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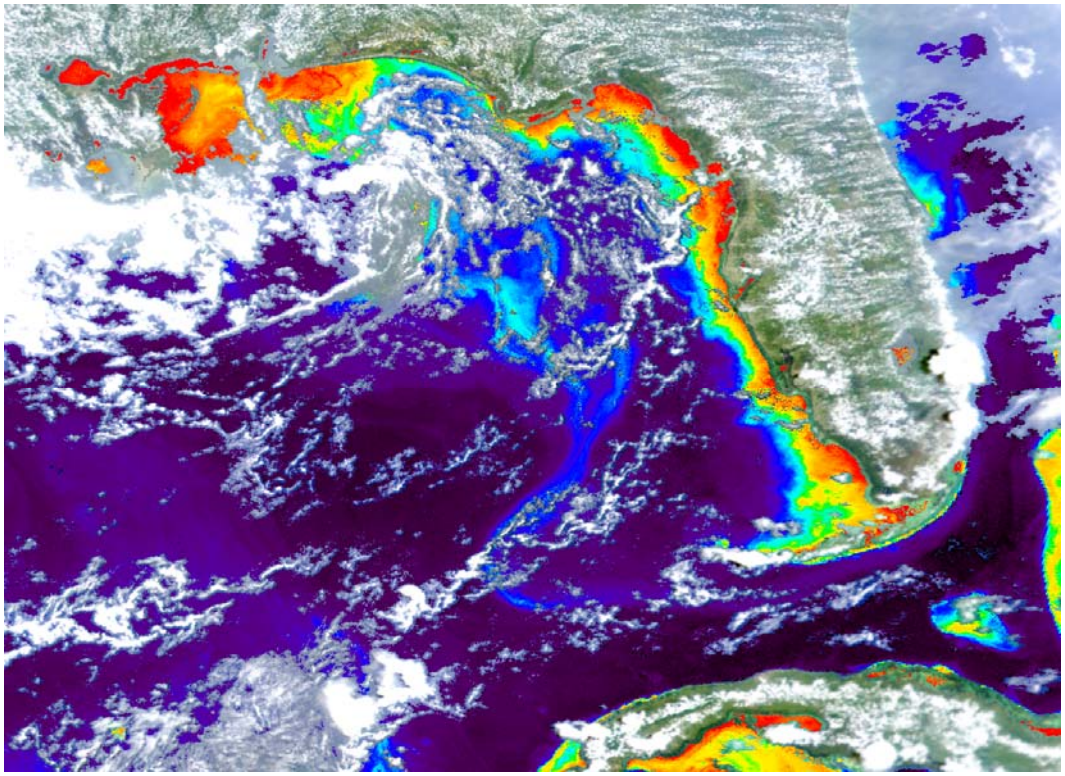

CONNECTIVITY
Science, People and Policy in the Florida Keys National Marine Sanctuary

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Ocean Service
Office of Ocean and Coastal Resource Management
National Marine Sanctuary Program

March 2008

About the Marine Sanctuaries Conservation Series

The National Oceanic and Atmospheric Administration's National Ocean Service (NOS) administers the National Marine Sanctuary Program (NMSP). Its mission is to identify, designate, protect and manage the ecological, recreational, research, educational, historical, and aesthetic resources and qualities of nationally significant coastal and marine areas. The existing marine sanctuaries differ widely in their natural and historical resources and include nearshore and open ocean areas ranging in size from less than one to over 5,000 square miles. Protected habitats include rocky coasts, kelp forests, coral reefs, sea grass beds, estuarine habitats, hard and soft bottom habitats, segments of whale migration routes, and shipwrecks.

Because of considerable differences in settings, resources, and threats, each marine sanctuary has a tailored management plan. Conservation, education, research, monitoring and enforcement programs vary accordingly. The integration of these programs is fundamental to marine protected area management. The Marine Sanctuaries Conservation Series reflects and supports this integration by providing a forum for publication and discussion of the complex issues currently facing the National Marine Sanctuary Program. Topics of published reports vary substantially and may include descriptions of educational programs, discussions on resource management issues, and results of scientific research and monitoring projects. The series facilitates integration of natural sciences, socioeconomic and cultural sciences, education, and policy development to accomplish the diverse needs of NOAA's resource protection mandate.

CONNECTIVITY
Science, People and Policy in the Florida Keys National Marine Sanctuary

Brian D. Keller and Fiona C. Wilmot, eds.

U.S. Department of Commerce
Carlos M. Gutierrez, Secretary

National Oceanic and Atmospheric Administration
VADM Conrad C. Lautenbacher, Jr. (USN-ret.)
Under Secretary of Commerce for Oceans and Atmosphere

National Ocean Service
John H. Dunnigan, Assistant Administrator

National Marine Sanctuary Program
Daniel J. Basta, Director

Silver Spring, Maryland
March 2008

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National Oceanic and Atmospheric Administration
National Marine Sanctuary Program
SSMC4, N/ORM62
1305 East-West Highway
Silver Spring, MD 20910

COVER

SeaWiFS image on 28 July 1999 shows a plume from the Mississippi River and northern Gulf of Mexico meandering toward the Florida Keys. Image provided by Dr. Chuanmin Hu, University of South Florida.

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CONTACT

Brian D. Keller, Ph.D.
National Marine Sanctuary Program
c/o Florida Institute of Oceanography
830 First Street South
St. Petersburg, FL 33701
(727) 553-1100
Brian.Keller@noaa.gov

Preface

The Connectivity Colloquium was held in August 2004 in Key West, Florida. The purpose of the meeting was to bring together a range of perspectives on the concept of connectivity, from scientific to human dimensions, and their applications to management and policy. Parts of this proceedings volume were edited from transcripts prepared by Fiona Wilmot from tape recordings of many of the sessions; these sections are self-evident. Technical difficulties prevented recordings of the sessions on resource conditions, water quality, and coral and seagrass habitats as well as the plenaries by Terry Done, Steven Miller, and Rod Salm and the ensuing discussions. The section on shifting baselines is an op-ed piece by Dr. Randy Olson, which is posted at http://www.shiftingbaselines.org. The rest of the sections are manuscripts submitted by the presenters; Mark Eakin (NOAA) and Bob Ginsburg (U. Miami/RSMAS) were not able to submit contributions, but we thank them for their presentations. We thank Bob as well for leading a memorable Coral Polyp Dance during one of those unpredictable pauses.

In the three years it has taken to complete these proceedings, the monitoring data have been supplanted, but most of the patterns evident then still apply. The ideas and concepts are still as fresh and relevant today as they were just after the passage of Hurricane Charley, when the organizers breathed a sigh of relief about the timing of storms affecting Key West in 2004.

Our thanks go to Joanne Delaney, Nancy Diersing, Erskine Robinson, Heidi Schuttenberg, and Carolina Sullivan for their support before and during the meeting. Monroe County Commissioner George Neugent of Sanctuary Friends of the Florida Keys, with characteristic prescience, ensured material support early in the organizing stages of the meeting. We also thank Dr. Carl Safina for a thoughtful and moving evening presentation based on his work with albatross. Finally, we thank Ted and Diana Wilmot for providing a quiet space amenable to several periods of intense editing, without which this volume most likely would not have been completed.

The Editors, September 2007
The Malt House, Barford, Warwick, England

Organizing Committee

Billy D. Causey; Southeast Atlantic, Gulf of Mexico, and Caribbean Region; National Marine Sanctuary Program
Brian D. Keller, Florida Keys National Marine Sanctuary
Nancy Klingener, The Ocean Conservancy
Bill Kruczynski, U.S. Environmental Protection Agency
Fred McManus, U.S. Environmental Protection Agency
Jody Thomas, The Nature Conservancy
Fiona C. Wilmot, Florida Keys National Marine Sanctuary (Chair)

Contributors

Katharine (Kacky) Andrews, Office of Coastal and Aquatic Managed Areas, Florida Department of Environmental Protection, Tallahassee, FL. Present address: Coastal States Organization, 444 North Capitol Street, NW, Suite 322, Washington, DC, 20001. E-mail: cso@sso.org.

Dr. Jerald S. Ault, University of Miami, Rosenstiel School of Marine and Atmospheric Science, 4600 Rickenbacker Causeway, Miami, FL, 33149. E-mail: ault@rsmas.miami.edu.

Dr. Carl R. Beaver, Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute, 100 Eighth Avenue SE, St. Petersburg, FL, 33701. E-mail: Carl.Beaver@MyFWC.com. (Sadly, Carl died in a tragic accident in 2007)

Dr. Donald C. Behringer, Jr., Department of Biological Sciences, Old Dominion University, Norfolk, VA, 23529. Present address: Department of Fisheries and Aquatic Sciences, University of Florida, 7922 NW 71st Street, Gainesville, FL, 32653. E-mail: behringer@ufl.edu.

Dr. Rodney D. Bertelsen, Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute, 2796 Overseas Highway, Suite 119, Marathon, FL, 33050. E-mail: rod.bertelsen@myfwc.com.

Dr. James A. Bohnsack, NOAA Fisheries Service, Southeast Fisheries Science Center, 75 Virginia Beach Drive, Miami, FL, 33149. E-mail: jim.bohnsack@noaa.gov.

Dr. Joseph N. Boyer, Southeast Environmental Research Center, Florida International University, Miami, FL, 33133. E-mail: boyerj@fiu.edu.

Dr. Mark J. Butler IV, Department of Biological Sciences, Old Dominion University, Norfolk, VA, 23529. E-mail: mbutler@odu.edu.

Michael Callahan, Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute, 100 Eighth Avenue SE, St. Petersburg, FL, 33701.

Billy D. Causey, Florida Keys National Marine Sanctuary, P.O. Box 500368, Marathon, FL, 33050. Present address: Southeast Atlantic, Gulf of Mexico, and Caribbean Region; National Marine Sanctuary Program; 33 East Quay Road; Key West, FL, 33040. E-mail: billy.causey@noaa.gov.

Mark Chiappone, Center for Marine Science Research, University of North Carolina at Wilmington, 515 Caribbean Drive, Key Largo, FL, 33037. E-mail: chiapponem@uncw.edu.

Joanne Delaney (moderator), Florida Keys National Marine Sanctuary, 33 East Quay Road, Key West, FL, 33040. E-mail: joanne.delaney@noaa.gov.

Gabriel A. Delgado, Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute, 2796 Overseas Highway, Suite 119, Marathon, FL, 33050. E-mail: gabriel.delgado@myfwc.com.

Dr. Terry Done, Australian Institute of Marine Science, PMB 3, Townsville MC, Townsville 4810, Queensland, Australia. E-mail: t.done@aims.gov.au.

Dr. James W. Fourqurean, Department of Biological Sciences and Southeast Environmental Research Center, Florida International University, Miami, FL, 33199. E-mail: fourqure@fiu.edu.

Stephen Frink, Stephen Frink Photographic, MM 102.5 Overseas Highway, P.O. Box 2720, Key Largo, FL, 33037. E-mail: info@stephenfrink.com.

Robert A. Glazer, Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute, 2796 Overseas Highway, Suite 119, Marathon, FL, 33050. E-mail: bob.glazer@myfwc.com.

Douglas R. Gregory, University of Florida/IFAS Extension, 1100 Simonton Street #2-260, Key West, FL, 33040. E-mail: drg@ufl.edu.

Dr. Lara Hansen, World Wildlife Fund, 1250 24th Street NW, Suite 500, Washington, DC, 20037. E-mail: lara.hansen@wwfus.org.

Dr. Chuanmin Hu, Institute for Marine Remote Sensing, College of Marine Science, University of South Florida, 140 Seventh Avenue South, St. Petersburg, FL, 33701. E-mail: hu@seas.marine.usf.edu.

Peter Ilchuk, Florida Keys & Key West Lodging Association, 3152 Northside Drive, Suite 101, Key West, FL, 33040. E-mail: president@keyslodging.org.

Walter C. Jaap, Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute, 100 Eighth Avenue SE, St. Petersburg, FL, 33701. Present address: Florida Institute of Oceanography, 830 First Street South, St. Petersburg, FL, 33701. E-mail: wjaap@tampabay.rr.com.

Dr. Elizabeth Johns, Atlantic Oceanographic and Meteorological Laboratory, 4301 Rickenbacker Causeway, Miami, FL, 33149. E-mail: libby.johns@noaa.gov.

Dustin Johnson, Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute, 100 Eighth Avenue SE, St. Petersburg, FL, 33701.

Dr. Brian D. Keller (editor and moderator), Florida Keys National Marine Sanctuary, P.O. Box 500368, Marathon, FL, 33050. Present address: c/o Florida Institute of Oceanography, 830 First Street South, St. Petersburg, FL, 33701. E-mail: brian.keller@noaa.gov.

Doug Kelly, Bonefish & Tarpon Unlimited, 24 Dockside Lane, PMB 83, Key Largo, FL, 33037. E-mail: dkelly@tarbone.org.

James Kidney, Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute, 2796 Overseas Highway, Marathon, FL, 33050.

Selena Kupfner, Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute, 100 Eighth Avenue SE, St. Petersburg, FL, 33701.

Dr. Thomas N. Lee, University of Miami, Rosenstiel School of Marine and Atmospheric Science, 4600 Rickenbacker Causeway, Miami, FL, 33149. E-mail: tlee@rsmas.miami.edu.

Elizabeth Mcleod, Global Marine Initiative, The Nature Conservancy, 923 Nu'uama Avenue, Honolulu, HI, 96817. E-mail: emcleod@tnc.org.

Dr. Steven L. Miller, Center for Marine Science Research, University of North Carolina at Wilmington, 515 Caribbean Drive, Key Largo, FL, 33037. E-mail: millers@uncw.edu.

Martin A. Moe, Jr., Green Turtle Publications, 222 Gulfview Drive, Islamorada, FL, 33036. E-mail: martin_moe@yahoo.com.

Sandy Moret, Florida Keys Outfitters, PO Box 603, Islamorada, FL, 33036. E-mail: info@floridakeysoutfitters.com.

Dr. Frank E. Muller-Karger, Institute for Marine Remote Sensing, College of Marine Science, University of South Florida, 140 Seventh Avenue South, St. Petersburg, FL, 33701. Present address: School of Marine Science and Technology, University of Massachusetts Dartmouth, 285 Old Westport Road, North Dartmouth, MA, 02747. E-mail: fmullerkarger@umassd.edu.

Ken Nedimyer, SeaLife, 212 Silver Palm Avenue, Tavernier, FL, 33070. E-mail: sealifefl@bellsouth.net.

Dr. Elliott A. Norse, Marine Conservation Biology Institute, 2122 112th Avenue NE, Suite B-300, Bellevue, WA, 98004. E-mail: Elliott@mcbi.org.

Dr. Peter B. Ortner, Atlantic Oceanographic and Meteorological Laboratory, 4301 Rickenbacker Causeway, Miami, FL, 33149. Present address: University of Miami, Rosenstiel School of Marine and Atmospheric Science, 4600 Rickenbacker Causeway, Miami, FL, 33149.E-mail: portner@rsmas.miami.edu.

Dr. James W. Porter, Institute of Ecology, University of Georgia, Athens, GA, 30602. E-mail: jporter@uga.edu.

Dr. Cheri A. Recchia, The Ocean Conservancy, Washington, DC. Present address: California Marine Protected Areas Monitoring Enterprise, California Ocean Science Trust, 1330 Broadway, Suite 1135, Oakland, CA, 94612. E-mail: cheri.recchia@calost.org.

Dr. Kimberly B. Ritchie, Mote Marine Laboratory, 1600 Ken Thompson Parkway, Sarasota, FL, 34236. E-mail: ritchie@mote.org.

Leanne M. Rutten, Center for Marine Science Research, University of North Carolina at Wilmington, 515 Caribbean Drive, Key Largo, FL, 33037. E-mail: ruttenl@uncw.edu.

Dr. Rodney V. Salm, Global Marine Initiative, The Nature Conservancy, 923 Nu'uama Avenue, Honolulu, HI, 96817. E-mail: rsalm@tnc.org.

Heidi Schuttenberg (moderator), National Marine Sanctuary Program, Silver Spring, MD. Present address: James Cook University, Townsville, Queensland 4811, Australia. E-mail: heidi.schuttenberg@jcu.edu.au.

Dr. Jeffrey Shields, Virginia Institute of Marine Science, Gloucester Point, VA, 23062. E-mail: jeff@vims.edu.

Manoj Shivlani, University of Miami, Rosenstiel School of Marine and Atmospheric Science, 4600 Rickenbacker Causeway, Miami, FL, 33149. E-mail: mshivlani@rsmas.miami.edu.

Dr. Daniel Suman, University of Miami, Rosenstiel School of Marine and Atmospheric Science, 4600 Rickenbacker Causeway, Miami, FL, 33149. E-mail: d.suman@miami.edu.

Dione W. Swanson, Division of Marine Biology and Fisheries, Rosenstiel School of Marine and Atmospheric Science, University of Miami, 4600 Rickenbacker Causeway, Miami, FL 33149. E-mail: dswanson@rsmas.miami.edu.

Cecelia Torres, Institute of Ecology, University of Georgia, Athens, GA, 30602.

Dr. Tracy A. Villareal, Marine Science Institute, The University of Texas at Austin, 750 Channel View Dr., Port Aransas, TX, 78373. E-mail: tracy@utmsi.utexas.edu.

Shannon Wade, Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute, 100 Eighth Avenue SE, St. Petersburg, FL, 33701.

Jennifer Wheaton, Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute, 100 Eighth Avenue SE, St. Petersburg, FL, 33701.

Fiona C. Wilmot (editor), Florida Keys National Marine Sanctuary, P.O. Box 500368, Marathon, FL, 33050. Present address: 2513 Granada Circle East, St. Petersburg, FL, 33712. E-mail: fionawilmot@earthlink.net.

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Executive Summary

The Connectivity Colloquium evolved from an exhortation by Dan Basta, Director of the National Marine Sanctuary Program, to come together and assess what we know about the condition of our natural resources, identify information gaps and how to fill them, and transform science and management from an emphasis on documentation to a nexus for action. This purpose in some ways reflects the initiation of the Florida Keys National Marine Sanctuary itself, which was designated by an act of the U.S. Congress in 1990 in the aftermath of the 1989 *Exxon Valdez* oil spill in Alaska and three major ship groundings on the Florida Reef Tract in late 1989. Over the next seven years NOAA worked with federal, state, and local partners to develop a comprehensive management plan for the Sanctuary implemented under a co-trustee partnership between NOAA and the State of Florida.

Keynote Address and Plenary Presentations

Do the Keys Hold the Keys to Our Ocean's Future? Insights from a 57-year Transect
Threats to the ocean may be categorized as *proximate threats* including over-exploitation, physical alteration, marine pollution, alien species, and global atmospheric change, which in turn are driven by five *ultimate threats*: there are too many of us, we consume too much, we don't know enough, we don't care enough, and as a result our institutions aren't effective enough. Many people do not associate physical alteration with marine systems, but there has been an appalling destruction of ecosystems at the interface of land and water. Offshore, the biggest threat to the marine world is fishing: we kill fish faster than they can replace themselves and we have altered and destroyed habitats where fish live, diminishing the capacity of the ocean to produce fish. In addition there is some sort of interaction between killing fish and destroying the habitats upon which they depend. Trawlers are ubiquitous agents of physical disturbance to the sea floor, and the loss of structurally complex habitats likely reduces fish diversity and abundance.

Coral reef ecosystems are particularly complex because they are spectacularly diverse, and some of the problems are that we do not know what all the parts are. There are species that are strong interactors, which include sea turtles, big fish, and the sea urchin *Diadema*, and their populations have crashed in many places. Structure formers in the ecosystem such as elkhorn and staghorn coral have been dramatically reduced in many places around the world, including in the Keys. As a result we have flipped from one state of an ecosystem to another state in what we call "regime change." If structure formers are removed, fish habitat is eliminated, and if the strong interactors are removed, the recovery of structure formers is prevented, especially after a major disturbance such as localized ship grounding or a widespread hurricane or bleaching event. If both are removed, then there are synergistic effects, and that caused the phase change we have seen from a coral-dominated to an algal-dominated ecosystem.

Marine reserves are not always the answer because small, fast-maturing organisms can recover quickly, but large, slow-reproducing organisms take a long time. Ecosystem-wide impacts of humans must be managed comprehensively; we have to take all the things that are forcing the system and alleviate all the forcings so that the system can recover, and that is not simple. In the next few decades the best way to comprehensively manage human impacts is place-based anagement: ocean zoning. The Great Barrier Reef Marine Park is the largest comprehensively zoned piece of

underwater real estate on Earth. The Florida Keys has potential, but only if there is the support of people pushing leadership to do better.

Preserving Coral Reefs and Other Coral Communities: The Perspective of the U.S. Commission on Ocean Policy
The value of coral reefs can be evaluated in several dimensions. From an ecological point of view, they house tens of thousands of species of plants and animals, making them among the world's most diverse and productive habitats. They have significant tourism and recreation, as well as shoreline protection value. Globally, it is estimated that the value of reefs approaches ~$375 billion per year and they support 500 million people. The Florida Keys generated ~$105 million in income and supported 8,000 jobs in 2001. Finally, the cultural and aesthetic value of reefs is really enormous and hard to calculate.

The health of coral reef ecosystems is decreasing at an alarming rate. It is clear that human activities have and will continue to adversely impact the environment if we do not manage these activities. It is particularly difficult to see what happens beneath the surface of the ocean, and this makes management of resources like coral reefs and fish very complicated. It should be obvious that we can't manage resources without understanding them. Yet we regularly under-invest in science, technology, and education. Managing marine resources is also difficult because of an intricate system of state and federal government jurisdictions seaward of the coast.

Congress and the President recognized the staggering problems we face and mandated the creation of a new U.S. Commission on Ocean Policy through the Oceans Act of 2000. The objective was to study the state of our ocean knowledge and governance, and to recommend a national ocean policy. The Commission embarked on what became 15 public meetings and additional site visits around the country, including various sites around Florida in February of 2002. In parallel to this process, the Pew Oceans Commission carried out its own assessments and published its findings in June 2003. Both commissions' findings are essentially the same; the point is that the oceans are in trouble and we need to make changes. The U.S. Commission on Ocean Policy delivered its final report on 20 September 2004, which may be found at the Commission's web site.

Addressing the myriad problems affecting oceans and their resources cannot be done without having a clear and visionary ocean policy, a blueprint for managing the oceans. The U.S. desperately needs a new integrated management mechanism to treat ocean resources as interrelated and interdependent ecosystem components, rather than as a collection of isolated fragments managed independently from each other, as practiced today. The Commission recommends a National Ocean Policy Framework that creates a more effective and coordinated federal management system. A core element is the creation of a National Ocean Council (NOC), housed within the Executive Office of the President. Effective ocean policy should be based on unbiased, credible, and sufficient scientific information, and the Commission recommends that significant attention be put into reviving our research and technology infrastructure. A high priority is to implement an Integrated Ocean Observing System based on a backbone of coordinated, linked regional monitoring systems and strong connections to Global Ocean and Earth Observing Systems.

The Commission supports a national ocean policy founded on high-quality, effective education that promotes lifelong learning, an adequate and diverse workforce, informed decision making, science literacy, and stewardship. In addition, the Commission dedicated one full chapter to recommendations on coral reef management. Significant change, however, cannot be achieved without commensurate investment. The U.S. Commission on Ocean Policy outlines the costs

associated with making improvements to our ocean policy, and presents a proposal for meeting those costs through the establishment of a new "Ocean Policy Trust Fund." High tides raise all boats. It is our collective task to make sure everyone understands that the oceans are both a public resource and a public trust, and that conservation for future generations is critical for our survival on Earth. This can only be done by working together.

Lessons from the Great Barrier Reef: Sister System of the Florida Keys

The theme of this public meeting about conserving and using the Florida Keys National Marine Sanctuary (FKNMS) stresses the importance of building connections among scientists, the general public, and policy-makers. In Australia, these same players have also made good connections in relation to the Great Barrier Reef (GBR), in some ways, a sister to the Florida Keys. The GBR World Heritage Area is an area of ocean and reefs the width of Florida that, if transplanted to the U.S. east coast, would stretch the 1,200 miles from Key West to Baltimore. Like the Florida Keys, the GBR is managed as a multiple use marine management area, with goals of balancing use, production, and access, while protecting its economic and natural values.

There are important and striking differences between the GBR and the FKNMS apart from sheer size. Whereas the Keys loom small in the consciousness of the American general public, "Our Reef" looms large in the consciousness of Australians. The creation of the FKNMS and the effort to restore the Everglades is evidence that the great value and importance of the linked ecosystems of the Everglades, Florida Bay, and the Florida Keys are clearly recognized. In Australia, it was in the 1960s and 70s that public groundswell to "Save the Reef" came to the consciousness of generations to come. There were shortcomings and delays in the transfer of the considerable science knowledge that was relevant to policy and management. Also, there was inadequate engagement between scientists and would-be users of science – not only the managers and policy makers, but also the traditional, commercial, and recreational users of the GBR.

Two concrete initiatives to redress these shortcomings had their genesis in the 1990s. The first was a two-year, skillfully facilitated process of extensive workshops and working groups orchestrated by the GBR Marine Park Authority that produced the *Twenty-five Year Strategic Plan for the Great Barrier Reef*. The second concrete initiative was the Australian federal government's Cooperative Research Center (CRC) Program. Over 12 years, it provided billions of dollars a range of Centers, and in particular, about $90 million of new money to coral reef science with important strings attached: interest groups must be involved in the identification of issues, the allocation of research funds, and where possible, the logistic support of the research.

Like the Florida Keys, the ecology and economy of the GBR are subject to the same set of pressures as have been enumerated for tropical coastal systems the world over. Given the huge size of the GBR, there is enormous variability in the extent to which these pressures have caused damage, and to which they represent ongoing threats. Overall, the Great Barrier Reef is considered to be in relatively good condition, and current management is a mix of reducing manageable pressures, and improving the system's capacity to accommodate effects of runoff and fishing, and to rebound from inadvertent and natural disturbances. Zoning of access and use has been the major management action for almost two decades, along with management of fisheries in that section of the area that is open to fishing (> 90% until 2004), regulation of reef-based tourism, restriction of large shipping to designated lanes, and initiatives to maintain or where necessary, restore, good water quality. These strategies, collectively and adequately applied and targeted, should lay the groundwork for

improvement in what has become the Holy Grail for managers of all sorts of natural and managed systems: ecological resilience.

Two pieces of science – the quantification of land-based inputs and the demonstration of a detrimental effect on coral reefs – have provided scientific support and impetus for the introduction of a major regional water quality rehabilitation program. In addition, in July 2004 the Great Barrier Reef Marine Park Authority implemented a revision of zoning of the GBR that increased the level of no-take protected areas from 4% to 33%. The rezoning has enhanced protection of the region's biodiversity by introduction of a network of highly protected areas typical of all the different habitats and communities. That we now have a zoning plan that can do great good for the people and "Our Reef" is perhaps one of the world's best examples of science-people-policy connections. This is big sister's lesson for little sister.

Shifting Baselines

Shifting baselines are the chronic, slow, hard-to-notice changes in things, from the disappearance of birds and frogs in the countryside to the increased drive time from L.A. to San Diego. Among environmentalists, a baseline is an important reference point for measuring the health of ecosystems. If we know the baseline for a degraded ecosystem, we can work to restore it. But if the baseline shifted before we really had a chance to chart it, then we can end up accepting a degraded state as normal – or even as an improvement. Data from around the world show that overfishing has been the most important alteration to the oceans over the past millennium. Humans have had such a strong effect on the oceans for so long that, in many locations, it is difficult to even imagine how full of life the oceans used to be. Without knowledge of the past, it is easy for each new generation to accept baselines that have shifted and make peace with empty kelp beds and coral reefs. That is why it is so important to document how things are – and how they used to be.

Building Resilience into Coral Reef Management

Large-scale coral bleaching events have increased in intensity, frequency, and geographic distribution in the last two decades; the 1998 El Niño Southern Oscillation (ENSO) event and 1999 La Niña caused mass coral bleaching of unprecedented proportions worldwide and near complete loss of live coral at some sites. We now recognize that climate-related bleaching events pose a serious global threat to coral reefs, raising concerns about appropriate response strategies. Marine Protected Areas (MPAs) have been identified as one of the most effective tools for conserving reefs and related marine systems. However, protected area managers must incorporate climate change as well as increasing human pressures into their conservation strategies, or MPAs may not be able to safeguard biodiversity effectively. Networks of MPAs, including no-take areas, have been identified as a critical way to protect coral reefs from human stresses.

Despite the widespread bleaching-related mortality of coral reef organisms, it is rare for living corals to be completely eliminated from a section of reef. Even in the most severe cases, some coral communities appear to be more resistant (i.e., they don't bleach) or more resilient (i.e., they bleach and may die but recover quickly) to bleaching. A variety of environmental and biological factors appear to influence the differences in responses to bleaching among various coral communities. These include factors that: 1) reduce temperature stress; 2) increase water movement and flush harmful toxins; 3) decrease light stress; 4) harden corals to adverse conditions and develop stress tolerance; and 5) favor conditions that enhance recovery potential. Sites where these factors reliably occur would make good candidates for MPA selection and the investment of conservation effort and funds.

MPA managers, accustomed only to addressing direct and usual threats related to fishing and tourism, for example, find it difficult enough to address the impacts of coastal development and inland activities, and may consider climatic sources of environmental stress totally beyond their sphere of influence. This perception is reinforced when even well managed reefs in the remotest MPAs succumb to a climate related bleaching event. However, there are some direct actions that MPA managers can take immediately, even as the scientific understanding improves. It might be possible to mitigate the negative impacts of bleaching on coral reef biodiversity in two broad ways:

1. Identify and protect from direct anthropogenic impacts, specific patches of reef where local conditions are highly favorable for survival generally, and that also may be at reduced risk of temperature-related bleaching and mortality
2. Locate such protected sites in places that maximize their potential contribution to the recovery of damaged or vulnerable reefs that are connected through larval dispersal

The Nature Conservancy has developed a "Resilience Model" to assist conservation planners and managers build resilience into coral reef MPAs. The most effective configuration would be a network of highly protected areas nested within a broader management framework. Such a framework might include a vast multiple-use reserve managed for sustainable fisheries as well as protection of biodiversity. The ideal MPA system would be integrated with coastal management regimes to enable effective control of threats originating upstream, and to maintain high water quality.

There are compelling reasons for conserving the reefs in the Florida Keys and for selecting the FKNMS as a place to develop our global understanding of resilience and how to apply it to MPA design and management across the U.S. and the world. The extensive research and monitoring in the Florida Keys and the high levels of public visitation have generated a vast body of knowledge from which to draw information on the location of coral community types, which ones bleach and which do not, and possibly even why the communities respond differently. So there is the opportunity to make quick progress on application of all elements of the resilience model to protection and management strategies in the Keys. The Sanctuary is well placed to play a leading role in developing practical application tools and approaches both locally and globally to build resilience into coral reef management.

Regional Connections

Regional Connections and the Coastal Ocean Observing System

A variety of processes influence coral reef ecosystems across a range of time and space scales. It is increasingly clear that different regions separated by great distances are connected through physical processes of ocean and atmospheric circulation, which carry nutrients, pollutants, pathogens, larvae of coral reef organisms, weather, and heat and salinity. The Florida Keys National Marine Sanctuary (FKNMS) experiences the influence of riverine discharge from the Everglades as well as rivers emptying into the Gulf of Mexico. It also feels significant impacts of water and other materials carried from the Caribbean and Gulf of Mexico into the Atlantic by the Loop Current, as well as local circulation features. Significant knowledge, experience, and infrastructure exist in South Florida and in the Intra-Americas Sea region to assist in linking science and ecosystem management efforts in the FKNMS. The FKNMS should engage the Coastal Ocean Observing Systems of the region to address the issues of monitoring and scientific observation in the Florida Keys, including both the SEACOOS (http://seacoos.org) and the GCOOS (http://gcoos.org) regional associations of the

Integrated Ocean Observing System (IOOS). This effort needs to include satellite remote sensing to achieve repeated and synoptic views of factors affecting the FKNMS and changing conditions within the FKNMS.

On the Connectivity and "Black Water" Phenomena near the FKNMS: A Remote Sensing Perspective
Satellite color images from SeaWiFS and MODIS for 1997-2004 show dark water plumes and patches in coastal waters off southwest Florida including the FKNMS that appeared to originate with coastal runoff from the Everglades and from the vicinity of Charlotte Harbor and Sanibel Island. Because the FKNMS is located downstream of these areas, the dark water patches, which field sampling confirmed may contain elevated nutrients and both colored living and non-living materials, lead to stress to the ecosystem. Waters from more remote sources, such as the Mississippi River and the Caribbean, routinely affect this region via ocean circulation patterns (e.g., the Loop Current). Florida's red tides, which occur every year along the west coast, may also meander toward the Keys. The connectivity of the FKNMS to local and remote systems requires an integrated observing system to better understand the effects of these dark patches on the coral reef ecosystem.

East-West Connections in the Gulf of Mexico
The FKNMS is part of the continuum of global and regional processes that affect the biology and chemistry of the Gulf of Mexico. Some of these processes influence events well upstream of the Keys and operate indirectly through biological cascades. The linkages are often indirect, but highlight the complexities inherent in the Keys ecosystem and its connections to the world around it. Examples include complex linkages between the influx of African dust and red tide and coral disease outbreaks, Loop Current eddies that introduce a common flora and fauna into the eastern and western Gulf, and the large number of oil production platforms in the northwestern Gulf that may influence barracuda movements and the spread of ciguatera.

Connectivity of the Coastal Waters Surrounding the FKNMS
Cruises conducted by the NOAA South Florida Program have mapped reduced salinities along the southwest Florida coast and in Florida and Biscayne Bays that are indicative of freshwater sources in the Everglades. Trajectories of satellite-tracked surface drifters demonstrate the direct upstream connection between the coastal waters of the southwest Florida shelf, Florida Bay, and the FKNMS, as well as the downstream connection of the FKNMS with the U.S. east coast via the Loop Current/Gulf Stream system. Real-time observations are critically important for monitoring the often complex and inter-related oceanographic and meteorological events that occur in South Florida marine ecosystems and for assisting with NOAA's goal of science-based resource management of the FKNMS. Evolution of the South Florida Program will include increased capabilities for real-time observations and rapid response to unusual events.

Connectivity between People and Marine Fishery Resources
The connection between people and fishery resources has a very long history and is a value system and a focal point for energy consumption and sustainability. The issue comes to numbers: the South Florida coral reef generated 71,000 jobs and $6 billion in economic activity in 2001, which contributed to the designation of Florida as "Fishing Capital of the World" by the State legislature. A problem to discuss is the goods and services that we derive from the system; ecosystem goods and services are threatened by increased exploitation and environmental changes from a rapidly growing human population. The physical environment of the South Florida system, which includes the Loop Current that comes around the Tortugas, is very rich and productive (session on Regional Connections}.

An interesting aspect of connectivity in addition to physical transport of larvae, which we tend to overlook, is adult migration. For example, the tarpon fishery has been focused in Florida, but in fact Florida is a stop-over in a larger circuit that includes the Carolinas, Louisiana, and Veracruz, with tagged tarpon swimming speeds of 30 miles per day. A different connectivity problem is serial overfishing, in which people first fish-out the longest, largest, most vulnerable animals and then move down the resource chain, e.g., from grouper to snapper to grunts.

Over the years, people have found out about sight fishing; many of the techniques and methods that are used throughout the world were discovered here in the Florida Keys on the flats. There probably are 500 skiff guides who pole shallow-draft boats up and down the Florida Keys. There may be $40-50 million in guide fees a year, as well as income for hotels, motels, airfares, restaurants, and stores. There is a corresponding fishery offshore for sailfish part of the year. Most of the guides and captains involved in the industry have taken it upon themselves over the years to do a lot of things to steward the resource, for example switching to an all-release format.

Do we need a new ocean ethic? Of course we do. What is it, what is it going to be? Whatever it is, it needs to be communicated. It needs to be communicated with the public if we are planning to talk about anything more than speeding up the ongoing evolution of awareness among the fishing public, of the need to be more civil to the environment, particularly of the need to take a personal responsibility for protecting our marine resources. The connectivity between people and marine resources is most obvious to those who make their living from the ocean; they know how complex it is. We need the marine community to go beyond simple compliance; which is but an interim goal. We need the fishing public to develop a personal sense of responsibility toward stewardship of our marine resources. To instill a new ethic in the fishing public there should be a concerted effort to create epiphanies, through education, recognizing that education is an ongoing, cumulative process that helps individuals increase their knowledge or awareness. Education is the only means of guaranteeing a permanent, sustainable result, and is the only means for implementing any new ethic.

There is an estimate of $6-10 billion in the state of Florida just concerning bonefish and tarpon use. So, it is important for fisheries managers and the government to realize that even though certain fisheries do not end up on a plate, they may still be important to the economy. If in fact the tarpon that we catch at certain times of year off of the Gulf Coast or the east coast of the United States around Florida are the same fish that are migrating at certain times of the year to Mexico, Guatemala, Belize, Honduras, and those areas, there are implications for resource management. Many of those countries unfortunately are not as enlightened about catch-and-release as we are in Florida, and as a matter of fact many of those fish are killed. So connectivity between fish habits, where they migrate, where they spawn, is directly relevant to the health of those fisheries and what we can do about it.

Hopefully, we have learned from the connections of the past, and how things have changed, and how they will connect to things of the future. To paraphrase Aldo Leopold, what we are working toward is a state of harmony between man and the *ocean*. Leopold developed what is called the Biotic Ethic, under which humans are part of the ecosystem, and part of his idea was that some areas should be set aside with minimum human disturbance. The connection to people that Leopold developed is that of self-interest. You do this not because you have to, but through self-interest. If you want goods and services, if you want jobs, if you want employment, if you want recreation, if you want to catch fish, all those things you do for your self-interest – you are going to do the right

thing for your self-interest. An alternative to single-species fisheries management is ecosystem-based management, under which we need to balance our activities within the system's capabilities. The emphasis becomes long-term persistence of a system, not short-term economics. The result is sustainable fisheries, and in this case no-take reserves have an essential role that allows us to understand how the system works. The word "beauty" is a word that scientists abhor because it is subjective. But beauty is the human hook – that is why you are in this room, that is why fishermen are fishermen. An ecosystem approach to fisheries is essentially trying to get the Aldo Leopold idea geographically specified. It is adaptive, takes into account ecosystem knowledge and uncertainties, considers local and external influences, and strives to balance different social objectives. That is the beauty of the human connection. We cannot prevent the alteration, management, and use of our resources, Leopold pointed out. We do affirm a right to their continued existence and the continued existence of natural systems.

Climate Change

Rethinking Conservation to Incorporate Coral Reef Resilience in the Face of Climate Change
The composition of the Earth's atmosphere has been changing since the beginning of the industrial revolution owing to the emissions of greenhouse gases from the burning of fossil fuels. Projections for the next century are that greenhouse gas concentrations could increase by two to three times above pre-industrial levels. This has implications for coral reefs around the world, including Florida. Increasing temperatures are expected in increase the incidence of coral bleaching. This may also affect harmful algal bloom frequency. Sea level rise and associated land-use change will further exacerbate damage to reefs relating to climate change. These changes will require that we change our approach to conservation in the face of climate change. The World Wildlife Fund (WWF) has created guidelines for developing conservation strategies to respond to climate change that are based on four tenets: 1) protect adequate and appropriate space, 2) limit all non-climate stresses, 3) use adaptive management and start testing strategies now, and 4) reduce greenhouse gas emissions to slow the rate and extent of climate change.

Resource Conditions

Corals and Microbial Power Shifts … What Does It Mean?
Bacteria associated with the surface mucus layer of corals form diverse communities that differ significantly from communities in the surrounding water mass and among different coral species. Bleaching is the loss, or degradation, of carbon-fixing zooxanthellae from otherwise healthy coral tissue; there is a significant shift in microbial community structure when corals become bleached. It is likely that many different microbial species, both marine and land-based, can become pathogenic once environmental stressors have compromised the coral host. There is a range of disease assaults recorded for coral reef communities of the Caribbean. The current thinking on coral diseases is predominantly single pathogen-based, but there are likely to be more interesting and complex processes at work. For example, the microbial "power shift" from *Pseudomonas* to *Vibrio* may compromise coral primary immune responses, as normal associates that produce protective compounds are compromised. This may leave the coral animal open for opportunistic infection. Known coral diseases for which pathogens have been identified range from terrestrial fungi to marine bacteria. This suggests that the *putative* causative agents of marine diseases are much more complicated than just new invasive species. Bacteria may not be the problem, but a symptom of a change in an environment more conducive to bacterial overgrowth, or microbial processes that trigger a chain of environmental effects.

Resource Conditions: Discovery of a Viral Disease Infecting Lobster and Impact of Sponge Fishing on Hard-bottom Communities

Spiny lobsters support one, if not the, most economically valuable fisheries within the FKNMS, the State of Florida, and indeed the entire Caribbean. Commercial sponges, on the other hand, are targeted by a much smaller and largely artisanal fishery that operates within the FKNMS. However, both fisheries depend on healthy, shallow hard-bottom areas that provide habitat for commercial sponges and serve as nurseries for lobster. In 2000, a lethal virus was discovered that infects Caribbean spiny lobster. It is the first viral disease known for any lobster, and it alters the behavior and ecology of this species in fundamental ways. Infected juvenile lobsters have been identified from sites throughout the Florida Keys and from a few other locations in the Caribbean. The prevalence of infection varies with age; most infections occur within the smallest lobsters. Healthy individuals, which are normally social, detect and avoid diseased conspecifics – the first report of such behavior in any animal species in the wild. Surveys of hard-bottom areas provide a spatio-temporal record of community structure for a modeling framework and for commercial sponge population assessment and detection of habitat change. Common large sponges found in the Florida Keys including species that are commercially fished grow slowly, their fecundity generally scales linearly with size, and they die when exposed to atypical salinities. Natural mortality of sub-legal sized commercial sponges (< 5 inch diameter) is approximately 7% of the population annually, with little difference among species. The fishery appears to operate legally with minimal impact on non-targeted species. About 40% of the fishable area during a six-month study period was never visited or fished. In areas that were fished, fishers removed 33% of the legal sized sponges, 3% of the sub-legal sponges, and virtually none of the non-commercial species. Experiments designed to assess the impact of sponges on planktonic water column communities confirm that all seven species tested consume primarily bacteria rather than larger planktonic size fractions.

The Tropical Fish Resources of South Florida's Coral Reefs

Coral reefs of the tropical Western Atlantic and their living resources have been under great stress and have been in steep decline since the 1970s. The small and colorful tropical fish of these reefs have been collected for the marine aquarium trade since the 1960s, and with the great increase in popularity of marine aquariums in the 1980s and 90s, collection of marine tropical fish and invertebrates in South Florida has grown into a significant fishery. The fishery is now well managed and rules and regulations are in place to protect populations of the most popular species and to restrict the fishery as necessary to protect the environment. Nevertheless, without ecological restoration of coral reef environments of South Florida, the value of coral reefs and the fisheries that depend upon them, including the marine ornamental fishery, will continue to decline. Restoration of coral reefs, however, is not an easy or uncomplicated task. One of the strongest possibilities is restoration of herbivory on certain reefs through re-establishment of populations of the keystone herbivore, the long-spined sea urchin *Diadema antillarum*.

Water Quality

What We Know About the Water Quality of the FKNMS

Several important results have been realized from monitoring water quality over the past decade in the FKNMS. First, there are spatial differences in water quality across the Sanctuary. Second, is documentation of elevated dissolved inorganic nitrogen in the inshore waters of the Keys, but not in a comparison transect in the nearly uninhabited Dry Tortugas. This type of distribution implies an

inshore source, which is diluted by low nutrient Atlantic Ocean waters, and the presence of a similar gradient in total organic carbon and decreased variability in salinity from land to reef also support this concept. Another observation is that the "Backcountry" north of the Lower Keys exhibits elevated levels of dissolved inorganic nitrogen, total organic carbon, turbidity, total phosphorus, and chlorophyll-*a*. Most of these distributions are probably driven by the Southwest Florida Shelf waters moving through this area. In addition to this Shelf influence, elevated nitrate is a regular feature of Backcountry waters, where some of the highest concentrations are observed in non-populated areas. This is probably the result of the benthic flux of nutrients in this very shallow water column. The third important result is that the highest chlorophyll-*a* concentrations occur on the Shelf and show a strong N-S gradient toward the Marquesas and Tortugas. This is because of higher total phosphorus concentrations on the Shelf as a result of southward advection of Gulf of Mexico waters along the coast with entrainment of coastal rivers and runoff. The fourth result is that trends in water quality showed most variables to be relatively consistent from year to year. Clearly, there have been large changes in FKNMS water quality over time, and some sustained monotonic trends have been observed; however, we must always keep in mind that trend analysis is limited to the window of observation. This brings up another important point: when looking at what are perceived to be local trends, we find that they seem to occur across the whole region but at more damped amplitudes. This spatial autocorrelation in water quality is an inherent property of highly interconnected systems such as coastal and estuarine ecosystems driven by similar hydrological and climatological forcings. It is clear that trends observed inside the FKNMS are influenced by regional conditions outside Sanctuary boundaries.

Why Don't Queen Conch Reproduce in Nearshore Florida Keys Waters?

Both adult and larval conch may be affected by declines in water quality associated with nearshore environments. In the case of adult conch, extensive surveys of conch populations throughout the Florida Keys have shown no spawning occurring nearshore even though anecdotal accounts indicate that this was once common as late as the mid-1980s. In South Florida, queen conch exist in two spatially distinct regions: nearshore and offshore, and there has been a cessation of spawning in adult queen conch inhabiting the nearshore region. The offshore population continues to spawn with regularity. Histological examinations of gonadal tissues from nearshore adult conch indicate that gametogenesis is deficient in nearshore females and males relative to their offshore counterparts. Reciprocal transplant studies demonstrated that the gonads of conch transplanted from offshore to nearshore degraded, whereas those transplanted from nearshore to offshore regenerated gonads after about six months. Additionally, collaborative research between the Florida Department of Environmental Protection and the Caribbean Marine Research Center indicated that larval abundance was significantly lower in Florida than in an analogous location in the Bahamas. Thus it now appears certain that conch larvae obtained in nearshore plankton tows originated from either offshore breeding aggregations or from other upstream sources. These deficits in reproduction and larvae are consistent with exposure to man-made chemicals in the environment that simulate naturally occurring, biologically active compounds (i.e., endocrine disrupting compounds) and to sub-optimal environmental conditions. Man-made chemicals may enter Florida Keys nearshore waters via sewage discharges and surface water runoff, vessel discharge and oil spills, fish house discharges, discharges from the South Florida mainland, and mosquito pesticide application. The lack of reproductive development in nearshore conch coupled with these widespread sources of pollutants suggests that there may be a linkage between water quality and reproductive development in Florida's conch population.

Episodic Nutrient Transport to Florida Coral Reefs

Changes in nutrient fluxes associated with internal tidal bores arriving on Florida Keys coral reefs suggest biological use of nitrate brought onshore by this mechanism. Internal bores on Conch Reef, Florida Keys, are associated with 10–40 fold increases in nutrient concentrations and 1–2 orders of magnitude increases in nutrient flux relative to ambient, non-bore conditions. The magnitude and duration of cool-water nutrient transport events increases significantly with increasing depth on reef slopes. In June 2001, the gradient of increased exposure to subsurface water with depth corresponded to increased percentage of N and $\delta^{15}N$ and decreased C:N ratio in a common benthic macroalga. Internal tidal bores are widespread throughout the Florida Keys reef tract, with cool-water episodes influencing reefs up to 10%–25% of the time during summer months and with significant variability among years. Estimated inputs of nitrogen and phosphorus by internal tidal bores to Florida Keys reef slopes are as much as 40-fold larger than published estimates of inputs to near-shore waters from waste water and storm water runoff. Internal tidal upwelling represents an important, previously underestimated, episodic source of nutrients on the Florida Keys reef tract. In order to assess nutrient availability in this system accurately it is esential to understand natural sources of high-frequency variability.

Coral and Seagrass Habitats

EPA/NOAA Coral Reef Evaluation and Monitoring Project

Between 1996 and 2003, for a total of 105 stations at 40 sites Sanctuary-wide, the number of stony coral species declined at 76 stations (72%), increased at 15 stations (14%), and remained unchanged at 14 stations (13%). A decline in the number of stony coral species was recorded in all habitat types. In 2003, offshore deep and patch reef stations had the greatest numbers of stony coral taxa with 17 and 16 species, respectively. Hard-bottom stations had the fewest number of stony coral species, averaging nine species per station. In 1996, coral disease was observed at only five stations Sanctuary-wide. By 2002 coral disease was observed at 102 stations; incidences of stony coral disease were reported for 95 stations in 2003. Sanctuary-wide, mean percent stony coral cover declined from 11.9 in 1996 to 7.4 in 1999, a decline of 38%. Stony coral cover has not changed significantly since 1999; in 2003, mean stony coral cover Sanctuary-wide was 7.2%. In 2003, functional group data showed the benthic community was composed of 64.5% substrate, 12.6% octocoral, 11.1 % macroalgae, 7.2% stony coral, 2.2% sponge, 2.0% zoanthids, and 0.5% seagrass at the 40 coral reef and hard-bottom sites.

Assessment and Monitoring of Florida Keys and Dry Tortugas Coral Reefs and Hard-bottom Habitats

The UNCW assessment and monitoring program measures a suite of variables to determine the abundance, size, and condition of benthic coral reef organisms. Sampling sites are stratified across a range of habitat types, among regions of the Florida Keys, and between fully protected marine zones and reference areas. Most of the information and data are collected underwater on pre-formatted slates, allowing for relatively rapid data entry and summary analysis once each year's fieldwork is completed. Habitat types include mid-channel and offshore patch reefs, low-relief hard-bottom, high-relief spur and groove, rubble, and low-relief spur and groove. Several patterns were evident from data collected during 2001 in high-relief spur and groove. Fully protected marine zones had greater coral cover than corresponding reference areas open to fishing. This is the result of the non-random placement of the zones that encompass some of the best shallow-water coral areas along the main reef tract. Even among fully protected zones there was substantial variability in coral cover, ranging from ~4% to ~16%. Overall coral cover in this habitat type was relatively low compared to coral cover historically, probably the result of storms, disease, and bleaching. Also, most of the

corals were no longer *Acropora palmata*, but instead smaller colonies of the "weedy" coral species *Porites astreoides* and *Agaricia agaricites*. Algae were the dominant components of the sea bottom in this habitat type, covering as much as 90% of the available substratum at some sites. Most algal cover in this habitat type consisted of filamentous algal turfs, crustose coralline algae, and calcareous algae such as *Halimeda*, all of which are generally indicative of relatively high grazing intensity and low nutrients. Juvenile coral densities varied greatly among individual reefs, with no clear pattern relative to protection level. Densities in this habitat were relatively low compared to other habitat types and especially compared to other areas in the wider Caribbean. Most of the juvenile corals were small colonies of species that brood their larvae, such as *Porites*, *Favia*, and *Agaricia*, instead of the massive reef framework builders. A regional pattern was evident for gorgonian density: gorgonians were dominant on upper Keys reefs, but appeared to be replaced by the colonial zoanthid *Palythoa* on lower Keys reefs. Relative to elkhorn coral, staghorn coral was more abundant, occurred in more diverse habitats such as patch reefs and low-relief hard-bottom, and appeared to be less affected by disease-like symptoms. Between Key Largo and Key West, the population estimate for staghorn was approximately 13,200,000 colonies compared to 400,000 for elkhorn, with large error terms for both estimates; disease prevalences were 0.4% and 13.2%, respectively, again with large error terms. Densities of the urchin *Diadema antillarum* still remain about an order of magnitude lower than historical data prior to the 1983-84 mortality event. Despite this pattern, we have found several locations, including the Dry Tortugas, with large (3.5-5 cm test diameter) *D. antillarum*, with clear effects of grazing on the substratum. Many other sites have relatively high densities of other urchin species. We were surprised at the amount of marine debris, represented mostly by hook-and-line gear that was recovered, even within the fully protected zones. From all 86 sites representing a total survey area of only 25,200 m^2 during the summer of 2001, we recovered more than 0.5 km of hook-and-line gear and trap rope. Of the 349 m of hook-and-line gear recovered from the fore reef, 112 m (32%) was recovered from fully protected zones. We recognize that lost fishing gear and other debris is probably a relatively minor factor affecting Florida Keys reefs; however concerted efforts need to continue to remove this material due to the cumulative biological impacts that may occur.

