E. 'WHITE PAPERS'

The opening day of the workshop focused on presentations derived from 14 position papers, to provide context and concepts for the break-out group discussions. The presentations, included in this section, covered key topics:

- *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?*

I. INTRODUCTION—SETTING THE STAGE

CORAL DISEASE AND HEALTH CONSORTIUM (CDHC)

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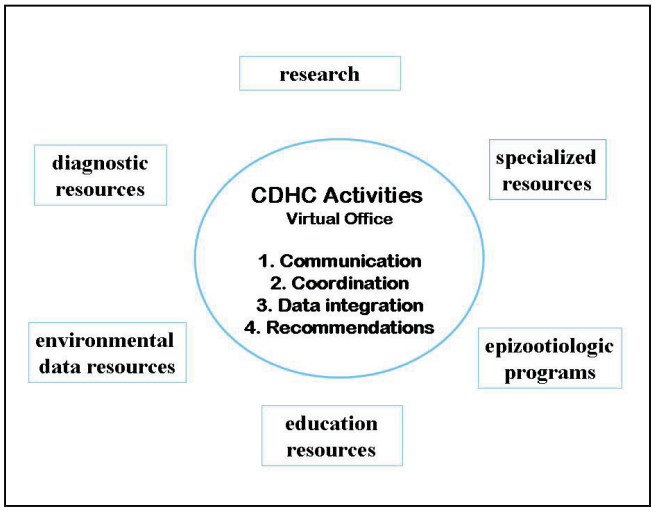
CDHC - VISION

"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."

CDHC - WHO ARE WE?

The Coral Disease and Health Consortium (CDHC) was created in 2002, in response to the U.S. Coral Reef Task Force's (USCRTF) National Action Plan to Conserve Coral Reefs (United States Coral Reef Task Force 2000). Our goal is to provide coastal and ocean managers with scientific understanding and tools to help protect healthy coral reef ecosystems and restore degraded ones. The CDHC is a network of field and laboratory scientists, coral reef managers, and agency representatives devoted to understanding coral health and disease. It is extensive, highly collaborative, and completely voluntary. Currently over **150 partners,** from federal agencies, EPA, DOI, NOAA along with academia, non-profit and industry, contribute their time and expertise to the CDHC, while the organizational infrastructure is supported by the congressionally funded NOAA's Coral Reef Conservation Program.



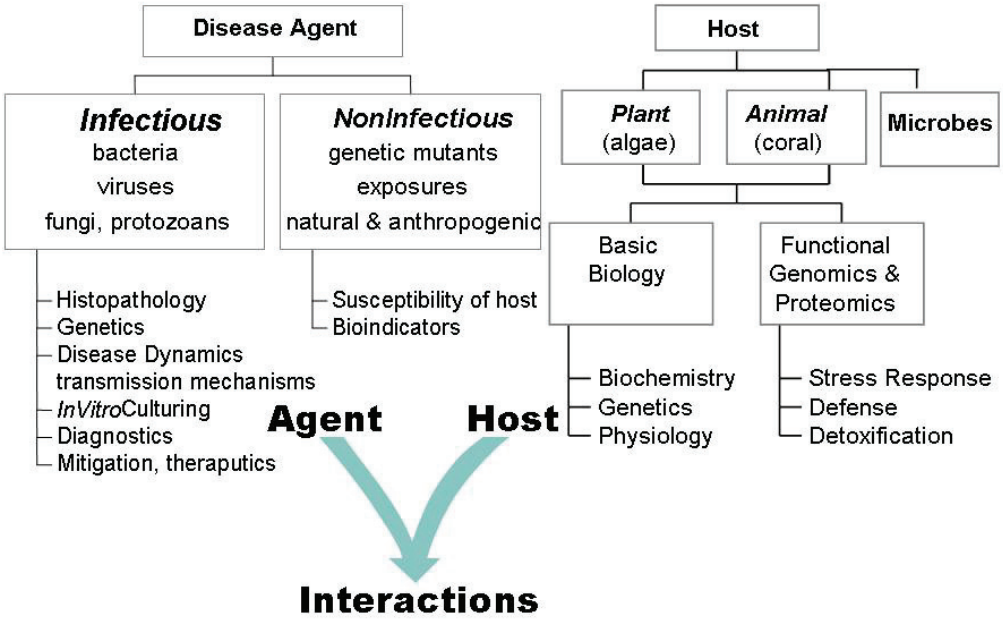
The commitment to share information, ideas, and common goals led to the development of a national research plan, *Coral Disease and Health: A National Research Plan* (Woodley et al. 2003), that has inspired many to seek funding and devote new resources to the study and amelioration of coral disease. Members of the CDHC come from a variety of backgrounds, but all have a common commitment to share information, ideas, and common goals to further the study of coral

disease and in so doing identify ways to better manage coral disease. We encourage participation of anyone sharing our vision and goals.

