EXECUTIVE SUMMARY

The health and continued existence of coral reef ecosystems are threatened by an increasing array of environmental and anthropogenic impacts. Coral disease is one of the prominent causes of increased mortality among reefs globally, particularly in the Caribbean. Although over 40 different coral diseases and syndromes have been reported worldwide, only a few etiological agents have been confirmed; most pathogens remain unknown and the dynamics of disease transmission, pathogenicity and mortality are not understood. Causal relationships have been documented for only a few of the coral diseases, while new syndromes continue to emerge. Extensive field observations by coral biologists have provided substantial documentation of a plethora of new pathologies, but our understanding, however, has been limited to descriptions of gross lesions with names reflecting these observations (e.g., black band, white band, dark spot). To determine etiology, we must equip coral diseases scientists with basic biomedical knowledge and specialized training in areas such as histology, cell biology and pathology. Only through combining descriptive science with mechanistic science and employing the synthesis epizootiology provides will we be able to gain insight into causation and become equipped to handle the pending crisis.

One of the critical challenges faced by coral disease researchers is to establish a framework to systematically study coral pathologies drawing from the field of diagnostic medicine and pathology and using generally accepted nomenclature. This process began in April 2004, with a workshop titled *Coral Disease and Health Workshop: Developing Diagnostic Criteria* co-convened by the Coral Disease and Health Consortium (CDHC), a working group organized under the auspices of the U.S. Coral Reef Task Force, and the International Registry for Coral Pathology (IRCP). The workshop was hosted by the U.S. Geological Survey, National Wildlife Health Center (NWHC) in Madison, Wisconsin and was focused on gross morphology and disease signs observed in the field. A resounding recommendation from the histopathologists participating in the workshop was the urgent need to develop diagnostic criteria that are suitable to move from gross observations to morphological diagnoses based on evaluation of microscopic anatomy.

As a continuation of building the foundation and framework for coral disease diagnostics, the CDHC convened the *Coral Disease and Health Workshop: Coral Histopathology II* in Charleston, South Carolina, July 11-14, 2005. The workshop was hosted by the Department of Pathology and Laboratory Medicine at the Medical University of South Carolina, Charleston, SC which provided expertise, facilities and equipment in support of the workshop. All of the histological slides and related photographs used in the discussions were prepared and supplied by the IRCP. This workshop brought together 15 experts in veterinary and medical pathology and coral biology from national and international research institutes and government laboratories. The mission was to devise a standardized approach to examining microscopic anatomy and pathology of corals and a standardized nomenclature to facilitate accurate descriptions of the microscopic morphology of corals and enhance communication among specialists investigating causes of coral death.

The participants of this workshop deliberated for 3 days to refine the nomenclature for gross and microscopic anatomy of corals and systematically described microscopic changes associated with selected coral diseases. The findings and recommendations from the deliberations will be submitted to the research community for peer review. The standardized nomenclature and descriptions produced at this workshop will ultimately be made available to the scientific community through a variety of media including the World Wide Web.

An exciting highlight of this meeting was provided by Professor Robert Ogilvie (MUSC Department of Cell Biology and Anatomy) when he introduced participants to a new digital technology that is revolutionizing histology and histopathology in the medical field. The Virtual Slide technology creates digital images of histological tissue sections by computer scanning actual slides in high definition and storing the images for retrieval and viewing. Virtual slides now allow any investigator with access to a computer and the web to view, search, annotate and comment on the same tissue sections in real time. Medical and veterinary slide libraries across the country are being converted into virtual slides to enhance biomedical education, research and diagnosis. The coral health and disease researchers at this workshop deem virtual slides as a significant way to increase capabilities in coral histology and a means for pathology consultations on coral disease cases on a global scale.

GOAL: Set an internationally recognized standard for the description of coral microscopic anatomy and pathology.

SPECIFIC OBJECTIVES:

- Refine nomenclature of gross and microscopic anatomy.
- Describe microscopic changes associated with selected diseases.
- Develop diagnostic criteria for coral conditions for a web-based learning tool for coral histology and histopathology.
- Set internationally recognized standards for the description of coral histology.
- Standardize terminology for the description of microscopic lesions of corals.
- Develop morphological diagnoses for the histopathology of lesions from selected coral syndromes.

