the host being investigated. Other studies have been conducted in the field with no containment or control over the dispersal of the inoculum into the surrounding environment. These types of experimental studies are analogous to attempting to elucidate the cause of a farm animal disease by conducting studies in the barnyard. An important outcome of this workshop was the **recommendation by the participants to the CDHC to accept the following guidelines** for the care and handling of corals in experimental settings:
  - Field Challenges using agents grown in a laboratory setting should not be done. Just as we would not grow bacteria or viruses in the lab and infect livestock, wild animal populations or humans (vaccines being the one controlled exception), in open systems with no containment, nor should we do it in corals.
  - The export of laboratory reared coral back into the field is not currently recommended, until suitable tests are available for assuring these coral do not pose a threat to the wild populations.
  - The need for biosecurity and bio-containment guidelines for conducting laboratory challenge experiments with candidate infectious agents and toxicants is recognized and it is recommended that CDHC establish a steering committee to develop these guidelines that are consistent with existing guidelines for handling and containment of infectious agents in wildlife as well as protocols for hazardous materials handling.

- **Foster the Development of a Cohesive Coral Disease Research Community.** The goals outlined in this document can only be achieved through a cohesive group of people focused on common goals and a passion for healthy coral reefs. The participants of this workshop recommend that the CDHC provide a focus for cross-cutting priority research needs and a framework for interaction and collaboration among the coral disease research community.

OPENING REMARKS
(Transcribed from this Workshop's Opening Address presented by Gary K. Ostrander)

When I was thinking about my comments last night, since I do publish in the field of coral reef biology, I realized that I had a unique opportunity today to talk to the leadership in my scientific community. This is in addition to my responsibility as the Vice Chancellor to welcome you to Hawaii. This is significant to me in that you are a special group of scholars. You were all invited to this meeting because you are outstanding researchers and many of you represent and/or collaborate with top research groups and laboratories in the world.

I realized that if I actually had something significant to say, that it might impact you and in doing so it might extend to others in the field. So, my initial comment is as follows:

When are we going to get our act together as a research community?
At best, we're pathetic. If that puts you on the defensive or makes you uncomfortable, that's my intent. We are studying, arguably, the most complicated ecosystem on the face of the Earth and it is under serious threat. Yet, we are disproportionately under-funded, in terms of funding whether it's in the United States, at NSF or EPA, in Europe, Australia, etc. We are disproportionably under-represented in the top research journals: *Science, Nature, PNAS, Cell* and even in the second and third-tier research journals.

What's the problem, what are we doing wrong?
I tell my graduate students and staff that I don't have a problem if you come to me with your problems, but I do have a problem if you don't come to me with a solution or a starting point for a solution. So, I am going to hold myself to the same standard this morning and I'm going to offer the following for your consideration.

What are the causes of the problem that we currently face and what is a possible solution?
Are we stupid? I don't think so. I've met a lot of very smart people in this field. I didn't start out in this field--I'm a guest. I started my career in cancer biology. When I think of the solution and I think of the causes, I turn my attention to the zebrafish community. Does anybody in this room not know what a zebrafish is? Of course you do!

Twenty years ago, when I started working in fish cancer, nobody was working on zebrafish. In fact, I would argue that there was probably an order of magnitude, if not two orders of magnitude, more people working on coral reefs than on zebrafish. Yet in 20 short years, zebrafish have become recognized as a predominant model for developmental biology. They were on the cover of *Science* a few weeks ago. They continue to be in the top journals. If you sit on the panels at NIH, NSF and EPA, etc. in the United States, it's zebrafish work that's getting funded. They (i.e. the zebrafish community) did two things well. One is they asked important questions. I don't think that's a problem for us. But, secondarily and most important, they came together as a community very early on. They supported each other. Before there was an Internet, they put together the zebrafish handbook, the bible for zebrafish researchers. They went out of their way to make it easy for people to join the community, to work in the community. If someone had a line of zebrafish, if someone had a cell line, you could ask them for it, they would FedEx it to you and they would pay the shipping, and then they'd call you to find out if you had questions or needed help. When you sat on a NIH Study Section or an NSF panel and a zebrafish grant would come through, it would get the "regular" reviews from everybody. However, from the fish people, whether they supported the grant or not, they supported the particular application of fish, they supported the individual, and they were an advocate for the type of work. Zebrafish scientists joined the boards in the major societies in North America and throughout the rest of the

world as well as journal editorial boards. And though they could be just as critical and just as scathing, and just as nasty as we are to our colleagues, they didn't do that. When they were critical, they were critical in a positive and a productive way. Look at where it's gotten them.