Status of Seagrass Beds in South Florida

The general objective of seagrass monitoring in the Florida Keys National Marine Sanctuary (FKNMS) is to measure the status and trends of seagrass communities to evaluate progress toward protecting and restoring the living marine resources of the Sanctuary. Both inter-annual and intra-annual trends in seagrass communities are being assessed. A mix of site types is utilized to monitor trends through quarterly sampling at a few permanent locations and to annually characterize the broader seagrass population through less intensive, one-time sampling at many more locations. Observations of the spatial pattern of changes in seagrass communities and the agreement of these changes with models of the system suggest that there is regional-scale change in nutrient availability that is causing changes in seagrass beds over a wide portion of the FKNMS. In 2004, resurveys of 251 stations that were last visited during the summer of 1997 indicate that there were no large-scale spatial trends in the abundance of the dominant benthic plant types between the two years. Monitoring data indicates a large spatial gradient in the N:P ratios of *Thalassia testudinum* across the Sanctuary, with N:P ratios predicting nitrogen limitation in the offshore parts of the Sanctuary and predicting phosphorus limitation in nearshore areas. At four nearshore sites there has been an increase in the relative abundance of macroalgae over the period 1995 - 2004 that is consistent with increased nutrient availability. At none of these has there yet been a decrease in seagrass abundance, but a conceptual eutrophication model predicts that increases in fast-growing macroalgae should precede decreases in seagrass abundance. The lack of any such changes in the Upper Florida Keys suggests that the factor driving these observed changes is not present across the entire Sanctuary, so

factors acting at the global scale (like global warming or coastal overfishing) are not likely responsible for the observations. These surveys have provided clear documentation of the distribution and importance of seagrasses in the FKNMS. The seagrass bed that carpets 80% of the FKNMS is part of the largest documented contiguous seagrass bed on earth. These extensive meadows are vital for the ecological health of the FKNMS and the marine ecosystems of all of South Florida.

Human Perspectives

Connections between the Tourism Industry, the Environment, and Society in the Florida Keys

The tourism that we see in the Florida Keys is really a type of sun and sand and beach tourism similar to what we see throughout the Caribbean. The differences, of course, are that in the Keys there is a road and a lot of mainland visitors as well as cruise liners and air traffic. The tourism pressure in the Florida Keys is greater, perhaps, than in other island destinations, or even mainland destinations around the wider Caribbean. Tourism is perhaps one of the world's largest industries. In the Florida Keys there are about 4 million visitors now because of the dramatic increases in cruise passengers over the past few years in Key West. In the Caribbean, tourism is a major economic player, contributing heavily to the economies of Caribbean islands, and to our economy, providing a lot of jobs, as well. Throughout the area, despite the setback of a few years ago, we see a rapidly growing industry that is threatening the resource base. Tourists are involved in water–based activities – snorkeling, diving, recreational fishing, spending time on the beaches, and viewing nature and wildlife. The number of people snorkeling and diving on Florida Keys reefs ranges between 600,000 and 800,000 people per year. Tourism is the major economic engine of the Florida Keys, accounting for over a million dollars spent and about half of the employment in the county; reef activities themselves are responsible for creating 10,000 jobs. The potential environmental impacts of tourism are great, including problems of anchoring, groundings, and diver contacts. The increase in tourism may have led to an increase in demand for local seafood products, which in some situations can lead to over-fishing. The infrastructure for hotels and resorts results in major land-use changes and habitat damage during the construction phase and the operation of these facilities. Some of these operations also generate large amounts of solid waste. Social impacts may be great, as well. We see some decrease in satisfaction with the environmental product, with the environmental amount of use, and certainly throughout the Caribbean and here in the Florida Keys an increase in mass tourism. Of course this inevitably leads to decreased and diminished environmental amenities, and could result, has resulted in some places in the Caribbean in a tourism spiral, *the tourism death spiral.* The tourism industry and local policy makers, local decision makers, and local governments need a recipe for suitable policies for sustainable tourism development. There needs to be an integration of tourism and tourism planning into the broader sector of planning, through integrated coastal management, or applying more aggressively restoration and environmental mitigation. Another approach is increasing the effectiveness of coastal and marine protected areas and adopting or recommending best management strategies for the tourism sector. We can see coastal resources as "capital" that will provide interest through rational use and interest that benefits the tourism industry. Without a wise and rational use of the resources, we will begin to erode the capital base, which will diminish the interest that the county and the Caribbean region as a whole obtain from the resource base.

Remarks: The Lodging Association of the Florida Keys and Key West

Unlike the rest of Florida, we cannot advertise fabulous Keys beaches. We are on top of an old coral rock formation. We do, however, have great year-round sun in a tropical environment and America's only living coral reef six miles off shore. In the late 1980s, the lodging industry was among the first to raise concerns over the growth of visitor numbers. In the early 90s, we fought the trend toward attracting spring breakers in March, at that time the biggest month of the year for lodging. Also in the early 90s, the cruise industry started to grow exponentially. We have not been successful at limiting growth in this area and today we see a million or more cruise passengers enter our port; we continue to urge limits on this market. We also fought to prevent large numbers of day trippers coming to the Keys, particularly on day bus tours converting Key West to an attraction on view from a bus window. The City of Key West has wisely put limits on that activity. A growing threat is the increasing residential population in the southernmost part of peninsular Florida, which is projected to expand by an order of magnitude by 2050. Another major threat is the increasing numbers of people who are buying homes in the Keys as a second or vacation home. While this might seem at first an attractive prospect, it is an insidious threat to the well being of the Florida Keys and all its resources.

Diving and Snorkeling in the Florida Keys

The importance of diving and snorkeling in tourism cannot be understated; it is one of the fastest growing sectors. In 1996, 31.3% of 3 million visitors to the Florida Keys entered the water via a dive or snorkel trip, and 80-85% of all divers and snorkelers visited one of the 18 Sanctuary Preservation Areas. The use we found in the FKNMS is variable – it is not the same throughout – and that makes a big difference in terms of how to manage the resource. In 2001, visitors to natural and artificial reefs spent 2.5 million person-days in the Keys, which comes to an impact of $1.7 billion on the economy. Looking at diver and snorkeler resource perception, there are positive views in terms of how well the zones have performed in terms of the number of fish, the type of fish, the size of fish, and other resource indicators. They have positive views on social crowding issues, even in the most heavily dived sites, and this is a credit more to the operators than the users themselves, who tend to space out effort accordingly. Water clarity is an emerging and important issue. In two recent studies, experienced residents reported declining water quality and visitors reported that water clarity conditions did not meet their expectations. The dive industry on the whole supports the Sanctuary, and is strongly behind its management plan. There also is industry-wide recognition that diving and snorkeling are indeed not non-consumptive activities, i.e., do have some impacts, and therefore there is strong support for mooring buoys. Recommendations to FKNMS management include: 1) involve the dive and snorkel community more in research, 2) involve the industry more in self-policing and management, 3) consider limited entry to the industry to increase stability, 4) consider reef rotations, and 5) develop an integrated policy to manage reefs that can minimize environmental damage and maximize economic benefits.

Management Tools

No-Take Marine Reserves: Science, Values, and Choices for the FKNMS

Despite the relatively short period since implementation of the Sanctuary's management plan, it is reasonable and necessary to ask whether the Sanctuary appears effective in achieving conservation goals. For example, is there evidence that, overall, ecosystems are healthier inside the Sanctuary than outside? The answer appears to be no; threats to marine ecosystems of the Florida Keys are numerous, and include several operating at regional, hemispheric, and global spatial scales, and none of these can be addressed directly through actions taken within the Sanctuary. However, there is

reason to believe that the Sanctuary's ecosystems and the resources they sustain would be healthier if the Sanctuary included adequate no-take marine reserves. Less than 6% of the Sanctuary is designated as no-take reserves, and there is good reason – based on a considerable and growing body of scientific evidence - to believe this is woefully inadequate if the Sanctuary is to conserve the resources it was designated to protect. Although some controversy remains, common sense, theory, and increasing scientific evidence point to beneficial effects beyond reserve boundaries. Establishing additional no-take reserves in the Sanctuary would incur both costs and benefits. In the Florida Keys as elsewhere, it is really a question of values and choices. How do we want these world-famous reefs, the ecosystems of which they are a part, and the resources that are so critically important both ecologically and economically, to look and to function in 10 years, or in 50? There is no question: enforced, no-take reserves work. The best scientific information clearly points to the conclusion that, although no-take areas are by no means a silver bullet, Florida Keys National Marine Sanctuary will not succeed in halting further species and ecosystem decline without additional, adequate reserves.

Marine Zoning: A Management Tool for the FKNMS

The Sanctuary is managed through a co-trustee partnership with the state of Florida's Department of Environmental Protection, and the Fish and Wildlife Conservation Commission. It is a marine protected area that covers 2,900 square nautical miles. One of the Sanctuary's mandates is to facilitate to the extent compatible with the primary objective of resource protection, all public and private uses of the resources. That is quite a challenge. It took from 1991 to 1996 to develop a comprehensive management plan to manage the Sanctuary, which consists of 10 different action plans. Marine zoning is a key element of the management plan. It is a concept that has been used around the world, and met with considerable controversy in the Florida Keys. In the final plan that came out in 1997 there was one nine-and-a-half square-nautical-mile area zoned as an ecological reserve, but with a promise to come back and do something more in the future. Tortugas 2000: we promised to come back and do something, but we promised to come back and do it right. Participation was the key; we involved the general public more, we maintained an integrated group, and we tried to include all fisheries managers up front. We asked that they use an ecosystem approach, and we tried to make the process open and flexible. Science was an important part of this, and it was science really that helped everyone including socioeconomic research. We had to work with seven different jurisdictions, but we succeeded and reached consensus. We have used zoning on land for a long time, we are just starting to do it in the ocean, and we need to do more of it.

How Acoustic Telemetry Might Be Used in MPA Design

Managers usually want something very concrete and specific, yet scientists tend to couch their findings with lots of caveats. What we may be able to do with sonic technology is to provide something a little more specific. Some of the questions about which we may be able to provide some information that managers want are: How many marine protected areas should we have? How large should they be? Where should we put them? What shape should they be? What we have found, looking at size structure of spiny lobster across the Keys over the past few years, is that we are starting to see some large males showing up in some small protected areas, and this is probably the reason why: their movements are very localized. Another thing that we found out about inner channel patch reefs is that the females that live in here, if they are reproductive age, go charging off to the reef when they are getting ready to release eggs. Using a benthic habitat map we can correlate movements and home ranges with different habitat types, and once we understand that, at least for lobsters, we can provide information to managers, specifically what they need to do in order to protect them.

Connecting Microbes to Management

Marine microbial processes are important to the overall health of the global ecosystem, but are largely underestimated. Bacteria associated with the surface mucus layer of corals form diverse communities that differ significantly from communities in the surrounding water. This mucus layer is populated with numerous commensal microbial species that appear specific to each host, reflecting the phylogenetic relationships among corals. Bleaching is the loss, or degradation, of carbon-fixing zooxanthellae from otherwise healthy coral tissue. There is a significant shift in microbial community structure to opportunistic bacterial species when corals become bleached. Inshore patch reefs and mid-channel reefs show higher resistance and/or resilience to bleaching and diseases compared to offshore shallow bank reefs and spur-and-groove reefs in the Florida Keys. An important research question concerns the role bacteria play in normal host resistance to stress and disease.

Welcome and Introduction

Billy Causey and Katharine (Kacky) Andrews

Billy Causey
Connectivity: Science, People and Policy, and it is incredible that we have this great opportunity this morning. We have so many people from all around the world together to talk about some of the issues here in the Florida Keys and actually around the globe. I am Billy Causey, the superintendent of the Florida Keys National Marine Sanctuary, and I want to welcome each and every one of you to this meeting. I want to thank the steering committee, and I want to start with the primary person that pulled this together, Fiona Wilmot. Everyone has been pressed by Fiona once or twice in the last couple of months, using her incredible skills at pulling people together. Also I want to thank Brian Keller, Kacky Andrews, my state partner, Nancy Klingener with The Ocean Conservancy, Jody Thomas with The Nature Conservancy, and Bill Kruczynski and Fred McManus with EPA. All of them helped organize and pull together what you're going to see today.

I want to give you a little bit of history about the Florida Keys. In 1990 President George Bush signed into law the first congressionally designated national marine sanctuary. On November 16, 1990, there were a number of firsts that came with that, but it was on the heels of declining resources here in the Florida Keys: declining water quality, declining coral reef resources, and over-fishing issues. A number of factors were affecting the health of the Florida Keys. The culmination – probably the last straw – consisted of three major ship groundings on our coral reefs within a 17-day time frame, all on the heels of the *Exxon Valdez* incident in Alaska. It prompted the Congress to take action. Congress realized that this is a very special place, here in the Florida Keys, and Congressman Dante Fascell who was the sponsor of the bill in the House knew that if you were going to do anything in the Florida Keys, you had to include the people and you had to include the agencies that were working here. It was going to take a very special effort.

Congressman Fascell and his aides started drafting the Florida Keys National Marine Sanctuary and Protection Act. Senator Graham very quickly picked it up on the Senate side and we started seeing a piece of legislation move through Congress like nothing we had ever seen. George Miller in California was supporting it and everyone was really pushing it along, and yet Fascell and Graham in their wisdom realized there were three things they had to put in the act that people would agree on immediately. That was a permanent ban on oil drilling in the Florida Keys, establishing an Area To Be Avoided to keep ships greater than 50 m in length off of our reef tract, and third, they authorized EPA to develop a water quality protection program for the sanctuary. It was the first water quality protection program established for any national marine sanctuary. They directed NOAA to work with all of our federal, state, and local partners and start developing a comprehensive management plan.

It was at that time that we started working with community leaders and elected officials, different community leaders and the agencies that were down here. It was people who stepped up early on, people like Mayor Jimmy Weekley, who recognized the importance of working on water quality issues here in the Florida Keys, and it was people who started working with the high level Water Quality Steering Committee, working with people like Fred McManus, Bill Kruczynski, and others, and started looking at ways to address our water quality problems here in the Keys. The EPA has made a major commitment to this – to the water quality efforts here in the Keys, and they started

immediately pulling together high level officials at the local, state, and federal levels to start working in a very integrated way to come up with solutions. First, the problems were identified in the Water Quality Protection Program along with the technological solutions. The EPA also made a major commitment to monitoring the resources, and for over eight years EPA has been funding monitoring projects here in the Sanctuary: water quality as well as seagrasses and corals. NOAA has joined them in funding part of the coral and seagrass monitoring over the last few years, while EPA has continued to have a major commitment toward that effort.

It was just not too long ago, in January 2004, that the Water Quality Steering Committee was meeting here in the Florida Keys. My boss, Dan Basta, had spent about four or five hours of listening to the tremendous science that was coming from the scientists that were monitoring the resources. It was late in the afternoon, I don't know if it was the tardiness of the day or the heat or what, but he all of a sudden just threw a skunk into the room. He said, "Look, these resources are going to hell in a hand-basket; you're doing a fabulous job at monitoring them. We're monitoring the decline of corals, you're doing a great job, yet we're not seeing progress, we're not seeing movement. We need to do something about it." And that's what prompted this conference. He really charged us to go out and do something. First, he said we want you to develop a white paper. We really thought that to develop a white paper we had to come together as a group and start doing some assessments about what we know about our resources, what are the gaps, and how do we fill those gaps, and how does the science and management start turning from just documentation to action. That is what this conference is about.

Now I am going to turn things over to my state partner. The Florida Keys National Marine Sanctuary is managed through a co-trustee partnership between NOAA and the State of Florida. Kacky Andrews is the Director of DEP's Coastal and Aquatic Managed Areas for the State of Florida.

Kacky Andrews
Good Morning. As Billy said, I am Kacky Andrews and I'm with the Florida Department of Environmental Protection. I was appointed about two and a half years ago by Governor Bush and the cabinet to be Florida's co-trustee with the Florida Keys National Marine Sanctuary with Billy. I grew up in Ft. Myers, Florida, and I've been coming to the Keys since the early seventies. I did my check-out dive in the Keys and I've spent a lot of time down here and I've always appreciated the resources of the Keys. I have been in the environmental arena in Florida for nearly the last decade, so I knew that the Keys had problems. But it was when I got this job two and a half years ago that I truly learned about the magnitude of the problem, when I would go to Sanctuary Advisory Council meetings every couple of months and go to conferences on coral reefs. I was quite stunned to learn about the magnitude of the problem facing the Keys, and the threats to the survival of the coral reefs in the Keys. It is daunting. Every time you try to get your head around the problem, and it's just flat-out daunting. As I was learning about the magnitude of the problem here, I also came to understand the level of commitment to the resources of the Keys. It is nothing short of extraordinary. It's at all levels of government – the federal agencies, through NOAA and EPA, the State through DEP and the Fish and Wildlife Conservation Commission, the county commissioners, city officials, and the Sanctuary Advisory Council members, who give up a lot of their time to represent interests and to help make sure that the public is engaged in management. In addition, there are non-governmental organizations, the World Wildlife Fund, The Ocean Conservancy, The Nature Conservancy, and Reef Relief. There are recreational fishermen, commercial fishermen, and charter fishermen, along with the boating industry, the tourism industry, and dive shop operators, all

of whom are engaged and committed to saving the reefs of the Florida Keys. That is what gives me so much hope – that we are going to get our hands around these problems and we're not going to just monitor the death of the Florida Keys – that we are going to turn a corner. It is absolutely amazing what can happen when failure is not an option. Failure is not an option here, and so we will pull together, we will find new ways of doing things, and we will turn the corner. But I do think that we have to start moving now, and I know that the phrase "redoubling your efforts" is often a cliché, but that's about the truth. We have to redouble our efforts. So thank you all for coming and I look forward to working with you over the years to protect these remarkable resources.

Billy Causey
Thank you, Kacky. The goal of the conference is to connect science, people, and policy, and those of you who have worked in coastal environments know that certainly this is a very difficult challenge. It is something that we have been working on here in the Keys. In order to move things forward, you can have the very best science, you can have the very best goals, but you really need to have the policy makers working there with you, and you need to have the elected officials helping you implement that policy. Today and tomorrow and Saturday, we are going to be presenting a wide range of panels – from the most remote monitoring technology that we have down to monitoring the microscopic communities that make up this environment. We hope that by connecting these threads, we will start seeing what some of the problems are, what some of the gaps are, and what we need to come back with, with our information, and fill those gaps.

I think that you are also going to see some common-sense things that we should be doing now, and I hope, without giving you any preview, that it becomes clear that we have not been managing our marine resources as we have been managing our land. The National Park Service has been setting areas aside on land for dozens of years, and we have a different ethic on land as opposed to what we have in the marine environment. We are just starting to touch on the marine environment by setting areas aside as special areas, to even understand what's going on. A lot of our dilemma right now is that we just don't know what is going on. When there are scientists with different ideas, different concepts – that's good – science is to open up the debate, and it's to open it up and go through the scientific process to determine what the cause and results are. But when that debate continues to distract, then that gives decision makers a reason to not make a decision. And that's where we are right now – we need to get a focus on them.

A lot of you know that I'm from Texas, and I see this conference as drawing a line in the sand, and I can't help but think of the Alamo when I say that [laughter]. For one, here in the Keys, I think we need to draw a line in the sand. We cannot shift backwards, we need to step forwards and we need to take action, we need to stop passively watching the coral reefs decline, and we need to move forward.

With that, I get to introduce our first speaker. It is my pleasure to introduce an old-time friend who has been around awhile – he's not old [laughter] – but I get to introduce Elliott Norse, who is the president of the Marine Conservation Biology Institute. Elliott was an early visitor to the Keys. He came down in 1972 and spent some time doing his dissertation research on blue crabs, including the Keys in part of his research. He also spent about a month or so as a resident in the Keys, enjoying the resources around Pigeon Key, and then in the early eighties he became the chief scientist for the Center for Marine Conservation, which today is The Ocean Conservancy. Elliott became affiliated with; in fact organized and started the Marine Conservation Biology Institute in 1996, but I need to tell a little bit about Elliott's background. He is going to get into some detail about the Florida Keys

National Marine Sanctuary, but during the latter part of the Carter administration, many people don't know – but in one of his last acts as president, President Jimmy Carter signed the designation documents for the Looe Key National Marine Sanctuary, the Gray's Reef National Marine Sanctuary, and the Gulf of the Farallones National Marine Sanctuary. Elliott was instrumental in putting those papers in front of the president at that time, and having the right documents for him to sign. Elliott, welcome to the Florida Keys. [applause]

Keynote Address:
Do the Keys Hold the Keys to Our Ocean's Future? Insights from a 57-year Transect

Elliott Norse

I want to thank you for your gracious introduction. I want to talk with you today about connections. They are connections among things in nature, connections between nature and policy, and personal connections for me. I titled this "Insights from a 57-year Transect," and I want it to become clear that this is about personal connections in my case. This is a really important place to me and I am really glad to be here. I have a sense that the Florida Keys National Marine Sanctuary is a microcosm of all of the problems we are facing and it will be – or it might be – the place where we come up with the solutions. I have a feeling that at least we have a fighting chance.

I am a biologist, and biologists are people who are fascinated with, enraptured with, life. I am going to "out" myself – I am not going to apologize for it, and as we discuss things further, that is the context in which I am going to give my talk. I am interested in not only the individual pieces, but how the pieces fit together, and we have been blessed with a phenomenal piece of real estate in this country. Unfortunately, as time has passed, more and more of that piece of real estate has been altered. I am using a neutral word – altered, like when you get hit by a car and then run over by a couple of cars behind it, you've been "altered" [laughter] – just keep that in mind. And that evokes some personal reactions in me. I have to tell you, I have these fantasies, and when I talk with them to biologists and they come out of the closet, they tell me the same thing. If I could have any gizmo at all, I would want a time machine because I want to know what the biota was like, what the world was like before it was – "altered."

If you want to know what makes my heart sink, this makes my heart sink. I want to conceal this scene. Now this happened a long time ago. This happened before I was born [laughter] but it seems like this wasn't so ancient. The population of bison in North America in the year 1830 was estimated at between 30 and 60 million. That's a lot of bison. That's a lot of influence on the ecology of North America. You may know that the bison populations were reduced to somewhere around 600 by the early 1900s. They mostly existed as scattered herds in the wild or as herds in feedlots.

The passenger pigeon was the most abundant bird in North America, perhaps the most abundant bird in the world. Estimated population – five billion. One flock alone was two miles wide, 300 miles long in the 1840s. It was driven to extinction in one human lifetime, in 1914.

Fortunately that doesn't happen in the sea. These are Atlantic cod. They were so abundant that their schools were called mountains. The way people could collect cod off Newfoundland and Nova Scotia and Maine and Massachusetts was by lowering a basket and by pulling it up. Today the populations of this fish are much less than 1% of what they originally were. Ecological extinction. Commercial extinction. How could this be?

Here is one that is more recent. This is a fish I photographed a long time ago: black grouper (Fig. 1). I saw two of them yesterday, and I appreciate it, Billy. But I don't know if they were the size of this grandma or grandpa, because that is a male. When they get to that size, they are males. So this sweep of history, this sweep of time, and the phenomenal changes we have seen in our biota gets me to thinking. So what I am going to ask you to do is permit me to do something unusual for a scientist. I am going to get personal, and since I don't know all of you, I can't get personal with all of you, I'm going to get personal with me, and I'm going to ask you to fasten your seat belts [laughter], adjust your tray tables and make sure they're in the locked and upright position, and I'm going to take a little transect through my life, because my connection with this issue is personal.

Figure 1. Photograph of a black grouper at Looe Key Reef, 1977. [Credit: E.A. Norse]

I was born in Brooklyn, and I grew up on a little canal, like that. On my fifth birthday my parents gave me a boat, and it was a rowboat. They didn't give me oars, they gave me a pole and I poled myself up and down the canal and caught blue crabs. At the age of five I decided I knew what I wanted to be. I wanted to be what they called an ichthyologist. I didn't know that marine organisms were called invertebrates, I mean, nobody told me things – I had to be self-taught and it's been a continuing process. While I was growing up, things were happening. This is my hero, Rachel Carson, the marine biologist who said something that our country, intoxicated with post-war optimism, the kind of optimism that only has forward gears, no reverse, no brakes. Rachel said that progress has its price, and that we may find the price, in some cases, higher than we are willing to pay. That was a message that we as Americans really needed to hear, and we got that message driven home to us in 1969 when a Union Oil blow out in the Santa Barbara channel dumped a lot of oil. The reason that was important was that we had entered the television age, and the news reporters from Los Angeles sped up to Santa

Barbara and took the most appalling pictures. Just as the pictures of napalm and the naked girl running down the street ended the Vietnam War, just as the pictures of Bull Connor siccing the dogs on people in Alabama changed things there, so this changed things. This was a time when all of a sudden we could be reached by the visual media. And it changed our consciousness.

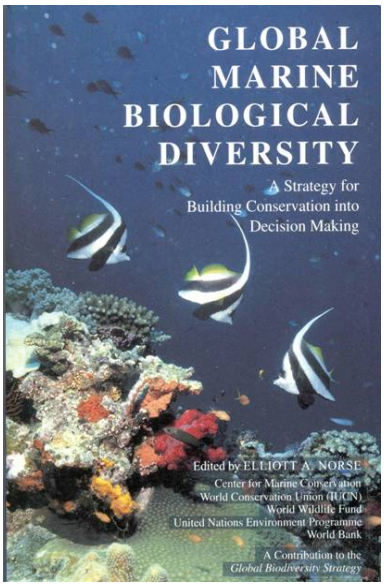
At the time, I was working on blue crab ecology. I studied the ecology of *Callinectes* in the Caribbean and tropical east Pacific, and it took me a lot of places, including here. I have to tell you that collecting blue crabs is hot, mucky work, especially if you're doing it in the mangroves, and it's hot and it's humid and stuff like that. Blue crabs were really big in my life for a long time, and I found it is a lot easier to collect blue crabs, not by hand netting, or not by trapping, but by going on a trawler and in 1971 I did that for the first time. There are a lot of blue crabs in there; in fact there are more blue crabs than shrimp. I am telling you all these things because they are going to affect what you will see later.

Figure 2. Photograph of divers and *Acropora palmata* at Looe Key Reef, 1977. [Credit: E.A. Norse]

When I first took my trusty Nikonos II and started snapping pictures in Looe Key, if you look in the background, there was lots of *Acropora palmata*. At the time, although I didn't know it, because I was in the cloistered world of academia, two things happened that were really important. The United States had passed the Marine Protection, Research and Sanctuaries Act a few years before, in 1972, and Australia had passed the Great Barrier Reef Protection Act in 1975. These two pieces of legislation affect a lot of what I am going to be discussing with you today.

My first conservation job happened in 1978. I had left the ivy-covered walls of academia, and I went to the U.S. EPA, where my job was to be the hotshot marine ecologist, working to push the oil and gas industry away from two little coral reefs in the Gulf of Mexico called the Flower Garden Banks. I worked with a young woman at NOAA named Nancy Foster. She was just a sprout, and so was I, and we didn't know what we were doing very well, but in the land of the blind, the man with one eye is king [laughter] and if we kept one step ahead of everybody else we were OK. We fought and we fought, back-to-back against Interior, against Exxon, against Shell and we lost. We got beaten pretty badly [laughter]. Flower Garden Banks was not designated in 1978 or 1979, I got my nose bloodied, but fortunately, fortunately [laughter] I got another job at the President's Council on Environmental Quality and became the staff ecologist, and that was exciting. That's intoxicating! Working for a president is like nothing else, I have to tell you. I was working on national policy! I had a bully pulpit, a place to stand on and speak my truth. And I did.

I did two things of consequence while I was in that job. One, was I developed a concept of biological diversity. That is the most important thing I have ever done or ever will do because biological diversity has become the driving force in conservation world-wide. It is a new way of looking at life. It means not just saving things because they are useful. It means not just saving things because they're about to disappear. It means saving the parts and the processes – the integrity of nature. And that is a completely new way of looking at Nature. That means even if something isn't as abundant as were the bison or the passenger pigeon, or the Atlantic cod, you don't destroy them. It's a different way of thinking. The other thing that I did that was useful, relevant here, is I got my boss, Jane Yearn [?], to get her boss, Jimmy Carter, to sign Looe Key, Gray's Reef, Channel Islands, and Gulf of the Farallones National Marine Sanctuaries into being at the end of 1980 and early into 1981. This was really great, because this is the only real estate on earth that I feel – other than my backyard – that I feel that I helped contain and nurture and I feel guilty about that, that there's a lot more out there that's in trouble that needs protection. But these are good ones, and Looe Key comes up again and again in my thinking.



Now, just a little bit more on biographical stuff and then I will explain to you why I am doing this. I was asked to write a book in 1989/1990 and it came out in 1993. It was part of the Process for the Earth Summit, and in pulling this thing together with folks at the World Bank and World Conservation Union and World Wildlife Fund, it became clear to me that we needed to have a taxonomy of what is happening to the ocean, what are the threats, and I divided them into proximate threats and ultimate threats and I want to talk with you about the proximate threats – some of them. They are: over-exploitation, physical alteration, marine pollution, alien species, and global atmospheric change. They in turn are driven by five ultimate threats: there are too many of us, we consume too much, we don't know enough, we don't care enough, and as a result our institutions aren't effective enough.

We are going to hear more later today about global atmospheric change and its effects on coral reefs, and I don't have to say a whole lot except that this is one that keeps me up at night sometimes. Coral bleaching is but one manifestation of this. Another manifestation of this is the weakening of coral skeletons in an ocean that has more dissolved carbon dioxide and so it goes. I don't know if any of you have seen this yet, but "coming soon to a theater near you" we have turkey fish, flying fish, zebra fish, whatever you call them [lion fish]. Terrible. They are coming up all over the eastern United States and I suspect this was not a natural migration [laughter].

Marine pollution. A lot of people think of marine pollution as – if you look at the polling – as Oh My God! Oil spills. And spilled oil is bad enough; don't get me wrong, I don't like spilled oil at all. The Great Barrier Reef Marine Protection Act said "No Oil." I fought the oil and gas industry. The

Florida Keys National Marine Sanctuary says "No Oil." But the biggest problem isn't oil. The biggest problem is nutrients. Nutrients. Too much of a good thing.

Physical alteration is something that a lot of people don't think a whole lot of in marine systems, but I'm going to talk with you about a kind of physical alteration that is even worse than this one – the appalling destruction of ecosystems at the interface of land and water. The biggest threat to the marine world offshore is fishing. That said, I can tell you, I have been here in the Keys and I eat fish. I'm an avid sport fisherman. I don't do it much, but Carl Safina and I went fishing just two weeks ago. Caught a bunch of blue fish. I love it. But I also recognize that too much of a good thing is a not good thing [laughter]. Carl also got this. [laughter]

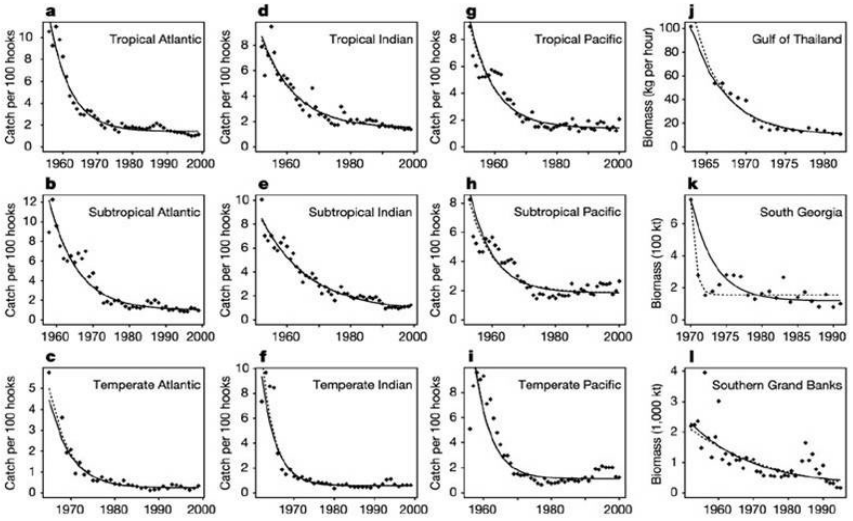


Figure 3. Declines in long-line catches in various parts of the world (from Myers and Worm 2003).

It's a good thing I am not a sea turtle, because I would be taking grief for this. Jeremy Jackson drew the cover on this one with this remarkable paper (Jackson et al. 2001). Similarly, Ransom Myers and Boris Worm produced these graphs (Fig. 3). I want you to take a look at these. These are the fish populations – large predatory fish populations – in all different regions of the oceans. Now this isn't very alarming to our leaders in Washington, DC, but I would ask you, if this was your stock portfolio [laughter] if it looked like this, would you have reason to be concerned? My guess is the answer is yes, so one of the important subtexts I would love to leave you with is – we have different ethics for different things. Billy Causey alluded to it when he said "We've done a better job with the land than we have with the sea," and I would say that is true. I would say with the land we have earned ourselves a sound D+ and with the sea we are at D/D-. And this is an indication of that. This is considered ideal portfolio management by agencies such as the Department of Fisheries and Oceans in Canada, National Marine Fisheries Service here, etcetera. This is – the agencies are keeping fish at their maximum sustainable yield. I guess that's what that is. And that bothers me a lot.

Daniel Pauly, mega-thinker, compiled a database that allows him to do this. This shows the biomass of large, predatory fishes in 1900 and 1999 and you can see the warm colors over there are a lot of fish, and the cool, light colors are where there are hardly any fish at all (Fig. 4). I am proud to say that there have been changes. We have gotten rid of those pesky fishes. [laughter]

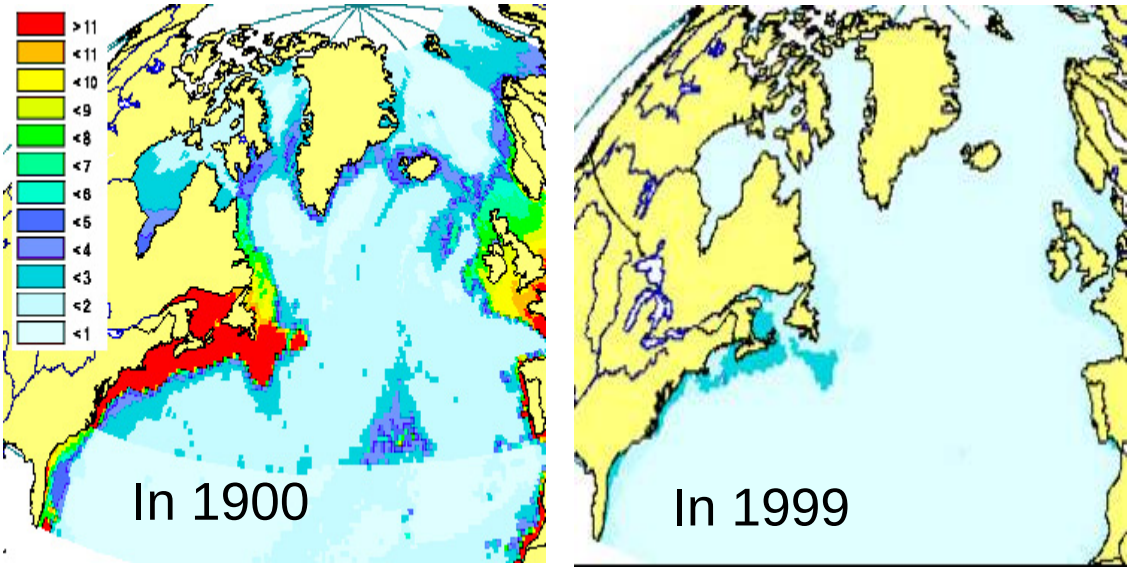


Figure 4. Distribution of fish biomass in the North Atlantic in 1900 (left) and 1999 (right) (from Pauly and McLean 2003).

Now, the straight, plausible explanation for why this is happening. One is that we kill fish faster than they can replace themselves. The second is we have mucked up the place where the fish lived, so we have diminished the capacity of the ocean to produce fish. The third is that there is some sort of interaction between these two. I became really interested in the habitat part of the equation, and so when I started the Marine Conservation Biology Institute, the first thing I did was hold a little workshop. It was the first workshop anybody had done on the effects of bottom-trawling on the world's marine ecosystems, and we came up with some interesting stuff. We published it in the journal *Conservation Biology* and had the cover paper which was really nice. What we found was that bottom-trawling is a lot like forest clear-cutting. Since I worked for about five years on forests in between my marine gigs, I felt pretty comfortable saying that, and I did a comparison on the ecology of forest clear-cutting and bottom-trawling. I found out that there is one **big** difference, and that is the area swept by trawlers on a day-to-day basis is about 150 times the area that is clear-cut worldwide. Let me give you that in a graphic term. The area that is clear-cut worldwide on an annual basis is about the size of the state of Indiana. The area trawled on an annual basis is about twice the size of the lower 48 states, or about half the continental shelf of the world. That doesn't mean that every spot gets trawled evenly, some do a thousand times in that period, and some don't at all.

Our chief scientist, a wonderful scientist from the Virginia Institute of Marine Science, pulled together this study called "Shifting Gears." It is the first comprehensive look at the impacts, the collateral damage from different kinds of commercial fishing gears and their findings reinforced what we had thought. Independent fisheries experts come up with the same idea. Trawling is really, really rough. I am talking about bottom-trawling because to me that is my entry into the habitat issue. That is what I work on the most. Trawlers – the big one on the left, the little one on the right – you can see what a trawler does – strikes along the sea floor, and you can see the doors, disturbing the sea floor, the foot rope, and [...] are all agents of physical disturbance to the sea floor. Trawlers are ubiquitous. There are many tens of thousands of them in the world. They operate from the Arctic Ocean to the sub-Antarctic and the continental shelves and slopes and seamounts all around the world. They leave their signatures.

You can see trawl tracks all around the world (Fig. 5). This just gives examples from five places, but you can see there are lots more, and I want to show you what trawling does to marine ecosystems. I am going to give you five examples because some of you folks probably don't believe me. You probably think since I work for a conservation organization I'm probably a little bit of an alarmist. So, use your own eyes. On your left is a hexactinellid reef (Fig. 5). Hexactinellids have been around since the Cambrian Period. There are hexactinellid reefs in Hecate Strait of British Columbia. They are, to our knowledge, unique in the world, and they are fast being destroyed by bottom trawling. On the right is a trawled hexactinellid reef. On the left are the deep coral forests of the Aleutian Islands of Alaska (Fig. 5). These are prime fishing grounds, so they are being discovered and they are being trawled for fish that are used in cat food and you can see on the right, after they have been trawled. On the left, northwest coast of Australia, photos by Keith Sainsbury, untrawled and trawled (Fig. 5). I can tell I am not making a convincing case yet. On the left, Norway, these are *Lophelia* reefs; monospecific stands of stony corals and many associated species of stony and gorgonian corals and hundreds and hundreds and hundreds of invertebrates and fishes and on the right you can see with the trawl trap running right through it, what trawling does. On the left are the deep *Oculina* reefs of the east coast of Florida (Fig. 5), in an area that used to be fairly extensive, compared to what it is today, because legally and illegally they have been trawled into oblivion. Now, there is a tiny bit of it left. Most of what it is looks like what is on the right.

So, I don't know if I have made my case – I can't do it any better. The Pew Oceans Commission was convened as an effort to take a comprehensive look at policy regarding living marine resources in the United States for the first time since 1969. The Pew Oceans Commission said we must stop doing this on hard bottoms – it's disastrous, it's not a good thing. And I am saying to them "Hear, Hear." Our chief scientist Lance Morgan and I drafted a little statement on deep sea corals and sponges. We said that we are really concerned about this, and it was signed by the world's leading scientists, 1,136 of them from 69 countries from around the world, including Jamaica, Samoa, and lots and lots of folks you know from here, including our dinner speaker Carl Safina. We have now gotten legislation introduced in both the Senate and the House by Senator Frank Lautenberg and Representative Jim Greenwood in the House, to get trawlers away from places where there are corals and sponges. And this leads me to what I think you guys wanted me here for, and that is "What is the nexus between the fishes and the structure and form of the sea floor?" How does this make something greater than the whole, and how is what we do changing this relationship.

Figure 5. Pairs of photographs of untrawled (left) and trawled (right) habitats at various locations around the world. Top, left pair: hexactinellid (glass sponge) reefs off British Columbia, Canada. Top, right pair: deep coral forests off the Aleutian Islands, Alaska. Middle, left pair: coral-sponge forests off northwestern Australia. Middle, right pair: deep coral reefs (*Lophelia*) off Norway. Bottom: deep coral reefs (*Oculina*) off eastern Florida.

Figure 6. Stand of *Acropora palmata* at Looe Key Reef, 1977. [Credit: E.A. Norse]

First of all my buddy and fellow graduate student Mike Risk published this in 1972, and I don't know if you know this paper. It tends to get lost in the Atoll Research Bulletin, but to me it is earth-changing. Mike said that the more rugose the habitat, the more structurally complex, the higher the diversity of fish. I took this photograph in 1977 (Fig. 6) and as far as I can tell, he was right. Looe Key had a lot of fish.

It had a lot of vibrancy, it had a lot of diversity, it was impressive, and it had a very rugose habitat of *Acropora cervicornis* (staghorn coral) and other species of corals, diverse corals (Fig. 7). That is not what I saw yesterday. What I saw yesterday is more like this (Fig. 7). The coral cover is much, much lower, gone from – I don't know – maybe 80% to maybe somewhere between 5 and 10%, from what I saw. The reef is covered with zoanthids, which look like dandelions on a lawn, and I have a feeling their ecology is similar. It is not the Looe Key I knew in 1977, and I was shocked.

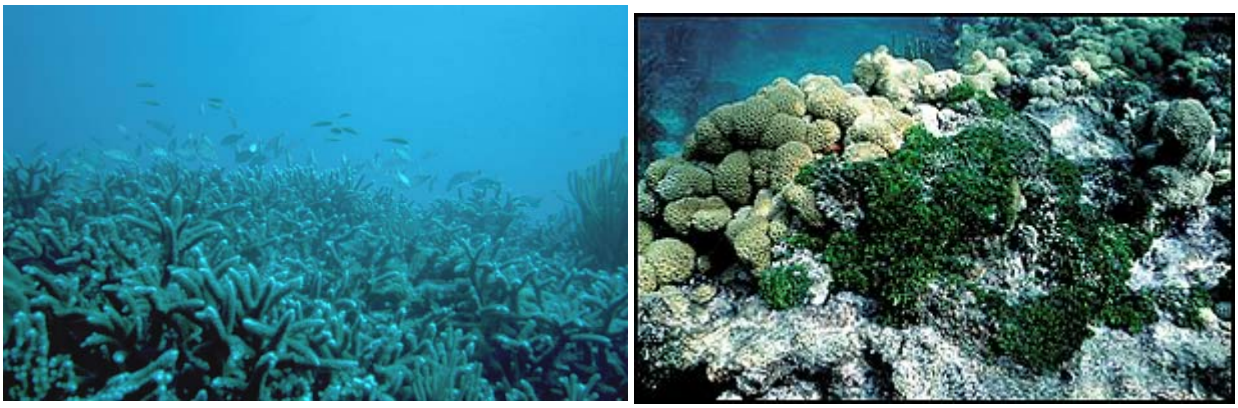


Figure 7. Stand of *Acropora cervicornis* at Looe Key Reef, 1977 (left) and 2004 (right). [Credit: E.A. Norse]

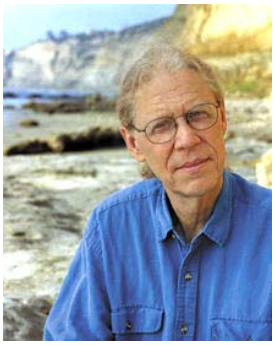
Folks at the Shifting Baselines website say this is what has happened. We have gone from coral reefs with lots of fishes, to just the remnants, and I am afraid to say that their vision, however stark and worrisome, is too optimistic, because we don't have *Acropora cervicornis* at Looe Key anymore. I didn't see any yesterday. The reason, I think, will become clear to us if we understand that ecosystems are complex. They have lots of components, and actually all these are aggregates. There are many, many more components than this, and we have to start thinking of these ecosystems as complex systems in general.

Now, what is a complex system? I have a definition up there that seems to work pretty well, and I am going to give you some examples of complex systems. I choose five of them. Our national sport. How are the Marlins doing this year? [laughter] Didn't they win the World Series last year? Well, what's different? Interesting. What about the stock market? How high was it in January? Well, not what it used to be. Climate: 2001, Florida was fighting wildfires all across the state. 2004, rainfall is above normal. What's that all about? Elections – Florida [laughter] 2000 versus 2004 [laughter]. We

don't even want to talk about that one. Ecosystems. I have to use this as an example [laughter] because there are two sets of folks who are running right now, and nobody knows who is going to win. Nobody. You can't tell. Now there is polling, there are millions and millions of dollars being spent on polling, including here in Florida, and we don't know what's going to happen in less than three months from now. I know what I'm going to do, but you know – I hope you know what you're going to do, but we don't know what's going to happen less than three months from now. Ecosystems are a lot more complicated than that.

I am going to give you an example of what I am saying. If we pull this shark out of the ecosystem, and Julia Baum and Ransom Myers have a paper that shows in the Gulf of Mexico, this shark has diminished more than 99% since the 1950s. *Carcharhinus longimanus*. If we pull this out of the ecosystem, the population of prey is going to go up or down, up or down? Up or down? Up or down? I know the answers, I know a simple trophic model, I know if I pull your predator out of the system, you're supposed to be getting more abundant. But when we pulled triggerfish out of the system and *Diadema* became more abundant, now where are the *Diadema*? So it's not simple. Ecosystems are complex systems.

Coral reef ecosystems are particularly complex because they are spectacularly diverse, and some of the problems are that we don't know what all the parts are. We don't know how the parts work, and we especially don't know how the parts interact with one another. So, in other words we're shooting in the dark here, folks. We know some things. We are not totally without knowledge, but we don't know all the things we need to know, and we need to know an awful lot more, fast. So we can say some things with confidence, right? We can be pretty sure that we know the components are tied to one another and they interact with one another, and some of these interactions we are beginning to understand are positive, not negative. We've got both. We know that eliminating some components reduces the ability of others to either resist stress or to recover from stress. Boy, did I see that yesterday in Looe Key! We know that there are species that are strong interactors, and in this system they include sea turtles, big fish, and *Diadema* and their populations have crashed in many cases and in many places. We know that the structure-formers in the ecosystem have been dramatically reduced in many places around the world, including in the Keys. And so what we see, I think, is that we have flipped from one state of an ecosystem to another state. That is what we call "regime change," right? [laughter] Oh, boy. Well we need to have another regime change.



Jeremy Jackson, my old buddy – we've worked together since 1970, when we were graduate students at the Discovery Bay Marine Lab – he says that the reefs throughout the western Atlantic have catastrophically dropped since the 80s and the main agent of that is overgrowth by algae following the removal of the herbivorous organisms in that system. Felicia Coleman has found – you may not have seen this paper – you've got to read this one, this is a honey. She found that red groupers keep spots clear of sediments on reef rock, and that reef rock is, of course, if you think about it, the kind of habitat that's important for recruitment of certain benthic organisms – structure forms, right? So, my summary of the situation is: if you take out the structure formers, you eliminate the fish habitat. If you take out the strong interactors, you prevent the recovery of structure formers, especially after you have a major disturbance, whether it's a local one like a ship grounding, or a big one like a hurricane or a bleaching event. If you remove both of them, then you have synergistic effects, and that caused the phase change we have seen from a coral-dominated (in many places, at least) to an algal-dominated ecosystem. And the darn thing is, it's like

Humpty Dumpty; it is much easier to break the egg than it is to put it back together because you don't know the assembly rules for eggs. You don't know how to do it. We have boxing gloves and we have spit, and we can't do the fine job of reassembling that egg, and that's what we've got here.

Organisms in many cases have disappeared from our system or are much less abundant than they used to be or their behaviors have changed. My buddy Callum Roberts also points out that marine reserves aren't always the answer. If you protect one quarter of a square mile some place in the ocean, you can't expect that it is going to replenish the system, even if that piece of ocean is nowhere else, and here's the reason: because the small fast-maturing organisms come back fast, but the big, slow-reproducing organisms take a long time. The failure of groupers to come back probably happens because we have eliminated them in so many places that we've lost our recruitment sources. In other words, we have taken our seed stock and we have gotten rid of it. Anybody who bakes bread knows that you always keep your sourdough culture. You've got a good culture, you nurture it. We miss that point. So that means if you want to protect the system and you want to bring the system back, you have to have a good, thick distribution of places where these things are safe and where they can reproduce. You can't just have one and say "Oh, we've done it now." That means fishery management isn't going to do it on its own. It hasn't done it, it has failed. Stopping nutrient pollution is not enough. If you have small and widely scattered reserves, that's not going to do the job. You have to manage the ecosystem-wide impacts of humans comprehensively. You have to take all the things that are forcing the system and alleviate the forcing so that the system can recover, and I'm not telling you that it is simple.

In the next few decades the best way to comprehensively manage human impacts is place-based management: ocean zoning. I am going to talk about zoning for a little bit. It is a framework that allows us to reduce the endless competition and the uncertainty and the costs by separating people whose activities are incompatible with what we value, whatever that is. The reason it is necessary and important is because it protects the parts and the processes. What Aldo Leopold called the "land ethic." It says we do this in the sea, and if you protect the parts and the processes, then you will get what you want from Nature. Again, I quote the Pew Oceans Commission, since their vision has impressed me greatly. They said that Congress should establish regional ecosystem councils, and there should be comprehensive zoning to improve resource conservation and reduce user conflicts. Makes it better, not worse. Two early examples of zoning are the Great Barrier Reef Marine Park and the Florida Keys National Marine Sanctuary, so I think we should talk about these for a little bit.

The Great Barrier Reef Marine Park (Fig. 8) is the largest comprehensively zoned piece of underwater real estate on Earth. The Australians [laughter] were humble enough and kind enough to ask for outside experts to say "What should we be doing?" And they got real wisdom, and their principles were: First, protect the resource. Everything else comes from protecting the resource. I traveled up and down the highway between here and Islamorada a few days ago, and

Figure 8. The Great Barrier Reef Marine Park, Australia.