Dr. Lou Sileo, facilitator of the July coral histopathology workshop. (Photo: Jim Nicholson)

PREFACE

Pathology is the study of the cause of disease and the modifications to cellular structure and function resulting from a diseased state. Diagnostic techniques such as histology, electron microscopy, immunocytochemistry and molecular pathology are powerful technologies for detecting such changes, but they have not been rigorously applied to coral disease investigations. The CDHC is organizing a series of workshops to focus on coral pathobiology to provide a forum for translating advances in biomedical and veterinary sciences, pathology, toxicology, and biotechnology to the study of coral disease and health. The cross-disciplinary nature of these workshops serves to provide the means by which coral disease researchers can interface with the mainstream biomedical community and allow more rapid progress in understanding the causes of coral disease and devising appropriate strategies for disease management.

The first workshop in this series, '*Coral Disease and Health Workshop: Developing Diagnostic Criteria*' held in 2004, focused on gross morphology and disease signs observed in the field. During deliberations, problems with inconsistent data collection and the lack of objective criteria to describe cellular changes associated with disease at the microscopic level (histopathology) were identified as major impediments. Furthermore, routine use of the principles and practices of epizootiology and pathology of corals are just beginning. Confusion and uncertainty as to how cellular changes in these organisms should be described are evident in the literature. The second Coral Histopathology Workshop, reported here, was convened to address this issue. The workshop involved coral biologists and pathologists from various institutions to refine nomenclature of gross and microscopic anatomy and to systematically describe microscopic changes associated with selected diseases.

Presumed white band disease observed on *Acropora palmata* in Puerto Rico. (Photo: Andy Bruckner)

Tissue sloughing in *Acropora prolifera* observed in the Dry Tortugas, USA (Photo: Dana Williams)

To date most field diagnoses have been descriptive in nature, failing to use traditional histopathological criteria. The workshop was organized around the review of histological slide sets from coral lesions associated with a variety of field diagnosed diseases. The workshop participants agreed to review a set of known coral lesions as a group and to develop a set of histopathological terms applicable to the description of these lesions. They also agreed to review independently unidentified histology slides containing coral lesions, followed by a group discussion of their independent observations, and to reach a consensus morphological diagnosis for the unknowns.

Workshop participants reviewing a photomicrograph. (Photo: Jim Nicholson)

Debra Hazen-Martin, Jim Nicholson and Bob Ogilvie of MUSC. (Photo: Jim Nicholson)

The work of the group was greatly facilitated by the logistical support and expertise provided by MUSC's Department of Pathology and Laboratory Medicine. The group had microscopes allowing pathologists to independently review slides, and a projection microscope for the group discussions. In addition photographs were captured from specific regions of each reviewed histological slide that illustrated the morphological diagnosis ascertained by the group.

Finally, the workshop participants were given the opportunity to view and use the latest in histopathology technology[1], Virtual Slides[2]. An Aperio Virtual Slide Viewer[3] was demonstrated during the first day of the workshop.

---

[1] Disclaimer: This publication does not constitute an endorsement of any commercial product or intend to be an opinion beyond scientific or other results obtained by the National Oceanic and Atmospheric Administration (NOAA). No reference shall be made to NOAA, or this publication furnished by NOAA, in any advertising or sales promotion which would indicate or imply that NOAA recommends or endorses any proprietary product mentioned herein, or which has as its purpose an interest to cause directly or indirectly the advertised product to be used or purchased because of this publication.

[2] Advances in Pathology, Microscopy & Molecular Morphology edited by Jiang Gu and Gerhard W. Hacker: 'Virtual Microscopy and Virtual Slides in Teaching, Diagnosis, and Research' by Jiang Gu and Robert W. Ogilvie; CRC, Taylor & Francis, Boca Raton, London, New York, Singapore, 2005, 356p.

[3] http://www.aperio.com/

Representative sections from each coral lesion under review were digitized using this system. These images were provided to each participant on a DVD for future viewing. Aperio viewing software is available (and downloadable) free from their website. The virtual slide viewer provides the same quality image, resolution, and magnifications that a user would get with a microscope. The scanner contains 80 micro lenses and has a 24 mega-pixel capability. A unique feature of the software associated with the scanner is the ability to conference and view slides jointly over the internet, with control of slide movement and focus available (permission granted by scanner operator) to each participant of the conference. It was agreed that this technology would be extremely useful to share information on histopathology among colleagues interested in coral disease diagnosis and as a teaching tool.

Aperio Representative demonstrating Virtual Slides to Bob Ogilvie (Photo: Jim Nicholson)