CDHC - WHY?

Recent reviews have documented an explosion in the incidence of disease, particularly in the Caribbean. The first disease report occurred in 1965 related to skeletal anomalies (Squires 1965), with the next report coming 8 years later by Antonius (1973), from these reports through the early 1990s, only four diseases had been recognized: skeletal anomalies, Black band, White plague Type I, and Shutdown reaction (Sutherland et al. 2004). Since the early 1990s, monitoring programs in the Florida Keys have documented a sharp increase **in the number** and **prevalence** (the ratio, for a given time period of the number of occurrences of a disease or event to the number of units at risk in the population) of coral diseases. Reports from the Indo-Pacific suggest an emerging crisis in coral disease as monitoring efforts are able to explore new areas.

The picture of coral disease has expanded from the simple perception of an infectious disease agent to a plethora of possible interactions with a variety of possible agents attacking not just the coral animal, but an intricate group of organisms consisting of plant, animal and microbial associates. The complexity of this growing disease problem made it



more difficult to design management regimes and increased significantly the need for cross-disciplinary tools to combat the problem (see diagram below).

Realizing these were complex and complicated issues, we recognized that our lack of understanding of the underlying mechanisms of coral pathologies was inhibiting our ability to manage the growing number of coral health problems. Also, to improve our ability to identify the factors responsible for coral health decline and increased disease incidence would require embracing a *new paradigm of scientific investigation* that incorporates new methods and new technologies able to help elucidate mechanisms that link cause and effect relationships so the field could move from just descriptive science into mechanistic science.

There was an obvious need to unify the coral disease community, build scientific skills and capacity, and provide standardization in investigative nomenclature, methodologies and technologies in order to competently communicate and interact with other main stream disease fields (e.g., pathology, cell biology, physiology, infectious disease, toxicology, medicine). In response, the CDHC was organized in 2002 when 50 experts from various disciplines and perspectives from science to management, met and developed what we now refer to as the *Coral Disease and Health: A National Research Plan* (Woodley et al. 2003). This document provided an integrated roadmap that began tying these ideas together. This document outlined gaps in our knowledge and recommended research directions needed to support this new paradigm. Four major themes with accompanying strategic objectives were identified: **Biology (6), Disease Identification and Disease Investigation (4), Disease Diagnostics (5) and Environmental Factors Affecting Susceptibility and Infectivity (11).** The 26 recommendations encompassed 9 topic areas: **Nomenclature, Model System(s), Field Assessment of Coral Reef Condition, Microbiology, Toxicology, Histopathology, Molecular, Bioinformatics, and Advanced Education and Outreach.**

CDHC: WHAT ARE WE DOING?

Research

Information is limited on the physiological parameters that define healthy coral and even less on coral pathology. Our challenge is to apply advanced technologies in functional genomics, proteomics, toxicology, and systems biology to expand our knowledge to understand and recognize coral health and elucidate disease dynamics. The knowledge gained from this research approach is positioning us to move aggressively toward characterizing the processes that control ecological connectivity among reefs and discover critical control points for management strategies. The first step is to establish and make available tools that can support discovery and applied research. For example, CDHC efforts have helped establish transcriptomic resources from expressed sequence tag (EST) cDNA projects with over 30,000 coral EST sequences publically available from five species: *Montastraea annularis, Oculina varicosa*, *Porites astreoides, Acropora palmata and A. millipora.* There are also over 28,000 ribosomal gene sequences cloned from coral-associated bacteria available to assist in microbial diversity

and pathogen research efforts. This type of information is vital and basic to developing an understanding for how an organism responds to its environment, is key to developing diagnostic tools to assess coral health and lays the foundation for identifying critical control points and viable management options.

Diagnostic Resources

There is limited application of medical/veterinary knowledge or protocols to the study of coral health and disease, resulting in ambiguous and often misleading communication of findings. Compounded by inadequate diagnostic tools and insufficient application of diagnostic procedures, the challenge is to develop standardized procedures based on medical principles that clearly define terminology, pathology and diagnostic criteria.

Education

Experts in coral biology, pathology and veterinary science are developing resources and web-enabled tools for use in recognizing gross signs of disease and in clinical diagnostic pathology as well as developing case definitions for selected coral syndromes. The web-tool will be used to guide investigators in the diagnostic process. Additional modules are planned that will include virtual slide technologies for distance learning coral histology and histopathology, consultation with experts on disease cases, and continuing education through regular 'grand round' web meetings.