You know what I saw painted on all the businesses, all the stores? I saw pictures of fish and dolphin. I saw concrete manatee sculptures, I mean, all the people here directly or indirectly are making their living from a healthy marine ecosystem. Either one that exists now or one that used to exist, but the rubes haven't figured it out yet, and they are going to figure it out and they are going to go some place else if you don't bring it back to health. So protect the resource first, protect a good bit of it, and we don't know how much, but 20% is a good minimum estimate. Get the full range from north to south, from onshore to offshore. Get all the different kinds of bioregions and the ecosystem types in the bioregions and make sure the public is intimately and integrally involved from the beginning to the end. Don't spring it on them, don't surprise them, don't hand it down from the top of Olympus, but get the folks who care about this issue – and it worked, Australia upgraded full protection of the Great Barrier Reef Marine Park from 5-33% this year, and increased the area where there is no trawling from 50-67%. It works. [lengthy applause] It works.

Now we have two partly zoned national marine sanctuaries, but they are much smaller and they have proportionately much less no-take area the Florida Keys and the Channel Islands. Our vice-president, Bill Chandler, has done an extraordinarily thoughtful analysis of the history of the National Marine Sanctuary Program since the 1960s before the Act was actually passed, and his conclusions are important and worth noting. First, its purpose was to preserve or restore areas for their values. Second, Congress has really interfered with the program, and third, the program has therefore, and I hate to say this, kids, fallen way short of delivering what it was intended to do. As far as we can tell there isn't yet a plan to change that, 32 years after the inception of the program, a time during which we have seen marine ecosystems and populations collapsing.

So, as an old guy, I would say, oh this is killing me, [laughter] this is a part that I have been for 26 years, so soon we forget the lesson, I'm Spiderman from Gotham and I want to tell you what that lesson is. Because I think pop culture is important and because not very many people read Conservation Biology or Atoll Research Bulletin [laughter]. A lot of people saw this, and they saw Uncle Ben, with his dying words, say: "With Great Power Comes Great Responsibility." I love my country and I want to see my country grow up and realize that we have big biceps and we have big pockets, and that gives us special responsibility. It humiliates me that Australia, a nation I love, with 5% of our population and 5% of our gross domestic product has done such a – such a beautiful job of protecting its Great Barrier Reef. It has protected 80 times as much – fully protected – as we have in the Florida Keys and the Channel Islands National Marine Sanctuaries. Those are no-take zones. It bothers the hell out of me that Australia has leaped way ahead of us. Not because I don't want them to do brilliantly – I do, but because we have lagged so much and that's a shame. I think our country needs to establish real sanctuaries, in the religious sense of the word sanctuary. A place where one is safe. Where the grouper and the *Acropora* and the *Diadema* and all the little

microorganisms that Kim Ritchie works on so effectively, all of these things can work as they evolved to work.

To mis-quote Shakespeare, the answer to this, Dear Friends, isn't in the stars, it's in ourselves. It is only going to happen if we make it happen. Don't expect your leaders to lead. Leaders follow. We need a new kind of leadership. These are rare people. I want to tell you about these eight people. Michael Soulé is the inventor of continent-scale conservation. He is the founder of the Society for Conservation Biology. I will bet that a sizeable fraction of the people in this room have never heard his name. Meet Michael. Read his works. Listen to his speeches. He inspires us to think bigger, on bigger spatial and temporal scales. Graham Kelleher. Graham played the role of Mother of the Great Barrier Reef Marine Park for several decades, and is still extremely actively involved in getting people to think of new ways about marine protected areas. Jane Lubchenco. Jane is the most visionary scientist I have known working on protected areas. She sees the big picture and has it together. Josh Riker. Josh, my friend, my sometimes funder, not now unfortunately, heads the Pew Charitable Trusts. Josh gets that fishing is the driving force.

People on the bottom are people traditionally more associated with decision-making. Teddy Roosevelt, who oversaw the dramatic expansion of the National Park system. Jimmy Carter, who doubled the size of the park system and nearly tripled the number of national marine sanctuaries. Mo Udall who got the Alaska Land Act passed. Bob Stafford, who in the darkest days of the Reagan administration, as the Republican head of the Senate Environment and Public Works Committee, stopped James Watt from dismantling the environmental laws that protected our landscape. We need visionary thinkers like these people. Now we have a chance to make up for it a little bit. Right now, the Northwestern Hawaiian Islands National Marine Sanctuary is just a concept, and it is a concept that is going to become a reality shortly in 2005. We can either get a little protection in limited areas and keep falling short, as we have been for 32 years, or we can take a great leap forward. The question involves nine fishing boats that fish the Northwest Hawaiian Islands and bring in a total of $700,000 a year from the fish they catch, versus the full protection for an area that is bigger than the entire U.S. National Park system.

The Florida Keys is a place that gives me hope, because we have leadership in this place. I think it has the potential, but it is not going to happen because we have a brilliant leader, it is going to happen because that brilliant leader is going to have the support of people pushing him to do better. This is what I want to leave you guys with: a picture of Looe Key in the year 2100 looking as I saw it in 1977. Now I am not going to be here because I am an old guy. I am not going to see this happen in my lifetime. I want you, or your children, or your grandchildren to see this happen, and my organization is going to devote all of its resources to helping make it happen here and make it happen in the Northwest Hawaiian Islands and happen around the country and around the world, and we need your help. It is only going to happen if we make it happen, and so I want to thank all these people who have provided guidance for this presentation, images or inspiration and let's have great time. Thank You. [thunderous applause]

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Discussion

Kelly Rankin: Hi, is there any work on spatial scales with sanctuaries with rates of recovery, getting a handle on the spatial scales?

Norse: That's an obvious, great question, and I never thought of it, and I don't know if anybody else has thought of it. I haven't seen any here, and the reason I say this is funny, is because – have any of you heard of Dan Simberloff? Dan Simberloff went to Florida Bay and fogged little, tiny mangrove islands, and studied the recovery of the insect and spider communities on those little islands, miles from here. He did that when he was a student in the 1970s or 1960s, so it was done in the terrestrial realm, decades ago, and I don't think that anybody has thought to ask that question. It's brilliant, it's obvious, and we should do that.

Phil Frank: Do you think we – non-government – do you think we should be buying commercial fish licenses, is that significant, and taking them out of circulation?

Norse: [bellows] OK, I'm going to show my ignorance here. I live in Washington State, and the Forest Service sells timber lease sales to the highest bidder. My friend, Mitch Freedman, of the Ecosystem Alliance had your idea, and he said "We're going to bid for a patch of forest, and we're going to take it out of circulation and not cut it." Anyway, he submitted the highest bid, but the Forest Service wouldn't give him the winning, they wouldn't designate him as the winner because he wasn't willing to cut the trees. Only if he was willing to cut the trees would they give him a license. So preservation – our country operates on the principle that capitalism works except if it doesn't agree with our policy, and our policy in this case was logging, it was not preservation. It might work here, making Fish and Game different from the Forest Service, I can't tell you. Great idea!

Cheri Recchia: Elliott, you talked about commercial logging and obviously that constitutes a problem. No-take reserves are opposed to all fishing, including recreational fishing. Why isn't that as big a problem as commercial fishing?

Norse: I am really glad you asked that question, because Cheri, as The Ocean Conservancy and everybody else here should know, the Perfect is the enemy of the Good, and when you think about what is harming marine ecosystems, I think you have to go for what you really want, but there are many interim steps. If somebody gave me the opportunity of diminishing the nutrient input to the Keys, even if we didn't get full protection, I would say "I'll take it. If somebody said "Get trawling out of our deep coral reefs in waters all around the United States and in international waters," even if we didn't get our full marine reserves, I'd say "I'll take it." What we want is full protection and I think what we can have is zoning: places where people can fish anyway and can do any legal activity and other places where people can only fish with certain kinds of gears, but do not harm habitat, whether they are recreational or commercial or subsistence, and other places that are fully protected.

I think as a society we have enough smarts, and enough decency to do what Billy let people do in the Florida Keys, and that is to say, "This we want to use for this, and this we want to use for that," and come up with something that is rational and makes sense, because we have a lot of legitimate interests in society, not just one. [applause]

Causey: As our next panel comes up and Dr. Brian Keller is our facilitator, I will explain very quickly, Brian, you want to start coming forward. I am going to tell a very quick story. What we are going to be doing is that we are going to give each speaker 15 minutes, but after 12 minutes we are going to stand up and start shuffling about and being rather obnoxious, at 15 minutes we're going to yank them off the podium. We've got to keep it tight. Our first speaker, and I know Brian is going to say some more, but I want to give you some perspective. I first heard of, or met, Dr. Frank Muller-Karger in 1988. I was down in St. Vincent and the Grenadine Islands, working with the Organization of American States in establishing a marine protected area around St. Vincent and the Grenadine Islands, actually around the lower Grenadines, Tobago Cay. After about two weeks, in October of 1988, of being down there, the water was pea soup green. This was an area that was east of everything, I expected to have crystal clear blue water, and I expected beautiful corals and fish. I expected a tremendous coral reef environment, yet we had pea soup green water. It looked like Looe Key on a day when the tide is flooding offshore. While I was there I asked the captain of the boat, "Captain, why is the water so green?" He said "It's Orinoco, mon." I said "The Orinoco? That's in Venezuela." He said "Yah, mon, every year it come across." The lower Caribbean, he explained the whole thing to me. I got back and I called John Ogden at FIO, and I said "John, do you know what's happening down in the lower Grenadine area?" And I explained it, and he said "You need to call this gentleman," so I called Frank, and Frank immediately sent me some satellite images of the work he was doing in that area. At that time, mind you, I was managing the little, tiny, five-and-a-half square-mile Looe Key Sanctuary that I could get my arms around. And I realized – I was in deep trouble – and I realized that what I was looking at, that little postage stamp of a site didn't really match up to the impacts that were coming from all over the region. Brian, I'll let you...

Keller: Well, Elliott, you said that you would knock people's socks off, and I'm pleased to see that you knocked your own off and Terry's lost his socks, even Frank has lost his socks, so thank you very much. We are going to have a series of panels, and this is our first attempt at bringing together a set of presenters. Billy laid out the ground rules. The Florida Keys receives an enormous volume of water that flows past it, through it, and into it from the Gulf of Mexico, and our first panel is going to be discussing various aspects of these regional connections, and our first speaker is Dr. Frank Muller-Karger from the University of South Florida. [applause]

Regional Connections

Moderator: Brian Keller

Regional Connections and the Coastal Ocean Observing System

Frank Muller-Karger, Chuanmin Hu, and the IMaRS Team

Abstract

A variety of processes influence coral reef ecosystems across a range of time and space scales. It is increasingly clear that different regions separated by great distances are connected through physical processes of ocean and atmospheric circulation, which carry properties like nutrients and other chemicals including pollutants, pathogens in addition to larvae of coral reef organisms, weather, and heat and salinity. The Florida Keys National Marine Sanctuary (FKNMS) experiences the influence of riverine discharge from the Everglades as well as various rivers emptying into the western and northern Gulf of Mexico. It also feels the significant impact of the water and other materials carried from the Caribbean and Gulf of Mexico into the Atlantic by the Loop Current, as well as local circulation features.

It is therefore important to move toward an ecosystem-based approach to address the problems of urban growth, coral reef decline, pollution, fishing, and connectivity in the FKNMS. Significant knowledge, experience, and infrastructure exist in South Florida and in the Intra-Americas Sea region to assist in linking science and ecosystem management efforts in the FKNMS.

The FKNMS should engage the Coastal Ocean Observing Systems of the region to address the issues of monitoring and scientific observation in the Florida Keys, including both the SEACOOS (http://seacoos.org) and the GCOOS (http://gcoos.org) regional associations of the Integrated Ocean Observing System (IOOS). This effort needs to include satellite remote sensing to achieve repeated and synoptic views of factors affecting the FKNMS and the changing conditions within the FKNMS.

Introduction

Coral reef ecosystems support a wide range of organisms, control water flow and protect the shoreline, play an important biogeochemical role, and offer significant cultural, recreational, and economic value. In general, the value of coral reef ecosystems is estimated at about ~$5,978 per hectare per year (Costanza et al. 1997). In Florida, coral reefs generate between $1.2 billion (Causey 2002) and $2.5 billion per year (Birkeland 1997), with $105 million per year in income and 8,000 jobs (U.S. Commission on Ocean Policy).

Of key interest in the last decade has been the apparent sensitivity of coral reef ecosystems to climate variability and to various types of pollution. This has raised concern about our poor understanding of pathways that connect coral reefs with possible threats. Specifically, it is of great interest to understand "connectivity" patterns that define the transportation of pollutants and pathogens to a reef, and of larvae between reefs and across a region such as the Intra-Americas Sea (the Caribbean Sea and the Gulf of Mexico). This realization comes along with increased emphasis on the need to implement "ecosystem-based" management of coastal and ocean resources, and to base such management on scientific information.

A Matter of Scales

The Florida Keys National Marine Sanctuary (FKNMS; Fig. 1) is affected by phenomena occurring at local, regional, and global scales (Lee et al. 2002), and by both natural and anthropogenic forcings. It may be viewed as part of a larger ecosystem that includes the deep ocean, land, and the atmosphere, all connected through various processes including ocean circulation, terrestrial discharge, and atmospheric deposition (the "Three Screen Doors," Jameson et al. 2002). The FKNMS is located in close proximity to an ever-growing urban South Florida environment and to the pollutant source of the commercial agriculture interests of central Florida.

As a coastal ecosystem, short (sub-millimeter to hundreds of meters) and event-scale (seconds to days) phenomena affect the reef. These include physical processes like variability in currents, turbulence, weather, and also biological productivity, and the spawning and survival of larger organisms. Fishing and local nutrient inputs may be event-scale phenomena, but they may occur over long time scales (seasonal to many years). Similarly, brief events like ship groundings, other types of traffic, and dumping can be instantaneous but have long-lasting effects.

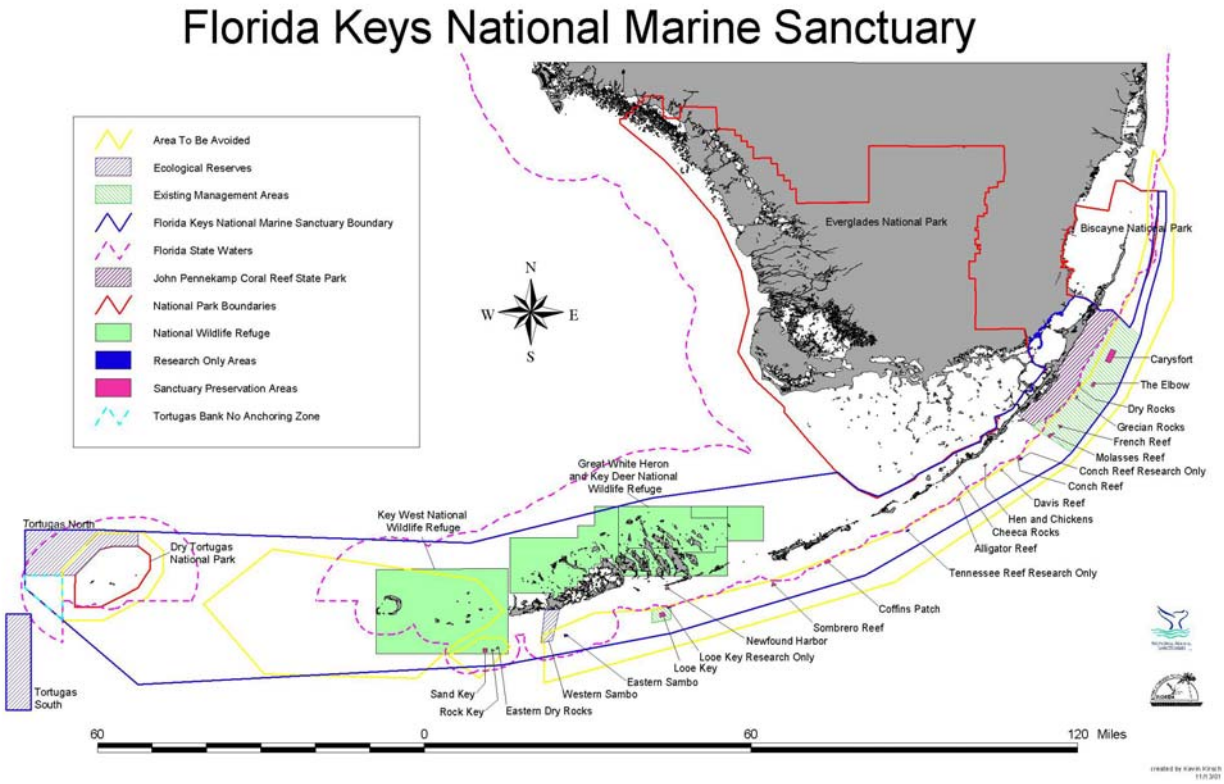


Figure 1. The Florida Keys National Marine Sanctuary (FKNMS).

Other phenomena tend to act over seasonal and regional scales. The FKNMS is repeatedly affected by freshwater discharge from the central western Florida coast (Hu et al. 2004) and from the Everglades (SWFDOG 2002), which are "dark water events" that have been associated with damage to benthic reef communities (Hu et al. 2003; Neely et al. 2002). Further, oceanic circulation may bring Mississippi River water to the Keys (Ortner et al. 1995). We are just beginning to realize the connections between different parts of the Intra-Americas Sea (Fig. 2; see also Andréfouët et al. 2002). Hurricanes and tourism have significant seasonal impacts, while even interannual phenomena such as the El Niño-Southern Oscillation on average leads to stronger winter-time winds, with stronger mixing and cooling of Gulf of Mexico surface waters, and rains with higher discharge from South Florida rivers. The effects of what we are generally calling climate change are unclear at this time, but may include sea level rise (now rising at approximately 1 mm per year), continuing warming of ocean waters and the air, and changes in the frequency of storms.

Global temperatures have been changing over the past few thousands of years (Fig. 3). This has affected sea level. Sea level during the last glaciation, which ended some 15,000 years ago, was about 120 m below present sea level. Warming of the atmosphere and the ocean since then led to a rise in sea level. While this rate of sea level rise had leveled off in the last couple thousand years, it seems to have accelerated again in the last 100 years. South Florida seems to have one of the slowest sea level rise rates, relative to land, in the Intra-Americas Sea (Fig. 3).

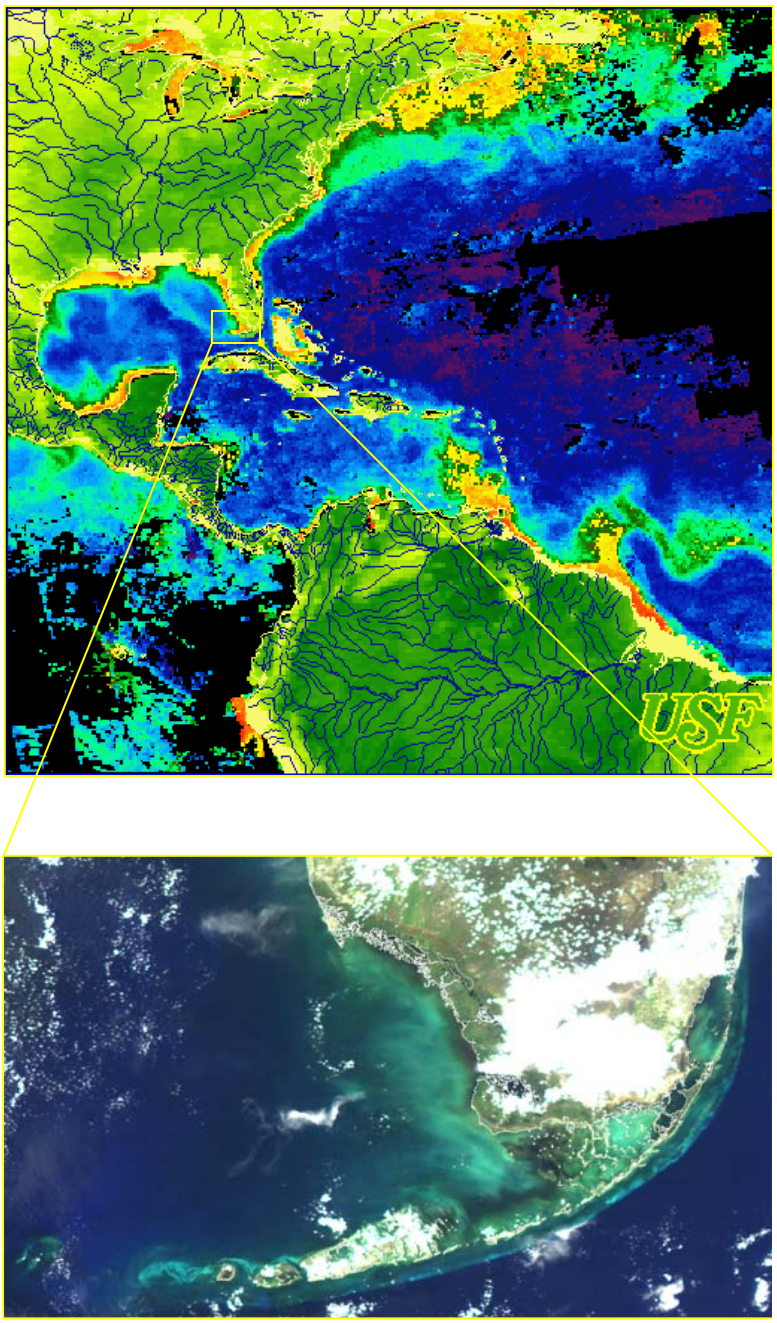
Possible Connectivity Assessment Priorities

The examples of processes and scales mentioned above are not intended to be comprehensive; they just give a general sense of the depth and breadth of scientific issues that need to be considered in addressing ecosystem management. It is of primary concern to understand processes acting across a wide range of time and space scales. A list of areas where management efforts may focus includes:

At the local level (FKNMS and adjacent continental shelf):
- -Pollutant dispersal : septic tanks, non-point, point sources
- -Eutrophication at bottom of food web
- -Overfishing at top of food web and bycatch
- -Larval dispersal
- -Conditions that lead to bleaching
- -Human health and safety
- -Relation to urbanization
- -Relation to industrialization

At the regional level (Gulf of Mexico, Mesoamerica, and Caribbean):
- -Larval dispersal patterns
- -Forcing of circulation

At the global level:
- -Weather and climate and forcing/feedbacks



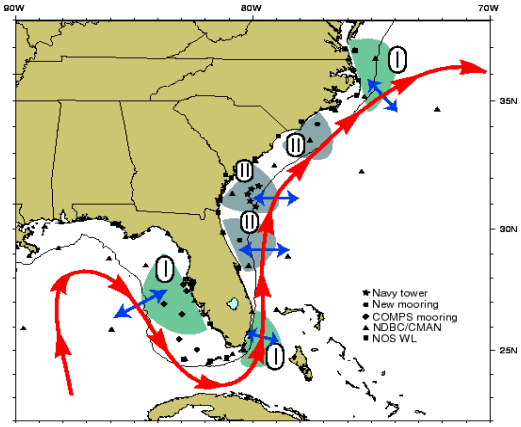


Figure 2. The FKNMS in relation to the Intra-Americas Sea, (above left) as land and ocean plant biomass derived using satellite data. In the ocean, clear water is shown in blue colors and turbid waters are shown as green, yellow, or red. On land, higher biomass is shown as deeper tones of green. The satellite image of south Florida and the Florida Keys (lower left) is shown in "true color" where colors approximate what a person would see from space. The panel on the right shows a schematic of the flow of the major Loop Current along the FKNMS.

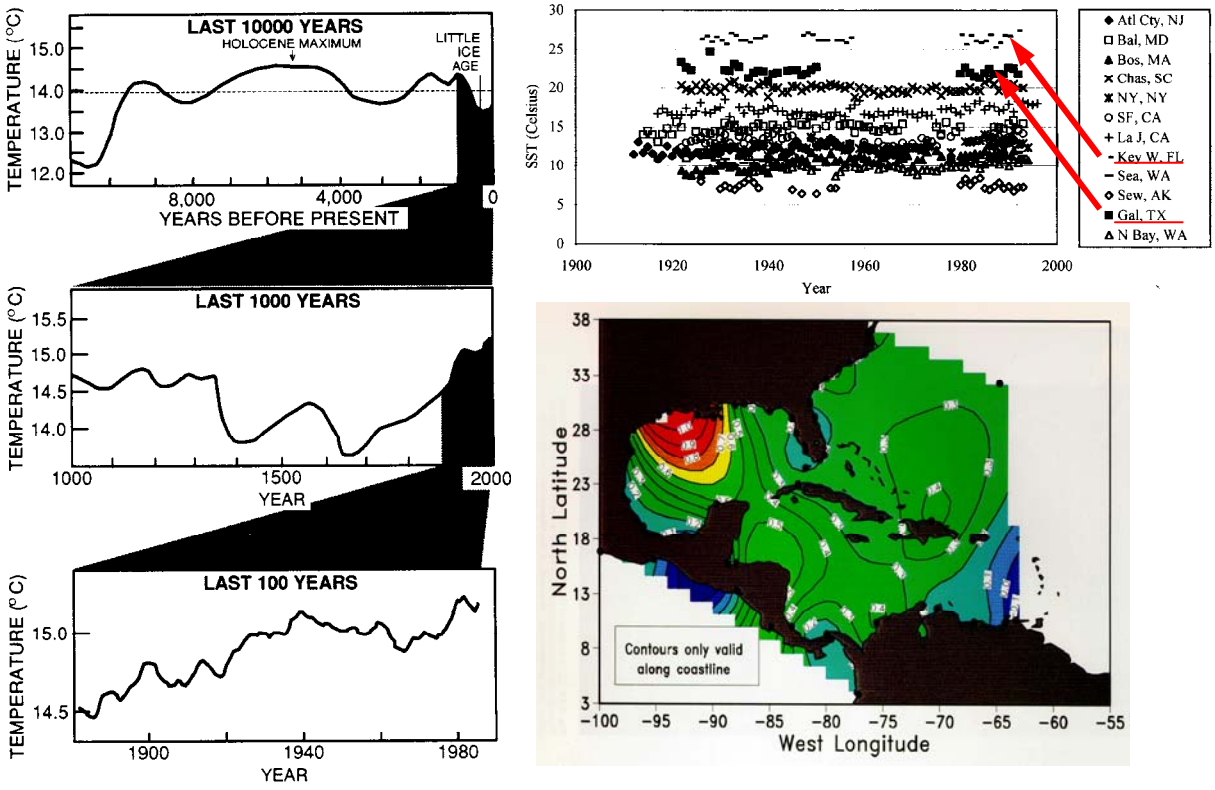


Figure 3. Left: Global air temperatures (reproduced from Maul 1993). Right top: Sea level measured at select tide gauges around the United States (reproduced from Maul et al. 2001). Right bottom: the rate of sea level change in the Intra-Americas Sea (reproduced from Hanson and Maul 1993).

The Role of Ocean Observing Systems

Research, monitoring, and ecosystem management therefore require observing and monitoring tools that span range of space and time scales, and a system to integrate similar and different observations into products useful to managers as well as the public in general.

Coastal Ocean Observing Systems (COOS) are being developed to address these requirements. The COOS are components of "Regional Associations" (RA's) that form the national Integrated Ocean Observing System (IOOS). The FKNMS is covered by two nascent COOS:

SEACOOS: Southeast Atlantic COOS (http://seacoos.org)
GCOOS: Gulf of Mexico COOS (http://gcoos.org)

Each COOS has a series of basic elements, namely:

Observing elements
Data Management
Outreach and Education
Modeling
Product dissemination

Data are integrated from a variety of established or new programs, including satellite data. Figure 4 gives an example of a web-enabled mapping system which displays a variety of data layers according to the needs of a specific user.

At this time, a variety of satellite-based measurements can be obtained concurrently and in real-time. Satellites provide synoptic and repeated views of the areas of interest. They allow for spatial as well as temporal context for point measurements obtained by buoys, drifting platforms, or ships, and they help validate model results. Since satellite data are inherently observations of only the surface of the ocean, the other datasets are critical to understand the three-dimensional nature of the ocean. Among the observations that can be made from satellite are sea surface temperature (SST) and pigment concentration (a measure of phytoplankton biomass, river plume dispersal patterns, or other turbidity events (Fig. 5). Several satellites provide synoptic wind speed and direction measurements as well as a measure of the sea surface height. We are all familiar with how satellite data can help track hurricanes and their impacts on the coastal ocean (Fig. 6).

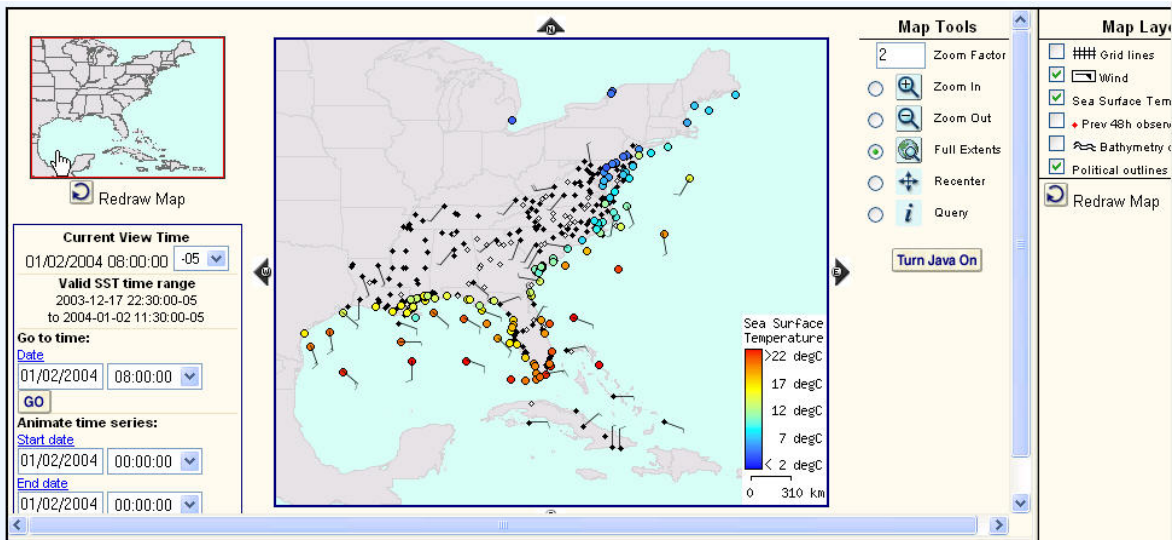


Figure 4. Sample screen from a web-deployed observing system, namely the Southeast Coastal Ocean Observing System (COOS).

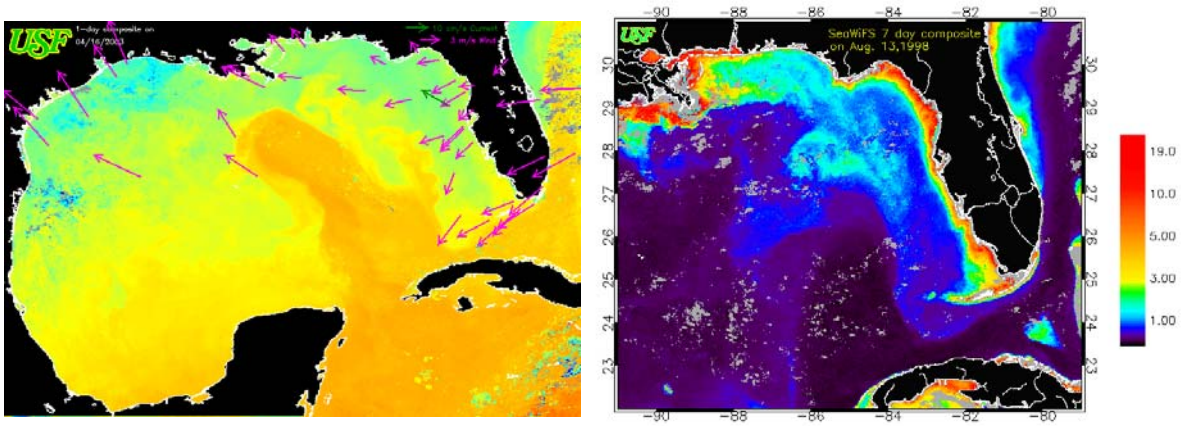


Figure 5. Left: Satellite-derived seas surface temperature of the Gulf of Mexico, derived with the AVHHR sensors. Right: Satellite-derived pigment concentration derived with the SeaWiFS.

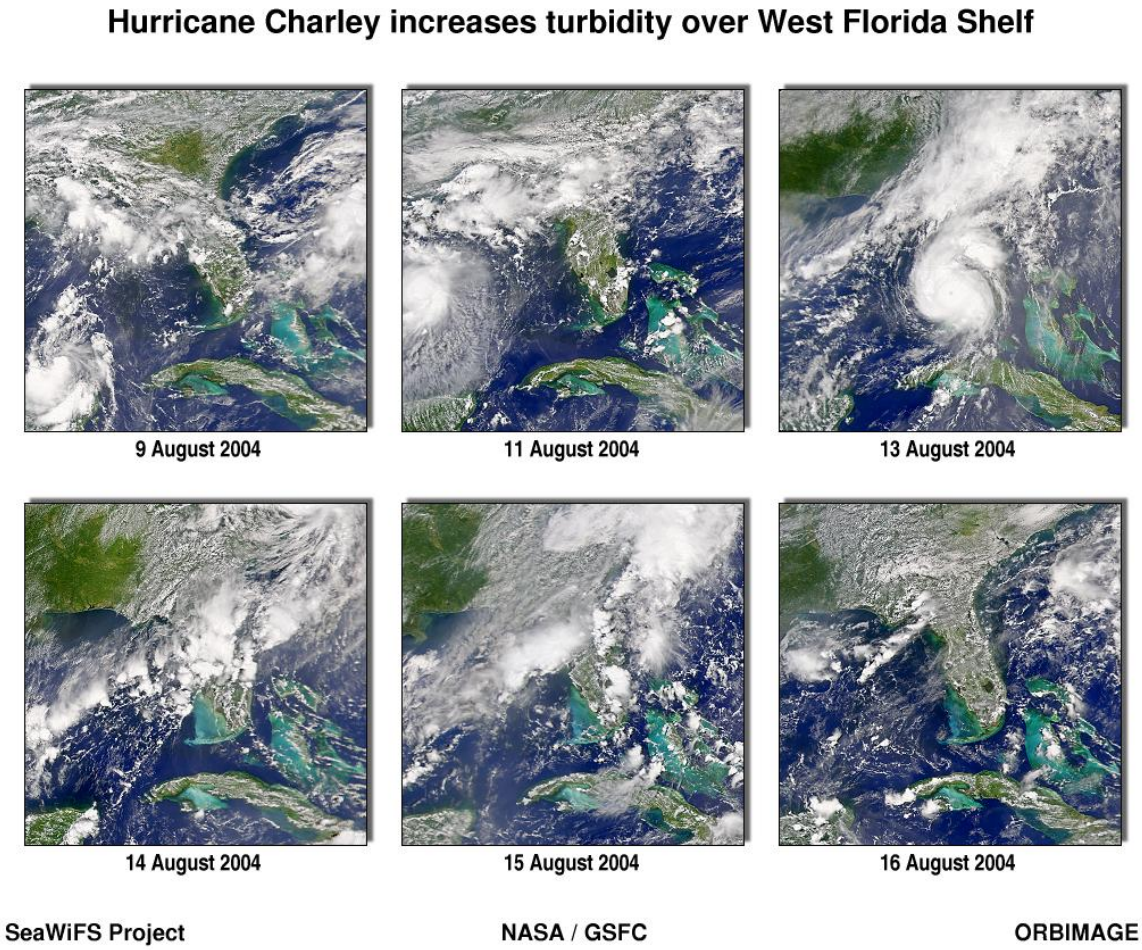


Figure 6. SeaWiFS image sequence showing Hurricane Charley, which affected Florida and the West Florida Shelf in August 2004.

Important contributions from satellites are high spatial resolution images, which are useful to map and monitor coastal zones and shallow submerged areas like coral reefs. In particular, the Landsat, SPOT, IKONOS and other high resolution images can help managers get very detailed spatial maps of coral reefs (Andréfouët et al. 2004a, b; Andréfouët and Riegl 2004).

Examples of the application of high resolution satellite data to assess change in coral reef communities over time are presented in Palandro et al. (2003a, b). A relevant example is shown in Figure 7, which depicts a decrease in live coral reef cover in Carysfort reef since 1984, from about 30% to less than 10% in the year 2000.

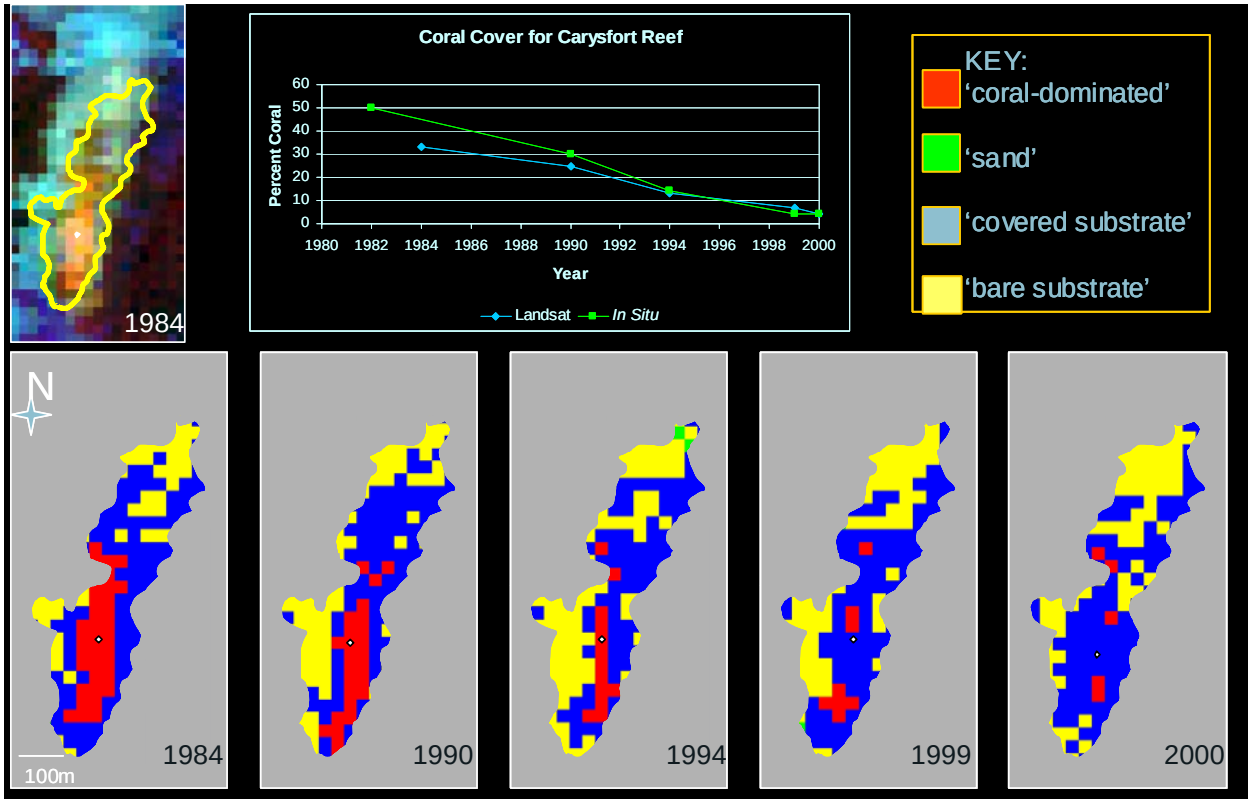


Figure 7. Change in live coral reef cover in Carysfort Reef sine 1984.

Conclusions

It is important to move toward an ecosystem-based approach to address the problems of urban growth, coral reef decline, pollution, fishing, and connectivity in the Florida Keys National Marine Sanctuary (FKNMS). Significant knowledge, experience, and infrastructure exist in South Florida and in the Intra-Americas Sea region to assist in linking science and ecosystem management efforts in the FKNMS.

The FKNMS should engage the Coastal Ocean Observing Systems of the region to address the issues of monitoring and scientific observation in the Florida Keys, including both the SEACOOS

(http://seacoos.org) and the GCOOS (http://gcoos.org) regional associations of the Integrated Ocean Observing System (IOOS). This effort needs to include satellite remote sensing to achieve repeated and synoptic views of factors affecting the FKNMS and the changing conditions within the FKNMS.

Acknowledgments

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On the Connectivity and "Black Water" Phenomena near the FKNMS: A Remote Sensing Perspective

Chuanmin Hu and Frank Muller-Karger

Abstract
Satellite color images from SeaWiFS and MODIS for 1997-2004 were examined for dark water plumes and patches in coastal waters off southwest Florida including the Florida Keys National Marine Sanctuary (FKNMS). Most of these dark features appeared to originate with coastal runoff from the Everglades and from the vicinity of Charlotte Harbor and Sanibel Island. Because the FKNMS is located downstream of these areas, the dark water patches, which field sampling confirmed may contain elevated nutrients and both colored living and non-living materials, lead to stress to the ecosystem. Waters from more remote sources, such as the Mississippi River and the Caribbean, routinely affect this region via ocean circulation patterns (e.g., the Loop Current). Florida's red tides, which occur every year along the west coast, may also meander toward the Keys. The connectivity of the FKNMS to local and remote systems requires an integrated observing system to better understand the effects of these dark patches on the delicate coral reef ecosystem.

Introduction

The Florida Keys National Marine Sanctuary (FKNMS) is one of the nation's premier marine protected areas, and it annually attracts 3 million tourists who spend $1.2 billion (Causey 2002). It is home to a major coral reef ecosystem and many important commercial and recreational fisheries, and it is a critical location for early larval development of a number of marine species.

Similar to many other delicate marine ecosystems, the FKNMS is not isolated, but connected to the deep ocean, land, and the atmosphere through various processes including ocean circulation, terrestrial discharge, and atmospheric deposition (the "Three Screen Doors," Jameson et al. 2002). The FKNMS is located in close proximity to an ever-growing urban South Florida environment and to the pollutant source of the commercial agriculture interests of Central and South Florida. Therefore, this ecosystem is under significant environmental stress. Further, water-circulation brings other fresh water, such as that from the Mississippi River, to the Keys (Ortner et al. 1995).

Recently, some "black water" events have been reported in the vicinity of the FKNMS (Hu et al. 2003, 2004; Neely et al. 2002; SWFDOG 2002). These are characterized as dark colored waters with high concentrations of unicellular marine plants (phytoplankton) and yellow substance (colored dissolved organic matter, CDOM) where fish seem to be absent according to numerous accounts. Adverse impacts on benthic habitats also seem to occur after a prolonged "black water" event, even though the mechanism is not very clear (Hu et al., 2003).

The cause of "black water" is still a research topic and requires an integrated study that combines multi-disciplinary observations and modeling. Because the FKNMS is located downstream of the Everglades, its discharge, and that from several other major rivers, a reasonable hypothesis is that "black water" is related to coastal runoff. Remote sensing is a powerful tool to study large-scale connectivity (Andréfouët et al. 2002), and we use it to examine how the FKNMS is connected to other ecosystems. Specifically, we study the frequency of the dark water events and discuss future directions for an improved observing system.

Methods

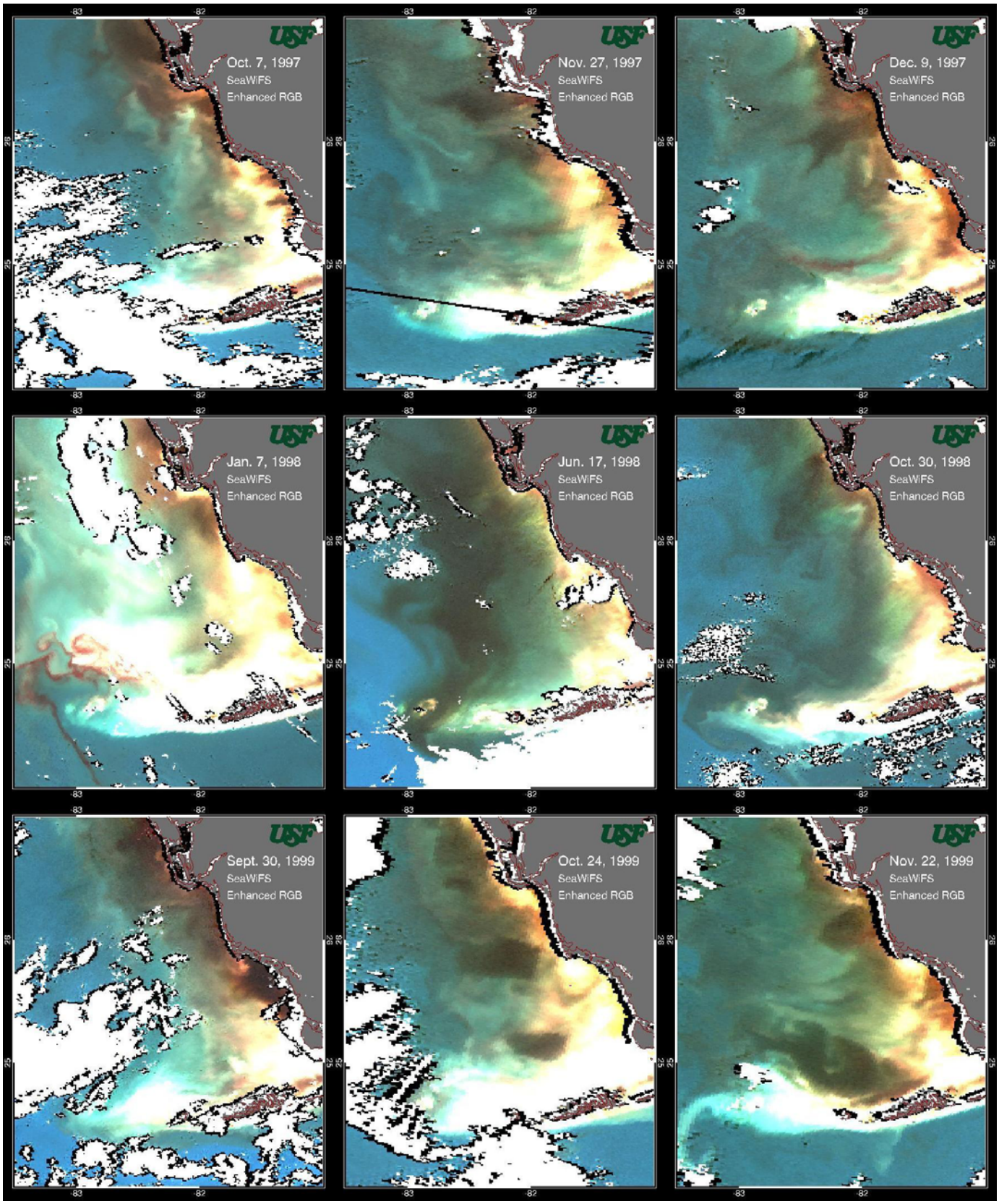
We used operationally available ocean color satellite remote sensing data from the Moderate Resolution Imaging Spectroradiometer (MODIS; Esaias et al. 1999) and the Sea-viewing Wide Field-of-View Sensor (SeaWiFS; McClain et al. 1998), and sea surface temperature (SST) data are from MODIS and the Advanced Very High Resolution Radiometer (AVHRR). These data were captured, processed, and archived in near real-time at the University of South Florida with standard algorithms as well as software developed in house, and broadcast via the internet to the public. Of particular interest were the color data, which yield information on water constituents including phytoplankton abundance (through chlorophyll concentration), CDOM (through its absorption), total suspended sediment concentration, and bathymetry. As the algorithms to retrieve these parameters from satellite measurements are not robust in the complex coastal environment, products were used in a relative sense. Specifically, coastal features were examined through three separate color bands (555 or 551, 490, and 443 nm) after atmospheric effects were removed. Sun-stimulated phytoplankton fluorescences from MODIS were also examined to determine whether features that absorbed blue light were phytoplankton blooms or not. SST data were used mainly to see if a feature was associated with coastal upwelling.

We examined the daily color imagery (1-km resolution) from September 1997 (beginning of SeaWiFS data collection) to date. Some examples are shown here, and a complete series is available upon request.

Results and Discussion

Figure 1 shows some images where dark water plumes or patches can be found near the Florida Keys. The colors do *not* reflect the real colors when viewed with a human eye, but were manipulated by computer to enhance the contrast between various features. For example, the dark color indicates high concentrations of phytoplankton and/or CDOM. Further, the various colors can be used as effective tracers to monitor water movement.