Sadly, this is not the case for the coral reef community. I am on the Editorial Board for *Aquatic Toxicology*. When's the last time you saw a coral reef paper in *Aquatic Toxicology*? It's a top journal, there's lots of coral work in aquatic toxicology. It's amazing, when you send a coral paper out to someone who is not a coral biologist, you get a reasonable review, when you send it out to a coral biologist, you usually get a pretty scathing review, because everybody's defending their own territories. I see this when I sit on study sections at EPA or NSF. When I was in the fish community, you wanted a fish person to review your stuff, not because they would automatically approve it. No, you wanted them because you would get a constructive review if they didn't.

In my brief time in the coral reef community, I have learned that I don't want coral biologists reviewing my work. I am willing to take my chances with competent reviewers who don't know anything about coral biology.

Five years ago, approximately, Cheryl convened the first of these workshops. They have tremendous potential to help the coral community. Out of that workshop came the idea: could we sequence the coral genome? So, Craig Downs, Craig Venter, Claire Fraser, Steven Salzsberg and I got together to write a 'white paper'. The middle three individuals are some fairly significant names in the human genome community. Let me tell you a little bit about that effort and where it got us. The first question we had to address was which species do we sequence? That created quite a bit of controversy in the coral reef community. In the end, *Porites lobata* was suggested. And, parenthetically, I will tell you that was not my first choice even though I was leading the effort to write the white paper. Once the species was selected it was necessary to get letters of support. NHGRI had mandated that we be able to demonstrate that the community was going to rally around the organism selected and would actually use it because of the high costs of sequencing a genome. I'm not going to name names, but I have to tell you that I was really disappointed that when I went to colleagues who had "lost" as they viewed it, in their efforts to get "their species" sequenced, that they didn't provide letters of support, even when I emailed them a couple times.

We ended up submitting an application with 45 letters, and it was a good application. However, I was further disappointed that after it was submitted to NHGRI, some of our colleagues, hopefully nobody in this room, took it upon themselves to go to members of the panel to lobby for their own species and to disparage the rest of us and the species that had been selected. This did not send a good message to the NIH. They eventually came back to us with their decision: they said they would support pilot sequencing on three species, which they did. Ironically, one of the species they came back to us with was not even among the final three we had selected ourselves. Obviously, more politics was involved. At one point, somebody from the coral community went to the officials overseeing the website that runs the listserv we were using to solicit letters of support for the effort and wanted everything taken down because they presupposed members of our team were using this effort to patent sequences to make drugs. That is, we were doing this as a money making venture. Nobody came to ask me if that was the intent. No one came to me and said, 'Hey, we heard this rumor, is this true.' No one ever talked to us about it, they just went around us. Clearly, it was not true and it was not even possible if you understood the NHGRI program.

In the end, NHGRI provided funds and we did pilot sequencing on three coral species. I am told they are still planning to select one of them for full sequencing. However, I am also told it is not a

priority right now. What's I have heard through back-channels is that there's concern on the part of NHGRI as to whether our community is going to embrace whatever species that was selected and whether it would be used. Some people mistakenly assumed that if it was not their species that was sequenced, that it would have no value to their research. Now whether they are just ignorant of RT-PCR or some of the other technologies, or whether they are just being selfish, I don't know, but it's a real problem for our community.

So let me conclude. I challenge you, all of you, to take the first steps to create a more cohesive community, a community that works together. People will follow by example, it's been done before. We have an incredibly important message, if this ecosystem dies, if this ecosystem is otherwise perturbed to an extent that it cannot recover it spells disaster not only for this spaceship we call Earth, but for more than 80 emerging economies, nations that are entirely or nearly entirely dependent on coral reef ecosystems for their existence. This is an incredible opportunity, an incredible moment. One of our colleagues posted something on the coral list-serve that said in part '….the problem with the coral reef community is that they eat their young.' It's a nice analogy, I think its time we do something to reverse it. So with that I will conclude my welcome from the University of Hawaii.

Thank you for your time."