Diagnostic Tools

Consortium members have achieved significant advances in diagnostic assay development that assist researchers in identifying coral stressors. Examples of new techniques include:

- DNA probe for the White Plague agent – Dr. Laurie Richardson, Florida Atlantic Univ.
- DNA sequence analysis for the White Pox agent *Serratia marcescens* (newly designated 'White Pox Serratiosis' when the presence of *S. marcescens* is confirmed) - Dr. Kathryn Sutherland, Rollins College, Winter Park FL
- Coral immuno-competence (IMCOMP) assay to assess the presence of antimicrobial agents within coral tissue by using a modified bacterial viability assay – Dr. Craig Downs, Haereticus Environmental Laboratory
- PCR-screening test for recognized pathogens – Dr. Shawn Polson, Univ. Delaware & NOAA NOS Charleston, SC
- DNA Abasic site lesions – NOAA NOS Charleston, SC
- Various toxicity tests are being adapted or modified to address development, mutagenesis, and cellular pathologies associated with toxicant exposures.

Specialized Resources

Several specialized resources that help build capacity and provide outreach and educational opportunities are being made available by members of the CDHC. These include:

- International Registry of Coral Pathology (IRCP) supported by NOAA, Oxford, MD, is a research tool and resource of voucher materials for the coral research community. Submission, holdings and acquisitions are located at http://www.chbr.noaa.gov/InternationalRegistry.html. For more information contact Dr. Shawn McLaughlin, shawn.mclaughlin@noaa.gov
- Annotated cnidarian bibliography containing >5000 references and abstracts available as an ENDNOTE™ library or on CD, is supported by a complete set of reprints and is accessible on an individual basis on site in Charleston, SC. Contact Dr. Sylvia Galloway, sylvia.galloway@noaa.gov for more information.
- CDHC Website and Listserve – Supported by NOAA's Coral Health and Monitoring Program at the Atlantic Oceanographic and Meteorological Laboratory in Miami, FL. http://coral.aoml.noaa.gov/mailman/listinfo/ http://www.coral.noaa.gov/coral_disease/

CDHC – VISION FOR ACTION - WHY ARE WE HERE AT THIS MEETING?

The overarching goal for us is to "**Promote the effective detection, identification and management of coral reef diseases".** To do this a plan of action is needed that will ***'Chart a course for coral health and disease in the Pacific and Indo-Pacific'.*** We have convened this meeting to:

- Synthesize the state of knowledge of Pacific coral diseases
- Develop a strategic plan to:
- Identify research needs to help understand etiologies, epidemiology and ecology of coral diseases
- Identify innovative strategies for disease management on coral reefs
- Identify novel strategies to engage public and political sectors in partnering with us to combat the spread of coral disease

Disease

"any impairment that interferes with or modifies the performance of normal functions, including responses to environmental factors such as nutrition, toxicants, and climate; infectious agents; inherent or congenital defects, or combinations of these factors" Wobeser 1981.

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STUDYING CORAL DISEASES; UNDERSTANDING THE NORM

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Coral disease incidence has been on the rise for the past thirty years. Within that time frame approximately 30 new syndromes and diseases have been identified. To date, only few diseases or syndromes have been characterized in terms of causality and even fewer have been characterized in terms of the physiological effect on the coral.

The coral holobiont may be considered a "super-organism" composed of the coral host, its algal symbionts, and accompanying microorganisms. Since disease is defined as "any deviance from normal physiological function of an organism" it then becomes no trivial task to ascertain the physiological norm of this complex "super-organism".

In corals, disease signs and symptoms are usually classified by superficial signs, such as color change, tissue loss pattern, or changes in gross colony architecture. This simplistic classification is due to the inadequacy of information available describing basic biological and physiological processes that could provide the baseline for comparison. For example, information pertaining to cellular processes responsible for coral calcification and growth is still rudimentary. This is also true for information pertaining to biochemical regulation of coral reproduction. Similarly though mechanisms of tissue repair and regeneration have been studied at the organismal level, only recently have they begun to be assessed at cellular and molecular levels. Since these are all vital biological processes without which corals could not survive, understanding them is crucial to our perception of normal coral physiology. In turn understanding the norm will allow for a proper diagnosis of deviation from it.

The use of "the diagnostic method" borrowed from the world of medicine may prove useful in elucidating disease processes. This method incorporates performing a "clinical" examination that includes historical and current information about the coral in order to determine its state and provide a diagnostic interpretation. The purpose of this examination is to detect overt changes in carefully chosen assessment end-points with known reference values. This will only really be possible though, once basic reference values have been established. The elucidation of physiological regulatory pathways will improve our understanding of how the coral holobiont responds to stress and will assist in formulating standards for proof of cause-and-effect relations and provide information on how environmental change could affect host-pathogen relations and immune defenses.

It is clear that assessment of coral health should be not be carried out only on a single level of biological organization, but should be evaluated across a hierarchy of organization including molecular, biochemical, cellular and tissue-level and whole organism phenomena, and include population metrics as well. Once these parameters are evaluated as a whole, we will be much better equipped to properly diagnose and mitigate coral disease.