The images show the complexity of the water environment and that dark water plumes or patches are not uncommon off the South Florida coast. Coastal runoff, upwelling, and red tides can all make water appear dark (their shades may be different). It is often possible to trace the dark water's origin to the coast following its distinctive color. For example, the images of 11/27/1997, 12/9/1997, 10/28/2000, and 11/30/2002 show that the dark/brownish "streamers" originated from Everglades outflows. The images of 10/30/1998, 8/30/2001, 2/15/2003, and 10/21/2003 show the dark water flowed from the vicinity of Charlotte Harbor to the Dry Tortugas. The movement can be better visualized if a series of images is animated.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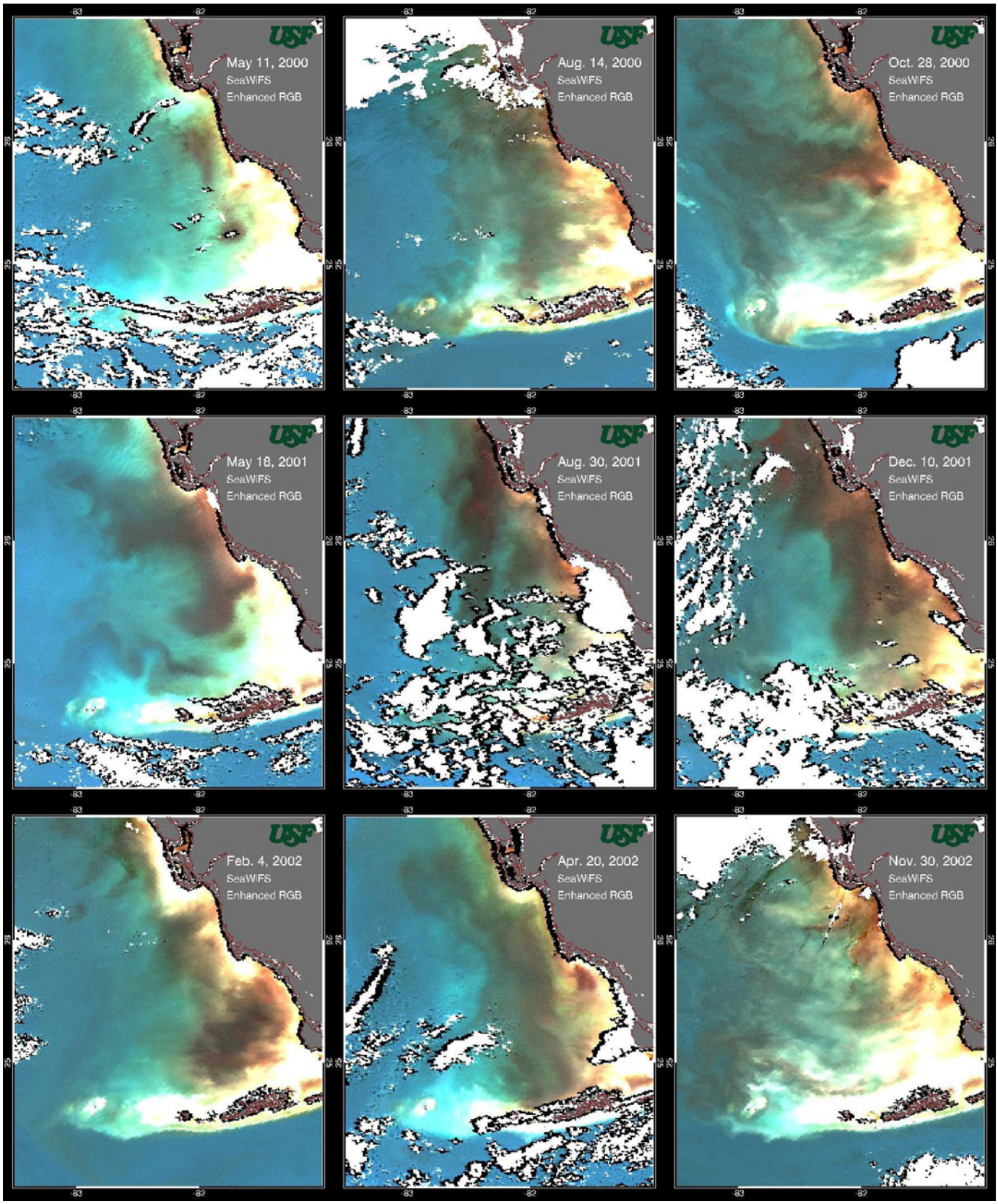
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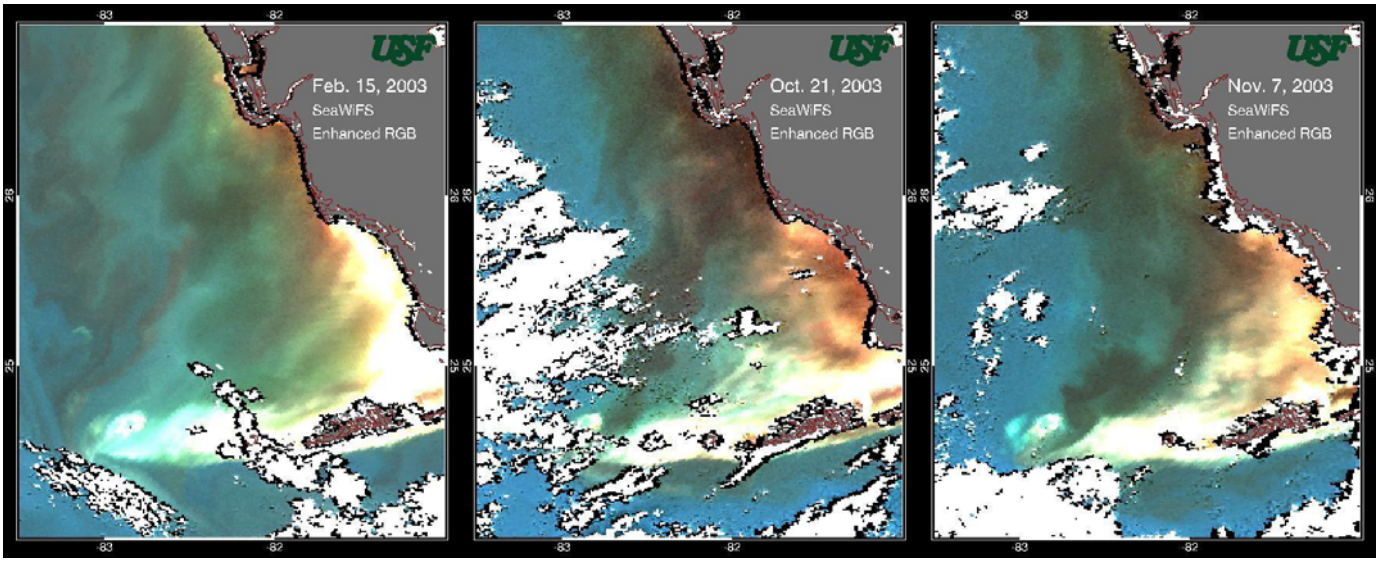

Figure 1. SeaWiFS images showing dark water plumes or patches near the Florida Keys. The RGB images were constructed using water-leaving radiance at 555 nm (red), 490 nm (green), and 443 nm (blue). Land was masked as grey and clouds white. The RGB data were stretched to show various features in the water, therefore the appearance does *not* represent the real color of water when viewed with a human eye. The offshore blue color represents the dark blue ocean. The nearshore white color (except for clouds) shows shallow water where bottom can be seen or also where high concentrations of suspended particles are present in the water. The brown-red color represents high concentration of phytoplankton or non-living particles (this type of water often carries high amount of CDOM). Dark color indicates high concentrations of phytoplankton and/or CDOM. In reality the dark color may appear as dark greenish or dark brownish water, depending on the relative amount of the two substances. The images were arranged in the order of 3 panels/year from 1997 to 2003. See text for more details.

The imagery illustrates the complexity of coastal circulation in the FKNMS region. For example, the 4/20/2002 image shows that there is a wide band of dark water along the southwestern Florida coast. The image series shows that the water originated from the south, near the Florida Keys and that the water moved from south to north, compared with the north-south water movement direction usually seen in this area.

Coastal runoff alone can result in dark water patches, as shown in Hu et al. (2004). Extreme climate conditions, such as higher than normal rainfall or heavy storms like hurricanes, may cause excessive coastal runoff from either river discharge or land drainage. This runoff may contain high concentrations of CDOM that strongly absorb sunlight, and high concentrations of nutrients that may stimulate phytoplankton blooms. For example, the dark water patches of 10/24/1999 and 11/22/1999 were a result of excessive discharges from the Everglades after Hurricane Irene. The image of 6/17/1998 was a result of higher than normal discharge of the Suwannee River due to high rainfall in the 1997-1998 El-Niño period (upwelling on the West Florida Shelf during the late spring and summer 1998 also likely contributed to this dark plume).

The complete series showed that most of the dark patches occur in the fall, after the wet season of Florida, and they clearly show the coastal origin. However, there are some cases when the origin of the dark water is not clear. For example, the early 2002 dark water event, as shown in the 2/4/2002

image, may be at least in part due to an earlier extensive red tide along the southwestern Florida coast (SWFDOG 2002). Indeed, red tide can appear dark in satellite color images, and it looks similar to water that contains non-toxic phytoplankton blooms and/or high concentrations of CDOM (Hu et al. submitted). It is presently very difficult to differentiate what substance(s) dark color patches contain due to technical difficulties in satellite data processing (i.e., the algorithms to obtain meaningful parameters from satellite measurements). Hu et al. (2004) showed that the MODIS fluorescence data helped identify a phytoplankton bloom in a dark patch (Fig. 2). However, it is currently impossible to tell whether a bloom is toxic (red tide) or not. Certainly, field samples under these circumstances are of great help to understand the composition of the water.

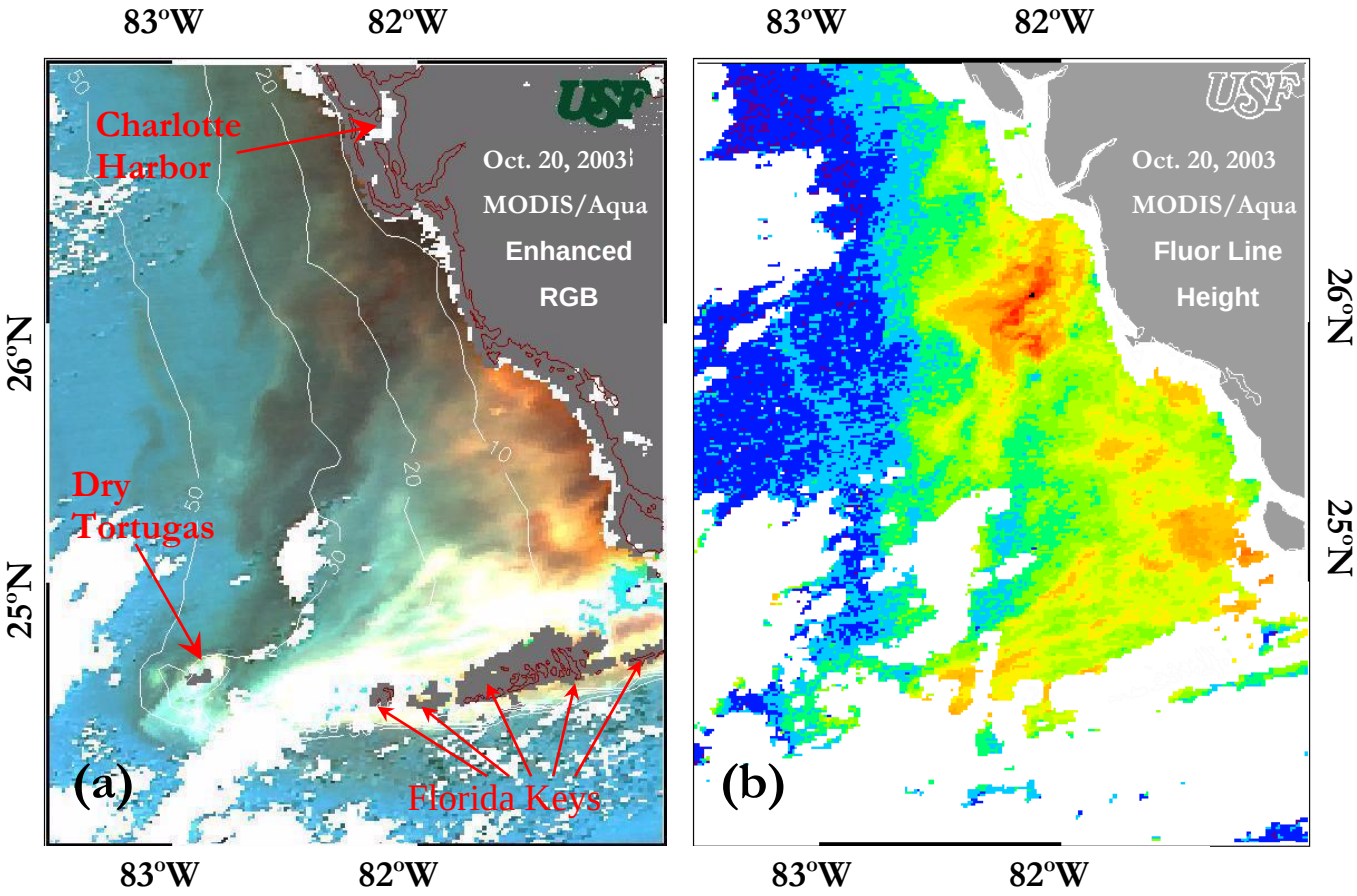

Figure 2. MODIS color imagery shows dark water plume from Charlotte Harbor to Dry Tortugas. (a) Enhanced RGB composite showing the plume; (b) Fluorescence data showing high concentration of phytoplankton in the upstream of the plume. Fluorescence increases from dark blue, light blue, green, yellow, to red.

In addition to local connectivity, ocean circulation brings "alien" waters to the Florida Keys. The Loop Current (Fratantoni et al. 1998) may bring waters from the Caribbean to the Florida coasts and it may also create local eddies that "pump" nutrients from deep waters to the surface and stimulate phytoplankton blooms. Further, the Loop Current can advect waters of the Mississippi River plume to the Keys (Fig. 3). Similar river plume features were seen in 1998, 1999, 2000, 2001, 2003, and 2004, respectively. The year 2002 was the only year between 1997 and 2004 that did not appear to feature a river plume that reached the Florida Keys, but during spring-summer, eastward and

southeastward movement of the Mississippi plume near the Mississippi Delta was observed. This plume entered the West Florida Shelf and dissipated gradually. We believe it reached the Florida Keys eventually.

Episodic dark water events may be of no harm to the Florida Keys ecosystem, but prolonged events, such as the one in early 2002 (Hu et al. 2003), seems to have been the cause of stress. For example, coral reef decline and benthic degradation followed the 2002 "black water" event.

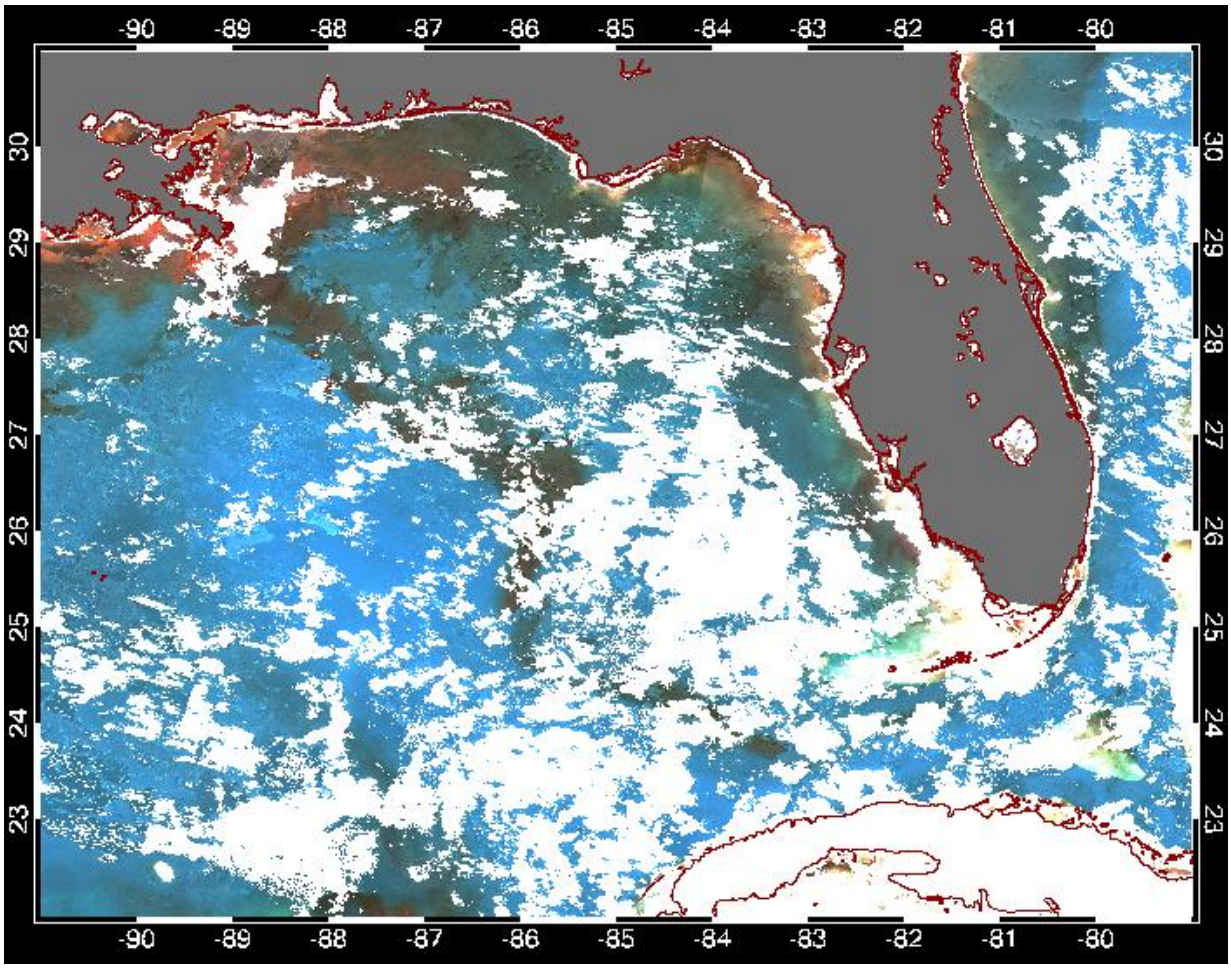

Figure 3. SeaWiFS color imagery on 4 August 2004 shows the Mississippi River plume that reaches the Florida Straits, following the path of the Loop Current.

Remote sensing cannot provide all the information needed to understand this complex ecosystem. This requires an approach that integrates various observing technologies. Of particular importance is field sampling, which can be used to study the vertical structure of the water mass, hydrography, composition of various phytoplankton species, and nutrient availability. Hu et al. (2004) illustrated how field information can be used to verify whether a dark patch is from coastal runoff (characterized by low salinity) or generated by local upwelling. These observation/modeling efforts should be an integrated component in an effective management plan for coastal resources. This is particularly important for the FKNMS and also for the entire southwestern Florida ecosystem, as in

the next 10 to 20 years Everglades restoration has the potential to impact the entire South Florida coastal ecosystem, including coral reefs and fisheries.

Conclusions

We examined the complete daily image series from SeaWiFS and MODIS covering the period of September 1997 – September 2004 looking for dark water patches in southwestern Florida coastal waters near the Florida Keys. The dark color is an indication of high concentrations of phytoplankton and/or colored dissolved organic matter, rich in coastal runoff.

Dark water patches in this area are not uncommon, as revealed by the satellite imagery. Their appearance, frequency, timing, duration, and spatial extent vary. Generally, more dark patches are found in the fall than in the spring, likely resulting from coastal runoff after the rain season. However, Florida's late summer/fall red tides, which occur every year (although their intensity and coverage vary from year to year), may also contribute to the dark color. The situation is further complicated when discharges from remote rivers such as the Suwannee and the Mississippi may reach the Florida Keys.

Clearly, the FKNMS is not isolated, but connected to other ecosystems (Lee et al. 2002). An integrated observing system that combines remote sensing, field observation and modeling is important to understand the various processes that may affect the FKNMS. In particular, a fast response team to study anomalous events is required to better understand the nature, origin, and impact of these events on the local ecosystem.

Acknowledgments

This work was supported by the National Aeronautics and Space Administration (NAG5-10738). SeaWiFS data are property of Orbimage Corp., and their use here is in accordance with the SeaWiFS Research Data Use Terms and Conditions Agreement of the NASA SeaWiFS project. We thank the NOAA/ Atlantic Oceanographic and Meteorological Laboratory (Elizabeth Johns) and University of Miami/Rosenstiel School of Marine and Atmospheric Science (Thomas Lee) for providing field hydrography data in this study.

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East-West Connections in the Gulf of Mexico

Tracy Villareal

The Florida Keys National Marine Sanctuary lies at the easternmost reaches of the Gulf of Mexico, and is influenced by the continuum of global and regional processes affecting the biology and chemistry of the Gulf. Some of these processes influences are well upstream of the Keys and operate through biological cascades. The linkages are often indirect and highlight the complexities inherent in the Keys ecosystem and its connections to the world around it.

The Keys lie in a latitudinal band of prevailing westerly winds and are downwind of the North Atlantic Ocean. Vast dust clouds from Africa (Sahara dust) are transported across the Atlantic Ocean annually and can produce spectacular sunsets from Florida to Texas. Darwin noted dust accumulation on the *H.M.S. Beagle* during his voyage, and correctly speculated that it was of African origin (Darwin 1860). These dust inputs are linked to both global climatological events and region-specific biological responses. Ice core records note dust concentration is inversely related to CO_2 concentrations suggesting a linkage between global temperature, climate properties, and aeolian transport. These planetary-scale events have direct relevance to the Gulf of Mexico through the potential for changing heat balances, wind fields, and current flow. In addition, iron is now known to be biologically available at only vanishingly low concentrations, and climatological changes in recent years have led to elevated inputs into the ocean that may be related to biological changes (Hayes et al. 2001). Dust inputs provide iron to the ocean, and in many places, are the dominant inputs. In the Gulf of Mexico, dust inputs are now suggested to be linked to blooms of the fish-killing dinoflagellate, *Karenia brevis* (Walsh and Steidinger 2001). The links are complex and require iron to stimulate nitrogen fixation in the cyanobacterium *Trichodesmium* (Fig. 1 [= Fig. 5]).

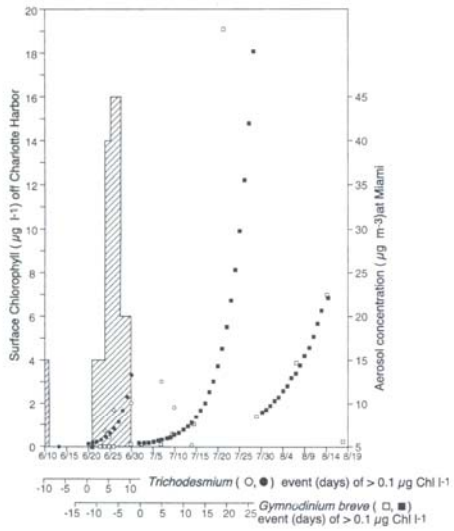


Figure 5. Mean observed (open symbols) and computed (solid symbols) daily biomasses (μg chl L^{-1}) at the surface of the nitrogen fixer *T. erythraeum* (open and solid circles) and the toxic dinoflagellate *G. breve* (open and solid squares) within ~5 km of the west coast of Florida at three sampling sites off Charlotte/Lee Counties (~26°40′N–26°55′N) in relation to Saharan dust (striped columns) events (>5.0 μg m^{-3} of mineral aerosols) observed during June 10 and 21–30, 1980, at Miami (25°45′N). Cell counts were converted to biomass, assuming 1.2×10^{-6} μg chl $cell^{-1}$ for the former and 1.0×10^{-5} μg chl $cell^{-1}$ for the latter.

Figure 1. Dust cloud inputs and outbreaks of red tides. Figure 5 from Walsh and Steindinger (2001).

This nitrogen is then made available to *Karenia* to support the annual blooms that often cover hundreds to thousands of km^2. Such blooms also occur along the Texas coast, and in at least one case where data is available, followed dust inputs (Biegalski and Villareal 2005).

Karenia blooms rarely penetrate the Keys, although limited fish-kills have been reported. There is much speculation in the harmful algal bloom literature that ocean warming will lead to altered current patterns (Tester 1993; Zingone and Enevoldsen 2000). When presented with a scenario of sea level rise, it is reasonable to consider that current patterns off south Florida could alter considerably as well and lead to increased exposure of the FKNMS to icthyotoxic dinoflagellate blooms.

Recent work has suggested that these dust clouds also carry pathogens that are linked to coral diseases (Shinn et al. 2000; Fig. 2). While there is a climatological link to dust inputs in the geological record, it is also apparent that human activity has a direct link to dust (Hayes et al. 2001). Desertification, both as a result of poor agricultural practices and global climate change, can be expected to lead to increased dust inputs in the future. While the consequences cannot be predicted clearly, the evidence suggests that these global scale phenomena will provide great challenges for the management of the FKNMS.

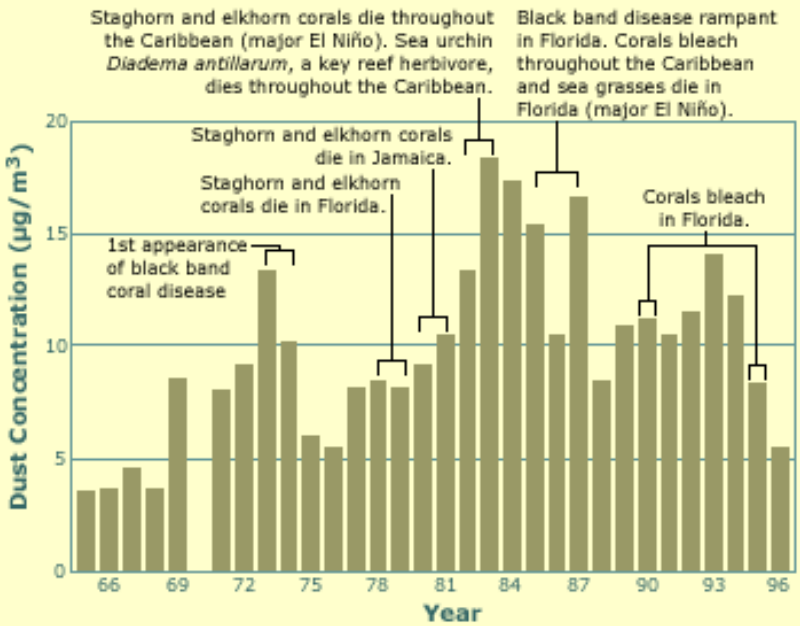


Figure 2. Dust cloud inputs and historical outbreaks of coral disease (http://earthobservatory.nasa.gov/Study/Dust). Dust input data provided to this link by Dr. J. Prospero.

Even in the absence of climate change, currents of the Gulf of Mexico provide hydrographic links between the various regions. The Loop Current sweeps into the Gulf of Mexico between Cuba and Yucatan and exits as the Florida Current south of the Keys (Fig. 3A), but covers a highly variable path while in the Gulf of Mexico. As noted elsewhere in this volume by Drs. Muller-Karger and Hu, penetration of the Loop Current into the Gulf can change dramatically over time, and significant changes in phytoplankton are noted as a result. Meanders pinch off to form mesoscale rings and eddies with lifetimes of months to years (Fig. 3B). These eddies drift westward across the Gulf and eventually dissipate in the eddy "graveyard" of the northwestern Gulf. In their wake, cyclonic eddies spin up and produce doming on isotherms, nutrient injection into the euphotic zone, and greater biological production (Biggs and Müller-Karger 1994). In a manner analogous to the warm-core and

cold-core rings of western boundary currents, the eddies of the Gulf of Mexico transport areas of distinct biological production across the Gulf. Unlike the rings of western boundary currents, the cores of the eddies are probably not transporting a flora and fauna from a different biological region into another. However, they do introduce a common flora and fauna into the eastern and western Gulf.

A

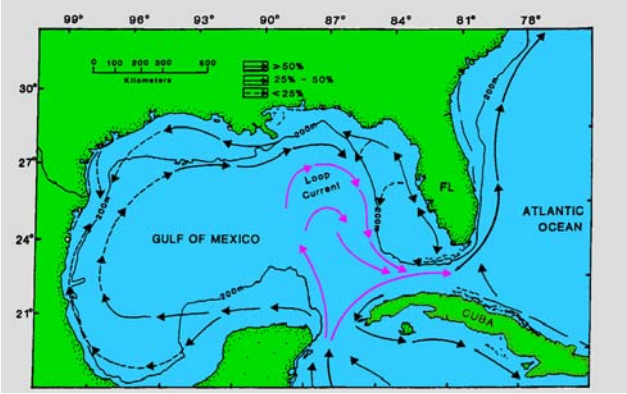
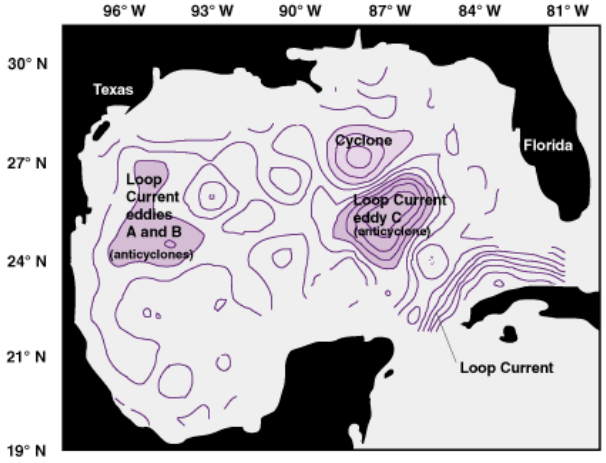


Figure 3. Average currents and mesoscale features.

A. "Average" circulation in the Gulf of Mexico. Modified from Tester and Steidinger (1997).

B



B. Snapshot of sea surface height showing the complex pattern of highs (anticylonic circulation) and lows (cyclonic circulation). Data from CCAR, published in Quarterdeck (www.ocean.tamu.edu/Quarterdeck/QD6.1/spin.html).

The Gulf of Mexico produces nearly one-quarter of the U.S. output of petroleum. Over 95% of nation's production on the outer continental shelf comes from the Gulf of Mexico. This activity requires the placement of oil production platforms (OPPs) along with a complex network of pipelines. At present, approximately 4,000 platforms are located in the Gulf of Mexico with the majority of these platforms located off Louisiana and Texas (Dauterive 2000). In addition, several hundred artificial reefs are distributed from Florida to Texas (Fig. 4). Both OPPs and artificial reefs are known as sites of enhanced fish populations. In addition, OPPs provide hard substrate in a region (the northwestern Gulf) noted for soft bottoms, and can notably alter the surrounding benthos independent of pollution effects (Montagna et al. 2002). The increase has been dramatic since the first rig was placed in 1942 (Pulsipher et al. 2001). Systematic surveys funded by the Minerals Management Service (MMS) have found a variety of species commonly associated with coral reef systems. While not all OPPs are located in regions favorable for coral reef species, there

clearly is now a subset of coral reef species, both invertebrate and vertebrate, in a region where they would previously have been very rare or non-existent.

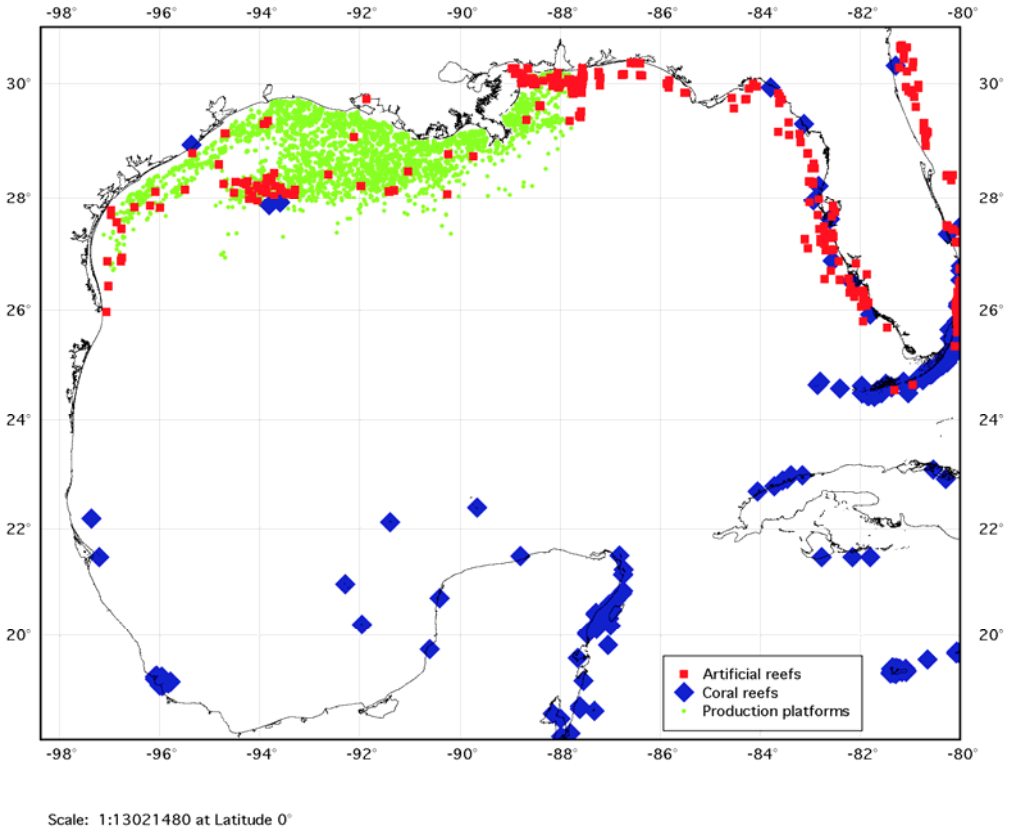


Figure 4. Coral reefs, oil production platforms and artificial reefs. Coral reef data from ReefBase, oil production platforms from MMS, and artificial reef data from state websites. The map was generated using PANMAP.

There are biological consequences that stem from this habitat alteration. Tagging data available from Fishtrackers, Inc. (Corpus Christi, TX) indicate that barracuda can traverse the entire width of the Gulf of Mexico. While only 4 of 432 fish were recovered, three of these fish had migrated from Texas to Florida waters, or vice versa (Fig. 5). Barracuda are structure-oriented species that migrate in response to seasonal warming (De Sylva 1963). While they are reported from the older literature from Texas and Louisiana (Colby 1943), OPPs are remarkable for the size and number of barracuda around them. Spearfishers regularly report dozens of fish around rigs. Given the natural history of barracuda and the tagging data, it is reasonable to conclude that OPPs have provided a novel means ("stepping stone") for barracuda to easily move in the waters of the western Gulf of Mexico. It is likely that other large, mobile predators do the same. With eddies introducing flora and fauna, coastal currents moving species from rig to rig, and fish migrations, it is hard to ignore the potential for OPPs to provide significant genetic exchange with regions as far away as the FKNMS. The MMS has called the oil fields of the northwestern Gulf the largest artificial reef complex in the world (Dauterive 2000). The artificial reefs in the Gulf expand this complex even further and provide a ring of structures around the Gulf (Fig. 4).

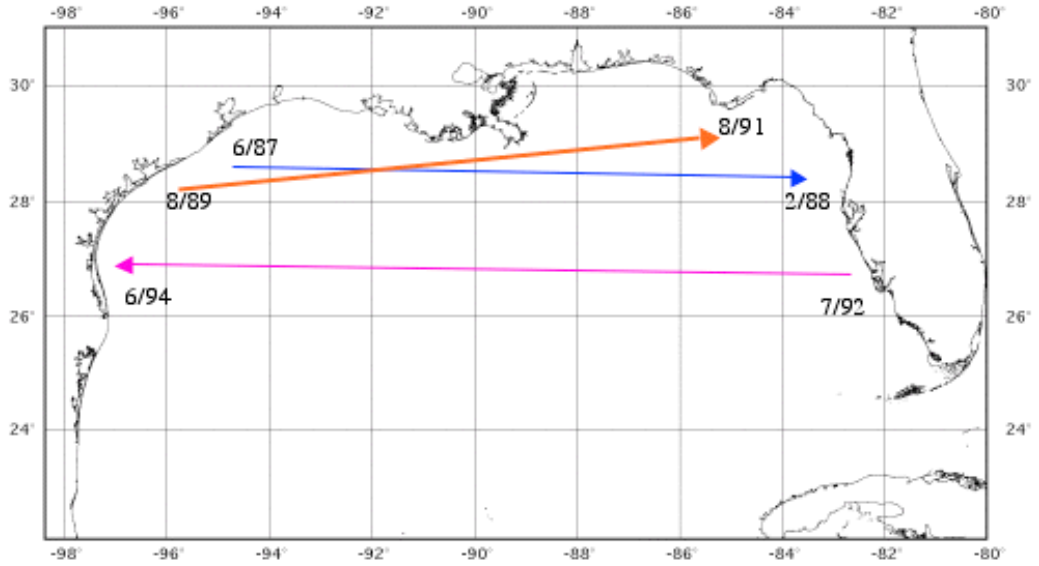


Figure 5. Movement of tagged barracuda across the Gulf of Mexico. Tags were implanted by recreational fishers. Data from Steve Qualia, FishTrackers, Inc.

There are implications for human health from these east-west linkages. Ciguatera is a disease that occurs when humans consume fish containing ciguatoxin and is endemic in coral reef systems throughout the world (Lewis 2001). Ciguatoxin is produced by the dinoflagellate *Gambierdiscus toxicus*, a tropical species that occurs in coral reef ecosystems, and is concentrated in upper level predators by food-web amplification (Fig. 6).

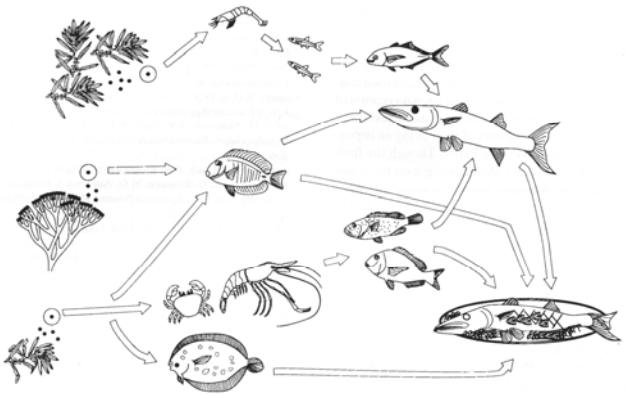


Figure 6. Ciguatera food web showing the food web amplification of ciguatoxin from the source dinoflagellate. After Kelley et al. (1992).

There is no clear historical record of ciguatera in the northwestern Gulf, although early workers were aware of the disease (Colby 1943). The disease has been reported from the tropics for centuries and the temperature range of the northwestern Gulf falls within a moderate risk category (Pottier et al. 2001). Both Texas and Louisiana have reported cases of ciguatera in the past 20 years (Inst. of Medicine 1991), although only the Texas case is known with certainty to have originated from an OPP (Bogart and Perrotta 1989). Several additional cases have surfaced recently and were associated with locally caught fish (Villareal et al. 2006). In a recent survey for ciguatoxin in Texas barracuda (Villareal et al. 2007), 2 of 20 barracuda tested positive for ciguatoxin at trace levels (< 0.15 ppb). *G. toxicus* has been found on all OPPs examined. While it cannot be said with certainty whether the species came from the south (Mexico) or the east (Florida), it is clear that new habitats of man-made

origin are spreading components of coral reef species around the Gulf of Mexico in ways that did not exist a century ago.

In summary, a variety of global and regional processes link the FKNMS and the Gulf of Mexico. These range from global scale phenomenon such as dust clouds traversing the Atlantic Ocean to fish movements around the Gulf. The Sanctuary exists in the broader environment of the Gulf of Mexico and is not independent of this larger regional context. For many of these linkages, it is not clear how they affect the Keys, or whether the Keys are source or sink.

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Connectivity of the Coastal Waters Surrounding the Florida Keys National Marine Sanctuary

Elizabeth Johns, Peter B. Ortner, and Thomas N. Lee

NOAA's South Florida Program (SFP) has provided sustained interdisciplinary observations of the interconnected marine ecosystems of South Florida since 1995. The scientific goals of the SFP are:

- To yield greater insight into the complex coupled ecosystems of South Florida coastal waters
- To provide real-time current and water quality data to support and validate regional circulation models
- To monitor and understand the causes of physical/chemical/biological "event scale" variability in South Florida coastal waters

Figure 1 shows a schematic of the major regional currents, the Loop Current/Gulf Stream and the Tortugas Gyre, as well as the SFP sampling regime as of 2005. The regional scale bimonthly survey track, conducted using the University of Miami's larger coastal research catamaran the *R/V F.G. Walton Smith* (Fig. 2), is shown in black. Monthly survey tracks for Florida and Biscayne Bays, conducted using the University of Miami's small research catamaran the *R/V Virginia K* (Fig. 3), are shown in blue and red. Shipboard measurements include temperature, salinity, chlorophyll fluorescence, light transmittance, and nutrients.

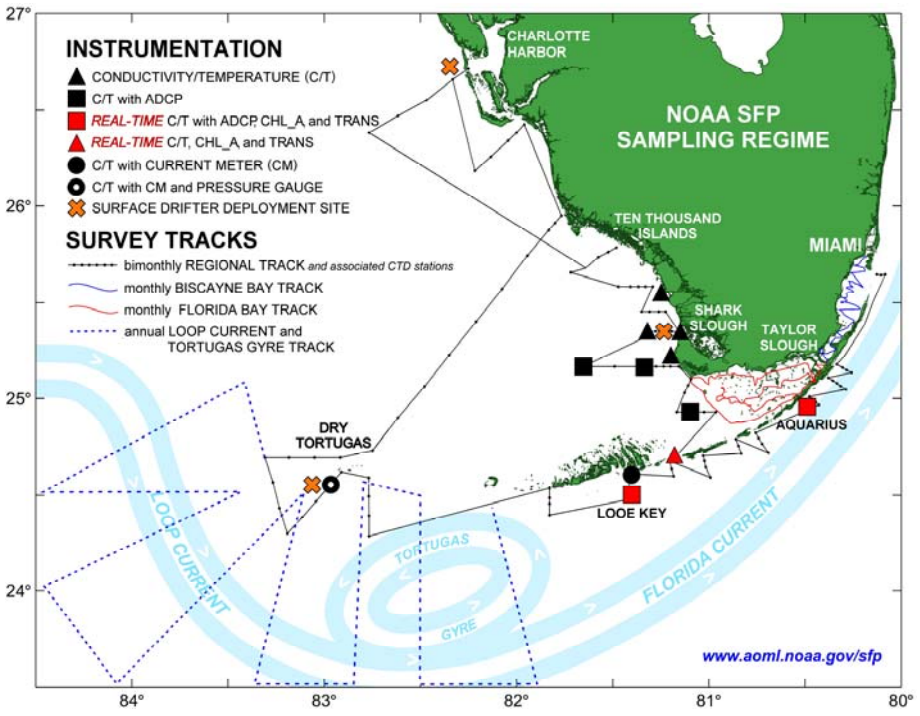


Figure 1. Diagram of major regional currents, the Tortugas Gyre, and instrument locations and cruise tracks.

Figure 2. *R/V F.G. Walton Smith.*

Figure 3. *R/V Virginia K.*

Figure 4 shows a representative salinity map from a survey conducted in February 2004. Lower salinities along the southwest Florida coast and in Florida and Biscayne Bays are indicative of freshwater sources in the Everglades. A direct connection between the mouth of the Shark River and western Florida Bay is evident in the salinity pattern. Figure 5 shows a salinity map from a Florida Bay survey conducted in October 1999 after the passage of Hurricane Irene. Point sources of freshwater are evident along the entire northern coast of Florida Bay. Figure 6 shows a similar salinity map from a monthly survey of Biscayne Bay, conducted in July 2002. The freshwater influence of the numerous canals transporting water from the South Florida peninsula into the Bay is apparent in this map. Maps such as these shown, as well as data files, are posted regularly to the SFP web site at www.aoml.noaa.gov/sfp/data.shtml.

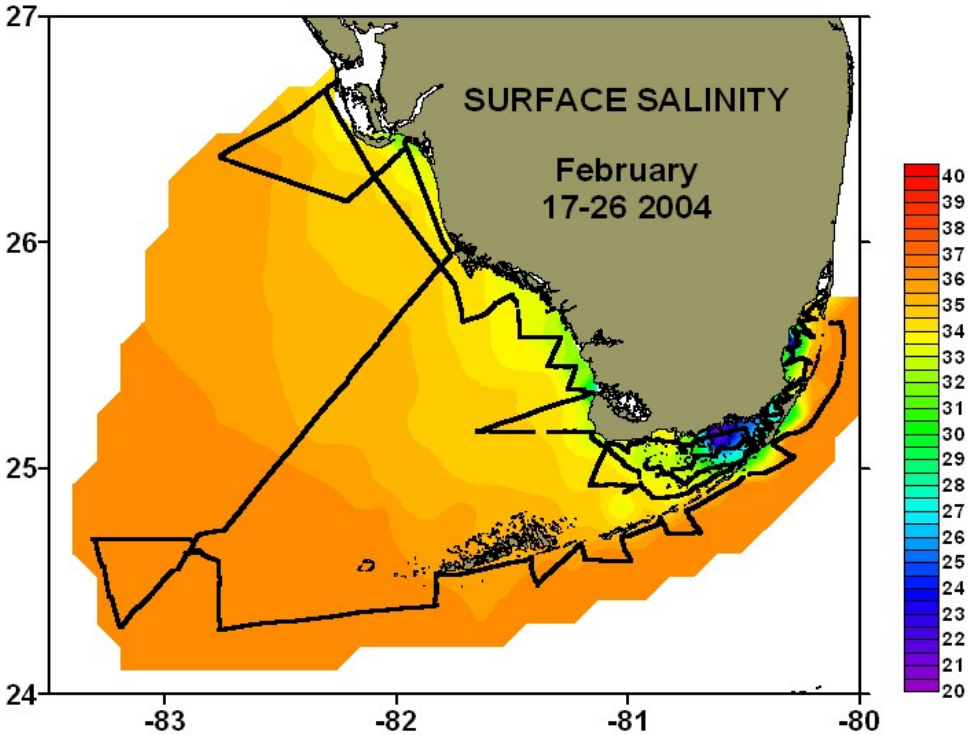


Figure 4. Surface salinity measured using a flow-through thermosalinograph during the February 2004 bimonthly 10-day survey. Fresh-water sources along the southwest Florida coast and in northern Florida Bay are evident.

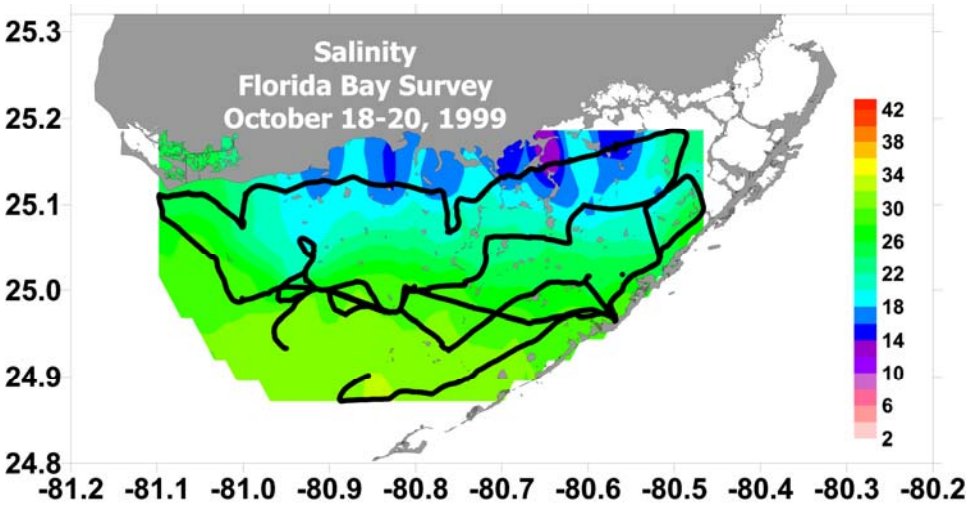


Figure 5. Monthly, two-day inter-disciplinary surveys of Florida Bay, initiated in 1996, provide a history of inputs to the Bay. This survey revealed low-salinity areas following the passage of Hurricane Irene.

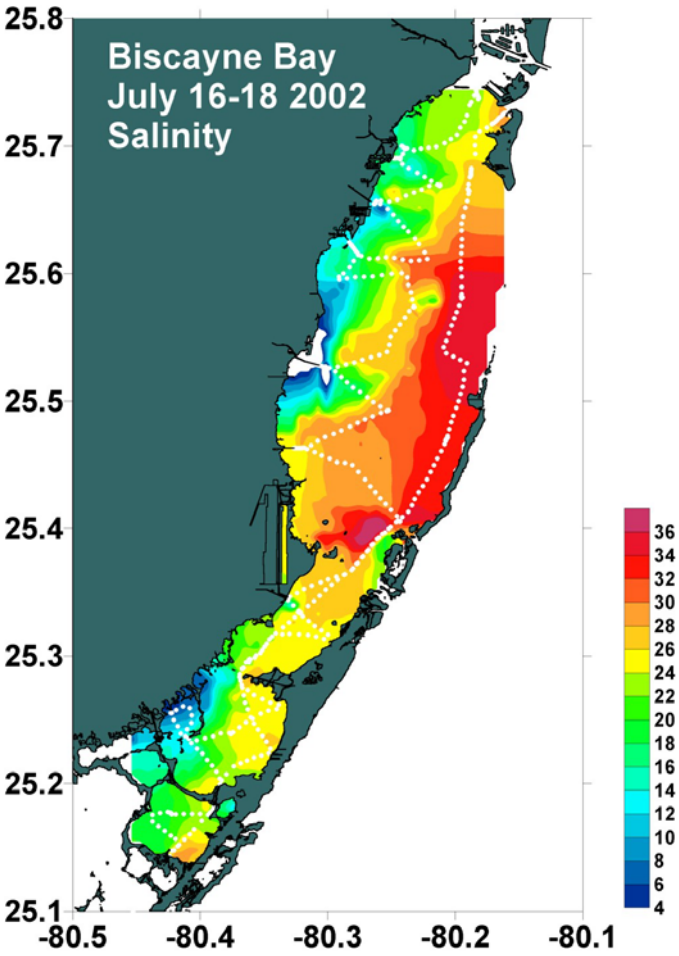


Figure 6. Similar monthly interdisciplinary surveys of Biscayne Bay were initiated in the summer of 2002. The one-day survey track is designed to resolve all significant freshwater inputs along the western shoreline of the Bay.

In addition to the hydrographic cruise data, satellite-tracked surface drifters (Fig. 7) are deployed at three locations marked on Figure 1. Figure 8 shows a set of seasonally representative drifter trajectories, indicative of the predominantly wind-driven subtidal currents in the region. These trajectories demonstrate the direct upstream connection between the coastal waters of the southwest Florida shelf, Florida Bay, and the FKNMS, as well as the downstream connection of the FKNMS with the U.S. east coast via the Loop Current/Gulf Stream system. Figure 9 shows a closer look at a drifter that was deployed at Riley's Hump in the Dry Tortugas in August 2002. This trajectory clearly shows the Tortugas Gyre. Gyres such as this are believed to be very important for the retention and dispersal of larval fish, spiny lobster, and shrimp because they allow the larvae to remain in the vicinity of the nursery grounds for longer than they would if they were entrained directly into the Gulf Stream. Drifter data and trajectory maps are posted automatically in near real-time to the SFP web site at www.aoml.noaa.gov/sfcoo/SFP_drifters. The accumulated data set provides a clear demonstration of the connectivity of the waters of the FKNMS with remote upstream and downstream regions.

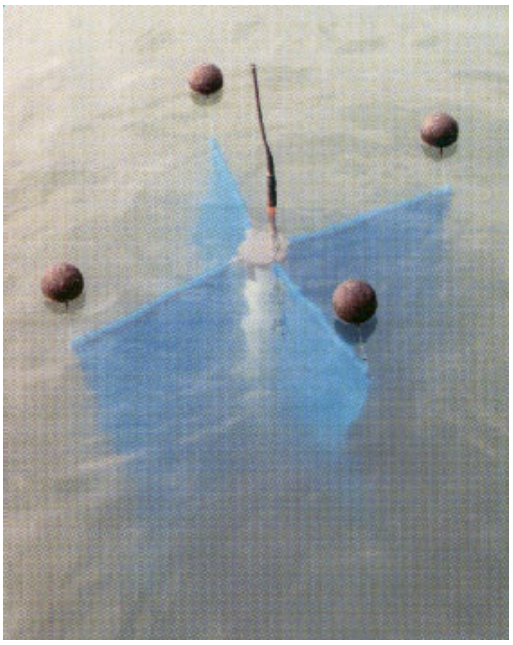


Figure 7. Satellite-tracked surface drifter. Drifters are deployed during bimonthly cruises off the southwest Florida coast near the mouth of the Shark River and at Riley's Hump, in the Tortugas South Ecological Reserve. Drifters are also deployed during events such as red tides off the southwest Florida coast.

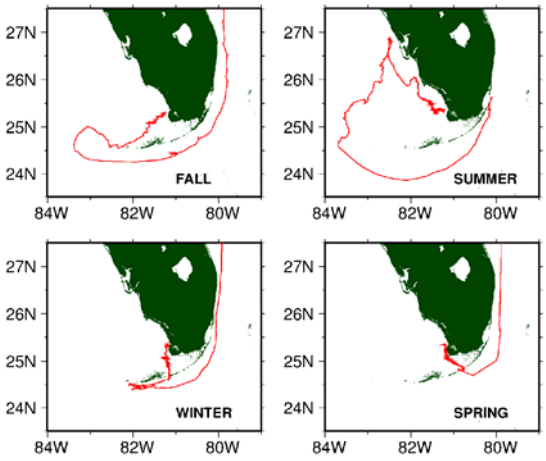
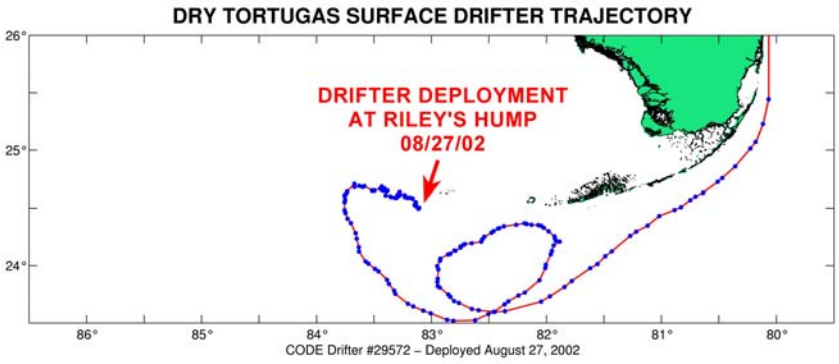


Figure 8. Representative seasonal trajectories of satellite-tracked surface drifters

Finally, a key element of any Coastal Ocean Observing System is a network of real-time, in situ oceanographic and meteorological instruments. As part of the South Florida Program, several real-time moored oceanographic stations have recently been added to the existing array of meteorological and oceanographic sensors in the FKNMS, and more are planned. Real-time data from the moored array are automatically posted on the SFP project web site listed above.