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June 19, 2006

PREFACE

Over the past three decades, coral reefs worldwide have experienced major changes in structure and function due to numerous anthropogenic stresses and natural factors. In particular, the prevalence and severity of coral diseases and the diminishing health condition among corals have contributed to unprecedented declines in live coral cover and altered the productivity of coral reef ecosystems. The Caribbean is referred to as a "hot spot" for diseases due to a rapid emergence and high virulence of new diseases, an increasing geographic distribution and wider host ranges of known diseases, and an increased frequency of epizootic events. The number of diseases and their distribution across the Indo-Pacific also appears to be on the rise. Increased anthropogenic stress, overfishing, changing environmental conditions associated with global climate change, and the synergistic effect of multiple stressors have been implicated as significant factors contributing to escalating disease levels. However, our ability to address the recent increases in coral disease is hampered by a paucity of relevant epizootiological data, an incomplete understanding of the mechanisms responsible for the diseases and their consequences, and few diagnostic tools to help managers evaluate and mange diseases. Responding to this growing threat requires improved scientific understanding and tools to: (1) detect and assess trends in coral diseases at scales relevant to scientific investigation and policy development; (2) determine the causes and consequences of increasing disease frequency and distribution; and (3) evaluate possible management options to mitigate the effects of disease on coral reef ecosystems and their users.

In 1998 the United States government issued Executive Order 13089 on coral reef protection. This Order called for the creation of the U.S. Coral Reef Task Force (US CRTF 2008) to develop, in partnership with federal agencies whose actions affect U.S. coral reef ecosystems, measures needed to understand, manage and restore coral reef ecosystem, with emphasis on reduction of impacts from pollution, sedimentation and fishing. The CRTF developed the National Action Plan to Conserve Coral Reefs (March 2000), which outlines 13 major themes focused on improving our understanding of reefs and quickly addressing human impacts to these ecosystems. This Plan, together with the National Strategy and the Coral Reef Conservation Act of 2000 has outlined a realistic strategy to improve the condition and health of coral reefs, and has helped focus our conservation efforts, especially in waters of the United States, our territories and commonwealths and the Freely Associated States. One of the key initiatives of the CRTF was the creation of the Coral Disease and Health Consortium (CDHC), focused specifically on coral health issues, with emphasis on the diagnosis and etiology of coral diseases and bleaching. The CDHC is a network of field and laboratory scientists, coral reef managers, and agency representatives devoted to understanding coral health and disease. Currently over **150 partners,** including three federal agencies (EPA, DOI, NOAA), academia, non-profit groups and industry are working *to understand and address the effects of natural and anthropogenic stressors on corals in order to contribute to the preservation and protection of coral reef ecosystems.*

In January 2002 the CDHC convened its first official meeting where recommendations to address the major gaps in coral disease and health research were identified and are detailed in *Coral Disease and Health: a National Research Plan* (Woodley et al. 2003). The major needs include:

- Establishing standard terminology, methodology and protocols;
- Expanding knowledge in basic coral physiology, biology and disease etiology;
- Developing model coral species; and
- Developing a centralized data/knowledge system, website, repository and core diagnostic facilities.

The CDHC working closely with partners have focused on five main activities. These include:

- Developing standardized procedures based on medical principles that clearly define the terminology, pathology and diagnostic criteria;
- Developing diagnostic tools to assist researchers in identifying coral stressors;
- Applying advanced technologies in functional genomics, proteomics and systems biology to expand our knowledge in coral health and disease dynamics;
- Providing local response capabilities to carry out formal disease investigations;
- Establishing culture facilities to maintain reef organisms for research.

The CDHC in cooperation with the research and management community has worked to 1) strengthen multidisciplinary collaborations and provide training for scientists and managers, 2) develop diagnostic capabilities (e.g., IRCP), 3) establish culture facilities to propagate model coral species for use in research and 4) develop educational materials, databases and web-based tools for scientists, managers and the public.

The CDHC recognized the need to improve collaboration among our U.S. Pacific and international colleagues. In June, 2006 experts from multiple disciplines were brought together in Honolulu, Hawaii to help chart a course for coral health and disease activities in the Pacific and Indo-Pacific. The intent of this meeting was to generate a strategic plan that addresses 1) research needs to help understand etiologies, epidemiology and ecology of Pacific coral diseases; 2) management needs in the context of identifying innovative strategies for disease management on coral reefs and 3) outreach and education needs to combat the spread of coral disease through novel strategies that engage the public and political sectors and enhance partnership with the CDHC. During the working group deliberations, participants identified five key areas for the CDHC to assist in organizing and coordinating scientific resources in:

- establishing diagnostic criteria and diagnostic tool development
- conducting mechanism-based research on coral health and disease
- leading outbreak investigations, training efforts, and epizootiological studies
- providing training and advanced continuing-education opportunities
- developing web-based communication and database tools