Figure 9. This drifter was deployed at Riley's Hump, in the Tortugas South Ecological Reserve. After slowly drifting to the northwest, the drifter became entrained in the Loop Current, made one transit in the Tortugas Gyre, and then rapidly exited the area in the Florida Current.



The real-time moored array consists of several elements:

(1) A spar buoy located at Looe Key (Fig. 10) records current profiles over the water column as well as surface and bottom temperature and surface salinity. The location of the Looe Key station is ideal for monitoring the Florida Current as it meanders closer to the reef, and also for monitoring reverse (westward) flows associated with eddies and countercurrents. Extreme events such as the passages of tropical cyclones are also clearly evident in the Looe Key record.

Figure 10. Spar buoy at Looe Key.

(2) A station at Moser Channel under the Seven-Mile Bridge (Fig. 11) records temperature, salinity, and water quality parameters such as light transmittance and chlorophyll fluorescence. This station is critical to monitoring any flows of southwest Florida shelf and/or Florida Bay waters as they move through the Keys passages toward the coral reefs of the FKNMS. When coupled with estimates of current direction and magnitude through the passages derived from sea level and wind data from nearby C-MAN stations after calibration using current meter and shipboard data in the passages, a tool for monitoring these possibly harmful flows in real-time becomes a possibility. Another station similar to that located in Moser Channel is planned for Long Key Channel and will be used to examine any significant differences between the flows through the two passages.

Figure 11. The Seven-Mile Bridge location for real-time temperature, conductivity, and fluorometry sensors. Communications are via cellular phone technology, with data delivered directly to a web server at AOML. These observations provide continuous water quality data to be used in conjunction with real-time, sea-level-derived transport through Keys passages.

(3) In collaboration with NOAA's National Undersea Research Center (NURC) and the University of North Carolina at Wilmington (UNCW), the undersea laboratory "Aquarius" located in the coral reefs off Key Largo, Florida (Fig. 12) will be instrumented with temperature, salinity, water quality, dissolved oxygen, and current and directional wave sensors. Data from the Aquarius station will be made available to the numerous coral reef researchers who conduct studies in the area. The data will also be presented at an expanded web site that takes into consideration the needs and interests of the commercial and recreational fishing, diving and boating industries, educators, and the general public.

Figure 12. NOAA's *Aquarius* buoy and underwater laboratory.

Recognizing the importance of real-time data availability, future plans for the evolution of the SFP into the South Florida Regional Observing System (SF-ROS) include:

- Additional water quality and wave height instrumentation at existing real-time locations
- An expanded network of real-time oceanographic moorings in the Dry Tortugas, in the FKNMS, along the lower southwest Florida shelf, and in Florida and Biscayne Bays
- Increased rapid-response event sampling cued by real-time mooring/platform data and satellite sea surface temperature, ocean color, and altimetry

Real-time observations such as those described here are critically important for monitoring the often complex and inter-related oceanographic and meteorological events that occur in South Florida marine ecosystems, and also for assisting with NOAA's goal of science-based resource management of the FKNMS.

Panel Discussion

Keller: Thank you very much Libby. I would like the four panelists to please come up to the table. It is quite clear that this is a data-rich area, just from this first panel, and furthermore, a lot of those data are becoming more and more publicly accessible, which I think is really significant. What we would like to do now is have about 15 minutes where the floor is open for any questions for the panelists. Richard.

Richard Grathwohl: Dr. Johns, I am Richard Grathwohl from the Marathon Guides Association. I take a lot of customers from up around Ft. Myers and Naples, and they say that when pulses of water released from Lake Okeechobee flow down the Caloosahatchee River, they have seen seagrass die, mangroves die, and they have also seen manatees die in the river. I wonder if – are we going to be able to monitor these pulses when they come out of Okeechobee?

Johns: Yes, we do have plans to do that. We have done one or two follow-up event cycles, maybe two years ago, when there was a planned release because they were concerned about the level of the lake. We took a small boat up there, did some surveying, and put a drifter in there. We thought we had the timing right, when the water was going to come out. This is kind of a tricky business; there is a lag, of course. We had been working with the people in the South Florida Water Management District and also USGS, and we all thought – it was a little bit disappointing that one time – but the concept is definitely to be able to go out and respond to exactly that type of event. We have a few extra drifters sitting in the warehouse, so we are able to throw one in unexpectedly. Perhaps we ought to get into communication with a wider group of people who can call us up if they have something. We want to get a shorter time frame for the alert part of this whole business. We all go to meetings about this constantly. I think we are getting closer to being able to do that.

Kelly Rankin: Kelly Rankin from the Stevens Institute. We were going for New York Harbor, and we initialized some modeling, collecting data, trying to get it real time. What we found was really helpful, and that was putting instruments on ferries, doing transects across the Hudson. Is there any effort to do that?

Johns: That is a great idea and in several areas it has been successfully used, and we do collaborate with the University of Miami on a cruise ship, the *Explorer of the Seas*, which has a full suite of oceanographic and meteorological instrumentation. But I am not aware of any ships of opportunity in the area that we are talking about that could be used that way, like a ferry or anything like that.

Muller-Karger: Yes, definitely. In the New England area they have done this a lot more, we are now taking advantage of this, too. The *Explorer of the Seas* is one example and there are several gambling boats [laughter] that go out in federal waters every day, and they spend quite a good part of the day there. We are trying to work with them and see if we can use them as a platform.

Rankin: We just found it was a really good control for capturing events, and that it was easier than using fishermen.

Muller-Karger: What we need, of course, is a sponsor, and we are hoping that the gambling industry themselves [tittering] will help.

Keller: I wanted to ask, I'm not sure, maybe Dr. Hu: the fact that apparently there have been blackwater events going on – we knew about the one that occurred more than a century ago with reports from the Dry Tortugas. Why such a massive, in-your-face phenomenon, occurred for so long with not much public notice until just a couple of years ago? Any ideas?

Hu: I cannot say for sure, but I believe that one of the reasons that we didn't see this event as intense up until now – and that was one that caught a lot of public attention – we know we have seen dark water patches even before that, but they are so short-lived and they are not usually that intense and that big. We have a time series from 1978 to 1986, and I think the answer is that people saw this earlier, and it will happen offshore.

Keller: That was probably an unfair question [laughter], but I also wanted to ask Tracy – the information on the movements of those three barracuda was fascinating. Is there anything in place to perhaps get more tagging for barracuda, or something, to find out more about that extreme east-west exchange?

Villareal: No, I think these were largely fortuitous data. This is a program sponsored by the Texas Department of Wildlife, mostly looking at the important recreational fisheries, red drum and the local fish. The fishermen enthusiastically just tagged everything that they could catch [laughter]. I think that for this to be replicated you would need a lot more training and specific handling techniques for these large fish, because they don't like being caught, they don't deal with it very gracefully. The short answer is no, there's nothing else in place.

Roger Griffis: I am Roger Griffis with the NOAA Coral program. I was fascinated to see these regional connections with the imagery there – it is so powerful, but that's a different question. I wanted to ask you – this is for the Gulf of Mexico – about the connectivity issue for larval transport, which is so important. Are there similar regional efforts south of here? You have mentioned the Gulf and the Atlantic, but are there other comparable efforts going on in other nations?

Muller-Karger: I can't give you a short answer to that. There are some efforts going on. The Mesoamerican Barrier Reef is the focus of at least a couple of very large World Bank funding efforts in trying to develop monitoring systems, and at least a modeling system that Libby talked about for that area between Jamaica and Honduras and the Yucatan peninsula, and there are other models. In terms of having an observing system that has physical and especially publicly available real-time information outlets, that doesn't exist right now. We are trying to get – the Intergovernmental Ocean Commission has tried to do this for many, many, many years. The IOC, the IFRE, the regional entity – they have been talking about doing this for at least 10 years, and it has been very difficult to organize the region into doing this. We are making some progress, but we are not there yet, by a long shot. I think also, one of the two things that needs to happen, and is actually happening, at least in words, is that NOAA and EPA and the State Department put together the WhiteWater2BlueWater effort. That is exactly the kind of thing that WW2BW should do, but I have no idea what has happened since that meeting in Miami. They have the right idea; they need to put their money where their mouth is.

Keller: Alright, thank you very much to all the panelists [applause]. The next panel, on fishing, will occur right after the break. We might hear a tarpon story that matches the barracuda story, so we will welcome you back in about 10 or 15 minutes.

Connectivity between People and Marine Fishery Resources

Moderator: Joanne Delaney

Connectivity between People and Marine Fishery Resources

Jerry Ault, Sandy Moret, Doug Gregory, Doug Kelly, and Jim Bohnsack

Joanne Delaney
Connectivity between people and the marine fishery resource. I just want to note that we have had a couple of speaker changes, so please note that you'll be hearing from Dr. Jerry Ault, who is going to spearhead things during this session, and then we'll hear from Mr. Sandy Moret. After that Doug Gregory is here from Sea Grant, then Mr. Doug Kelly is here on behalf of Mr. Tom Davidson, representing Bonefish & Tarpon Unlimited, and lastly we'll hear from Dr. Jim Bohnsack with NOAA Fisheries.

Jerry Ault
Thank you. I'm Jerry Ault. I thought it was a great prelude to talk about the physical and early organic interconnections that exist in the Keys. What we really want to talk about today is the higher order of organization of connectivity, and it involves people – humans, who think we are the most organized of all, and marine resources, which have a base of understanding that has existed in time and space much longer than any of us can think about. Fishes appeared over 300 million years ago in the geological record. Our scientific sampling of an entire year is like a speck of dust, and so gaining perspective about resources is a challenge.

I am going to draw on human connections through time, that is, reef fishery use. Exploitation of the reef fishery ecosystem goes back at least to Native Americans, the oldest records we have, so thousands of years of use that are beyond our direct knowledge. Secondarily, within the last few hundred years, folks came down to the Keys from New York, Chicago, etc. in the 1800s, writing about how beautiful this resource was – the first intrepid explorers. Flagler and his friends made sure that we had access to it. The other thing is the connections that have been written about by some of the most famous writers of all times, Zane Grey, Ernest Hemingway, etc. really extolled the virtues of this place. So the connection between people and resources goes a long way back and it is a value system. It is a system that is valued not only around the local region, but around the U.S. and around the world. It is a focal point for energy consumption and sustainability.

The issue comes to numbers. An earlier speaker talked about the numbers. These are real numbers generated by the NOAA economics group that looked at the reef fishery – reef system, and of course it involved fisheries, tourism, etc. The South Florida coral reef generated 71,000 jobs and $6 billion in U.S. economic activity in 2001. That's a mind-blower – these are large numbers and they are significant. They also contributed to the designation of Florida as "Fishing Capital of the World" by the State legislature for very obvious reasons. There is a rich mix of species across a broad range of habitats within the ecosystem that generates significant social and economic well-being that the State thinks is a big deal. But the problem I think that we are going to be talking about in this session is the goods and services that we derive from the system. I think that Elliott did a very nice job of laying out problems – ecosystem goods and services are threatened by increased exploitation and environmental changes from what we perceive and realize are a rapidly growing human population that *loves* Florida as much as we do.

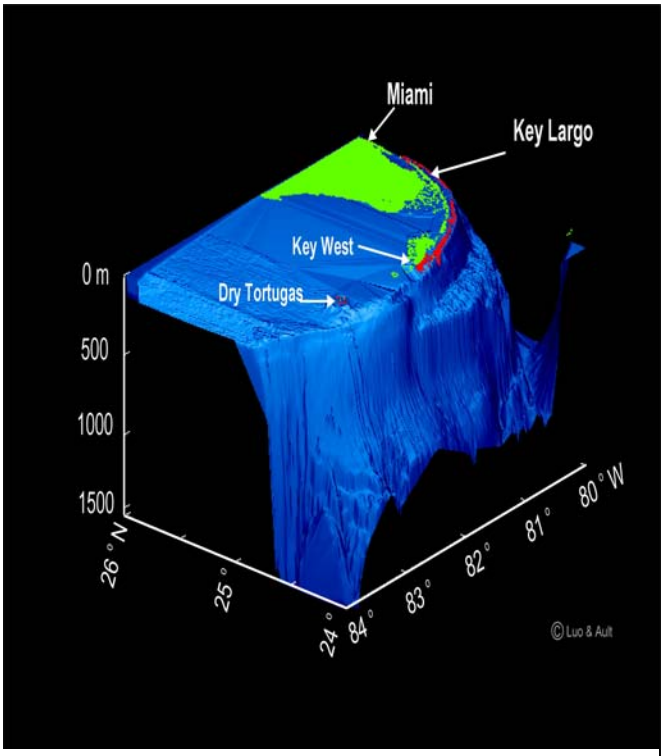


Figure 1. Vertically exaggerated bathymetry of South Florida, showing the Florida Reef Tract (red) extending from the Dry Tortugas to south of Miami.

Now I have my Reader's Digest version of everything we have heard [laughter] so I am going to do something a little bit different. There is a little bit of something for everybody – the geologists, the physicists, the biologists, the anthropologists. But one is the geology of Florida, which is very unusual and very steep (Fig 1). We are basically up on an escarpment as the ocean flows around us and it is not always intuitive that is the case. The living coral reef system starts near Miami and runs all the way to the Tortugas. For the coral reef ecosystem everything is interconnected, the nexus of physics, biology, chemistry, etc. The physical environment for this system, which includes the Loop Current that comes around the Tortugas, is very rich, for reasons that Frank and others talked about. The dynamics of this major reef ecosystem that we have modulated over the last hundred years is an essential part of why we have such incredible productivity. Nutrients coming off the land side and mixing with coastal waters along with abundant and diverse habitats for animals together create a luxuriant environment that extends all the way from land through the deep coral reef. The wildlife includes everything from largemouth bass to billfish. South Florida is an incredible place.

The physical environment itself, of course, sets up the conditions, and animals know when and where to spawn and ensure survivorship. The connection from inshore to offshore – when we think about most of the biomass on the reef – the reality is that this loop, this conveyor belt of biology that sends things, particles down the system, back to the inshore areas where they mature to come back to the reef system, and the cycle goes on and on. So breaking that down is a big problem for the fisheries, and here is the wall of humanity (Fig. 2), the concrete jungle that exists, one of our big problems, 6 million people (Fig. 3), probably going to double in 17 years. This is South Florida. The population is 16 million state-wide. There are a million vessels state-wide, a quarter of those in South Florida (Fig. 3). Big problem, big issues.

Figure 2. Satellite image of South Florida showing the greater Miami area to the southeast.

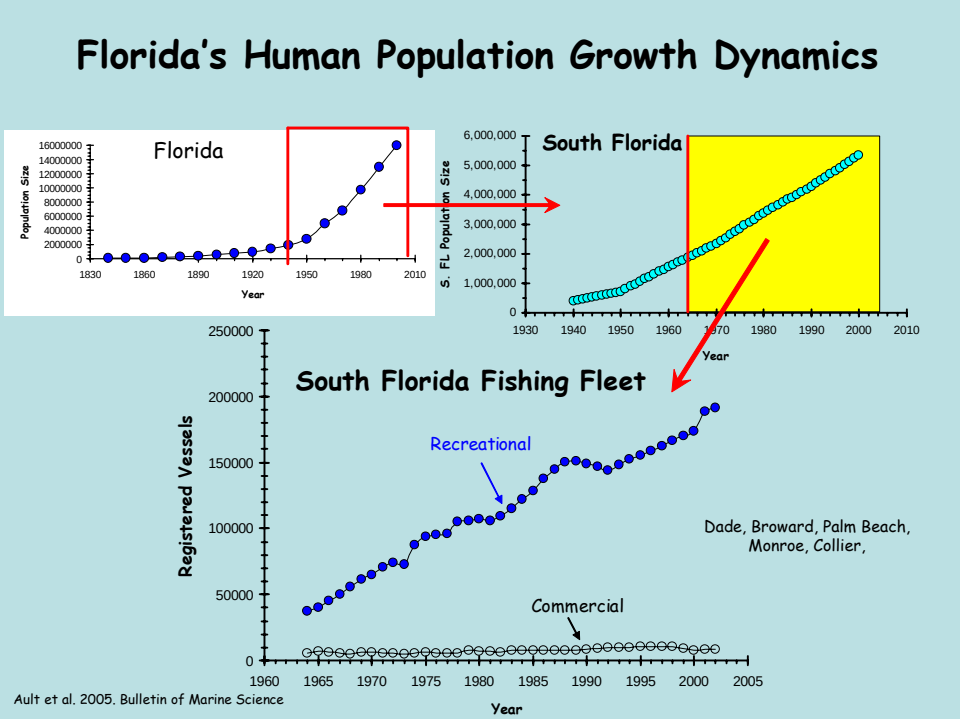


Figure 3. Growth in Florida: the human population statewide (upper left) and in South Florida (upper right), and the recreational and commercial fishing fleets in South Florida (bottom).

What we are going to talk about today, having said all this is really think about the ethic that is required to move forward – to sustain resources, to sustain the use, not to exclude the use, but to sustain the use that connects people to those resources. We are going to cite the Keys, and I am going to show you a bunch of beautiful slides that connect the animals and the people to the environment. What we really are trying to focus on are new approaches, and those approaches are going to ensure a state of sustainability. I want you to understand why it is so important to build our knowledge, both ecologically and economically, and our speakers going to try to bring those ideas forward. We are also going to explore the interconnections between these valuable fisheries resources both within the South Florida marine system itself and within the broader Gulf of Mexico and northern Caribbean, at least.

First, I wanted to stop and say "Elliott, you had a big black grouper, but I've seen bigger ones" [manic laughter] and that was actually just a couple of months ago, so they are still around. There is an incredible group of fish – grouper, hogfish, jewfish (goliath grouper), permit, and others – all of which are highly sought after, and form the economic basis of the system. An interesting thing about connectivity – we keep thinking about physical transport of larvae and we keep forgetting that larvae turn into adults, and it's all about migration.

The tarpon fishery for two centuries has been focused in Florida, the "center" of the fishery, but in fact Florida is a kind of stop-over in a larger circuit. We have been doing satellite archival transmitting tagging, in which we basically put a small computer that communicates with a satellite when it pops up off a tarpon, or at least you get a point. Our most exciting recent pop-off, this is where funding, funding, funding is so important, Brian, I've heard you talk a lot about it [laughter], the point is that this is not cheap work. It costs about $1300 a tag, but the information you get is extraordinary. The tag archives data, by the minute, on temperature, depth, and position and you can put other sensors on the device. What I want to point out to you is the connections. The short story is the Carolinas are connected to Florida, on this side, Florida is connected to Louisiana, and Veracruz, it turns out. We just had an animal swim from Veracruz that was tagged in May that popped off last week in Pine Island, LA [wows]. That's a long distance, about 1200 miles. We also

recorded an animal that swam about 700 miles from Veracruz to Padre Island National Seashore in 28 days. That is 30 miles a day, ladies and gentlemen [wows], so when animals want to connect, they connect.

The other point I want to make is that the only place in U.S. waters where we find juvenile tarpon is in Florida. No other place in the U.S., but we do find them in Mexico. The conundrum is – we catch and release tarpon in Florida, they catch and consume tarpon in Mexico, Cuba, and other places. So an industry is at risk in the Keys by these interconnections between them.

Another problem we have documented is serial overfishing, in which people first have taken the longest, largest, most vulnerable animals and wiped them out and then have moved down the resource chain (Fig. 4). Black grouper, for example are at least 5-10" short of the size they could reach, red grouper are at about 40%, and then we basically move into the snappers. We are fishing down the food chain if we continue this exploitation rate. This is an issue. So the fish and I are both asked, is it primarily the responsibility of people to maintain the systems, and the connections and the functionality of the process? That is really what our speakers are going to go through today: perspectives on that process, where we are all part of the problem and therefore need to be part of the solution. I hope that we uncover some of those issues that allow ourselves to understand more completely how humans and resources are connected together. So our speakers, basically in order: Sandy Moret will represent the recreational/industrial side, Doug Gregory will talk about commercial points of view, commercial fisheries, Doug Kelly will represent the public perspective, and then Jim Bohnsack will really define the environmental ethic/ocean ethic we have been groping for.

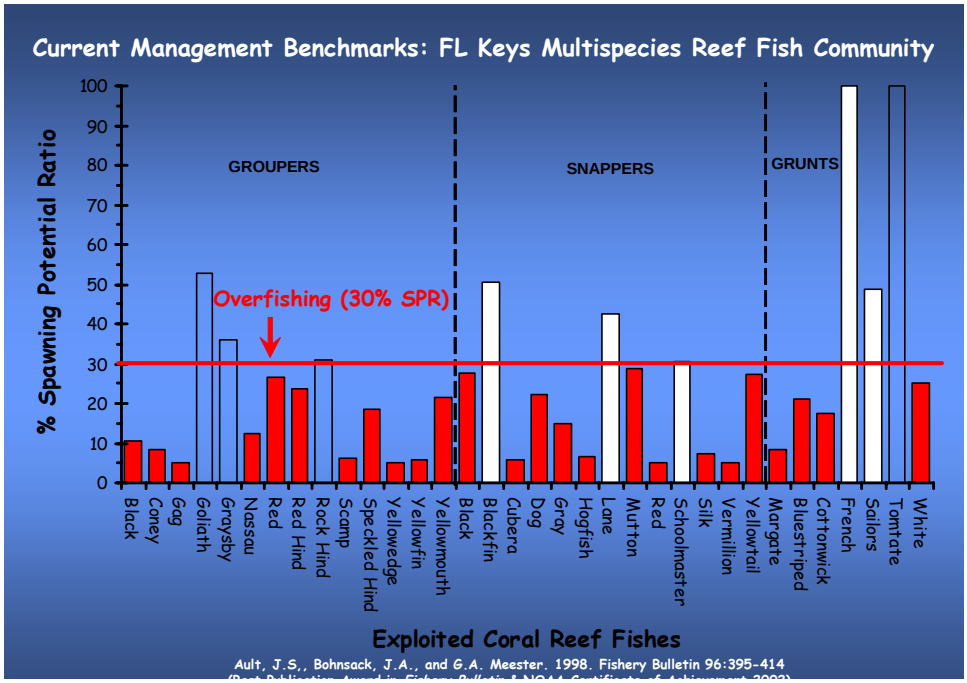


Figure 4. Serial overfishing in the Florida Keys, where most grouper and snapper species are heavily overfished.

Our first speaker, Sandy Moret – probably everybody knows that Sandy is the most famous fly fisherman in the world, an international celebrity, who is shown on just about every Saturday TV show you have ever seen about fly fishing. He runs Florida Keys Outfitters in Islamorada, which is the center of global bone fishing, where 75% of the world records come from. Sandy really has great respect for fishing. [applause]

Panel Discussion

Sandy Moret

Thank you, Jerry. Has everybody been bone fishing in the Florida Keys and caught bonefish on a fly rod? Has everybody caught one? [no] I moved to south Florida in 1972 and had no idea what a resource that we have here, and in fact it was a secret, actually. There weren't a lot of people doing what is called sight fishing, and there were not a lot of people who knew about bonefishing, tarpon fishing, which was such a unique situation. With the clear water in South Florida and the Keys, you can position yourself, or get on a boat, take the motor out of the water, take a push pole, and pole and stall on the flats to look for fish. You see a fish, probably 30 feet away, 40 feet away, you take a fly rod, make a cast to it and throw a "chicken and feather" on a hook, and then you have to light it, manipulate the lure to make the fish bite. It blew my mind when I saw the opportunities here.

Over the years, people everywhere that are involved in fishing or have an interest in fishing have found out about sight fishing. It is unique, and many of the techniques and methods that are used throughout the world today were discovered right here in South Florida, in the Florida Keys on the flats here. There probably are 500 skiff guides; when I say skiff guides, I mean the guys that go out and pole the boats up and down the Florida Keys. There may be $40-50 million in guide fees a year, not to even mention the hotels, motels, airfares, restaurants, and my fly shop, where we have tackle and equipment and clothing now that's associated with being on the flats, being out in the heat. We have a school, where people come from all over the planet, right here in the Keys, to learn how to do this and take it back to wherever they have come from.

So we have such a unique situation, and the culture that has developed around the fly fishing industry – I don't just use a fly rod – you can use a spinning rod, and I'm talking mainly about the inshore fishery here. Besides fishing, there ate other things here that are very unique, found nowhere else on the planet. This is the only place where bonefish are so large. Everywhere else – the Seychelles, Yucatan, the Bahamas – there is great bonefishing wherever there are flats with waters at this temperature, but there is nowhere that has bonefish the size of bonefish in the Florida Keys. I

think at some point Jerry is going to figure out why, but we haven't figured it out yet. So, there are two giant fish – most of the world records are from here in the Florida Keys.

There is a corresponding fishery offshore; a group of guys that run big charter boats, and they fish offshore, sailfishing is a high-end activity here for part of the year. We are catching a few sailfish now with fly rods, which is a hoot [laughter], get them behind the boat and pull the teaser away with the hook in it, throw a fly out there and maybe he'll bite it and maybe he won't. They are sporty fish, too.

Most of the people that are involved in the industry, the guides, the captains, they have taken it upon themselves over the years to do a lot of things to steward this industry, or steward the resource. Back in the late seventies, early eighties, things here were just like they are in Mexico. We would have tarpon tournaments where a guide would take a charter out and catch a tarpon, kill the tarpon, and put it up on the dock at night, and that would be good advertisement to take your clients fishing. The next day you would have a tournament and bring it in and weigh it. All those things changed; we changed when we realized we couldn't do that and didn't want to do that. This beast is too magnificent, and all the tournaments now in the Keys, and most of the state, have gone all release format. It is very rare that anybody kills a fish. I think at one point, there were 5,000 tarpon killed a year in the state of Florida and last year there were maybe three and those were all world records. You have to buy a tag in advance, and that was put through and pushed through by the guides in the Florida Keys fishery. These people were very influential in pushing for a fishing license in the state of Florida – saltwater fishing license!

We always want to have more enforcement and more education and apply them; also in outreach and restoration. We started in outreach, with a protection association in the early seventies and merged later with the Coastal Conservation Association of Florida. We worked very hard on the regulations and with the Everglades National Park. So this fishery, this resource, is precious not only to people who come from all over the world, but to the people who live right here and work here and have stewarded it, and it's just a great thing. And if you haven't caught bonefish on a fly or a shrimp, you ought to try it. Thank you. [laughter, applause]

Jerry Ault
The next speaker will be Doug Gregory. He will represent the commercial perspective on fisheries. Doug is the Sea Grant extension agent for the Florida Keys, which represents the commercial industry in South Florida. They have made some significant strides to move things forward and Doug has been, I think, a real stalwart to connect education to the commercial industry.

Doug Gregory
Thank you, Jerry. I am glad to be here. I hope I don't disappoint you. I am not a representative of the commercial fishing industry, in fact I am the best proxy Jerry could find at the last minute, so.. [laughter]. One of the problems, I think, is that this year happens to be one of the best lobster-fishing years in the last five years, and we just had a hurricane pass through, so everybody is out tending their broken traps and emptying their full traps. I can, however, provide my views based on my experiences working with various fishing industries.

Do we need a new ocean ethic? Of course we do. What is it, what is it going to be? I think that is what you are trying to define here, at least for the Florida Keys. But whatever it is, it needs to be communicated. It needs to be communicated with the public if we are planning to talk about

anything more than speeding up the ongoing evolution of awareness among the fishing public, of the need to be more civil to the environment, particularly of the need to take a personal responsibility for protecting our marine resources. That is what I see as a major thing that could be accomplished here.

The connectivity between people and marine resources is most obvious in a place like the Florida Keys, and it is most obvious when you work with, and get to know the fishermen who make their living from the ocean, whether it is the commercial fishermen, the fishing guides, a charter boat operator, or a dive shop operator. They are directly connected, day-in and day-out. They know how complex it is. They spend their lives trying to figure it out. They have a direct input in their livelihood into trying to figure this out. Jerry asked us to look at what new approaches and foci are required to construe the longer term sustainability of resources, and to particularly look at the responsibility of people. So that is the direction I am taking on this.

To maintain critical ecosystem connections and functions, and, again, this is based on my experience as a SeaGrant marine extension agent, what we need are new approaches and foci in community environmental education. Fishery resources are most directly impacted, as we have seen in previous talks, by the act of fishing, by people. Here in the Florida Keys we have the greatest concentration of boats and fishing effort probably anywhere in the world, yet our fishery resources are not in as dramatically a bad shape as you might think. We have these impacts because of our population demands, and because of these population demands, fishing needs to be tightly controlled. That is why we have a myriad of size limits, bag limits, closed seasons, etc. So what we need is management, and what we also need compliance with that management, but we also need a marine community to go beyond simple compliance. Compliance is but an interim goal. We need the fishing public to develop a personal sense of responsibility toward stewardship of our marine resources.

What are the problems in achieving that? Management is one of those problems. Management is a change in status quo. Human beings, human nature tends to resist that change, especially if the reasons and causes for those changes are not well understood. Compliance and understanding can also be more difficult to attain in a rapidly changing regulatory environment. You may not be aware of this, but it should be recognized that here in the southeast United States the last 10 or 12 years have been a period of the most intense and rapid regulatory change in history, for the southeastern United States. For example, no less than 13 fishery management plan amendments have been implemented or discussed by the South Atlantic Fishery Management Council, and no less than 16 by the Gulf of Mexico Council, and that's on reef fish alone. We are not talking about king mackerel, lobster, shrimp, or the other species. So we have had this intense regulatory environment.

The new focus I see as the primary mechanism for increasing the involvement of fishermen and improving the sustainability of our resources is education. What may be needed are new approaches to community education. It is certainly not easy. For those of you who have tried it, it is not easy. I don't care how much publicizing you do, it is hard to get people to a workshop. I would dare say that very few people from the public who are not associated with a research effort, an environmental group, or an agency are here today, even though this conference was highly publicized.

So, how do we go about getting this new ethic? And I think Aldo Leopold is a good analogy to start with. He is one of the folk heroes of the environmental movement. He is also recognized as the father of wildlife management in this country, and he had a close connection with nature from childhood. He enjoyed going out into the woods. He enjoyed studying nature. But it took him half a

lifetime to develop his land ethic. It took him half a lifetime before he realized it was wrong to exterminate predators and that it was wrong to subject the land to the whims of industry. His land ethic developed in his fertile mind from a progression of experiences. Although he had a number of experiences that were clear moments of epiphanies, his land ethic gradually evolved from an accumulation of experiences and knowledge. We can't expect all of us in the general public to have that same knowledge and progression, and his was not that quick.

What is needed to instill a new ethic in the fishing public is a concerted effort to create these epiphanies, artificially, through education, but yet to recognize that education is an ongoing, cumulative process, that helps individuals increase their knowledge or awareness. I contend that education is the most effective means for creating or increasing the awareness, of the need to develop a new behavior or a new ethic toward our natural resources. Education is also the quickest way to instill an awareness of the need for people to take greater individual responsibility in respecting our resources. There is nothing revolutionary here, and I would say, just review your own growing environmental awareness and I know we tend to be impatient. Things can tend to be falling down around our ears, but it does take time, and I think that education is the only effective, long-term sustainable way.

An example of this, and a powerful example, in the power education has in the campaign to reduce litter alongside the highways. Probably no-one in this room would casually roll down their window and drop the remains of your Big Mac meal. That sounds horrible. However, 50 years ago this was regularly done – by everyone. Maybe we can make this someone else's responsibility. The government will clean it up. Some of you older baby-boomers in the audience will remember how highways looked in the fifties. There was litter everywhere. Virtually everyone was throwing their trash out the car windows. It was until the Keep America Beautiful campaign was launched that through a focused educational effort to create a slogan of an Indian crying, that we had to realize that we had to take individual responsibility for disposing of our trash. Somebody wasn't coming along in a car and picking it up for us. And now in retrospect it seems pretty stupid and callous and lazy to just toss your wrappers and cans out the car window.

Again, education takes time. We should not expect immediate results. More importantly, education without empowerment can quickly become a wasted effort. You have got to go beyond being busy at communicating, to trying to communicate or educate the person or the group, so that they pick up the banner and run with it. You don't have to continue to lead them. However, I think that education is the only means of guaranteeing a permanent, sustainable result, and is the only means for implementing any new ethic. Thank you very much. [loud applause]

Jerry Ault
Thank you, Doug – very sage words. The next speaker will be Doug Kelly who will represent the folkloric point of view. Doug is the executive director of Bonefish & Tarpon Unlimited, which is a grassroots organization dedicated to global preservation of highly sought after game fish that Sandy was mentioning. He is also president of the Outdoor Writers Association of America, which connects him clearly to the public through the written word. Doug.

Doug Kelly
Thanks Jerry. Of all of the introductions I have received, yours is the most recent and I really appreciate it a lot [belly laughter]. By the way, Jim Bohnsack and Jerry and I are opening up a school of ballet in Miami, but that's for another occasion and talk.

There certainly is good connectivity it seems to me in various ways. There is connectivity of certain species of fish and territories. Some fish stay on their natal reefs with site fidelity, while others migrate long distances. There is evidence, of course, of propagation of larvae by gyres and currents, and then I think Darwin demonstrated that there are closed ecosystems where evolution takes place. There is connectivity between various researchers and the public, including various user groups, and in that same regard we know that non-fishermen greatly impact the quality of fishing, by water quality, by projects of development, etc. So there is not just one particular group that uses the resource, but also a public concern on how we regulate that.

We have connectivity between researchers and governments. That is part of the work that we are involved in with Bonefish & Tarpon Unlimited, and I will talk a little bit more about that in a second. And then we have connectivity with fisheries resources and our economies, and Jerry had mentioned something about the $4 billion in South Florida from all resource users. There is an estimate of $6-10 billion in the state of Florida just concerning bonefish and tarpon use. That is a guess, and we are hiring somebody to nail down exactly, or close, to what that real figure is. The reason for that is that bonefish and tarpon specifically, as many of you know, have really received precious few research dollars. They are not considered a food fish in the way of snappers or groupers or tunas or dolphin, etc. So, it is important for fisheries managers and the government to realize that just because it doesn't end up on a plate, it's still extremely important to the economies of the states, and for that matter of different governments.

Let's for a moment think that there are very few bonefish and tarpon left, say, in the Florida Keys. The impact would be enormous. Besides the fact that hundreds of guides would be out of work, there would be an impact to hotels, restaurants, bars, tackle shops, fuel, and marine supplies – from guides who purchase them, boat rentals, taxis, tourist attractions, retail stores, craft and souvenir makers, marinas, and on and on and on. So it really behooves us to approach fisheries management in a very thoughtful and careful manner, and make sure that we have the maximum cooperation from everyone, from all different groups.

I haven't seen that over the years. There has been a lot of conflict and divisiveness, and I think a lot of us have to put our hearts in the right place, do what we think is best, sacrifice if we need to sacrifice, and lo and behold, commercial fishing has certainly sacrificed over the years. Recreational anglers have accepted many restrictions and bag limits and size limits and tags and things, etcetera, etcetera and we have to go through it. If that is not enough, we have to go further. One of the ways that I am seeing cooperation is through an organization that I am very proud to represent. I bring it up not as a sales pitch to you, but as an example of cooperation.

Many people may know my opinion of the no-fishing zones – I've got some great reservations about them. But in the work with Bonefish & Tarpon Unlimited, Billy Causey is one of our founding members, Jerry Ault is our leading research scientist, Sandy Moret – we have hundreds of people with whom we work for our common goal and that is to improve these two particular species; hopefully others will step forward with their own concerns about species and become champions of those as well. But what does it do? What is it we're involved in? And this goes back to connectivity. Jerry was talking about our fish tagged off Veracruz that ended up in Louisiana. Well, what relevance is that?

Let me give you an example. If in fact the tarpon that we catch at certain times of year off of the Gulf Coast or the east coast of the United States around Florida of course, are the same fish that are also migrating at certain times of the year to Mexico, Guatemala, Belize, Honduras, and those areas. Many of those countries unfortunately are not as enlightened about catch-and-release. As a matter of fact, many of those fish are killed, for something – a 200-pound fish for a dollar to sell to a farmer who macerates it and uses it for fertilizer. This is actually going on. They catch the fish, spear them, hook and line them, net them, and they will sell them to restaurants. They will sell them as anything. Most people don't know the difference between snapper and grouper. Well, Billy Causey knows, but most people don't [laughter]. And it's a problem. These are fish that never make it back to our shores, which impacts our tourism. If we with our tagging studies can go to our legislators, our lawmakers and say "Hey, look, we've got – not anecdotal information – we've got tagging data supplied by Dr. Jerry Ault and others, and it is…" They can then go to these different governments and say "Look, you know that $25 million a year appropriation for tourism that we give you? You don't get it because you are hurting our tourism unless you're doing something about your tarpon resources." Money talks. If you just go over there, and Sandy and Billy Pate and different people have gone to these different fisheries managers in some of these countries and they nod their head, and as soon as you walk out the door they forget it. Nothing happens.

So, this connectivity between fish habits, where they migrate, where they spawn, is directly relevant to the health of those fisheries and what we can do about it. It requires a very proactive approach. I am going to pass around a couple of these tags. I am not going to get into too many definitions about the tagging and what we do, but this is called a P18 tag, a pop-up archival transmitting tag, and Jerry is kind of our champion with these. This tag rides in a large tarpon, at least 80 pounds; we put this up behind the head, under a scale. This metal foot goes into the musculature, and then this rides with the fish. We can set a timer, which is like an alarm clock, so that this will pop up in three months, two months, up to a year. There is a lithium battery in here, and when the tag pops up, it transmits all the data that it has been collecting, on a minute-by-minute basis, to satellites. That information is downloaded, and we get it right onto a laptop. We get information on depth and temperature preferences, and with different light level readings we can approximate the route of a tarpon that was tagged off North Carolina and ends up off Veracruz, Mexico – we can see where it went. If it is tagged off Veracruz and goes straight across the Gulf into Key West, we can tell. So, the beauty of these and the old-fashioned way of tagging, which was terribly exciting to people who had heard about tagging. It is an awing experience to hear about it, you don't have to recapture the fish. If you tag a fish with a regular tag at Point A, and it is never recaptured, you have lost it. If you do recapture it at a different point, all you know is how far it went between points. It could have gone ten times farther and come back and gotten caught. With this tag, it pops up, we get all the information, we don't have to recapture the tarpon, we don't even have to get the tag back, although we would like to.

For bonefish, this is an acoustic telemetry transmitter. This is actually sewn into the abdomen of a large bonefish, and the fish is sutured and put back and revived, and goes back in the water. Jerry's survival rate is really high on fish that are so tagged. Jerry's wife wanted us to put one of these in his rear end as a matter of fact [hysterical laughter]. Jerry wouldn't hold still – we tried a few times. He's too big to hold down. We put listening stations around various flats, and then we can measure schooling behavior of 200-250 fishes at a time coming into a flat. We can check them for site fidelity and tides, and overlay different charts and graphs of temperature and conditions, etc. I am going to pass these around, and if you look at it briefly and pass it on, and we'll check to get them back at the end. By the way these things cost $3,500, and this one is about $300, and the listening station, which we don't have here, is about $1,000, so it is an expensive proposition. I have some brochures about Bonefish & Tarpon Unlimited. If you are so moved and motivated to join our effort you can join for $25, and if you have deep pockets like Bohnsack, you can put up to $10,000 [laughter]. Thank you very much, and I appreciate your time.

Jerry Ault
Thanks, Doug, for that colorful and interesting snapshot of my life [laughter]. The next speaker probably doesn't need too much introduction, but Jim Bohnsack is without a doubt one of the best recognized, seminal biologists in reef systems in the world. He has championed a number of things, including marine protected areas, marine closures, and sensible kind of management for sustaining fishery resources. I am going to give him a different spin. He doesn't have his NOAA hat on today. He has his public, personally motivated, ethically-driven hat on today, to talk about marine resources and a new ethic.

Jim Bohnsack
Jerry, I thought I needed no introduction [laughter]. I appreciate the opportunity to talk to you. You have heard Aldo Leopold mentioned. Doug Gregory mentioned him. Is there anybody that hasn't read of his land ethic? It is in his book, *A Sand County Almanac*, and I urge everybody to read it. It is in about every bookstore I have ever been into. I have bought many copies and given them away. So you don't get bored, I suggest you start in the middle of the book. It starts off "Land ethic" – read that. He builds up to it. Everywhere he says "land" think of the ocean [laughter].

I am going to talk a bit about ethics. Following on from Billy's talk this morning, he mentioned our connection with the ocean, our connectivity with this process. I kept thinking of my connectivity to him, long before the Looe Key Sanctuary, and one thing Billy has taught me is of course the vision. He and George Barley and some of the early champions – Nancy Foster – a vision of the Looe of the future. Hopefully, we have learned from the connections of the past, and how things have changed, and how they will connect to things of the future. I want to talk about ecosystem-based management, and how one approach that could be used is Aldo Leopold's ethic. The point is that science does a lot of things, but it is not sufficient. It is necessary, but not sufficient. I use Aldo Leopold's quote "Conservation is a state of harmony between men and the land," but we can also put in the oceans and the sea, and that is the idea of an ocean ethic. So certainly, that said, I have touched on many people here in this room, and for the many people in the future. That is what we are working toward: a state of harmony between man and the ocean.

This is a more dynamic model, not that dynamic, but it gives you the idea that we have our resource and that is our foundation. There is a biotic dimension that you have heard about, the animals, the physical oceanography, geology, climate – you have heard about that. Those are important parts of our ecosystem. This forms our ecosystem structure and function. The point I want to make clear is scientists and environmentalists talk about our ecosystem structure and function, our eco-oriented point of view. Fishermen and people think about the services that provide the fish that they eat in the restaurant – that they catch – it provides a service. The fishing guide goes out there and people just want to go out there and enjoy the environment. The services, they are the same thing – two sides of the same coin. One is a human perspective and one is an environmental perspective. Obviously, with the human dimension, people have impact, whether we have good impacts, or we may have detrimental impacts. That is our ecosystem basis. The key elements are, the goal should be: maintaining marine ecosystem health.

Leopold defines health as the ability to regenerate. So if something has been damaged by hurricanes, it doesn't mean it's not healthy. It can regenerate itself. It may be damaged by environmental things like that. So, the ability to regenerate: that is one of our concerns in the Keys – are things regenerating? The second point is it is not just organisms and animals and fish by itself, it is people, too. People are part of it. A philosopher, Callicott, has talked about different conservation ethics. One is called the Golden Ethic, or a frontier Golden Ethic. The idea is that humans are superior to the environment. This is a common theme that some fishermen have this ethic; it's not any good unless you can sell it or eat it. The idea in the past was probably useful. It's how we developed this country two hundred years ago. We went out and caught the fish, killed the bears, cut the forest, and caught the fish. That was fine when resources were plentiful. There was very little conservation there. We just moved onto the next valley or the next fishery.

In contrast to that we have what we call the Romantic Preservation Ethic. These are raised by Henry David Thoreau, John Muir, and probably Sylvia Earle could be put in that category, as a modern-day

person – that the human and the environment are equal. The environment should be protected for its own sake. This is fine, and you have heard that expressed this morning also. The trouble is a lot of people just don't get it. You're kind of lumped in that group, you're a coral hugger or a tree hugger, you understand about biophilia that E.O. Wilson expressed – but a lot of people just don't get it. If I can't sell it, I can't cash it in, what good is it? It misses that key element in connection with people.

Most governments and societies operate under what we call a Utilitarian Conservation Ethic. The idea is that it is "one-way:" the environment here is to support our activities and it is primarily focused on economics. The big sin is not be wasteful, but not to be efficient. It is pretty much dominated by economics, but there is no ethics. I would remind you that economics is not ethics. There is no value system in it. It needs more, and Leopold pointed this out. We tend to do away with things that are not economically important because they have no value for us; it's a waste. Leopold made this idea of rights, that all these organisms have rights, mainly the right to a continued existence. He developed what is called the Biotic Ethic. The point is that humans – by the way, he is as human as he is environmentalist, I already should have said that – are part of the ecosystem, we are part of the marine ecosystem, and part of his idea was that some areas should be set aside with minimum human disturbance. The goal is to maintain the ecosystem. Keep in mind that what he did here was with a scientific basis for ethics. It was developed from the sciences of ecology and evolution. That was his contribution. People talked about ethics long before him, but they didn't have a science derivation.

The connection to people that Leopold developed is that of self-interest. You do this not because you've got to, but you do it through self-interest. If you want goods and services, if you want jobs, if you want employment, if you want recreation, if you want to catch fish, all those things you do for your self-interest – you are going to do the right thing for your self-interest. Every single person should have a connection with that. You don't have to have a love of the coral to appreciate that particular point. And that I think is one of the keystones of his idea. Also, by ethics he says you need to have obligation, responsibility, and self-sacrifice. Economics is not about having those. So that is the key difference that ethics requires for an ocean ethic.

Finally, I want to talk briefly about the differences and how ecosystem-based management works compared to classic single-species management. Fisheries focus on maximizing the yield. We want the maximum number of spiny lobster from the sea, the maximum number of fishing trips. The mode is: you fix it when it is broken; it is risk-prone. We have to break it and then we can do something to fix it. Requirement for action – you have to prove that the problem exists. We get sued. We don't prove there's a problem. If you want to take an action pre-emptively you have to prove there is a problem. The emphasis is on short-term economics – this year's boat payment, this year's catch; the future will take care of itself, hopefully. The results are boom-and-bust cycles, and no-take reserves really have no role in this sort of a system. I make the analogy like Arnold Beale – this is how my daughter used to do it – you know you run until the car breaks [laughter]. You know it's breaking, right, pull over and get it fixed, the battery dies you run over to Sears and a lot of years they can get away with it because they're not using our critical systems – our marine ecosystem is probably a little more critical.

The alternative is ecosystem-based management, which is more akin to airplane maintenance. The idea is you don't want your airplane to break [laughter]. You know, it's embarrassing, you go up in the air and the wing falls off right, the engines quit, you don't want those things to happen. So we

have all kinds of systems to prevent that from happening. The focus is Maintaining the Health of the Ecosystem: ecosystem structure, function, goods, and services. The management goal is to prevent failures. We don't want them to fail; people get hurt. Requirements for action: prove that the activities are within the capacity of that system. We need to balance our activities within the system's capabilities. Emphasis is long-term persistence of a system, not short-term economics. Results: sustainable fisheries, and in this case no-take reserves have an essential role that allows us to understand how the system works.

When you buy a new car or a new boat engine or something, you have a manual that tells you how to take care of it – when to change the oil, how many RPMs, you know, how to maintain it. We don't get a manual for our ecosystem. So some natural area set aside will allow us to understand how the system operates. What eats what. How the dynamics work, what is the variability, so that's the key idea. Leopold said this very simply. It is the integrity and stability and beauty that run an ecosystem. They are the fundamental criteria of his land ethic. The thing is right when it maintains and preserves the integrity and stability and beauty of a biotic community. There is the ethic. Think about it: integrity, all the parts are there. We don't eliminate something because we don't understand its importance. Stability: it persists through time; it doesn't just disappear on us. And finally, the word beauty. This is the one word that scientists always abhor because we don't like to hear the word 'beauty' because it is subjective and scientists hate subjective issues. But beauty – that's the human hook – that's why you are in this room, that's why fishermen are fishermen, that's why fishing got us involved, that's why the commercial fishermen are out there. It's the beauty, not just the aesthetic beauty, the beauty of the excitement of finding food, of providing jobs. You heard about the ocean circulation cycles, that's the beauty of the systems – that is the key element of ecosystem-based management.

I use an example of a case of ethics that occurred; you heard this before this morning. A boat manufacturer advertising: "Isn't it time that all tournaments were catch and release?" That is a fundamental change of ethics, which Sandy alluded to this morning, very nicely. We also have the Gulf of Mexico commercial fishermen, which showed you what happened without a turtle excluder in a shrimp net, this is what happens with one, the turtle gets out. Shrimpers tend not to like this idea, it is an extra piece of gear, it is an extra expense, and it is dangerous when it gets rough. But that's their obligation, responsibility, and self-sacrifice. They do it because it maintains the health of the ecosystem. Turtles are a critical part and we do it because it is the right thing to do, not because it necessarily pays.

Finally, I leave you with the last concept. Leopold pointed out, this is like a fisherman without a license. He noted that there is a clear tendency in conservation to relegate to government all necessary jobs – the private landowners in this case, fishers filled before them. The point is that it takes individual responsibility. We need the education that Doug Gregory talked about. Government cannot be there. You do not want government involved. It can't be in everybody's boat. It takes individuals, it takes people out there who say "We will not tolerate unacceptable behavior." And with that, I will point out that we do now have an official definition in my agency, NOAA Fisheries. We call it an ecosystem approach to fisheries, and it is essentially trying to get the Aldo Leopold idea geographically specified. It is adaptive, takes into account ecosystem knowledge and uncertainties, considers local and external influences, and strives to balance different social objectives. That is the beauty of the human connection. We cannot prevent the alteration, management, and use of our resources, Leopold pointed out. We do affirm a right to their continued existence and the continued existence of the natural systems. Thank you. [prolonged applause]

Jerry Ault
I think we have covered a number of great issues and topics in this discussion, and I was going to recapitulate things, but I think the coverage was so good that I'll let Joanne open the floor for questions. So, any questions?

Panel Discussion
Question/comment: Thank you all for your contributions. So if we start now, do you think we might be able to make it in the future to protect these resources, but what do you suggest we do in the meantime to change the political will, and especially for this country, to take the dollars that we give in aid to all these countries that are putting stress upon our resources here, migrating fish and other species, and how do we change the issues for those who are in this room, to lead us, to prompt us in the protection of these resources?

Ault: I will start with the science and give it up to the other folks. I think the driver for the political process that we have seen in the Keys is a lot like what Doug Gregory mentioned, education, education. Education starts with information, and what has been our Achilles heel in the entire process has been not having sufficient information describing where we are, how things function, and where we are headed. It gets to an even greyer area once you get into the political process. What I think we are seeing in the Keys is a little different ethic, but information requires a history and as near-term the information we have of the process. I think we need greater attention to understanding what these processes are and how they work. I think that Elliott mentioned that they are very complex. They *are* very complex and extremely non-linear. But good theory, good theoretical development in the future relies on us having a strong empirical base for developing new theory. Until we arrive at that kind of information we will be stuck in an old set of wheels when we are trying to drive a Cadillac.

Gregory: I can tell you a little bit about the fisheries aspect and I think what this group would like to see is an environmental influence. The only time we saw that was with the "Dolphin Safe" products, trying to deal with the Latin American countries, with turtle excluders in the shrimp fisheries in those countries. In general, foreign exchange used to be handled through something called GATT, now it's handled through the North American Free Trade Association, and that has just made matters even worse. When it comes to marine resources, fishery resources, it is such a small part of our international trade that our government quickly dismisses those concerns to offset their political needs and concerns in dealing with these other countries. We have a king mackerel fishery that could be hurting. One of the reasons we are having a hard time rebuilding it is that the Mexican fishery is not as regulated. We are not even getting data from Mexico, and we have much closer connections between Mexico and Florida with king mackerel migration than even with tarpon. With the lobster fishery, where we don't have lobsters walking from Mexico to here, I don't think, we have maybe a brood stock in the Caribbean that is being decimated by illegal harvest. We are talking about countries that do not have the luxury we have of living in a highly developed, highly energy consuming nation. They are trying to survive, and they have got laws on lobster, but they are being violated every day. We do have the Lacey Act, which says that if somebody brings a product into this country in violation of the law from another country, they can be prosecuted, and some prosecutions have occurred, I think, particularly with the Central American area that was exporting small lobsters. So I think it is very difficult to do that. And it is more difficult with NAFTA, but we do have the Lacey Act which could be used when a blatant violation does occur.

McManus: John McManus from the University of Miami. I just want to say that this was one the best sets of talks in one hour that I have ever heard in one place. I want to mention that I am really thrilled to see that people are really pinning down this connectivity issue. On the other hand, I want to make sure everybody is putting themselves in the places of people we are dealing with. The idea of the U.S. government telling the Mexican government, sort of prying out of them better control, probably isn't any more rational than the European Union telling the federal government that you should do catch-and-release in Florida. So what really has to happen is, it has got to be this international collaborative work, at the community level, at the science level, at the management level, and so on, trying to get these things going, and that would be greatly improved if some of the U.S. agencies had stronger international programs. NOAA has a pretty good one, but it could be better. EPA has a fairly weak one which could be much better, but if you're looking for ways to handle this connectivity issue, the idea is to get in there and work with people and try to get these activities implemented. I would suggest, for instance, for catch-and-release, that it is the people who do catch-and-release talking to the people who would do it over there; it is going to be much more effective than some officer coming from the government. But as I say, this is superb; this is like 10 steps forward from any conversation of its kind I have heard with regard to this connectivity.

Question/comment: More a comment. One of the things we have heard a lot today is about education. Before we can do anything with our neighbors throughout the Caribbean we have to get our effort squared at home. One of the things with education that we have seen, if we blow things up at the national level, such as the pollution ethic of the sixties and early seventies, or whether it was You Can Prevent Forest Fires, all of these were national campaigns that were run by the Ad Council. We need to get a national program, whether it be for fishing or for coral reefs, or for both, that really addresses this. A lot of NGOs are doing a lot of good grassroots work, but they are all small, little grassroots efforts, and there is no national campaign to drive this message home. Before we can do anything with our neighbors, we have to get that square, right and center at home, and we haven't done that. And this might be the forum to start talking about what can we do nationally at a really large scale.

Bohnsack: I was just going to say, following on from Aldo Leopold, it's not quantity of education, there is a lot of quantity of education, it's what we teach. Not how much we teach, but we are teaching the wrong thing, and it is clear we need to rethink what we teach.

Steven Miller: I'm just going to say, see you at 1:15 tomorrow. [laughter]

Question/comment: I would like to present the opposing view, and that is that I think there are a lot of encouraging signs out there, throughout the region. Maybe a little bit less in the U.S., but throughout the region of the Caribbean, there are a whole lot of NGOs in every country now that has as one of their mandates teaching education in fisheries and other resource managers. In fact, I would even argue the fact that in the Caribbean there is probably a greater ethic toward the development of marine protected areas than there is in the U.S. There are certainly a lot of fishermen who do buy into that now; whether or not they pan out and provide the opportunities that they are sold on is a different question. But I do think that there is a lot of encouragement – there are mutual efforts underway for education, both large-scale ecosystem projects in the eastern Caribbean and in Mesoamerica, as well as a lot of NOAA projects that are throughout the region that have as a primary component education. So I think not all is gloom, I think we are in a much better position now than we were 10 years ago, and certainly a lot better than we were 30 years ago.

Moret: I would agree with that on a whole lot of issues. I know that the Bahamas has made a huge turn-around with bonefishing in the last 10 years. When I first started going to the Bahamas, you would go out in a boat with a guy, and every day they wanted to take one bonefish home to eat. Well, you have a problem with people who are so close to sustenance level, I can't argue with that. But over the years the Bahamas, Yucatan, and certainly the Seychelles and many other places have come to realize that that bonefish swimming around is going to bring them a lot more meals over the next few years, if somebody comes and spends $2-3,000 to fish for a week and they will catch the same fish over and over. So I am seeing a lot of improvements in a lot of areas, but there is still a lot of work to do.

Ault: I think we probably ought to terminate the questions, but before we break out there are a couple of things. First of all I want you to thank my panel for a very stimulating and thought-provoking [thunderous applause]. The second thing I want to do is to recognize some folks here who have been – it is related to the mission of the Sanctuary – and that is we had some incredible support this year from folks in the room, who made possible the gut check, the process check, of marine reserve implementation. One moment please – we are experiencing technical difficulties. [laughter]

Part of the implementation process is to talk about fisheries resources, but you can't talk about fishery resources unless you talk about habitat resources, water quality, and all the things we have discussed. So, the issue is: it is a good idea, but how does it really work. This year, as a function of implementation of the United States' largest no-take marine protected area, in the Dry Tortugas – the Tortugas Ecological Reserve, which the Sanctuary manages, and the Research Natural Area in the Dry Tortugas National Park. Technically, that is nearly 200 square nautical miles of area. We conducted a research cruise, using visual assessments to assess the efficacy of that process, two years post implementation.

The 20-day effort involved a number of agencies within NOAA and the National Park Service, the Florida Fish and Wildlife Conservation Commission, several universities, etc. It was a multi-disciplinary, multi-agency research expedition, to what we called the U.S.'s last marine frontier because it is land's end, and it is an incredible place. We went to conduct a visual assessment of coral reef fisheries and habitat resources, two years post-implementation, and asked ourselves the question, are we seeing a difference? We also wanted to learn about the trends in reef fish populations and the effectiveness of the suite of management activities going on; the first and foremost issues were the marine protected areas as one of a suite of management techniques that can be used with the central mission of sustainability of populations, in this case coral reef fishes in the Florida Keys. This problem is not unique to Florida and the Caribbean, and you will probably hear a bit about that tomorrow, but it is a critical step in understanding efficacy of measures that could have greater utility than just the Florida Keys.

We used a large research ship with 42 of my closest friends and 10 dive support personnel and spent 20 days doing dawn-to-dusk diving in the Florida Keys. We covered an area of about 600 square miles with the unique brand of high-tech lasers, wireless network databases, and yadda, yadda, yadda, and performed the following miracle. This map shows the Tortugas area and the unit areas we classified. I am sure you have heard of Sherwood Forest, which is a formation of elaborate, layered coral. It turns out that Sherwood Forest, which was thought to be much smaller, is a 15 miles long by 4 miles wide area of terraced reef. So, this was quite a discovery of new habitat. Every one of these red dots on the map represents at least four scientific dives that were conducted over 20 days, so the statistics are 1,594 scientific dives for 37-1/2 days under water in 20 days for 42 personnel; it was an enormous effort conducted by multi-agency and multi-university crew.

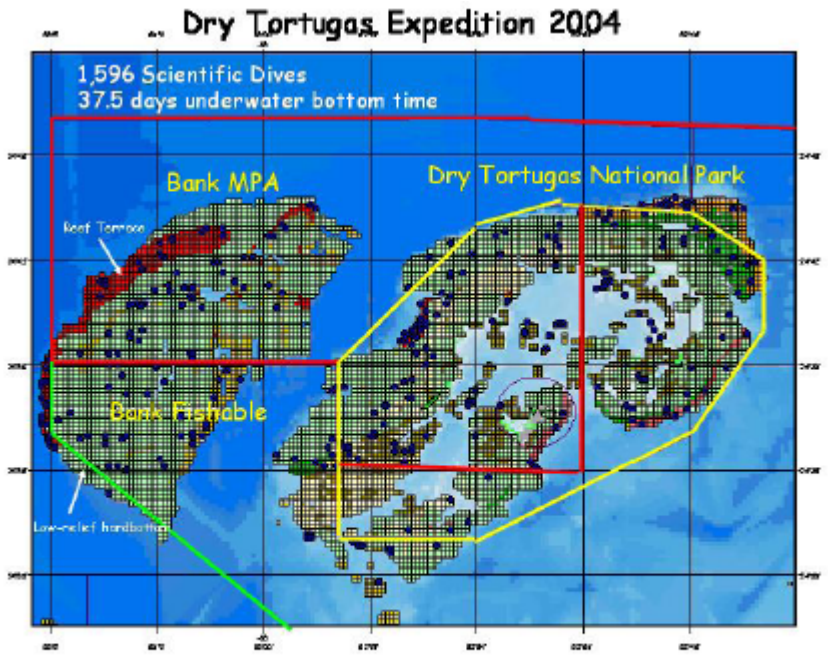


Figure 3.2.- Map of the Dry Tortugas region showing spatial management boundaries, habitat classifications at primary sampling unit (200 m x 200 m) level, and primary units sampled (blue dots) during 2004 expedition.

(From Ault et al. 2005)

I have a couple of awards that I would like to hand out in recognition of work and help they provided. The two most important, or the first two are Billy Causey and Brian Keller [applause]. The award reads "Dry Tortugas 2004 award for Significant Fiscal Contributions," thanking Brian Keller and Billy Causey for their heroic contributions to 1,594 dives and 37-1/2 days underwater at the Dry Tortugas, signed by myself and one of my colleagues. So thank you so much. Now for the second part of the award. No good cruise goes without the requisite t-shirt. Well, the t-shirt adds the brotherhood between Miami and NOAA, NOAA broadly, the backside lists all the scientific divers, the support agencies, and all the personnel involved. We would like you to have one of these each, and thank you so very much. Thank you, Billy.

The last award I can make is to the man sitting at the table, who really is The Man when it comes to insight and foresight. In 1979, before anybody was even whipped up about this stuff, Jim Bohnsack

began a process of visual assessment of coral reef fishes in the Keys, which essentially had an ecological orientation early on. It now extends over the 12,500 square miles occupied by the Florida Keys and Jim's ideas have basically grown into what now is probably the longest-term, most speciose, and most precise data-base on coral reef fishes in the world. I beg deference with my colleagues from the Great Barrier Reef, but clearly it is a gem [laughter] and what a gem it is in terms of all the things said, but the most seminal contribution is to Jim Bohnsack, because we really do appreciate [applause].

Bohnsack: You forgot one critical person: Joanne Delaney for getting our permits to us in time [laughter]. Thank you, Joanne.

Ault: The last thing I will say is that we do have some good news about the cruise. I won't go into great detail, but the quick observation, the take-home message is what we saw in this cruise. This was our fourth pass on the Tortugas at about that sampling density, and we saw more black grouper and red grouper on this cruise than we saw cumulatively over the last three passes on the region. All of those fish were mostly in the 2-5 year range, which suggests that things have been happening at least in time for there to have been a series of traditional increase in size limits. Things seem to be having a positive effect. The second point I will make, and for our bonefish and tarpon friends, is to say that we encountered the largest single schools of permit, schools of thousands of permit inside the closed area, by the way, in the sanctuary. So preservation of the resource is beyond the information in the survey report. Thank you very much!

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Ault, J.S., S.G. Smith, J.A. Bohnsack, J. Luo, D.E. Harper, and D.B. McClellan. 2005. Fishery-independent monitoring of coral reef fishes and macro-invertebrates in the Dry Tortugas. Final Report, National Park Service Contract No. H500000B494-J5120020275, Florida Keys National Marine Sanctuary R0500010, and NMFS Coral Reef Program NA17RJ1226.

Plenary Presentation:

Preserving Coral Reefs and Other Coral Communities: The Perspective of the U.S. Commission on Ocean Policy

Frank Muller-Karger
Member, U.S. Commission on Ocean Policy

The entire state of Florida is legally considered a coastal zone under the State's Coastal Zone Management (CZM) program. This program was developed in response to the Coastal Zone Management Act (CZMA), and defines the coastal zone of our state, both offshore and inland, since Florida recognized it needed to manage all activities with a direct and significant impact on coastal waters. The CZM program is implemented through a partnership of 10 agencies led by the State's Department of Environmental Protection. Indeed, Florida has this nation's second longest coast – some 8,400 miles of tidally influenced shoreline (1,350 miles of coastline) that supports over 12.3 million people in its coastal counties (35 of the state's 67 counties are coastal). Coastal counties generate over three-fourths of the state's gross retail sales ($354 billion), taxable retail sales ($157 billion), and jobs (about 6.2 million). Clearly, Florida reflects the nation's economy: coastal watershed counties contribute over $4.5 trillion, fully half of the nation's gross domestic product, and account for some 60 million jobs.

The value of coral reefs can be evaluated in several dimensions. From an ecological point of view, they house tens of thousands of species of plants and animals, making them among the world's most diverse and productive habitats. Nearly one-third of all fish species live on coral reefs, while other species depend on reefs, seagrass beds and mangroves. They have significant tourism and recreation, as well as shoreline protection value. Globally, it is estimated that the value of reefs approaches ~$375 billion per year and they support 500 million people. At least one-half of federally managed commercial fish depend on reefs. The Florida Keys generated ~$105 million in income and supported 8,000 jobs in 2001. Finally, the cultural and aesthetic value of reefs is really enormous and hard to calculate. Few people realize that, according to NOAA estimates, U.S. coral reefs cover ~7,600 square miles. Just those in the Pacific Freely Associated States (Palau, Federal States of Micronesia, and Marshall Islands) range 4,500- 31,500 square miles.

As we enter the 21st century, we have a tremendous opportunity to improve the lives and economies of coastal communities through better education, new technologies, and new strategies for managing our coastal zones and marine resources. As any good business, developing coastal lands, maintaining a vibrant and sustainable ocean, and having clean beaches requires review of how we have done things in the past, adjusting our strategies for the future, and particularly strong leadership to ensure proper stewardship. This requires using science for the protection of human life and property, an educated public, and effective management practices.

The health of coral reef ecosystems is decreasing at an alarming rate. Bleaching episodes are common and other diseases are becoming more frequent. The causes of these problems are varied and depend on the reef being considered, but can be the result of one or a combination of the following:

- Excessive fishing
- Pollution, sedimentation, and runoff
    - Includes hypoxia and light limitation
    - Pathogens
    - Eutrophication
    - Poisoning
- Temperature

It is clear that human activities have and will continue to adversely impact the environment if we do not manage these activities. The cumulative effects of our actions threaten the sustainable use of the oceans and coasts. We have already lost potential sources of food, areas of recreation, and wetlands that keep our water clean, and in many cases we have paid dearly with degraded water quality, lost jobs, increased health care costs, and decreased revenue. Surprisingly, Florida's coastal counties unemployment rates have been up to 20% higher than in non-coastal counties.

Understanding the oceans and their connections to land and the atmosphere means better weather forecasting and ultimately a better economy for our coastal communities. As a recent example, if we had had even slightly better hurricane forecasting capabilities during the summer of 2004, we could have saved lives and property in Florida. On land, we have weather stations everywhere, and these make regular reports to the National Weather Service and to meteorological services around the world. We take the daily weather reports for granted. Yet, because the oceans cover 71% of the Earth's surface, our weather maps are actually very crude approximations. We have few devices that measure water temperature and winds in the ocean.

It is also particularly difficult to see what happens beneath the surface of the ocean, and this makes management of resources like coral reefs and fish very complicated. It is indeed difficult for people to be aware of environmental problems lurking beneath the waves. It should be obvious that we can't manage resources without understanding them. Yet we regularly under-invest in science, technology, and education.

Managing marine resources is also difficult because of an intricate system of state and federal government jurisdictions seaward of the coast. At the federal level, marine resources and activities are managed by over 14 agencies that are controlled by over 60 Congressional committees and subcommittees. There are over 140 federal laws dealing with marine issues that in some cases overlap, in some cases conflict, or may have gaps.

At present, various different laws affect how we manage U.S. coral resources and management is shared by many federal agencies. For example:

- Coral Reef Conservation Act (2000)
    - Focus on NOAA activities:
        - National action strategy
        - Grants for conservation
        - Conservation fund for private-public partnerships
- Marine Protection, Research, and Sanctuaries Act (MPRSA; 1972)
    - NOAA may fund repairs to damaged habitat with cost recovery from responsible parties. Only immediate damage but not preventive (i.e., no navigation aids, etc.) nor long-term damage (pollution, overfishing, and disease).
- Magnuson-Stevens Fishery Conservation and Management Act
    - Regulates coral harvest and protects Essential Fish Habitat
- Coastal Zone Management Act
- Clean Water Act
- Sikes Act (U.S. DoD to rehabilitate/conserve corals on military bases)
- Endangered Species Act
  (Plus a whole host of state and territories laws.)

At present, there are several Federal interagency and intergovernmental initiatives, the most relevant of which are:

- U.S. Coral Reef Task Force
    - Created by Executive Order in 1998
    - Seeks to coordinate between agencies
    - Develop strategies (mapping, monitor, study, conservation, and sustainable use)
    - National and international focus
    - Relevant agencies that are absent: DoE, USACE
- U.S. All Islands Coral Reef Initiative
    - Cooperative: Hawaii, American Samoa, Guam, the Commonwealth of Northern Mariana Islands, Puerto Rico, and the U.S. Virgin Islands

How did we get here? The last comprehensive review of our nation's ocean policies was completed almost 35 years ago by the Stratton Commission. The Stratton Report, published in 1969, led to such things as the creation of NOAA, the Coastal Zone Management Act, and several other major pieces of legislation.

Congress and the President recognized the staggering problems outlined above and mandated the creation of a new U.S. Commission on Ocean Policy through the Oceans Act of 2000. The objective was to study the state of our ocean knowledge and governance, and to recommend a national ocean policy. The law stated that this process was to give equal consideration to environmental, technical feasibility, economic, and scientific factors in developing our recommendations.

To set the process in motion, President George W. Bush appointed the 16 members of the U.S. Commission on Ocean Policy in July 2001. The President selected twelve members from lists submitted by the Senate Majority Leader, the Senate Minority Leader, the Speaker of the House of Representatives, and the Minority Leader of the House. The remaining four members were chosen

directly by the President. The Commission members came from diverse professional backgrounds in federal, state, and local governments, private industry, and academic and research institutions involved in marine-related issues. Admiral James D. Watkins, USN (Retired), was elected chair by his fellow commissioners at the first Commission meeting on 17 September 2001.

The new Commission embarked on what became 15 public meetings and additional site visits around the country, including various sites around Florida in February of 2002. Through expert testimony and many excellent presentations by leaders in every field related to marine research, science, and policy, the Commission learned first-hand about the most pressing issues facing the nation regarding use and stewardship of ocean and coastal resources.

In parallel to this process, the Pew Oceans Commission carried out its own assessments. This privately funded group of dedicated individuals published its findings in June 2003. A natural question is how the recommendations from the U.S. Commission on Ocean Policy compare and contrast with those from Pew Oceans Commission. The Pew oceans report (http://www.pewtrusts.org/pdf/env_pew_oceans_final_report.pdf) highlights problems in the way we manage living resources and makes important recommendations for significant change in ocean governance and in management approaches. Our own U.S. Commission used the many documents generated by the Pew Oceans Commission as input to our own study.

In my opinion, both commissions' findings are essentially the same. We agree on the problems and in many of the recommendations. (It probably is not very useful to get bogged down comparing the commissions.) The point is that the oceans are in trouble and we need to make changes.

The U.S. Commission on Ocean Policy delivered its final report (entitled "An Ocean Blueprint for the 21st Century") to the President and Congress on 20 September 2004. This report (as well as all public input and various ancillary documents) are found at the Commission's web site, at the following address:

http://www.oceancommission.gov

The clock is ticking and your involvement is critical. The Oceans Act of 2000 states that the President has 90 days to submit a statement to Congress containing proposals to implement the Commission's recommendations, and this is now slated to occur before December 17, 2004. The Council on Environmental Quality (CEQ), located within the Executive Office of the President, has convened an Interagency Ocean Policy Group (IOPG) that is reviewing the report and coordinates input to the President in drafting the administration's proposals to Congress.

How does all this affect Florida?

Practically every recommendation of the report has relevance to how we govern our waters and manage our ocean resources. For example, State waters extend three nautical miles from the eastern coastline of Florida out to sea (measured from what is called the baseline, normally the low water line along the coast). But in the Gulf of Mexico, State waters extend nine nautical miles. Here, all resources belong to all Floridians, and the State has been entrusted with management of these public resources. Beyond "State waters" extend various "Federal waters" – first comes the Territorial Sea (12 nautical miles wide starting at the coast and overlapping State waters) and then the Contiguous Zone (also 12 nautical miles wide). The nation's Exclusive Economic Zone (EEZ; Fig. 1) extends

out to 200 nautical miles from the coast. All resources seaward of three nautical miles (or nine, depending on the coast) belong to all Americans, and the Federal Government has been entrusted with management of those public resources.

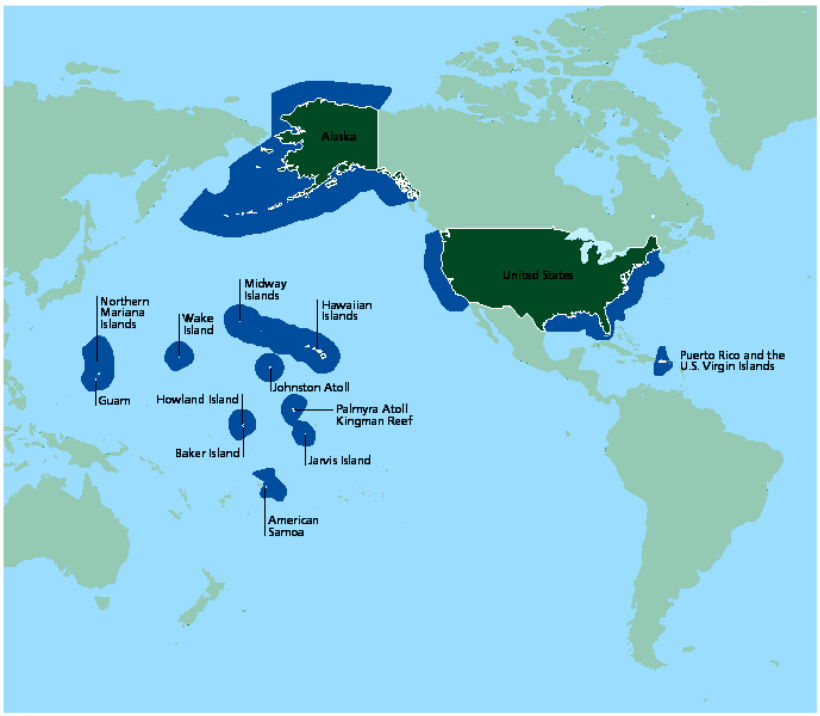


Figure 1. The U.S. Exclusive Economic Zone is the largest in the world, and is larger than the combined land area of the 50 states.

As mentioned above, tourism is probably the single most important industry in the state in terms of revenue and jobs. Drawing tourists to Florida and keeping them here requires, among many things (not arranged in order of importance):

- A healthy and attractive coastal ecosystem
- Clean beaches and good water quality
- Managing urban sprawl
- Good connections between ports, roads, railway, and air transportation
- Minimizing pollution by pathogens and chemicals
- Better managing commercial and sports fisheries and bycatch
- Advancing the Everglades restoration plan
- Maintaining healthy coral reefs
- Understanding connections between the Everglades and the Florida Keys
- Understanding beach geology and erosion/accretion
- Understanding natural hazards like red tides and storms
- Understanding climate change and sea level rise (now at about 1/20 inch/year)

In addition to coral reefs, another clear example of why we need to pay attention to policy is our fisheries. The Gulf of Mexico Fishery Management Council manages 57 species, but we know little about the health of some 44 stocks out of these 57. Indeed, perhaps at best 13 of these Gulf of Mexico stocks are assessed, and the NOAA Fisheries Service has concluded that at least seven stocks out of these 13 are overfished. Some fish have been considered for listing under the Endangered Species Act, including king mackerel, several species of snapper and grouper, and greater amberjack. Many other species are thought to be overfished or nearing overfishing, including many sharks, billfish, and several crustaceans.

A significant problem with fisheries is bycatch. These are unwanted species caught while fishing and they include unwanted fish but also marine mammals, birds, sea turtles, corals, etc. We need to

reduce bycatch. In Florida, manatees and dolphins, sea turtles, and birds fascinate tourists; we should recognize their economic value as well as their natural beauty.

As mentioned above, in Florida we have experienced an astounding decline in the health of coral reef ecosystems in the past 25 years. We cannot just continue to focus only on studying the problem; there is an urgent need to address the identified, major factors causing coral declines, and these include elevated sea temperatures caused by global climate change, direct and indirect impacts of fishing, and land-based pollution.

In Florida, we have about 2,000 beach closures and advisories per year for reasons that include pathogenic bacteria, hormones, other pharmaceuticals, nutrients, and other chemicals. But we also suffer significant pollution in our rivers by sewage and by non-point sources like power plants, trash burning facilities, and other sources of metals like mercury. Clearly, nutrients from agricultural runoff are not our only problem.

I encourage everyone to participate in volunteer beach cleanup programs. It is an eye-opener to see the amount and types of debris dumped by people visiting beaches, but also from boats and ships. I have found sofas and refrigerators among hundreds of thousands of bottles, flip-flops, and other trash along a single causeway in St. Petersburg, near where I live.

The Commission examined several aspects of pollution in great depth, and made specific recommendations on coastal water pollution, vessel pollution, sediment management, marine debris, and other issues such as invasive species.

Many of us may think our careless actions are insignificant, but indeed they are a problem because they happen in the same place, at the same time, and over a long time. Tourism, not to mention our own health, is affected by all this. These problems have real impacts on jobs and the economy of Florida. Imagine the positive impact we can have by changing our behavior even slightly.

To stimulate our economy and improve our lives over the long run, we need to address these problems. But this cannot be done without having a clear and visionary ocean policy, a blueprint for managing the oceans.

The Commission considered these issues in drafting its recommendations, which can be summarized as follows:

Ocean Governance

We all can agree that the U.S. desperately needs a new integrated management mechanism to treat ocean resources as interrelated and interdependent ecosystem components, rather than as a collection of isolated fragments managed independently from each other, as practiced today. The current insular and disjointed policy approach has led to confusion and contradiction and must be changed.

The Commission recommends a National Ocean Policy Framework that creates a more effective and coordinated federal management system, with strong high-level leadership, strengthened and improved agency performance, and greater opportunity for regional participation. A core element is the creation of a National Ocean Council (NOC), housed within the Executive Office of the President. It would be chaired by an independent Assistant to the President for Ocean Policy, and

would be integrated by the President's relevant cabinet members and directors of independent agencies. One way to visualize this NOC is as a parallel structure to the National Security Council. It does not create more bureaucratic layers and instead it provides a very important way for agencies to communicate with each other at the top, to coordinate budgets, and to resolve conflicts. Above all, it provides a mechanism for the President to provide leadership and override agency turf.

A second element of the new National Ocean Policy framework is to move the existing federal structure toward a more effective, less redundant, and more balanced ecosystem-based management approach.

Third, it is equally important to give local, regional, tribal, and state organizations a more active and effective role in managing the nation's oceans and coasts. The Commission recommended strengthening regional management and participation.

The Commission proposes solutions that transcend political boundaries and emphasizes the need to move toward an ecosystem-based management approach. We appreciate that one cannot call for ecosystem-based management without recognizing the direct linkages among the oceans, the atmosphere, the land, and the human activities that take place across these areas. Ocean management must be tied to land management, for example.

Science, Technology, and Engineering

Effective ocean policy should be based on unbiased, credible, and sufficient scientific information. This requires significant investment, an adequate infrastructure, a system for data collection and management, and the means to effectively translate science into useful and timely products. The federal investment in ocean research has been stagnant or decreasing. It has fallen from 7% of the federal research budget 30 years ago to less than 4% today.

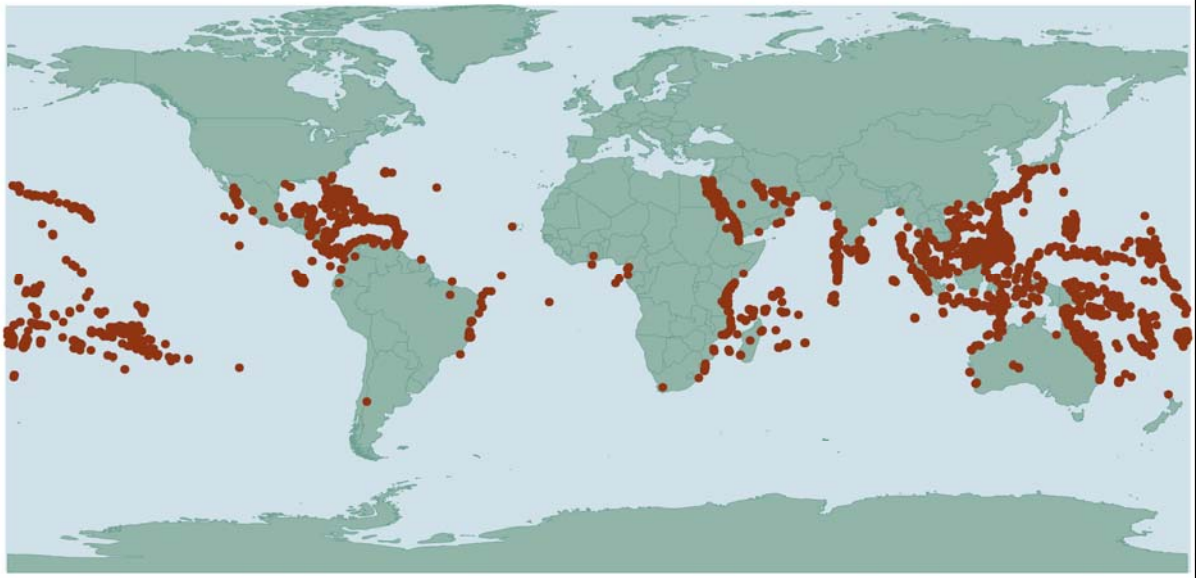
This is not good. Management in ignorance is not acceptable. So, we are recommending significant attention be put into reviving our research and technology infrastructure.

Today we have the technology to gather data from many different sensors deployed on the oceans on ships, buoys, and autonomous robots, as well as on satellites, but we need a system that integrates all these disparate datasets and generates products useful to the public, industry, and government entities. This should work like the National Weather System, which has established a network across the globe to collect data and integrate it to make products we use every day and now take for granted. A high priority, therefore, is to implement an Integrated Ocean Observing System (IOOS) based on a backbone of coordinated, linked regional monitoring systems and strong connections to a Global Ocean Observing System and to a Global Earth Observation System.

Education

The Commission supports a national ocean policy founded on high-quality, effective education that promotes lifelong learning, an adequate and diverse workforce, informed decision making, science literacy, and stewardship. All of the ocean-related agencies should be required to take responsibility for promoting education and outreach related to their missions. Lifelong education efforts need to be improved so that every individual recognizes the value of the ocean to their own lives and how their actions directly and indirectly affect the marine environment. We need an informed public that upholds and promotes a national stewardship ethic.

Figure 21.1 Warm Tropical Waters Are Home to the Majority of Known Reefs



● Coral reef (reef area not to scale)

Most of the world's known reefs are found in tropical and semitropical waters, between 30° north and 30° south latitudes. Because these reefs are often in shallow water and close to shore, their health is easily threatened by human actions, such as increases in sedimentation and polluted runoff and damage caused by fishing and recreation.

Source: National Oceanic and Atmospheric Administration. <http://www.coris.noaa.gov> (Accessed January 2004).

Coral Reefs

The Commission dedicated one full chapter to recommendations on coral reef management. Specifically, in Chapter 21 of the Final Report, we included the following recommendations:

> Congress should pass, and provide sustained funding for, a Coral Protection and Management Act that covers research, protection, and restoration of coral ecosystems.
>
> Congress should codify and strengthen the U.S. Coral Reef Task Force and place it under the oversight of the National Ocean Council (NOC).
>
> NOAA should develop national standards—and promote adoption of international standards—to ensure that coral reef resources are harvested in a sustainable manner. The U.S. Department of State should implement incentive programs to encourage international compliance with these standards.

Recommendation 21–4. The U.S. Coral Reef Task Force should identify critical research and data needs. These should guide agency research funding and be incorporated into the design and implementation of the Integrated Ocean Observing System.

NOTE: As per our July 22, 2004, public meeting, we dropped the recommendation that the U.S. Coral Reef Task Force have responsibilities over deep and temperate corals. Rather, we now explicitly recommend that NOAA lead the effort to study and manage these resources in partnership with other federal, state, and academic entities; perhaps later the U.S. Coral Reef Task Force would be the appropriate interagency coordinating entity.

Figure 21.2 Coral Reefs Exist Throughout U.S. Waters

● Known deep, cold water reefs (reef area not to scale)

Although most people are aware of the coral reefs that exist in the warm waters off Florida, Hawaii, and the U.S. island territories, few realize that deep, cold water reefs also exist throughout U.S. waters. While scientists continue to find new deep sea coral communities, little is known about their true extent. Learning more about these species is necessary to manage them wisely, and all states and federal agencies must realize that coral reef conservation is not an issue limited to tropical waters.

Source: Oceana. "Deep Sea Corals: Out of Sight, But No Longer Out of Mind." http://northamerica.oceana.org/uploads/oceana_coral_report_final.pdf (Accessed June 2004).

The Commission recognizes that to take things to practice requires access to a variety of management tools. Some of these tools are unpopular, largely because people feel they restrict freedoms. One example is "marine protected areas (MPAs)." We recognize the significant problem of confusion with the term MPA, because it seems to have become a catch-all phrase that, to many people, means locking an area away forever. We need better ways to define and implement MPAs. We believe that the development of MPAs must be based on good scientific information, when possible come from a bottom-up process starting at the local level, and that state and local citizens must be engaged in the development process. MPAs can be temporary and have flexible boundaries that change with time. They do represent an important

and useful management tool that promotes healthy oceans by purposefully managing portions of ecosystems.

The Commission also recognizes that the international dimensions of ocean policy are important. We urge the U.S. to lead the way in promoting better practices worldwide by ratifying the U.N. Convention on the Law of the Sea. Our nation needs to define a useful path to follow with other international programs, such as the Convention on Biological Diversity.

The U.S. has been an international leader in coral reef management. The State Department, NOAA, U.S. AID, and the U.S. FWS contribute significantly to developing countries in terms if capacity and capacity building, research, enforcement, management procedures, and environmentally sustainable harvesting techniques. Other international initiatives that we participate in are the Convention on International Trade in Endangered Species (CITES), where over 2,000 species of coral are listed. Also, the International Coral Reef Initiative (ICRI), developed in 1994, is an informal mechanism to develop best strategies for conservation. A final (but not exhaustive) example is the Global Coral Reef Monitoring Network, which has the only global estimates of coral reef coverage and status, although accuracy could be improved.

Costs

Significant change, however, cannot be achieved without commensurate investment. The U.S. Commission on Ocean Policy outlines the costs associated with making improvements to our ocean policy, and presents a proposal for meeting those costs through the establishment of a new "Ocean Policy Trust Fund." The sole intent of the Trust Fund is to ensure a dedicated source of funding for improved ocean and coastal management, including sustainable management of renewable resources. It is not intended to either promote or discourage offshore uses authorized under existing laws, and the Fund itself would not drive activities in offshore waters.

Although there is a considerable level of uncertainty in the cost estimate, the Commission estimated that the total additional cost to the federal government is approximately $1.5 billion in the first year, rising to roughly $3.9 billion per year in ongoing costs after full implementation. Monies for the Trust Fund would be generated through resource rents from certain approved uses in federal waters, including Outer Continental Shelf oil and gas revenues that are not currently committed to other purposes. The Trust Fund would help support the new responsibilities placed on federal, state, territorial, tribal, and local governments, and prevent the creation of unfunded mandates.

There are many other important activities, with significant implications for oceans and coasts, whose costs, even if known, were not included in the totals provided by the Commission. Examples include:

- The nationwide upgrading of wastewater and drinking water infrastructure
- Ongoing flagship projects such as restoration of the Florida Everglades
- Nationwide (inland) water monitoring
- Planning and implementation of an intermodal freight transportation system
- The National Science Foundation's Ocean Observatories Initiative
- Reestablishment of a Congressional Office of Technology Assessment
- Maintenance to federal offices, laboratories, and other facilities

- The costs of renewing the U.S. Coast Guard fleet, implementing Maritime Domain Awareness, and other broad ocean safety and enforcement needs

Although these are just a few of the issues we address in the report, I hope you see that we are striking a good balance. I am confident that our report will be a blueprint for action using ecosystem-based management as the organizing framework for improvements in governance, in science, and in education.

This process requires your active participation. You may not agree with all of our recommendations or you may think some particular area did not receive adequate treatment. That is understandable and inevitable, but it should not prevent you from supporting the creation of a comprehensive and coordinated national ocean policy.

Here are a few reasons why you should read the report and develop a strategy to help implement these recommendations:

- Stimulating research and development in our nation
- Ensuring that your children have fish to eat and beaches to enjoy
- Strengthening our nation's security—military and economic
- Improving your quality of life and that of the entire planet
- Developing new partnerships and business opportunities
- Helping universities start a curriculum focused on Commission themes and refocus the tenure process so it is broader than just counting research publications

High tides raise all boats. It is our collective task to make sure everyone understands that the oceans are both a public resource and a public trust, and that conservation for future generations is critical for our survival on Earth. This can only be done by working together.

You should take this opportunity and responsibility as an individual to provide input to the White House and to our leaders in Congress to act on the principles and recommendations laid out by the U.S. Commission on Ocean Policy.

Discussion

Muller-Karger What I want to emphasize again is that the – I know a lot of people are going to ask, well, what are the most important recommendations that come from this report, and it is not just the corals, it is everything. I encourage you to look at this report, it is on the website: http://oceancommission.gov. If we don't all work together in pushing our leaders, our congress people, if you don't write to the president, to the chair of the Council on Environmental Quality, if you don't write to these people, pushing this report forward, nothing is going to happen. We are going into an election cycle; this thing is noise in the eyes of many people. Many people in the federal government are paying close attention to it. There is some legislation going through, but it is a very turbulent time, and if we don't find support from the people, from the media, consistently keeping this momentum up and going, nothing is going to happen, neither with this president or whoever may come next. So it is your job to push this thing forward. I would be happy to answer any questions now. [applause]

DeeVon Quirolo: I was privileged to be at a conference in Washington, where for three days we analyzed the Pew Ocean Policy Commission recommendations and over a few hours, probably. One

of the big differences between the two was that Pew went a step up saying we need a new agency with a conservation mission, not one that is in Commerce to truly achieve our goals. In your final report is there any upward change in that position that you reported?

Muller-Karger: I touched on that area. We suggest that... For example, NOAA was created by executive order, so it doesn't really have the mandate from Congress to be the leading agency to manage our ocean resources. We proposed that that happen – that NOAA be given that task by law, by Congress. That would be a major step in that direction. We also say, very explicitly, that – there are many other agencies – that NOAA should be the lead agency for ocean issues in the federal government. So we know that caused commotion, because many agencies – in the U.S., which is the leader – because who wants to even step forward. It is frustrating to see this, and they don't even take the initiative to go forward and say "We are the leaders." So we proposed that NOAA be the leader. The reason we don't agree with the concept of moving NOAA to be an independent agency is that would cost an enormous amount, because you would have to destroy many other agencies and pull pieces out and move them into NOAA. We say that this should be done over the long term. We actually have it in the report that this has to be a long-term process. We even get to our natural resources...

Quirolo: I understand what you are saying, but the other side of the coin if you did create a new agency, you would be able to pull strong support from these various agencies that are competing for that...

Muller-Karger: What we have to...

Quirolo: It bears looking at is what I am saying...

Muller-Karger: I agree with you 100%. It is at this time, and in the life of this country, that we would probably do nothing if we recommended that. I think you have a good point, but we need two steps to get to an objective, and we say "This is our objective." But what we need is coordination between the agencies and focus, and leadership from the agencies and high level attention to these problems. There is a reason why just lifting NOAA out of Commerce would not work, for another reason, but there is some basic reasoning. NOAA's budget is on the order of $3 billion. The Department of Commerce's budget is $5 billion, so if you take NOAA out of Commerce, and Commerce is a very small department compared to even NASA, or especially the Department of Defense, if you take this agency out, you now have created two new small agencies, of the order of $2-3 billion dollars: the smallest agencies in the government. And in Washington, the way that you gain influence is by having a budget. So you now have created a worse problem for these agencies to function.

Quirolo: Unless you had a giant ocean bill to create a strong, new ocean commission, and powerful...

Muller-Karger: But you would have to pull pieces out of...

Quirolo: But that is the part of what I wanted... I don't want to dominate, but I have two quick more comments. The reports both came out with very important, and I applaud the effort to adopt nutrient standards, but I just want to voice my concern that if you create national nutrient standards, you make sure to protect the especially sensitive areas like coral reefs. So it would be virtually

impossible to create national standards, unless you create them to a level high enough to meet the particular nutrient preconditions for coral reefs. I just wanted to caution you about that. But it is so important and so good that the need to establish nutrient standards and reduce non-point source pollution is a very strong part of that report in my eyes. And finally...

Muller-Karger: Which is fine, but I think that we should not misread what the report said. There should be national standards, but that doesn't mean that that's the same number everywhere. That would make no sense.

Quirolo: You just need to account for local standards, such as coral reef areas, marine parks, and finally, meeting the Florida people everywhere, in the communities, to make a successful ocean bill, which would be successful in government. Granted that this is a top-down effort, it is a federal effort, but the closest you get to the grassroots are the regional councils, where you will have one or two people from whole regions representing the community. So I would strongly encourage you to go a lot further down into the grassroots community level, because that is where the stakeholders who truly care and love and will do what they need to do to protect the ocean, are working, and by connecting strongly with the grassroots level you will achieve far more community support and stakeholder involvement than you will with just another federal initiative.

Muller-Karger: Well, I agree 100%. I think that is exactly what the report says. The report strongly encourages partnerships, taking down things to the local management level, to the tribes and the territories and the states as much as you can. Still, a lot of what the report refers to is federal government structure and managing resources in federal water, so a lot of the things that you are talking about also happen in state waters. States have to work on themselves. So we state that initially these councils, these regional councils are voluntary – that does not mean that they shouldn't happen. It means that there is strong encouragement, because you have these regional problems, for people in the region, in the manner that you have just described, who have organized themselves, rather than resort to the federal government to deal with their problems. So we recognize that, every chapter has recommendations.

Question: This is kind of a follow-up. You have also described taking NOAA out of Commerce and putting it into Interior as a bad idea. Could you elaborate on your rationale for that?

Muller-Karger: Well, in defense of that, I don't think it is a good idea just to move the boxes around. That accomplishes nothing. Just moving boxes from one agency to another, it's typical government management, and we want to get away from that. I don't want to be cynical about it, but just moving it from here to here doesn't do anything. So you would literally have to take pieces from USGS, from the management services, from EPA, given the functions, you would have to define which agency is regulatory, which one is this – and that. We are going through that right now with the intelligence community, you can see how big of a mess that is, and it is exactly the same problem, exactly the same problem. We went through that with the homeland defense process in creating a new agency, and it almost tore our political process apart. It was very painful. So, knowing that this is the climate that we are dealing with right now, we put a goal up of what this nation should be doing in how it manages its resources. But we cannot now, at this point in time, recommend creating yet another agency that basically guts all the other agencies to make a new one, just to get the critical mass in terms of budget and people. Probably people would not even pay attention to it at this point in time. The problem is mismanagement of our resources and the lack of

coordination between the agencies. If you wanted to harness all the energy and coordinate it in a proper way, you would be better off than we are today. [applause]

Kacky Andrews: Before we move on to the next agenda item, I just want to mention and make sure you are all aware. As Frank mentioned, the U.S. Coral Reef Task Force, every fall, has a meeting in states and territories on a rotating basis, and next month it is in Florida. It is in Miami Beach, September 14th through 15th. We have some workshops on the 13th as well. There are some pamphlets on the back table if you want more information, but I do want to make sure all of you are aware of that, that it is next month.

Causey: Thank you, Kacky, and that is going to be the first joint meeting of the Task Force with the South Florida Ecosystem Restoration Task Force, so we are going to have the two overlapping. I just want to say a couple of things. We have a couple of elected officials who have joined us. Arlene Corbin, who is the vice-mayor of Key Colony Beach. I didn't see her this morning, and now I have embarrassed her. No, she was here for your whole talk. I also want to point out county commissioner George Neugent. Would you mind standing – county commissioner George Neugent? [applause] George is also the chairman, speaking of grassroots efforts, George is the chairman of our Sanctuary Advisory Council, and we have many members of our advisory council here that are stakeholders and grassroots people, will you all stand up, all of you that are here? These people, these folks volunteer their time [applause], and Fiona, you all know Fiona, she is the SAC liaison coordinator, look at her, she's embarrassed, anyway, give her another big hand [applause].

Heidi Schuttenberg: And with that we move on to Climate Change.

Climate Change

Moderator: Heidi Schuttenberg

Rethinking Conservation to Increase Coral Reef Resilience in the Face of Climate Change

Lara Hansen

The composition of the Earth's atmosphere has been changing since the beginning of the industrial revolution owing to the emissions of greenhouse gases from the burning of fossil fuels. Projections for the next century are that greenhouse gas concentrations could increase by two to three times above pre-industrial levels. This has implications for coral reefs around the world, including Florida. Increasing temperatures are expected in increase the incidence of coral bleaching. This may also affect harmful algal bloom frequency. Sea level rise and associated land-use change will further exacerbate damage to reefs relating to climate change. These changes will require that we change our approach to conservation in the face of climate change.

The World Wildlife Fund (WWF) has created guidelines for developing conservation strategies to respond to climate change (Hansen et al. 2003). They are based on four tenets.

1. Protect adequate and appropriate space
   Ecosystems with high biodiversity and those that maintain crucial structural components are thought to recover more easily from climatic disturbances. Traditional conservation methods such as creating protected areas, whether in terrestrial or marine areas, will thus have another justification in the next several decades. It will become increasingly important, however, to take into account projected impacts of climate change when designing new protected area systems, and to expand spatial scales through buffer zones and corridors to aid species migration. In particular, planners should look for climate refugia, areas that experience less change than others. With respect to coral reef systems this may include identifying those locations which can be referred to as "cool spots," places where thermal anomalies exceeding bleaching thresholds appear to have not occurred to date (Fig. 1). Using the remote sensing data generated by the NOAA HotSpot monitoring we can look for these sites with low warming probability (Kassem et al. accepted). Planning marine protected areas and other reserves will now require an eye for potentially dramatic future changes in protected areas; thinking about not only current but future configurations of habitats, communities, and ecosystems. Managers will need to be even more strategic, creative, and flexible in designing protection strategies to address traditional land/sea uses, existing threats, and also climate change stresses. Protecting not just space but functional groups, keystone species, climatic refugia, and multiple microhabitats within a biome to provide adequate representation is essential.

2. Limit all non-climate stresses
   Climate change is not occurring in a vacuum. There are myriad stresses affecting natural systems, including habitat fragmentation, overharvest, invasive species, and pollution, to name a few. The limited body of research on interactions between climate and non-climate stresses suggests synergistic responses (McLusky et al. 1986). For example, when rainbow trout (*Salmo gairdneri*) are exposed to the pesticide permethrin over a range of temperatures, the toxicity increases as temperature increases (Kumaraguru and Beamish 1981). In coral reef systems, synergistic responses have been identified between temperature and UV to induce bleaching. To support ecosystem resilience you must reduce the number of

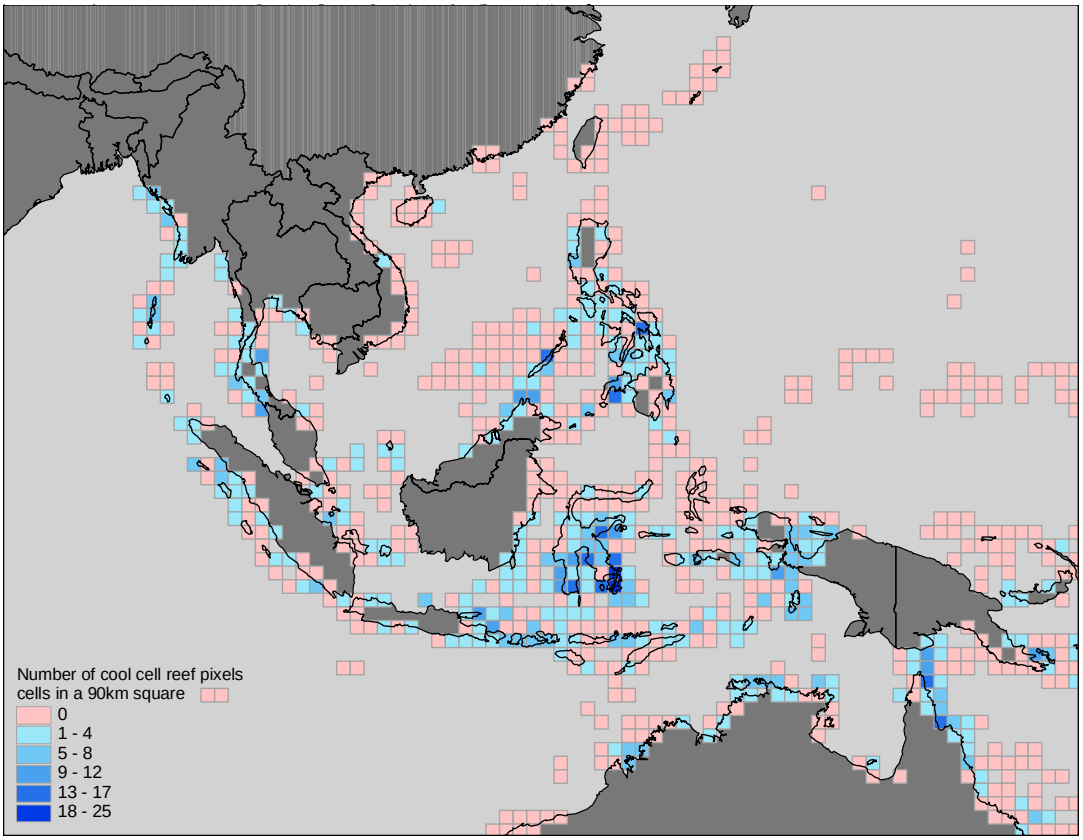


Figure 1. Cool spot identification for southeast Asia and northern Australia. The number of cool cell reef pixels is shown in these 90 km x 90 km bins to illustrate the regional patterns of cool cell distributions. At the native resolution of the PFSST (9 km), individual reef pixels are too small to be seen on regional maps. Darker blue represents more cool cells per bin. Red bins have had at least on extreme thermal anomaly (From Kassem et al. Accepted).

Simultaneous insults faced by that ecosystem. Fortunately many stressors are more locally controllable than climate change. In a marine system this may mean establishing "no-take zones" to reduce fishing pressure and associated habitat destruction. In a freshwater system this may require limiting the concentration of toxic substances in effluent from an upstream industry; to protect related marine systems it may mean lower acceptable nutrient and pollutant run-off concentrations through regulation. It may mean protecting alpine watersheds by limiting extraction of water by downslope agriculture and cities, or limiting harmful grazing practices in grasslands. Forests could require limiting fragmentation from road construction and logging. None of these tasks are easy, but they are approachable on a local level.

3. Use adaptive management and start testing strategies now
   Given uncertainty about the exact nature of local ecosystem impacts of and responses to climate change, effective management of protected areas will require a responsive and flexible approach. The success of various conservation approaches should be continually reassessed as the system changes, and approaches should be adjusted as new information becomes available. In instances where impacts are relatively clear, active intervention to increase adaptive capacity coupled with

monitoring is necessary. Such intervention may include assisted migration or reintroduction of species, non-chemical control of pest or disease outbreaks, controlling invasive species and decreasing nutrient-enhanced run-off into marine and freshwater ecosystems. Where extinction in the wild is inevitable, ex situ conservation of species via the collection of germ plasm, seed banks, gardens, aquaria, or zoos can be used as an option of last resort.

Regardless of management strategy, on-going monitoring is essential to assure that actions are truly of the "do no harm" variety. Monitoring with adaptive management sets up an in situ experiment, providing data for modification of management strategies and allowing for exchange of results between protected areas for better strategy development worldwide. This exchange of information will also be crucial as much of the world will be unable to afford extensive monitoring techniques but will require new conservation strategies to protect ecosystems from climate change.

The WWF has begun to study what approaches to conservation may increase the resilience of coral reef systems to climate change. In American Samoa for example, we are attempting to determine what factors may confer resilience and resistance to coral reefs in regard to coral bleaching. We know that increased sea temperatures, relating to climate change, are increasing the incidence of coral bleaching. What we are interested in determining is if there are local factors that can affect the likelihood of bleaching or the ability to recover from bleaching. To test the role of local factors we are conducting quarterly sampling at seven unique sites to examine the condition of coral reefs in relation to nutrient concentrations (from terrestrial run-off), presence of UV-protective compounds in the water (chromophoric dissolved organic matter) and within corals (mycosporine-like amino acids), zooxanthellae variability, marine protected area status, and water temperature. We are looking for variability in these sites with regard to their bleaching response, as well as overall health. If factors are identified as being associated with altered responses, they may prove useful in making decisions relating to selection of new marine protected areas, or for improving management approaches. We are also conducting similar projects at WWF field sites in Indonesia and hope to expand the project to sites in the Indian Ocean and Caribbean region.

4. Reduce greenhouse gas emissions to slow the rate and extent of climate change
Since the industrial revolution the average global temperature has risen 0.7 ºC as atmospheric CO_2 concentrations have risen from ~280 ppm to 376 ppm. Emissions scenarios from the Intergovernmental Panel on Climate Change (2001) suggest that if humans do not act to reduce emissions we will see CO_2 levels of 550 ppm within the next 40 to 100 years, roughly a doubling of pre-industrial concentrations. Other scenarios predict a potential tripling by the century's end. This range of scenarios implies an additional increase in average global temperature of 1 to 5.8 ºC. Recent papers suggest that the upper end of this range is more likely and that even higher high temperatures are possible, especially if climate sensitivity has been underestimated (Caldeira et al. 2003). This higher range of temperatures will also mean greater sea level rise and greater potential changes in precipitation and oceanic currents.

Clearly most systems will be dramatically challenged and subsequently altered by changes of this magnitude. It is unlikely that any local strategies could provide adequate protection for biodiversity under these conditions. Conserving biodiversity will therefore require a two pronged approach. First, greenhouse gas emissions must be dramatically reduced in order to slow the rate and extent of global climate change. Under current scenarios, all outcomes result in dramatic

changes beyond the reach of adaptive measures. WWF proposes that we aim to reduce greenhouse gas emissions to limit change to less than a 2 ºC average temperature increase above pre-industrial levels. Second, assuming that we can limit the rate and extent of change, we will still need to respond to the change that is already inherent in the system and buy some time for ecosystems as emissions are reduced. Because the effects of greenhouse gases in the atmosphere have a substantial lag time we are locked into additional change from the concentrations of greenhouse gases already in the atmosphere today. This does not mean that reducing emissions is futile; rather it means that we must reduce emissions quickly and deeply and take local action to protect biodiversity by increasing the resistance and resilience of natural systems so they can better survive the changes to come.

While it is not the role of resource managers to lobby for policy implementation in relation to greenhouse gas emissions, they can make a contribution to explaining the urgent need for such action. By identifying the vulnerability of their systems to climate change, as well as observing and reporting the changes they are already seeing, they can communicate to those in positions to affect climate policy the need for taking such action. Policy is swayed by economics and evidence. In addition to providing evidence, it may be possible to determine the economic cost of current and future climate change impacts to systems. Increasing the resilience of a system is not inexpensive. This means that resource management, an area already existing on limited funding will become more challenged to work effectively as climate change continues. Additionally many of the resources that are managed are themselves of substantial economic value and will be affected by climate change, such as fisheries and tourism.

What can Florida conservation practitioners do about climate change?

1. Develop local strategies to respond to climate change to protect natural resources
2. Encourage local policy makers to take action on climate change
3. Use stories of climate change in Florida to mobilize global action on climate change to afford real long-term protection for coral reefs from even more dramatic climate change

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Panel Discussion

Schuttenberg: I am going to ask our speakers to move up to the table, for all of the questions that have come up for the last four discussions. Who would like to start it off with a question?

John McManus: I just wanted to build on something that Mark said. He was pointing out that these increases are not uniform at all, they are patchy. In other words if there is one degree change, that means it is going to be two degrees in some places, and zero degrees in others, which makes some people feel happy. But the other realization is that those two-degree places are going to sweep around like a razor that is shaving a face, which is something that some of us still do, and that would be a problem. What is the record and the feeling with regard to the El Niño phenomenon, and the fact that we're having trouble finding out if there is a trend or not?

Eakin: The problem that we have had in the past is that most of the global climate models have not done El Niño very well, and they can't do a very good job of really representing what El Niño does. I am not talking about the prediction models; those are good – they are different from normal models. If they can't do a very good job of showing what El Niño does now, how can you really believe what they are saying about the future? That has changed. Those models are improving and the story is starting to come out, but it is still a bit mixed. If El Niño is going to become more frequent and more severe, some of the models say yes. Some of the models are indifferent. There are very few that say that El Niño is going to tend to go away. If we look just from a theoretical perspective though, El Niño is theorized as being basically a piece of the radiator system of the globe that allows us to blow off steam, as it were. As the temperature differences between the eastern and western Pacific get stronger, you've just got to blow the steam off, and El Niño goes and dumps heat out and changes things around; then it goes back to normal. If you increase temperature there would be more of a need to do that, and so there is some indication from some of the models and from theory, that indeed the tendency for increased El Niño is likely in the future, but I am afraid the answer to that question is very wishy-washy because that ss what the data are saying right now.

Terry Done: Another one for Mark. What bothers me about CO_2 is another story in a recent report about another calcium carbonate pool – calcite – dissolving, and buffering the increase in acidity. Was that discussed in Okinawa and was it given any credence?

Eakin: It wasn't really discussed because the problem you run into with any scientific meeting like that is you get what people happen to be working on at the time, what they are interested in, and there really wasn't much discussion that went on at the meeting. I don't think that there is any feeling that there is a lack of credence to that. But again, it is one of these things. If we are looking at a large scale, globally, what happens in the laboratory may or may not happen the same in the field. One of the questions that has been raised, looking at the paleoclimatic studies, is looking at growth rate over time, why does it not look like the corals have changed in growth rate as CO_2 has gone up. And we are probably dealing with non-linear systems, and so you may be – insofar as the CO_2 increase hasn't reached a point where the corals suddenly have a serious problem. The other possibility is that the concentrations of calcium carbonate around reefs may be naturally buffered, they may be protected. In fact, only time is going to provide an answer on that one as well.

Elliott Norse: I have two questions. These are going to be different. The first one physical, the second one biogeological. I have had a sense for a while that linear forcing, pushing a little more, a little more, a little more, incremental increases in CO_2 may bring linear responses, but that they may bring non-linear responses in currents. And I can imagine that changes of currents could have more effects on coral reefs than linear increases in temperature. What is the latest on whether or not we are likely to have non-linearity, rearrangements of current structure that could help, or harm, coral reefs, greatly? Second question: has anybody looked at how increasing temperature, or increasing CO_2 and decreasing the acidity of coral skeletons might affect bioerosion rates, will they go up or down, because there already is an effect.

Eakin: The first of those – I don't think we have a really good answer about changes in current patterns, especially because most of the global models tend to handle ocean very roughly, very coarsely. The last thing they are interested in are coastal areas, so I don't think there is any good answer to the first one. The second – and, in fact, that is something we are working on right now. I am preparing a paper, working with Joanie Kleypas and some others, looking at the whole question of if, and in some areas such as where I have worked in the Pacific. After the El Niño in 1982-83 we saw a tremendous mortality, which was followed by huge amounts of bioerosion, and areas of the lower reef are just flat gone. They are sand. The question is, are there differences in systems such as the eastern Pacific compared to areas that are already, that have less CO_2 in their current systems. Are there analogues out there, and the evidence seems to support this, yes indeed. Where you have weaker skeletal structure you have a more fragile system that is more capable of being driven to collapse by bioerosion, whereas in other areas the physical structure is just more robust.

Rod Salm: When you were asking that question, I was thinking of some of those other reef structures of those subtropical areas, some of the worm reefs and things that are more fragile and that you can break easily with your fingers and how they have adapted their growth form perhaps. These are reefs, I am thinking of the southern Mozambique coast that I know quite well, and these are reefs in very high energy environments. So if one wants to look for an optimistic interpretation, perhaps there would be ability for those more fragile coral skeletons to survive by changing their morphology and being better able to withstand wave energy and other similar stressors.

Schuttenberg: I am going to ask this question as a proxy for someone else. Lara came and gave a similar presentation to the Sanctuary Advisory Council earlier in the week and quite inspired some of the SAC members, so that at the reception yesterday, several of them came up and asked her "What are you going to do about that climate change thing?" So, given the collective expertise, if you were writing a prescription for some concept – what are you going to do, how are you going to answer the members' question? [laughter from the panel]

Hansen: I get to start. Well, I sort of gave my prescription in the last slide of my talk. I think we need to be taking care of local conservation efforts, we need to be motivating our local policy makers to start taking action, and we need to motivate our global policy makers to look at what is happening in our systems locally that we care about, and persuading them that they need to do something. It is one of the things I have been chatting about with people in the Keys. If sea-level rise has dominantly, in the past couple of decades, been caused by the melting of glaciers in Alaska. Alaska is another state, Florida is a state, perhaps your senators need to meet and have a little chat about how they are not willing to do anything about climate change that is impacting folks here. Yes, it's true, Elliott. [applause]

Bob Ginsburg: I'd have to say I agree with Greg Nalter [??]. Coral reefs and corals especially have gone through some pretty serious ups and downs of sea level, and I tried to indicate that on this graph. In the past – what, 125, the last 10,000 years sea level has risen 120 meters, and the corals had to accommodate that. And previous to that there were four or five episodes where they had to accommodate to almost equally large lowerings of sea level, not to mention the associated climatic changes. So I think, first of all, we are certainly going to have coral reefs. I agree with Greg Moulter [??], and I would also like to point out that the geologic record is replete with extinctions and disappearances of individual taxa. So Greg, we may not have the same reefs that we have today, but I can assure you we will have coral reefs.

Eakin: I think that the plan that you had up on the screen from the WWF report is a very good one. I think that the only thing that I would add is if – people need to realize, and I would include the policy makers in this, that global actions have important local consequences, as well as of course local actions have important global consequences. We really have to make sure that people are working together on this one, because it is a big problem. I mean, it is a huge problem that we don't, I think, collectively, globally have an answer to really get it solved. We could easily sit up here and say "Cut CO_2 emissions," but the economic consequences of doing that are huge. So there is a lot that goes into this equation, just like Elliott was talking about complexity of systems earlier today. This is a huge, uncontrolled global experiment, and if anyone knows the answer of how to put it back together, please step forward.

Ginsburg: How many people in this room's families have two cars? Are you willing to give up one? How many people have one car? Are you willing to give it up?

Hansen: I live in Washington, DC, and I'm a driver. [laughter] The other thing that I want to talk about is a paper that I have been touting at every talk I have given this week. The issue of *Science* that came out last week was focused on the hydrogen economy. There was a paper in it by two scientists at Princeton who talked about their proposal for how we reach stabilization, not full stabilization, but a 50-year stabilization, to allow us the time to get more technologies to allow us get to longer term stabilization. I recommend that everyone take a look at that paper. No one is proposing that we stop driving cars, no one is proposing that we stop using electricity. They actually have a blueprint of how they think we can get to this, and there are a lot of other people who put out similar blue prints. We have a lot of technologies and a lot of ways that we can do things. The economic pressure is the big issue right now, because the people who sell fossil fuels are making a *whole* bunch of money.

Schuttenberg: Alright, then, well perhaps a new issue for the Florida Keys Sanctuary! Thank you very much, we want to thank the panel very much. [applause]

Keller: I would just like to make a couple of concluding remarks and set us up for tomorrow. I think this has been a truly extraordinary day for the Florida Keys and I want to thank our plenary speakers and all of our panelists and speakers, the audience that has come here to partake of all this, and I want to thank you all very much for a fantastic day. [applause] And tomorrow is going to be another extraordinary day with three plenaries: on our sister coral reef system in Australia, on the Great Barrier Reef; on Shifting Baselines; and on the recent history of South Florida and the Everglades. There will be three more excellent panels. Thank you all very much. [applause]

Plenary Presentation:
Lessons from the Great Barrier Reef: Sister System of the Florida Keys

Terry Done

Introduction

The theme of this public meeting about conserving and using the Florida Keys National Marine Sanctuary (FKNMS) stresses the importance of building connections among scientists, the general public, and policy-makers. In Australia, these same players have also made good connections in relation to the Great Barrier Reef (GBR), in some ways, a sister to the Florida Keys. The GBR World Heritage Area is an area of ocean and reefs the width of Florida that, if transplanted to the U.S. east coast, would stretch the 1,200 miles from Key West to Baltimore (Fig. 1). The GBR is a sister not just in terms of its ecological structure of coral reefs, seagrass areas, islands, mangroves, sea creatures, and wildlife. It is also a sister in the sense that there has been a long history of increasing use of the ecological system in both places: coastal development, shipping, ports, fishers, divers, tourists and tourism operators. In both places, there are people who may never visit the reef tract themselves, but greatly value its existence and its intrinsic qualities nonetheless. Like the Florida Keys, the GBR is managed as a multiple use marine management area, with goals of balancing use, production, and access, while protecting its economic values (mainly tourism, fishing, ports, and shipping) and natural values (the scenic qualities, biodiversity, and ecosystem function that underpin most of the economic values – which are valued at billions of dollars annually).

But there are important and striking differences between the GBR and the FKNMS apart from sheer size. Whereas the Keys loom small in the consciousness of the American general public, "Our Reef" looms large in the consciousness of Australians. Most if not all Australian schoolchildren learn of the GBR as a national treasure from an early age, as much as American school children learn of Yellowstone and the Grand Canyon National Parks: it is unthinkable that we humans inadvertently do anything to diminish them. The strength of care for and ownership of the GBR by the people is translated into bi-partisan political support for strong measures to conserve the system, while balancing access and sustainable use of its resources. The creation of the FKNMS and the effort to restore the Everglades is evidence that the great value and importance of the linked ecosystems of the Everglades, Florida Bay, and the Florida Keys are clearly recognized.

Connections Inherited, Built, and Maintained

In Australia, it was in the 1960s and 70s that public groundswell to "Save the Reef" came to the consciousness of my generation. At that time, the main perceived threats were mining of reef limestone and drilling for oil. (Then we just worried about mass spillages of oil; now we also worry about burning it). An engrossing account called *The Coral Battleground* from the perspective of poet Judith Wright (1973) juxtaposes the imagery of the coral paradise at risk, the vested interests standing to make a fortune from oil, conservationists from diverse walks of life who saw the issues, created and committed themselves to the "Save the Reef" cause, and scientists in the Great Barrier Reef Committee (formed in 1922 – now the Australian Coral Reef Society) walking a line between science and advocacy, informing the public debate, and

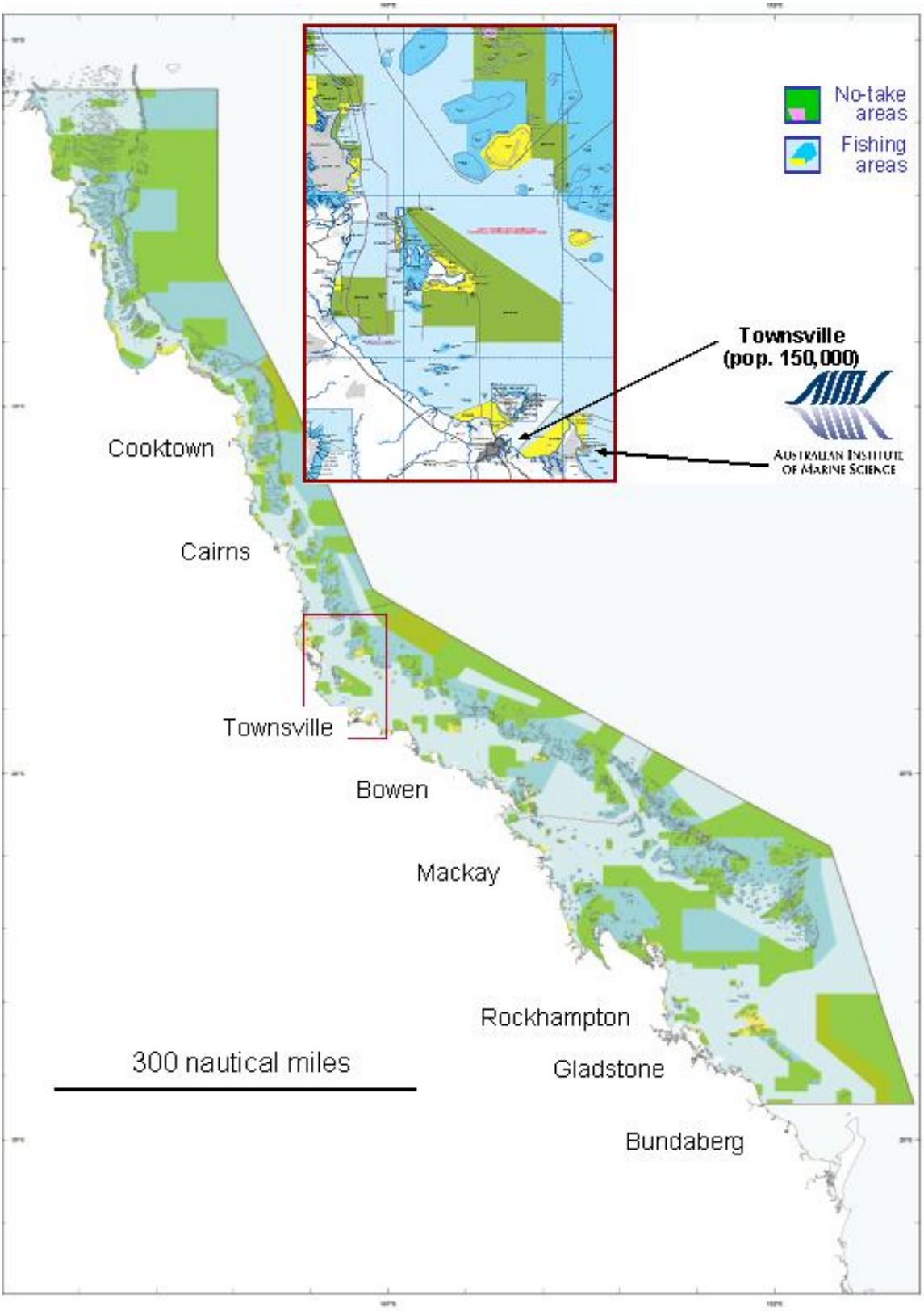

Figure 1. Map of the Great Barrier Reef Marine Park, showing revised zoning introduced in July 2004.

highlighting the paucity of scientific understanding of the very thing that we wanted to save: "Our Reef." Wright's account has inspired many a coral reef scientist, advocate, and manager, and indeed, the political impetus that led to today's research institutions and the GBR management agency by and large came out of those days: the Department of Marine Biology at James Cook University (JCU; 1969); the Australian Institute of Marine Science (AIMS; 1972); and the Great Barrier Reef Marine Park Authority (1975). All have made their mark since, and built much of the foundation of basic science about tropical marine systems in general, and the GBR in particular, that managers and policy makers can now take for granted. But there were also shortcomings and delays in the transfer of the considerable science knowledge that was relevant to policy and management. Also, there was inadequate engagement between scientists and would-be users of science – not only the managers and policy makers, but also the traditional, commercial, and recreational users of the GBR. Two concrete initiatives to redress these shortcomings had their genesis in the 1990s.

The first was a two-year, skillfully facilitated process of extensive workshops and working groups orchestrated by the GBR Marine Park Authority that produced the *Twenty-five Year Strategic Plan for the Great Barrier Reef* (Anon. 1994). The Plan's vision, broad goals, and specific strategies, signed off by the leaders of all the major interest groups of the time, have been reflected in many recent GBR policy and management initiatives. In the process of meetings and workshops to develop the plan, scientists were not afforded the status of an elite group with a unique and disinterested view of the system. Rather, we were considered "just another interest group," a decision that, if not immediately appreciated by the scientists involved, was vital in building the science-people connectivity. The second concrete initiative was the Australian federal government's Cooperative Research Center (CRC) Program. Over 12 years, it provided billions of dollars a range of Centers, and in particular, about $90 million of new money to coral reef science with important strings attached: interest groups must be involved in the identification of issues, the allocation of research funds, and where possible, the logistic support of the research.

Those same interest groups that defined the vision and created the *Twenty-five Year Strategic Plan* signed up to the partnership that became "CRC Reef": The CRC for the Ecologically Sustainable Development of the GBR (1993 – 1999) and The CRC for the GBR World Heritage Area (2000 – 2006). Institutions including AIMS, JCU, and the Queensland Fisheries Service, by making commitments of time, staff, and resources to CRC Reef programs, were able to bolster their staff, income, and resources to undertake research in areas prioritized by the CRC Reef Board of interest group leaders, and the science institutions themselves. The outputs of all the science organizations increased substantially; there was a greater focus on problems as perceived by interest groups and there were mechanisms of consultation to translate "issues" into targeted research projects to better know and understand not only the physical and ecological system, but also the human dimensions – who does what where, how, and how much, and how better could it be done. Importantly, in some studies, especially a large "effects of fishing project," the process of engagement and consultation was equally as important as the science. Brochures, media briefings, and web sites have been important parts of connectivity building. There is now a greater appreciation of the issues and the scientific process – warts and all – and a greater willingness across the community to be part of the solution, not "the problem."

Pressures, Symptoms, and Management for Resilience

Like the Florida Keys, the ecology and economy of the GBR are subject to the same set of pressures as have been enumerated for tropical coastal systems the world over (Fig. 2): land-based runoff, fishing, tourism, diseases, pest outbreaks, and occasional ship groundings; extremes of natural climate variability such as hurricanes, heat waves, and floods; climate-change related changes in frequency and intensity of hurricanes, floods, and heat waves; and other more insidious climate change impacts such as slow increases in average ocean temperature and acidity. Given the huge size of the GBR, there is enormous variability in the extent to which these pressures have caused damage, and to which they represent ongoing threats to wildlife, ecological function and revenue generating activities and opportunities for fishing and tourism. Overall, the Great Barrier Reef is considered to be in relatively good condition (Wilkinson 2002), and I see current management as a mix of reducing manageable pressures, and improving the system's capacity to accommodate effects of runoff and fishing, and to rebound from inadvertent and natural disturbances. Diverse and sometimes subtle symptoms of degradation in the ecosystem at large, or in any local spatial or habitat subset, may be loosely categorized into three broad classes (Fig. 2B): 1) degradation of the environment (e.g., water or sediment quality), 2) a paucity of fish or other key functional group that could reasonably be expected to be abundant at that place, and 3) failure of ecological processes (such as corals not returning after a hurricane, or a target population of fish or invertebrate not rebounding after relaxation of fishing pressure). Any one of these symptom classes can signal a need for better policy and management in relation to a particular place; conceptually and operationally, the symptoms merge and overlap (Fig. 2B).

Zoning of access and use has been the major management action for almost two decades, along with management of fisheries in that section of the area that is open to fishing (> 90% until 2004), regulation of reef-based tourism, restriction of large shipping to designated lanes, and initiatives to maintain or where necessary, restore, good water quality. These management actions also fall into three broad overlapping categories (Fig. 2C): 1) rehabilitation (of water quality or substrate quality), 2) fisheries management (with an eye not only on market forces, technology, catch, and profitability, but also on in situ ecological function of fished target and incidental populations), and 3) zoning of use and access (discussed in more detail below). I portray the response to climate change as "coping" (Fig. 2C), recognizing that while reef managers do not do climate management, they can try to prevent other stresses at times and places of extreme climate stress, and so improve coral survival or recovery prospects.

These strategies (Fig. 2C), collectively, and adequately applied and targeted, should lay the groundwork for improvement in what has become the holy grail for managers of all sorts of natural and managed systems: ecological resilience (Best et al. 2002). At any given site, be it mangrove or seagrass area, the open sea floor, or a coral reef, two things need to be 'OK' for that place (Fig. 2D): timely and adequate natural replenishment of depleted populations, especially key functional groups, and an environment that will expeditiously produce 'the right' outcome: a mangrove forest that supports prolific fish nurseries; a seagrass meadow that supports dense shrimp populations, turtles, and dugongs (like manatees); another area of sea floor where fields of sea-fans, sponges, worms, and lace corals regain a trawl-damaged area; and a coral reef with

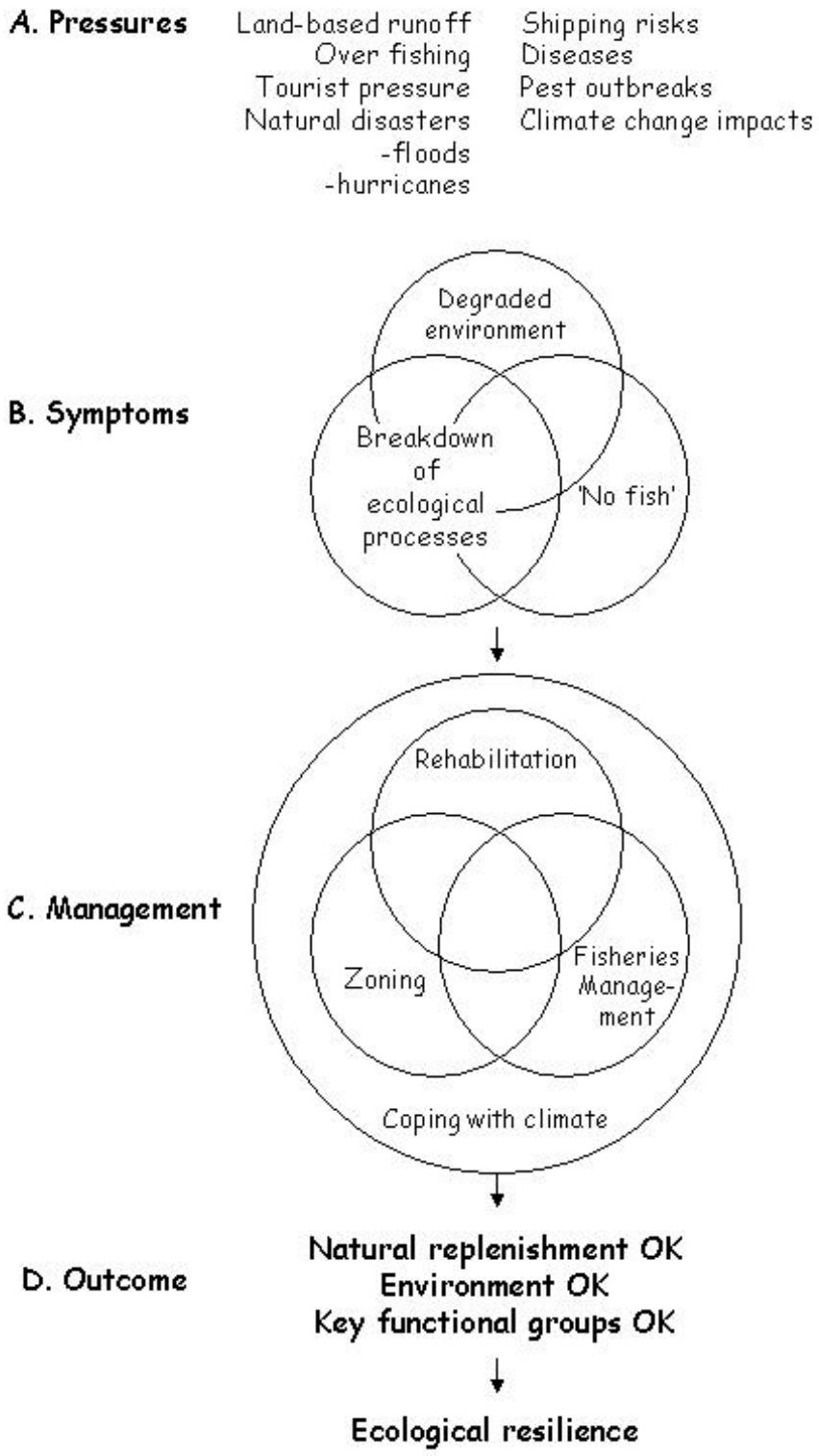

Figure 2. Schematic representation of pressures (A) and a classification of symptoms (B) and management (C) as a package of macro-scale strategies. These strategies that should work together to build resilience (D) into the system at the regional scale.

lots of corals, fish, and all the other creatures that make up a rich coral reef community. We can think of the broad management strategies (Fig. 2C) as the regional macro-ecological management necessary to set up success of micro-ecological management carried out at individual sites, or by individual enterprises, be it fishery or tourism activity.

Rehabilitation

In the GBR, rehabilitation is primarily concerned with maintaining or improving water quality impinging on the habitats and ecosystem. (Fortunately, there has only been a small need for site rehabilitation following ship groundings and channel dredging). In relation to land-based sources of pollution, the differences between the Keys and the GBR are more striking than the similarities. The towns of the Keys, with their septic systems and storm-water runoff, may be thought of as point-sources of domestic pollution, sitting within the more diffuse and episodic plume of runoff entering Florida Bay from the catchment that is mainland Florida, and sweeping onto the Keys and reef tract from the west. The Great Barrier Reef catchment comprises about 40 rivers draining highland ranches and lowland croplands, ranches, and towns. There are no towns on the islands of the GBR, but many do have tourist resorts within a stone's throw of coral reefs. The sewage from all these resorts is now tertiary treated and discharge points are sited to minimize impacts on the reefs. Looking at the regional scale, scientific study has shown that the main sources of nutrients and sediments to coastal waters of the GBR are the crops and farmlands adjacent to the 40 rivers (Furnas 2003), and that there are demonstrable impacts on several indicators of coral reef health on those reefs closest to the area of greatest coastal development (Fabricius and De'ath 2004).

These two pieces of science – the quantification of land-based inputs and the demonstration of a detrimental effect on coral reefs – have provided scientific support and impetus for the introduction of a major regional water quality rehabilitation program called the Reef Water Quality Protection Plan (RWQPP). The RWQPP is currently setting the groundwork for a process that will assist farmers and ranchers keep their soils and fertilizers where they want them: on their farms and ranches. It will eventually set targets for river-mouth loadings of sediments and nutrients for each of the catchments feeding into Great Barrier Reef waters. The solution must thus be built on connectivity and collaboration among land-users, who are in a number of cases organized into integrated catchment management committees, and whose actions will be backed by dedicated state and federal funds. For reef scientists, the still evolving river-mouth target approach poses a number of challenging questions. What is the relative importance of floods and normal flows in contributing to targeted amounts? How are the materials are dispersed, diluted, and taken up biologically once they reach the sea? How much, where, and how will the benefits in the marine system will be expressed?

Zoning

The Great Barrier Reef Marine Park Authority (GBRMPA) recently (1 July 2004) implemented a revision of zoning of the GBR that increased the level of no-take protected areas from 4% to 33%, an 800% increase in protection at a cost of a 30% reduction in area available for fishing. The 90 no-take zones are areas usually of 10s to 100s of square miles scattered along the length and breadth of the GBR (Fig. 1). In all these areas, previously fished species will be able to play out their roles in ecosystem function relieved of fishing as a source of mortality, and with the habitat relieved of effects of direct impacts of fishing gear. Many of the technical details of the rezoning process are outlined in Day et al. (2002).

Previous zoning did not adequately protect the full range of biodiversity, and it reflected a historical focus on coral reefs and remote areas. The rezoning has enhanced protection of the region's biodiversity by introduction of a network of highly protected areas typical of all the different habitats and communities. A scientific advisory group worked with GBRMPA staff to compile and collate biophysical data and use GIS to produce a classification of about 70 contiguous reef and non-reef bioregions covering the entire GBRWHA. Scientists also took a leading role in defining a set of operational principles (amounts, replication, and configuration) that they believed would produce a network of no-take zones that would provide a high level of insurance for all biological diversity by eliminating any extraction of species and incidental effects of fishing. Others developed and helped implement a computer-aided reserve selection process that provided a great flexibility of options that would meet conservation goals while minimizing economic, cultural, and social costs. The GIS map of the area was divided into > 50,000 hexagons that were grouped into candidate areas according to specific rules consistent with the operational principles, such as minimum size, replication, spatial distribution within a bioregion, specified number or area of each biological feature type, inclusion of 'special' places, adjacent land or sea uses, and pre-existing zoning. From fishers' perspectives, however, the zoning measures constitute a reduction in areas open to fishing from around 96% to 67% (Fig. 1) and loss of access to particular areas and stocks that were previously used recreationally or commercially (see discussion of compensation measures, below).

Management of Fishing

In the Great Barrier Reef, the language in laws and regulations covering fishing emphasizes not only sustainable fish stocks, but also the sustainability of ecosystems on which they depend. Meeting these dual fishing objectives alongside the responsibilities Australia has to protect and present the reef as a World Heritage Area is a balancing act for the management agencies. Fishing in the GBR is diverse: trawling, line fishing (for frozen, fresh, and live trades), netting, crabbing, and several "collection fisheries," including corals and aquarium fishes. There are bag and size limits, and seasonal closures explicitly to protect reef fish spawning aggregations. Starting in 2004, there are three nine-day closures to all reef fishing based on the moon phases that are cues to summer time mass fish spawning on reefs.

The no-take zones, though explicitly for biodiversity conservation, restrict fishing to 66% of the area, with implications for the viability of fishing enterprises through new restrictions placed on the distribution of effort, and the potential for concentration of effort in the remaining open areas. A well funded, joint federal and state government compensation plan has been introduced for fishing enterprises that can attribute disadvantage to the increase in no-take area. The federal government supplies the funds, and the state manages them as the Great Barrier Reef Marine Park Structural Adjustment Package 2004 through the Queensland Government Rural Adjustment Authority. Its scope can be appreciated through the main types of assistance offered: Business Advice Assistance; Business Exit Assistance; Business Restructuring Assistance; Employee Assistance; Social Impact Assistance; and Employee Assistance (see http://www.qraa.qld.gov.au/).

The federal government identified ecosystem-based fisheries management as the broad ground rules for accessing this scheme. Like the concept of resilience, and overlapping with it, ecosystem-based management is an intuitively appealing idea and an incentive for research to refine how it is done. Certainly, actions like zoning, protection of water quality, and protection of spawning aggregations are elements of ecosystem-based fisheries management. There are two causes for optimism in relation to both fisheries and biodiversity conservation in the Great Barrier Reef: the vast size and diversity of the area over which biodiversity conservation and fisheries are practiced; and the real

prospects that, uniquely in the world so far, the number, size, and distribution of no-take zones will have important flow-on and spill-over benefits in replenishing fished stocks within the area at large, and in supporting fishing at large.

Coping with Climate

Climate change is a major threat for coral reefs and allied systems (Buddemeier et al. 2004; Done and Jones 2006). Sea-level rise and increases in ocean temperatures will potentially affect local survivorship, extent of individual formations, and regional distributions in mangroves, seagrass meadows, and coral reefs – the iconic habitats of both the GBR and the Florida Keys. Increasing concentrations of atmospheric CO_2 will directly affect plant productivity and indirectly affect growth rates in calcareous organisms such as corals, clams, and many marine plants, potentially impeding a reef's ability to grow vertically in pace with sea-level rise. The greater the climate change, the greater the potential detrimental effect on humans through the loss in area of productive habitat, and loss of ecosystem goods and services in areas that remain. Coral reefs are now widely recognized as an iconic natural system at risk of serious degradation under the effects of global climate change, being regularly covered in the scientific and popular press. To that extent, scientists have been very successful in informing the public debate.

A recent statement from the influential International Coral Reef Initiative included the words "reefs are deteriorating from coral bleaching and mortality due to warming seas," and coral reef managers should "counteract these trends by adopting a number of risk minimizing strategies." The current initiative to build resilience into coral reef management pioneered and developed by Salm and colleagues (these proceedings) is one risk-minimizing strategy based on "picking winners." Another, based on "spreading the risk" rather than picking winners, is the implementation of a dispersed and replicated configuration of no-take areas such as we have in the Great Barrier Reef. Though "no-take" confers no protection from ocean hot-spots, our configuration should minimize the risk of all protected areas being damaged by any unmanageable external event, such as a summer heat wave, a flood plume, or hurricane waves, all of which are patchy at the scale of the whole Great Barrier Reef.

Conclusion

At the Great Barrier Reef or at "little sister" Florida Keys, any of us can drop an anchor, swim around, and enjoy or despair at the sights we see. We are aware that what we are seeing is a snapshot in time. Things you hear from scientists may color what you see through your facemask. For example, on a damaged or over-fished coral reef in Florida or the Great Barrier Reef, you might take heart if you can see evidence of resilience: new corals and young fish, lots of them, and many varieties of them.

What is OK in terms of "lots" and "many varieties" will depend not only on whether you are in the GBR (high species richness) or the Keys (low), but also where in those places (some of my favorite places in the GBR have low species richness of corals and fishes). Science can attempt to tell us what is OK at local scales, and what processes produce OK or not OK. It can help define reasonable expectations for place A, as compared to place B a few yards, miles, tens of miles, or hundreds of miles away. If science is good enough, it can make the distinction between "it's not OK and its prospects are bad" and "it's not OK now, but its prospects are good because…", or "…it would be OK if only…" "If only" might typically include "the place weren't so choked up with seaweeds,", or "it had a better supply of coral or fish larvae," or "it wasn't so close to that shipping lane or sewage outfall." Scientists may, through good connections with each other and a collective understanding of processes, so characterize many such points on the map, and also learn to

interpolate and extrapolate sensibly to points for which they have no direct observations. This is a major part of the scientific challenge on the vast expanses of the GBR and the Florida Keys reef tract, where in situ data points are extremely sparse, be they ecological observations on coral reefs, seagrass beds, hard-grounds, or the sea floor, or be they samples of water or plankton communities, or sediment cores.

When scientists needed to connect with the GBR Marine Park Authority, this type of thinking fed into the process that laid the ecological ground rules for the new Zoning Plan. When, to finalize the zoning, the managers connected with the broader, sometimes antagonistic, fishing community, they were able to negotiate on two broad premises: 1) that the ecological ground rules were considered by a scientific panel to be necessary to meet criteria for biodiversity conservation, and 2) that there could be flexibility in zone boundaries, but only within bounds of the ecological ground rules. That we now have a zoning plan that can do great good for the people and "Our Reef" is perhaps one of the world's best examples of science-people-policy connections. This is big sister's lesson for little sister.

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Resource Conditions

Corals and Microbial Power Shifts… What Does It Mean?

Kimberly B. Ritchie

Coral Microbial Associates

Corals are complex consortiums consisting of a number of mutualistic individuals: the coral animal, the symbiotic endosymbionts (dinoflagellates), and a host of other microbes, both endosymbionts and exosymbionts, which associate with the coral host. Culturable heterotrophic bacteria associated with the surface mucopolysaccharide layer of corals (Fig. 1) form diverse communities that differ significantly from communities in the surrounding water mass. Living in a nutrient-rich matrix, bacterial populations are competitive and appear to be specific to the chemical environment in which they live. For example, the microbiota associated with healthy corals are different among coral species. These similarities reflect the phylogenetic relationships among corals. Bleaching is the loss, or degradation, of carbon-fixing zooxanthellae from otherwise healthy coral tissue. There is a significant shift in microbial community structure when corals become bleached.

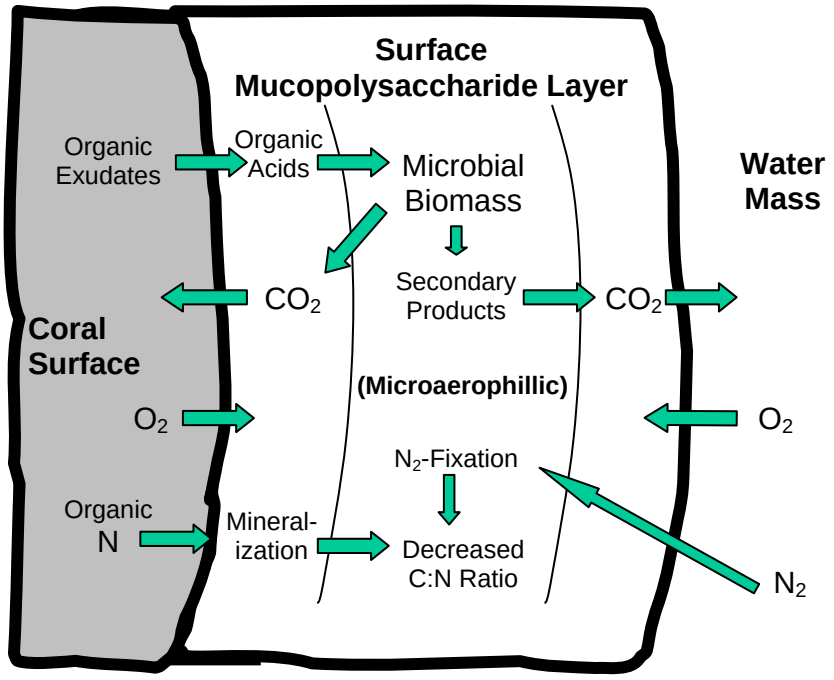

Figure 1. Diagram depicting the surface of a coral colony, the surface mucopoly-saccharide layer of the coral, and the adjacent water mass. Also shown are the complex processes associated with microbial communities within the surface mucus layer.

Coral Stress and Susceptibility

We have shown that shifts in organoheterotrophic microbial populations in the surface mucus layer of corals occur when corals are stressed, either due to disease or during bleaching (Fig. 2). We have also shown that *Vibrio* populations tend to increase during bleaching, but return to previous levels during recovery. Conversely, populations of *Pseudomonas* decrease during bleaching, but also return to previous levels during recovery. It is not clear whether this population shift to predominantly opportunistic *Vibrio* populations is a response to available carbon sources after bleaching alters the mucopolysaccharide composition, or whether environmental conditions, such as temperature or available nutrients from the water mass, contribute to an environment conducive to *Vibrio*

overgrowth, resulting in subsequent virulence and bleaching. It has been shown by other groups that various isolated *Vibrio* species can cause coral bleaching and disease symptoms. It is likely that many different microbial species, both marine and land-based, can become opportunistic once environmental stressors have compromised the coral host.

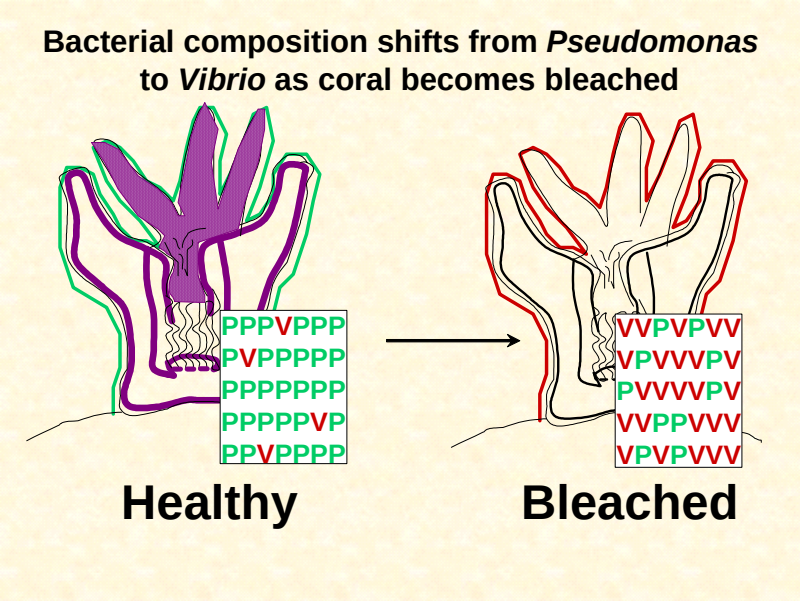

Figure 2. Illustration of the shift in microbial community composition between a healthy coral polyp (left) and a bleached coral polyp (right). P: *Pseudomonas*; V: *Vibrio*.

Coral Diseases

There is a range of disease assaults recorded for coral reef communities of the Caribbean. Black Band Disease is the best documented one. Among other known coral diseases are Aspergillosis (a fungal disease of sea fans caused by *Aspergillus sydowii*); White Pox disease (a disease of *Acropora palmata* caused by *Serratia marcescens*) (Fig. 3); White Plague Disease (a disease of massive corals caused by *Aurantimonas coralicida*); and White Band Disease (putative causative agent, a *Vibrio* sp.). It is estimated that White Band Disease has destroyed up to 95% of the acroporid corals on many reefs. The precise source of known pathogens is still unclear. To cause more uncertainty, there are a number of diseases affecting corals for which the causative agents have not been identified. These include Yellow Band Disease, Dark Spots Disease, and a myriad of additional white diseases.

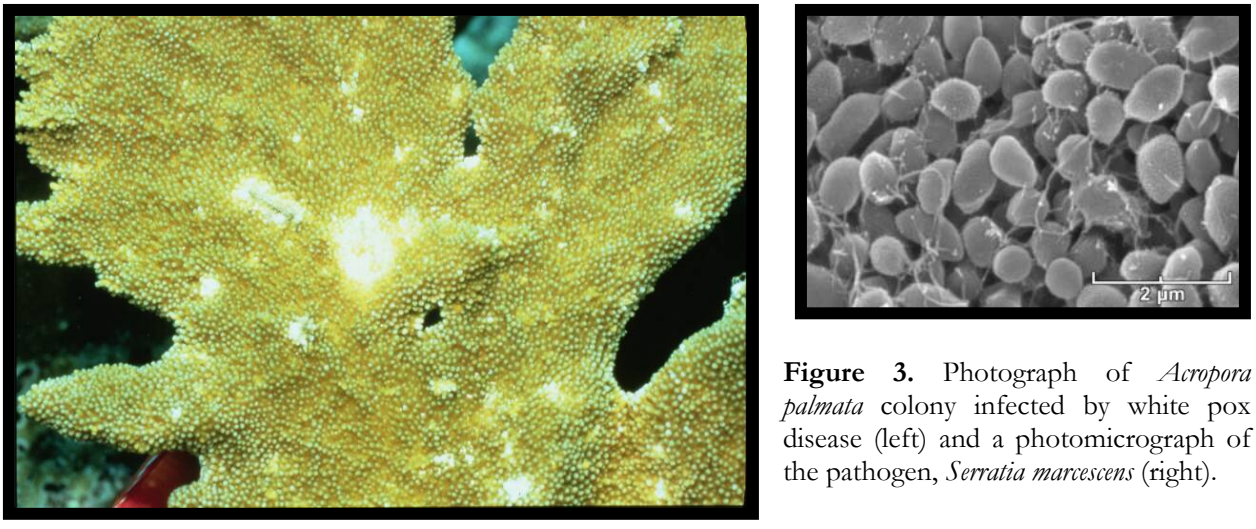

Figure 3. Photograph of *Acropora palmata* colony infected by white pox disease (left) and a photomicrograph of the pathogen, *Serratia marcescens* (right).

The current thinking on coral diseases is predominantly single pathogen-based, but there are likely to be more interesting and complex processes at work. For example, the microbial "power shift" from *Pseudomonas* to *Vibrio* may compromise coral primary immune responses, as normal associates that produce protective compounds are compromised. This may leave the coral animal open for opportunistic infection. Theoretical and observed consequences of environmental changes can also lead to the disruption of the normal communities associated with healthy corals. In some coral diseases, the mucopolysaccharide matrix appears to break down at the site of the lesion. Because it is likely that the normal microbiota protects the coral animal from invading microbes, changes in microbial community structure may result in the development of some coral diseases. It is important to understand the role of these normal microbial communities in the health of corals when asking why some corals are more resistant to stress and disease than others.

Microbes Are Not the Problem

Known coral diseases for which pathogens have been identified range from terrestrial fungi to marine bacteria. This suggests that the *putative* causative agents of marine diseases are much more complicated than just new invasive species. Do pathogens become pathogenic through a programmed adaptive process, or are they *made* pathogenic by the circumstances in which they find themselves? If they become pathogenic, opportunistically or otherwise, then this suggests that *bacteria are not the problem, but a symptom of a change in an environment more conducive to bacterial overgrowth, or microbial processes that trigger a chain of environmental effects*. It is much more likely that many different types of microbes can cause infection, given the opportunity.

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Resource Conditions: Discovery of a Viral Disease Infecting Lobster and Impact of Sponge Fishing on Hard-bottom Communities

Mark Butler, Donald Behringer, and Jeffrey Shields

Our presentation summarizes recent research developments pertaining to two fishery resources that occur within the Florida Keys National Marine Sanctuary (FKNMS), namely: the Caribbean spiny lobster (*Panulirus argus*) and several species of commercial sponges. Spiny lobster support one, if not the, most economically valuable fisheries within the FKNMS, the State of Florida, and indeed the entire Caribbean. Commercial sponges, on the other hand, are targeted by a much smaller and largely artisanal fishery that operates within the FKNMS. However, both fisheries depend on healthy, shallow hard-bottom areas that provide habitat for commercial sponges and serve as nurseries for lobster.

Shallow, hard-bottom habitat is a ubiquitous feature of the shallow waters within the FKNMS, and both sponges and spiny lobster are prominent constituents of these communities. Yet, remarkably little is known about the structure, ecological function, or resilience of hard-bottom communities. Our poor understanding of these communities has been highlighted in recent years by questions about the possible ecological impacts of Everglades restoration and commercial sponge fishing on hard-bottom communities.

In the case of sponges, resolution of these issues has been hampered because so little is known about their biology and ecology. For example, there is no stock assessment for sponges, the most basic population dynamics for the pertinent sponge species is largely unstudied, their tolerance to changes in water quality has not been tested, their impact on planktonic communities is not well known, and the effect of the fishery on commercial sponges and allied species has never been examined. Although we know more about the biology of spiny lobsters, the recent discovery of a pathogenic disease that infects juvenile lobster has raised concerns about its possible impact on the fishery and its possible linkage with environmental quality. Our research on hard-bottom

communities over the past two decades has yielded important scientific insights, not the least of which is new information on the lobster virus and the potential impact of the sponge fishery on sponge communities within the FKNMS. It is these two topics that we summarize below.

Lobster Virus

In 2000, we discovered a lethal virus (PAV1) that infects Caribbean spiny lobster (*Panulirus argus*) in the Florida Keys. It is the first viral disease known for any lobster, and it alters the behavior and ecology of this species in fundamental ways. We have identified infected juvenile lobsters from sites throughout the Florida Keys and from a few other locations in the Caribbean. The prevalence of infection varies with ontogeny; most infections occur within the smallest lobsters. In contrast, < 1% of the more than 1,500 adults sampled showed visual signs of PAV1 infection.

The virus is highly pathogenic, with successful transmission demonstrated via: (a) direct injection of hemolymph from infected donors, (b) oral ingestion of infected tissue, (c) contact transmission among lobsters, and (d) waterborne transmission over short distances of < 1 m. In all cases, transmission declines with lobster size. The other decapods commonly found with *P. argus* (e.g., stone crab, *Menippi mercenaria;* spider crab, *Mithrax spinomosissimus*; and spotted lobster, *P. guttatus*) are unlikely carriers of the disease as none acquired PAV1 infections after direct inoculation.

Field observations indicate that lobsters infected with PAV1 are found alone in dens more often than uninfected lobsters. Laboratory experiments confirm this and show that healthy individuals, which are normally social, detect and avoid diseased conspecifics – the first report of such behavior in any animal species in the wild. The evolution of this behavior may be an adaptation that thwarts transmission of disease in these social creatures and field experiments confirm that disease prevalence is independent of local population density.

We are continuing our studies of this disease on a number of fronts, including: (1) testing whether habitat change or alteration of individual condition alters susceptibility to infection, (2) developing immunological and genetic diagnostic tools to assess infection at earlier stages, and (3) spatially explicit, individual-based modeling of disease transmission under varying scenarios of habitat structure, behavioral attributes, and fishing pressure to better understand disease dynamics and the evolution of traits to minimize transmission.

Hard-bottom Community Ecology with an Emphasis on Sponges

There are several goals associated with our research on hard-bottom communities, one of the first of which was establishing a long-term monitoring program for hard-bottom habitat in cooperation with the Florida Fish and Wildlife Conservation Commission/Fish and Wildlife Research Institute (FWC/FWRI). In addition, we have conducted or are conducting a series of field and laboratory studies including:

- a field experiment to assess potential factors that control recruitment of sessile hard-bottom species,
- observational field studies to determine growth, reproduction, and natural mortality of commercial sponges,
- an experiment conducted with the assistance of sponge fishers to assess the impact of the sponge fishery on sponge communities,
- field and laboratory experiments to determine if various species of sponge differ in their impact on planktonic community abundance or composition, and
- spatially explicit, individual-based modeling of changes in sponge, octocoral, and spiny lobster populations in response to various natural and anthropogenic stressors.

Our hard-bottom monitoring program is of hard-bottom sites at depths of < 4 m from Key Largo to the Lakes region west of Key West, extending on the ocean side of the Keys south to the edge of Hawk Channel and on the bay/gulf side up to 15 km north of U.S. Highway 1. We currently survey the abundance and, for some species, size structure, of > 60 species on each of 35 permanent sites once a year. Those sites were chosen from > 135 sites that we surveyed from Key Biscayne to the Marquesas in 2001 in a double-stratified, random sampling design. We are also monitoring recruitment on settlement plates at half of the permanent sites and at some we are also conducting experiments to examine the effect of local scour, microscale topography, and adult abundance on recruitment. Our current monitoring of hard-bottom habitat and select motile invertebrates is conducted in conjunction with FWC/FWRI, who also periodically monitor fish communities at these same sites. These surveys provide a spatio-temporal record of hard-bottom community structure that we use as a modeling framework and which may be used for commercial sponge population assessment and detection of habitat change.

In addition to hard-bottom habitat monitoring, we are also conducting experiments designed to reveal more about sponge population biology and the potential effect of the commercial sponge fishery on the sponge community. Our results suggest that the common large sponges found in the Florida Keys (including species that are commercially fished) grow slowly (~3 cm diameter/yr; Fig. 1), their fecundity generally scales linearly with size, and they die when exposed to atypical salinities. However, these responses vary somewhat among sponge species and among seasons. We estimate that natural sponge mortality of sub-legal sized commercial sponges (< 5 inch diameter) is approximately 7% of the population annually, with little difference among species.

The fishery appears to operate legally (i.e., harvests only permitted species and sizes) with minimal impact on non-targeted species. We estimate that mortality of sub-legal commercial sponges due to fishing activities is approximately 3% of the populations annually, with that for most desirable species (sheepswool sponge) being slightly higher overall on fished sites than that for yellow or glove sponges. Our estimates are in line with estimates of the fishers themselves (1–3%) based on daily logbook records. We estimate that about 40% of the fishable area during our six-month study period was never visited or fished. In areas that were fished, fishers removed 33% of the legal sized sponges, 3% of the sub-legal sponges, and virtually none of the non-commercial species. Undersized commercial sponges are not landed, but are thrown back into the sea to become "rollers." We found that rollers grow at rates comparable to attached sponges. The probability of reattachment varies among species and depth of sediment; sheepswool sponges readily reattach within a few months whereas glove sponges rarely do. We also found that rollers actually move little; the median distance moved after 6 months is ~1 m.

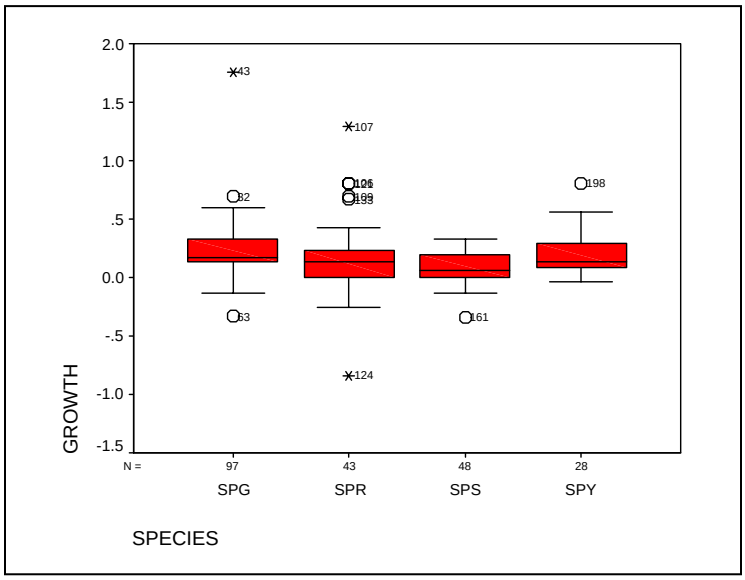

Figure 1. Comparison of annual growth (cm diameter/yr) for four species of commercial sponges: glove sponge (spg), grass sponge (spr), sheepswool sponge (sps), and yellow sponge (spy). Plotted are medians with 25th and 75th percentiles (in red) and ranges of observed values within 1.5 box lengths.

Our field and laboratory experiments designed to assess the impact of sponges on planktonic water column communities confirm that all seven species that we tested (golf ball sponge, yellow sponge, sheepswool sponge, glove sponge, brown branching sponge, loggerhead sponge, and vase sponge) consume primarily bacteria rather than larger planktonic size fractions. Completion of ongoing data analysis will yield information on possible differences in selectivity with season.

The Tropical Fish Resources of South Florida's Coral Reefs

Martin A. Moe, Jr. and Ken Nedimyer

The coral reefs of the tropical Western Atlantic and their living resources have been under great stress and have been in steep decline for many years, most dramatically since the 1970s. The small and colorful tropical fish of these reefs have been collected for the marine aquarium trade since the 1960s, and with the great increase in popularity of marine aquariums in the 1980s and 90s, collection of marine tropical fish and invertebrates in South Florida has grown into a significant fishery. And as with all major coral reef fisheries, the status and impact of the marine life fishery is of great concern to the fishermen and to fishery and environmental management. This presentation at the Connectivity conference provides a brief report on the current status of the tropical fish resources of South Florida coral reefs.

Sources of Decline

Environmental (natural) impacts

Storms. Storms, particularly hurricanes, can have devastating effects on coral reefs and their inhabitants. Physical damage to the structure of reefs can be widespread and extensive. There is a loss of living and dead complex coral structure that results in an immediate loss of tropical fish and a long-term loss of the environmental structure that would have supported future recruitment and survival of many species of marine tropical fish and invertebrates. Although loss of habitat can be immediately severe, a healthy reef environment can, over time, rebound from such impacts. It is when storm damage compounds other environmental stresses that recovery from such damage is slow and problematic. South Florida has had numerous large and small storm impacts in recent years and the marine life fishery, as has other Florida fisheries, suffered from these impacts.

Temperature extremes. Typically, temperature extremes create localized, temporary stress and loss of tropical reef fish. If the habitat has not been injured or destroyed, juvenile fish recruit to these areas within six months to a year and the loss to the fishery and the environment is only temporary.

Warm water. Throughout tropical areas all over the world, including southeastern Florida, coastal waters occasionally become extremely warm, and approach the upper limits that many reef organisms can tolerate. Although most reef fish can withstand extremely warm water or move into deeper cooler water, long periods of calm, hot weather can stress corals and other sessile organisms to the point of death and this destroys the habitats of many species of tropical fish. Although this is an indirect impact, over time, the loss of habitat equals the loss of tropical fish. A direct impact of warm water, however, is the proliferation of some protozoan fish parasites (see below), which can erode the tissues of some species of tropical reef fish to the point of death. Warm water stress affects tropical fish, and other organisms, over a broad area and over an extended period of time.

Cold-water upwelling. Occasionally, due to unusual winds and especially deep-water tidal fluctuations, cold water from the depths just off the Florida shelf rise to shallower areas and spill over into the shallow warm waters of the reefs. When this happens water temperatures in the 30 to 100 foot (10 to 30 m) depths may drop rapidly from 80 to 90 ºF down to 50 to 60 ºF (26 to 32 ºC down to 10 to 15 ºC). Although these upwellings usually occur off the steeper shelf of the lower east coast, they are not at all unknown in the Keys. Many species of marine tropical fish, especially those that are strongly tropical in distribution, are stunned and usually die from such cold-water exposure. Unlike

warm-water events, cold-water upwellings affect relatively local areas of the reefs and are short-term events.

Another source of cold-water stress is sometimes experienced during extreme cold fronts during the winter months. Usually these cold fronts with surface wind temperatures ranging from 45 to 60 ºF (7 to 15 ºC) affect mostly shallow inshore waters, but severe events can lower nearshore oceanic water temperatures and stun and kill some reef fish as well as some tropical species, mostly juveniles that inhabit shallow inshore waters.

Disease. There are many sources of disease in marine tropical reef fish, corals, and other reef organisms. Bacteria, viruses, and protozoans are the most common disease organisms in fish, with protozoan parasites apparently accounting for the greatest loss, especially in captive fish. One protozoan parasite in particular, however, *Brookynella hostilis*, is particularly virulent. This ciliate attacks the external tissues of angelfish and other species and since it can complete its life cycle on and in the tissues of the fish, it can quickly destroy skin and muscle and kill the fish. This parasite is responsible for epidemics of parasitic disease on marine angelfish, particularly in areas of extremely warm water. Such epidemics are relatively rare, however.

Ecological (habitat) change. Destruction and decline of coral reef habitats results in permanent change and decline of populations of tropical fish and other organisms that exist only because of the presence of coral reefs. This change and decline usually, except in the case of rapid and extreme storm or disease damage, occurs slowly, over a span of years. Global warming, algal overgrowth due of loss of herbivores, cumulative storm damage, heavy visitation and fishing, and coral disease are factors that are contributing to the decline of coral reefs off southeastern Florida. The tropical reef fish resources of this region have suffered from these impacts over the last 30 years and as these factors continue to degrade reefs, they will continue to impact these and other resources.

Unfavorable recruitment conditions. An environmental factor that is seldom recognized or considered is the environmental changes that impede or deny the successful recruitment of juvenile fish and other organisms. There may be an abundant, or at least adequate, supply of larval and post-larval organisms that drift into coral reef areas, but do not settle and/or survive due to an inhospitable environment. Changes in the environment that foster dense algal growth that harbors micro-predators, lack of a required food supply, loss of a suitable substrate, and many other factors can severely limit the successful recruitment of many species of tropical reef organisms.

Consumptive and other human impacts

Marine life fishery (aquarium collection). The marine life fishery has been active since the late 1950s. However, it has been recognized as a significant fishery and managed as a fishery only since the late 1980s. In 2004 there were about 300 licensed marine life fishermen and about 75 part-time (bycatch) fishers. In 2005 the marine life fishing industry helped promulgate and install management measures including a limited entry provision. A total of 108 marine life fishermen qualified for the transferable dive endorsement (full-time marine life fishermen), 29 qualified for the non-transferable dive endorsement (part-time marine life fishermen), and 42 qualified for the bycatch endorsements (mostly lobster and crab trap fishermen that sell marine ornamental organisms taken in traps). In order to limit the effort of the fishery, the marine life fishery has been closed to new entrants since 1998 and new marine life fishermen can enter the fishery only through purchase of a transferable dive endorsement.

The fishery is now well managed and rules and regulations are in place to protect populations of the most popular species and to restrict the fishery as necessary to protect the environment. The fishery, for the most part, targets juveniles of the more popular reef fishes and many species are harvested under slot restrictions for size that protect smaller juveniles that may not survive captive conditions and larger sizes to protect breeding populations. In addition to size restriction on small and large individuals (slot restrictions), daily bag limits on both fish and invertebrates are place.

Food and sport fish fisheries. There is an impact on marine tropical fish resources from the traditional food and sport fish fisheries, but it is not great. Some fish that are sometimes taken in the food fish fisheries are taken as juveniles in the tropical marine fish fisheries, but these are only a few species. However, as populations of ethnic Caribbean cultures increase in the South Florida area, use of what we consider ornamental species for food purposes may well increase. There is a live landing requirement for all fish and invertebrates considered ornamental marine life, so other than multi-use fish, most marine life fish are protected from food fishery pressures. Parrotfish and tangs are currently not protected as exclusively marine life species and are being targeted as food fish by some trappers.

Another apparently minor impact on ornamental fish populations comes from the lobster and stone crab trap fisheries from the loss of fish trapped and destroyed in lobster and stone crab traps and from the collection of juvenile ornamental species that are taken by trap fishermen and sold in the ornamental trade. Trap bycatch is limited to the recreational catch for fish, which is 20 fish per day, and it must be landed live.

Visitation pressure and recreational collection (sport divers). There is a variable and undocumented pressure on populations of ornamental species that occur in popular dive sites just through the frequent (daily) visitation by sport divers. This is probably a negligible impact; however, frequent visitation to specific dive sites does impact the natural environment in these areas and this must extend to some degree to ornamental species as well.

Also, there is a recreational fishery for ornamental aquarium species and this probably contributes a minor impact on these populations. To collect tropical fish a recreational fisherman must have a saltwater fishing license, and is limited to 20 specimens per day, only five of which can be angelfish. Size limits on ornamental fish do not apply to recreational catches.

Habitat degradation (pollution, direct impacts, ecological change). As mentioned previously, habitat degradation produces serious and permanent ecological change that results in the decline of many ornamental species. This can be alleviated only through the process of ecological restoration of coral reefs. Control of all sources of pollution and elimination of unnecessary human impact is the only way that these negative impacts can be decreased.

What We Know

Populations vary (good years/bad years)

There are variations in the annual abundance of juvenile ornamental species (from year to year and place to place), just as with all marine organisms. Wind, currents, upstream spawning success or failure, plankton patches, and weather events all contribute to the variables that dictate the abundance of particular species in nursery areas each year. Most of this variation is natural and unavoidable, and the fishery works with this natural variation and enjoys good years and laments bad years.

Overall, impacts from storms, disease, and cold water are localized and are not important long term
Storms, disease, and other short-term natural events are usually local events and do not affect the fishery on a long-term basis. These events interact with the success or failure of "good years/bad years" and can enhance or diminish the results of natural annual recruitment. Although the impact for good or ill in any year may be quite significant, the long-term effects on the fishery from such events are not important.

Ecological changes greatly affect tropical reef fish populations over the long term, both species and abundance. Habitat is everything.
This is a reoccurring theme throughout this presentation, but it has to be so; ecological decline is at the core of the decline of ornamental marine species.

Biology and ecology of a few species
We know something of the biology and ecology of many ornamental reef species, but most of that knowledge is anecdotal and is not in the scientific literature. Observant individuals engaged in the ornamental marine fishery for many years have a good working knowledge of much of the biology and ecology of their target species, but this knowledge is not structured or published. What is known is largely available in the popular literature of the marine aquarium hobby.

Natural longevity of some species
Marine life fishermen and marine aquarium hobbyists have some indications of the life cycles and longevity of many ornamental reef species, but this information is not in the scientific literature. Many of the targeted fish and invertebrates are short lived in the wild (about a year), and some are long lived (ten years or more).

Knowledge Gaps
The marine life fishery for ornamental species is composed of a great many species of fish and invertebrates that inhabit coral reefs and associated marine environments. Most of these species are valuable only in the marine life fishery and very few have been the subject of intensive biological study. Thus there are extensive knowledge gaps on the biology and ecology of most of the individual species that make up tropical coral reef environs. Gradually, especially with the death and decline of corals on the reefs of Florida, the Bahamas, and the Caribbean, much more scientific attention is now directed toward corals and we are learning much more about reproduction and disease in corals. However, the biology of the many species of small fish and crustaceans that make up a large part of the ornamental aquarium trade is still largely unknown.

These are the major subject areas for research on these species:

- Reproductive biology of important species
- Post-larval and juvenile biology and ecology
- Effects of ecological change on specific species
- Origin of post-larval fishes (current patterns that distribute larvae)
- Effects of ecological change on fish behavior and population dynamics
- Effects of collecting pressure on the local ecology of reefs

Management Actions Accomplished

Marine life fishermen of South Florida have long been concerned about the impact that their fishery may have on the resources and environment of the coral reefs of this great area and formed an organization in the 1970s to protect and help manage the fishery and the resources. This organization has been instrumental in working with fishery and environmental scientists and managers to inform and guide the development of rules and regulations to protect the resource and establish sustainability of the fishery. The work of this organization over the years has helped in development of legislation in the following areas:

- Marine life endorsement requirements
- Recreational catch limits and license requirements
- Live rock aquaculture licensing program
- Daily bag limits for certain fish and invertebrates.
- Size restrictions (slot restrictions)
- Closed areas (all National Parks, SPAs, and State Parks)
- Gear restrictions (traps, nets, chemicals, elimination of nitrox rebreathers)
- Elimination of fish traps (except in Gulf of Mexico)
- License moratorium beginning in 1998 eventually leading to a limited entry into the marine life fishery

Habitat Restoration is Critical

Restoration of Diadema antillarum *populations is essential to reef recovery!*

Without ecological restoration of the coral reef environments of South Florida, the value of the coral reefs and the fisheries that depend upon them, including the marine ornamental fishery, will continue to decline. Restoration of coral reefs, however, is not an easy or uncomplicated task. Many factors far beyond the control of local or even state-wide efforts contribute to the ecological changes that affect the reef environment. However, there are programs that can be developed that will aid restoration of the ecology of specific reef areas. One of the strongest possibilities is restoration of herbivory on certain reefs through re-establishment of populations of the keystone herbivore, the long-spined sea urchin *Diadema antillarum*.

Plenary Presentation:
Shifting Baselines

Steven Miller

[Editors' Note: Steven Miller's presentation included showing public service announcements that are available at: http://www.shiftingbaselines.org/index.php. We strongly encourage viewing these film clips and sharing them widely. The following summary of the Shifting Baselines program was published by Dr. Randy Olson as an op-ed in the 17 November 2002 *Los Angeles Times*, and is posted at the Shifting Baselines web site.]

ENVIRONMENT

Slow-Motion Disaster Below the Waves

By **Randy Olson**

There is a new term in the environmental movement. It sounds esoteric, like the kind of thing you don't really need to understand, something you can leave to the more technical types.

The term is "shifting baselines," and you do need to know it, because shifting baselines affect the quality-of-life decisions you face daily. Shifting baselines are the chronic, slow, hard-to-notice changes in things, from the disappearance of birds and frogs in the countryside to the increased drive time from L.A. to San Diego. If your ideal weight used to be 150 pounds and now it's 160, your baseline – as well as your waistline – has shifted.

The term was coined by fisheries biologist Daniel Pauly in 1995. It was a term we'd apparently been needing, because it quickly spread to a variety of disciplines. It's been applied to analysis of everything from deteriorating cities to declining quality of entertainment.

Among environmentalists, a baseline is an important reference point for measuring the health of ecosystems. It provides information against which to evaluate change. It's how things used to be. It is the tall grass prairies filled with buffalo, the swamps of Florida teeming with bird life and the rivers of the Northwest packed with salmon. In an ideal world, the baseline for any given habitat would be what was there before humans had much impact.

If we know the baseline for a degraded ecosystem, we can work to restore it. But if the baseline shifted before we really had a chance to chart it, then we can end up accepting a degraded state as normal – or even as an improvement.

The number of salmon in the Pacific Northwest's Columbia River today is twice what it was in the 1930s. That sounds great – if the 1930s are your baseline. But salmon in the Columbia River in the 1930s were only 10% of what they were in the 1800s. The 1930s numbers reflect a baseline that had already shifted.

This is what most environmental groups are now struggling with. They are trying to decide: What do we want nature to look like in the future? And more important: What did nature look like in the past?

These questions are particularly important to ask about oceans, my main research interest. Last year Jeremy Jackson of the Scripps Institution of Oceanography brought the problem into focus with a cover article in *Science* that was chosen by *Discover* magazine as the most important discovery of the year.

Jackson and his 18 co-authors pulled together data from around the world to make the case that overfishing had been the most important alteration to the oceans over the past millennium. Furthermore, humans have had such a strong effect on the oceans for so long that, in many locations, it is difficult to even imagine how full of life the oceans used to be.

One of scientists' biggest concerns is that the baselines have shifted for many ocean ecosystems. What this means is that people are now visiting degraded coastal environments and calling them beautiful, unaware of how they used to look.

People go diving today in California kelp beds that are devoid of the large black sea bass, broomtailed groupers and sheephead that used to fill them. And they surface with big smiles on their faces because it is still a visually stunning experience to dive in a kelp bed. But all the veterans can think is, "You should have seen it in the old days."

Without the old-timers' knowledge, it's easy for each new generation to accept baselines that have shifted and make peace with empty kelp beds and coral reefs. Which is why it's so important to document how things are – and how they used to be.

For the oceans, there is disagreement on what the future holds. Some marine biologists argue that, as the desirable species are stripped out, we will be left with the hardiest, most undesirable species – most likely jellyfish and bacteria, in effect the rats and roaches of the sea. They point to the world's most degraded coastal ecosystems – places like the Black Sea, the Caspian Sea, even parts of the Chesapeake Bay. That's about all you find: jellyfish and bacteria.

We have already become comfortable with a new term, "jellyfish blooms," which is used to describe sudden upticks in the number of jellyfish in an area. The phenomenon has become sufficiently common that an international symposium was held on the subject in 2000. Meanwhile, other types of world fisheries are in steep decline.

It is easy to miss changes in the ocean. It's big and deep. But sometimes, if people have studied the same oceanic trends over time, we get a glimpse of a highly disturbing picture. The Scripps Institution's Jackson, for example, has documented the nearly complete disappearance of the ecosystem he built his career studying: the coral reefs of Jamaica. "Virtually nothing remains of the vibrant, diverse coral reef communities I helped describe in the 1970s," Jackson says. "Between overfishing, coastal development and coral bleaching, the ecosystem has been degraded into mounds of dead corals covered by algae in murky water." Nothing you would want to make into a postcard.

Next year two major reports will be released on the state of the oceans: the Oceans Report from the Pew Charitable Trusts, and the report of the U.S. Oceans Commission. The advance word on both is that the news will not be good.

The last major U.S. report on the oceans was 30 years ago. That report warned that "there may be a risk some day of severely declining oceans." The inside word on the upcoming reports is that they will conclude that the oceans are today in severe decline.

The Ocean Conservancy, Scripps Institution and the Surfrider Foundation are mounting a major media campaign for early next year to call attention to the overall fate of the oceans and the problem of shifting baselines. The solutions are already known: We must care more about the environment and work to prevent its decline. Hundreds of environmental groups have action plans to help achieve such goals. The only thing they are lacking is mass support.

The oceans are our collective responsibility. We all have to ask the questions: What did they used to look like? What are we putting into them? Where did these fish we are eating come from? Are my food preferences jeopardizing the health of the oceans?

And, in a more philosophical vein, we should consider the shifting baselines in our own lives, examining how and where have we lowered our standards to the point that we accept things that once would have been unacceptable. Our environment has clearly suffered from our increasing comfort with shifting baselines. I suspect our lives have suffered in other ways as well.

Randy Olson *is a filmmaker and faculty member in marine biology at USC.*

Water Quality

Moderator: Bill Kruczynski

What We Know About the Water Quality of the Florida Keys National Marine Sanctuary

Joseph N. Boyer

This report serves as a summary of our efforts to date in the execution of the Water Quality Monitoring Project for the FKNMS as part of the Water Quality Protection Program. The period of record for this report is Mar. 1995 – Sept. 2004 and includes data from 37 quarterly sampling events at 154 stations within the FKNMS including the Dry Tortugas National Park (Fig. 1). The specific objectives of this project are to:

1. Assess the current status of water quality in the FKNMS by developing a long-term database
2. Assess the current trends in water quality in the FKNMS
3. Integrate the FKNMS project with other existing water quality monitoring projects to provide a more regional view
4. Evaluate the relative effects of terrestrial vs. Gulf/Ocean influences on water quality

Field parameters measured at each station include salinity (practical salinity scale), temperature (ºC), dissolved oxygen (DO, mg l^{-1}), turbidity (NTU), relative fluorescence, and light attenuation (K_d, m^{-1}). Water chemistry variables include the dissolved nutrients nitrate (NO_3^-), nitrite (NO_2^-), ammonium (NH_4^+), dissolved inorganic nitrogen (DIN), and soluble reactive phosphate (SRP). Total unfiltered concentrations of nitrogen (TN), organic nitrogen (TON), organic carbon (TOC), phosphorus (TP), and silicate ($Si(OH)_4$) were also measured. The biological parameters included in the study were chlorophyll *a* (CHLA, μg l^{-1}) and alkaline phosphatase activity (APA, μM h^{-1}).

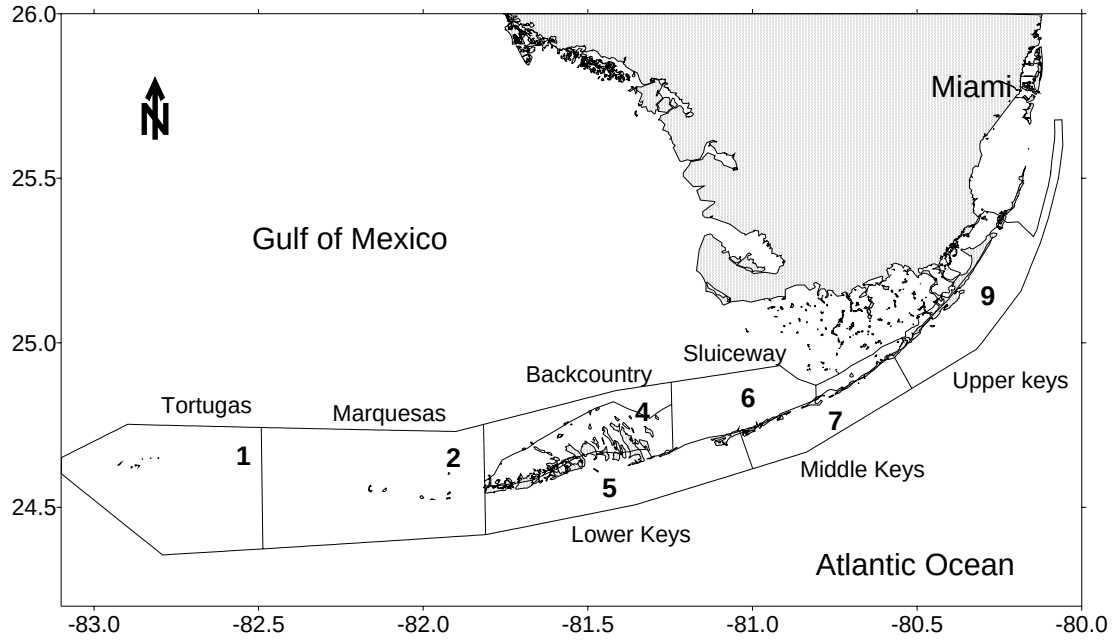

Figure 1. Map of the study area, showing sub-regions; Dry Tortugas National Park is in sub-region 1.

Several important results have been realized from this monitoring project. First, there are spatial differences in water quality across the study region (Fig. 2). DIN is elevated in the Backcountry because of its shallowness and potential to be most affected by benthic flux. There are lower concentrations of DIN, TP, CHLA, and turbidity in Upper Keys compared to the Middle and Lower Keys; water quality in the Upper Keys is most comparable to the Tortugas area. The Marquesas have highest CHLA and turbidity as a result of influences from the Southwest Florida Shelf.

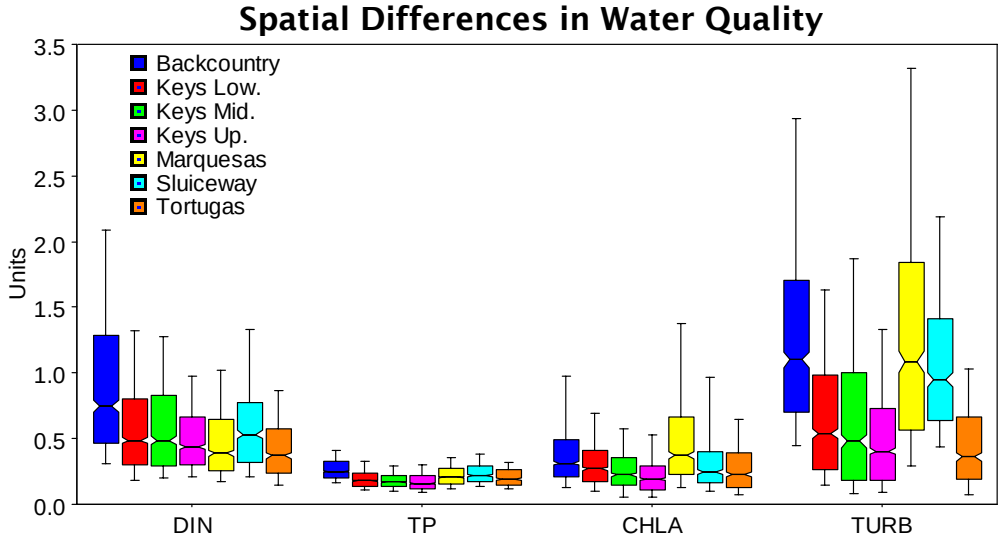

Figure 2. Variation of DIN, TP, CHLA, and turbidity among sub-regions.

Second, is documentation of elevated DIN in the inshore waters of the Keys (Fig. 3). This result was evident from the first sampling event in 1995 and continues to be a characteristic of the ecosystem. Interestingly, this gradient was not observed in a comparison transect in the Tortugas. This type of distribution implies an inshore source, which is diluted by low nutrient Atlantic Ocean waters. Presence of a similar gradient in TOC and decreased variability in salinity from land to reef also support this concept. There were no trends in either TP or CHLA with distance from land.

Another observation is that the Backcountry exhibits elevated levels of DIN, TOC, turbidity, TP, and CHLA. I believe most of these distributions are driven by the Southwest Florida Shelf waters moving through this area (median DIN = 0.7 μM, TOC = 298 μM, turbidity = 6.4 NTU, TP = 0.48 μM, and CHLA = 1.6 μg l^{-1}). In addition to this Shelf influence, elevated NO_3^- is a regular feature of Backcountry waters, where some of the highest concentrations are observed in non-populated areas (Fig. 4). This is probably the result of the benthic flux of nutrients in this very shallow water column.

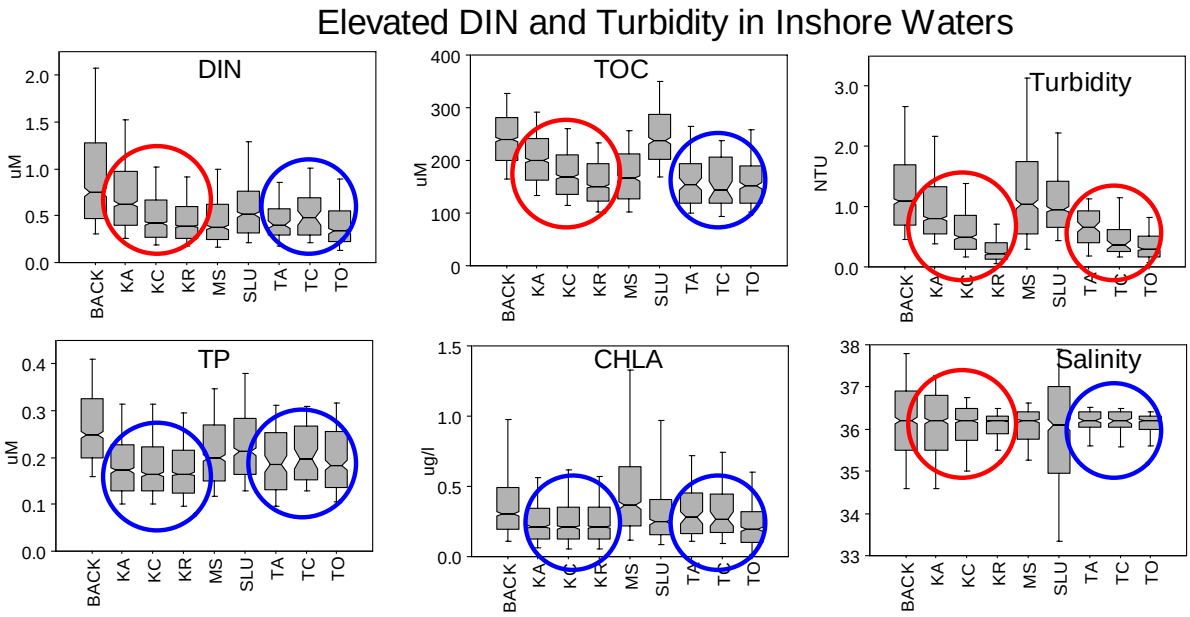

Figure 3. Variation in DIN, TOC, turbidity, TP, CHLA, and salinity, including onshore-offshore variation in the Keys (KA-KC-KR) and Tortugas (TA-TC-TO).

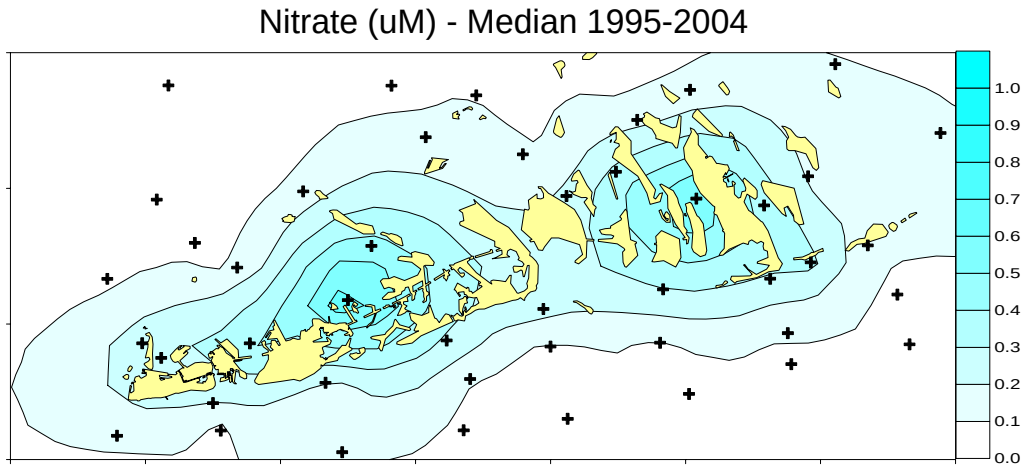

Figure 4. Spatial variation in nitrate concentrations.

The third important result is that highest CHLA concentrations occur on the Shelf and show a strong N-S gradient toward the Marquesas and Tortugas (Fig. 5). This is because of higher TP concentrations on the Shelf as a result of southward advection of Gulf of Mexico waters along the coast with entrainment of coastal rivers and runoff.

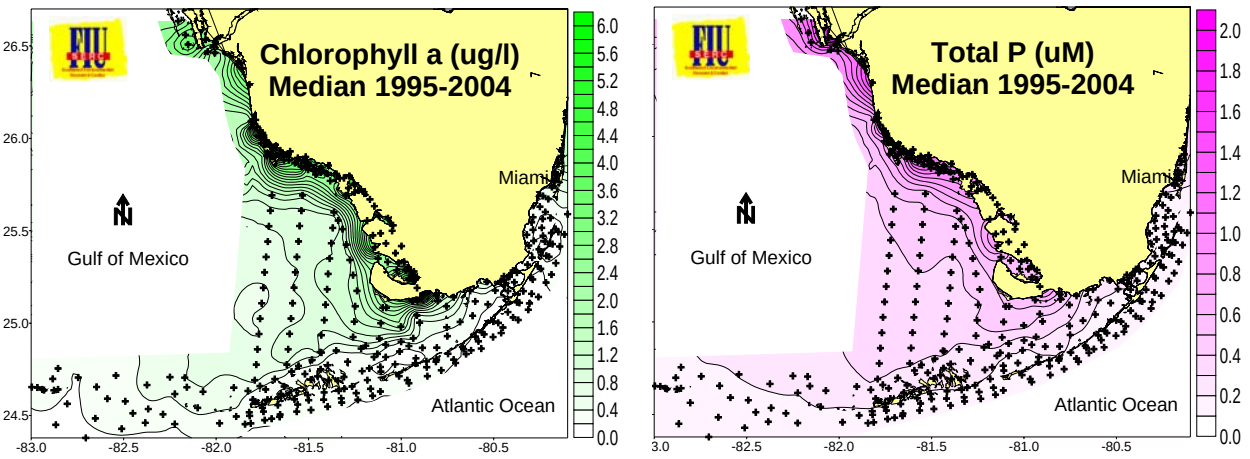

Figure 5. Spatial variation in CHLA and TP.

The fourth result is that trends in water quality showed most variables to be relatively consistent from year to year (Fig. 6), with some parameters showing seasonal excursions. Overall, there were statistically significant **decreases** in DIN, TON (except for increases in Tortugas), TP, TOC, and DO throughout the region. This is contrary to some of the trend analysis reported last year. Clearly, there have been large changes in FKNMS water quality over time, and some sustained monotonic trends have been observed; however, we must always keep in mind that trend analysis is limited to the window of observation. Trends may change, or even reverse, with additional data collection.

This brings up another important point: when looking at what are perceived to be local trends, we find that they seem to occur across the whole region but at more damped amplitudes. This spatial autocorrelation in water quality is an inherent property of highly interconnected systems such as coastal and estuarine ecosystems driven by similar hydrological and climatological forcings. It is clear that trends observed inside the FKNMS are influenced by regional conditions outside Sanctuary boundaries.

The large scale of this monitoring program has allowed us to assemble a much more holistic view of broad physical/chemical/biological interactions occurring over the South Florida hydroscape. Much information has been gained by inference from this type of data collection program: major nutrient sources have be confirmed, relative differences in geographical determinants of water quality have been demonstrated, and large-scale transport via circulation pathways has been elucidated. In addition we have shown the importance of looking "outside the box" for questions asked within. Rather than thinking of water quality monitoring as being a static, non-scientific pursuit it should be viewed as a tool for answering management questions and developing new scientific hypotheses.

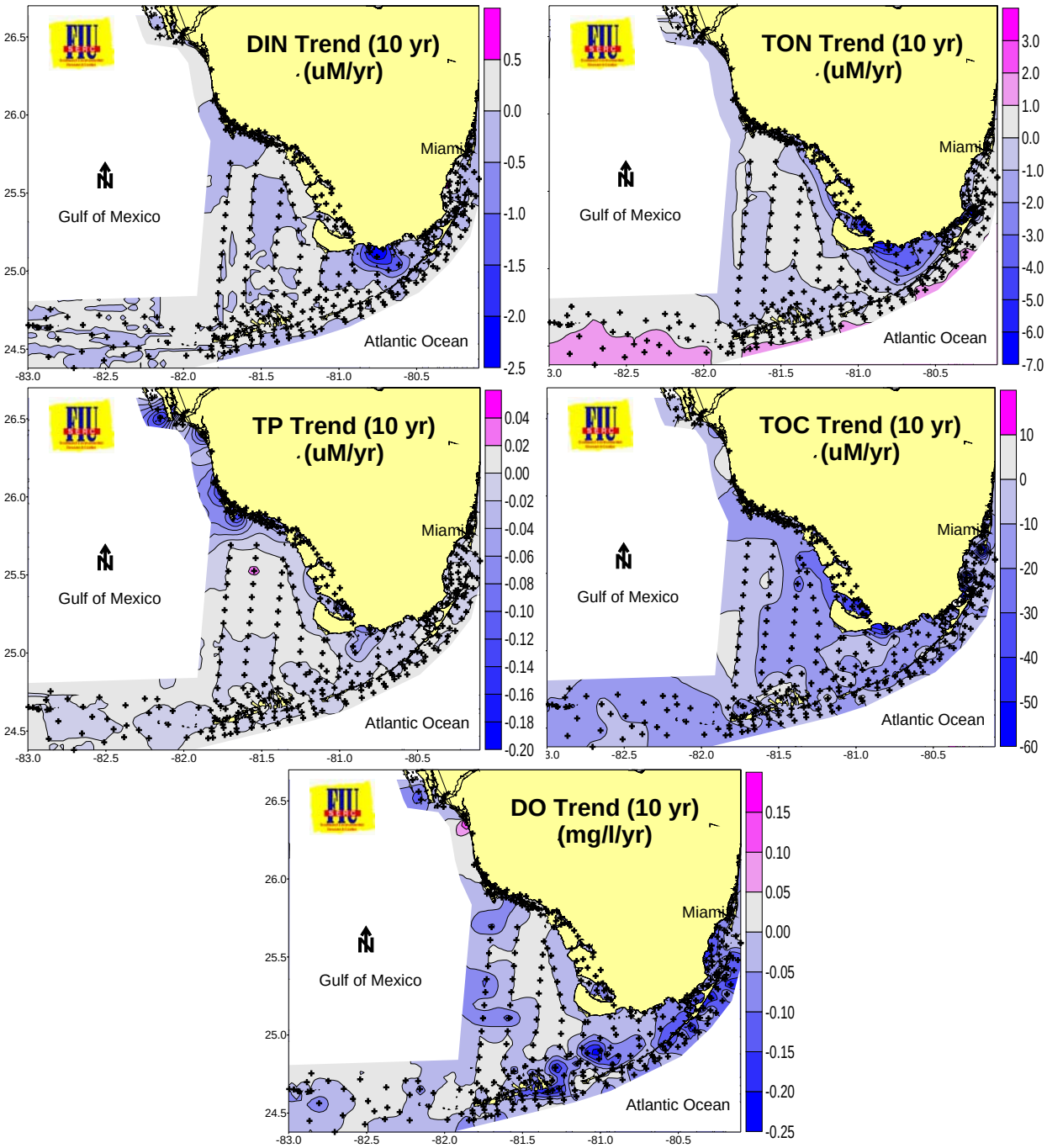

Figure 6. Spatial variation in temporal trends of DIN, TON, TP, TOC, and DO.

We continue to maintain a website (http://serc.fiu.edu/wqmnetwork/) where data from the FKNMS is integrated with the other parts of the FIU/Southeast Environmental Research Center water quality network (Florida Bay, Whitewater Bay, Biscayne Bay, Ten Thousand Islands, and Southwest Florida Shelf) and displayed as downloadable contour maps, time series graphs, and interpretive reports.

Acknowledgments
I thank all the field and laboratory technicians involved with this project, especially Pete Lorenzo, John Fulop, George Meichel, Ruth Justiniano, Pura Rodriguez de la Vega, Pierre Sterling, and Frank Tam. Special thanks to Danielle Mir-Gonzalez for help with time series analysis. We also thank the captains and crew of the R/V Bellows of the Florida Institute of Oceanography for their professional support of the monitoring program. This project was possible due to continued funding by the U.S. EPA (Agreement #X994621-94-0) and the South Florida Water Management District (Contract #C-15397). This is Contribution #366 of the Southeast Environmental Research Center at Florida International University.

Why Don't Queen Conch Reproduce in Nearshore Florida Keys Waters?

Bob Glazer and Gabriel Delgado

The queen conch, *Strombus gigas*, is a marine gastropod that inhabits the tropical western Atlantic. In South Florida, it once comprised significant commercial and recreational fisheries (Stevely and Warner 1978). In the mid-1980s, the stock declined precipitously resulting in a moratorium on collection in 1985 in state waters; this ban was extended to federal waters in 1986. Until very recently, the population showed no sign of recovering (Berg and Glazer 1995; Glazer and Berg 1994; Glazer and Delgado 2003).

Both adult and larval conch may be affected by declines in water quality associated with nearshore environments. In the case of adult conch, extensive surveys of conch populations throughout the Florida Keys have shown no spawning occurring nearshore even though anecdotal accounts indicate that this was once common as late as the mid-1980s. In South Florida, conch exist in two spatially distinct regions: nearshore (i.e., adjacent to the islands and north of Hawk Channel) and offshore (i.e., oceanside of Hawk Channel; Glazer and Berg 1994; Fig. 1). Over the course of our studies, we observed there has been a cessation of spawning in adult queen conch inhabiting the nearshore region (Glazer and Quintero 1998; McCarthy et al. 2002; Delgado et al. 2004). However, anecdotal reports from several sources indicate that as late as the mid-1980s, they used to spawn there. Examinations of gonadal tissues from nearshore male and female conch showed serious deficits in

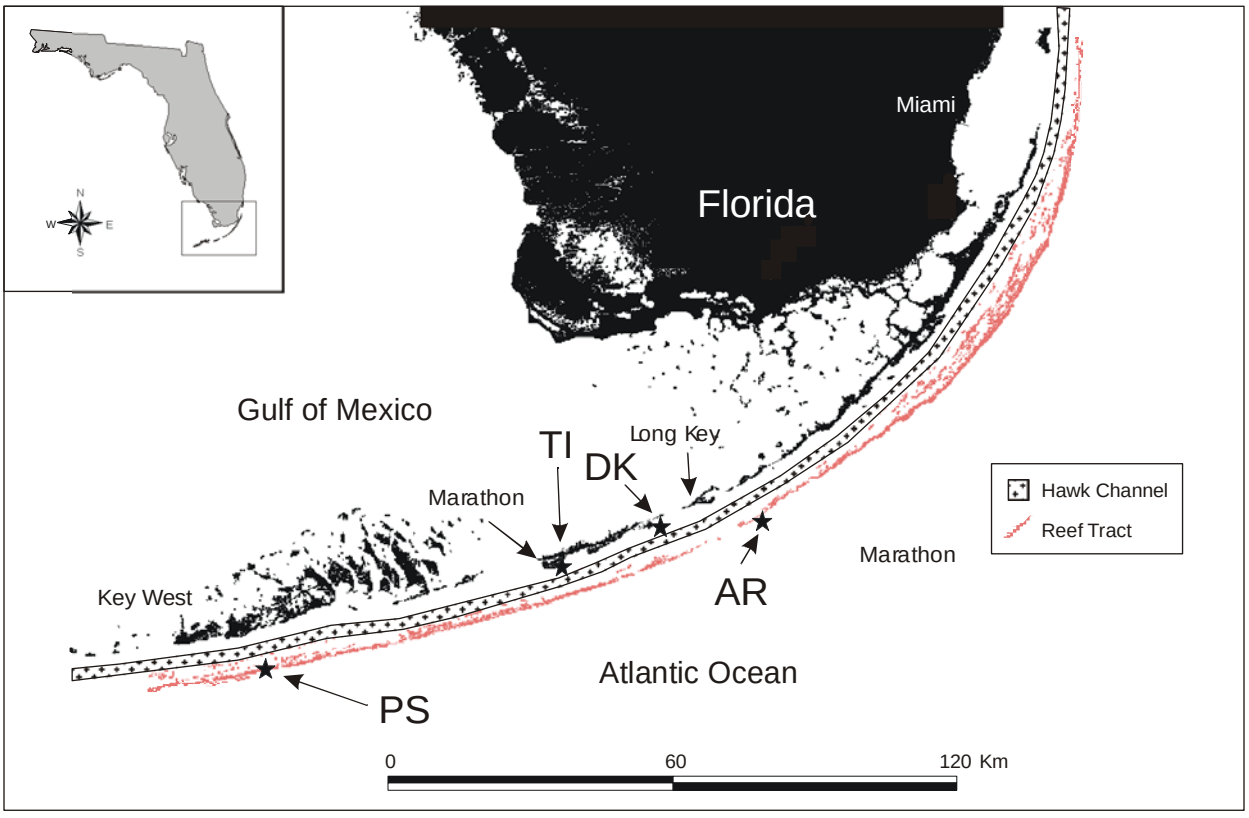

Figure 1. Offshore (PS, AR) and nearshore (DK, TI) sites from tranplant experiments

gonadal condition when compared with offshore counterparts (Delgado et al. 2004; Fig. 2). Reciprocal transplant studies demonstrated that the gonads of conch transplanted from offshore to nearshore degraded, whereas those transplanted from nearshore to offshore regenerated gonads after about six months (McCarthy et al. 2002; Delgado et al. 2004). The greatest impacts were observed in female conch (Delgado et al. 2004). Additionally, collaborative research between the Florida Department of Environmental Protection and the Caribbean Marine Research Center indicated that larval abundance was significantly lower in Florida than in an analogous location in the Bahamas. Thus it now appears certain that conch larvae obtained in nearshore plankton tows originated from either offshore breeding aggregations or from other upstream sources. Larval abundance and juvenile recruitment may be affected directly by water-quality degradation through three mechanisms: (1) larval growth retardation prolonging the larval cycle and increasing larval mortality, (2) direct mortality of larvae because growth has ceased and metamorphic competence is never attained or, (3) direct mortality from toxicity.

These deficits are consistent with exposure to man-made chemicals in the environment (i.e., xenobiotics) that simulate naturally occurring, biologically active compounds (i.e., endocrine disrupting compounds) and to sub-optimal environmental conditions. Among the xenobiotics implicated in endocrine disruption are the alkylphenol ethoxylates (APEs) which function as estrogenic endocrine disrupters (see Gronen et al. 1999 for a review), butyltins implicated as the causative agent in molluscan imposex (see Matthiessen and Gibbs 1998 for a review), polycyclic aromatic hydrocarbons (PAHs) that depress both female and male reproductive development (Spies and Rice 1988), currently used and banned organochlorine pesticides that may impact the endocrine system (Celius and Walther 1998; Cross and Hose 1988), and human-use pharmaceuticals.

Xenobiotics may enter Florida Keys nearshore waters via a variety of mechanisms including sewage discharges and surface water runoff (Heatwole 1987), vessel discharge and oil spills (Zheng and Van Vleet 1988), fish house discharges (Heatwole 1987), discharges from the South Florida mainland (Jaap 1984), and mosquito pesticide application (Pierce 1998). The lack of reproductive development in nearshore conch coupled with these widespread sources of pollutants suggests that there may be a linkage between water quality and reproductive development in Florida's conch population.

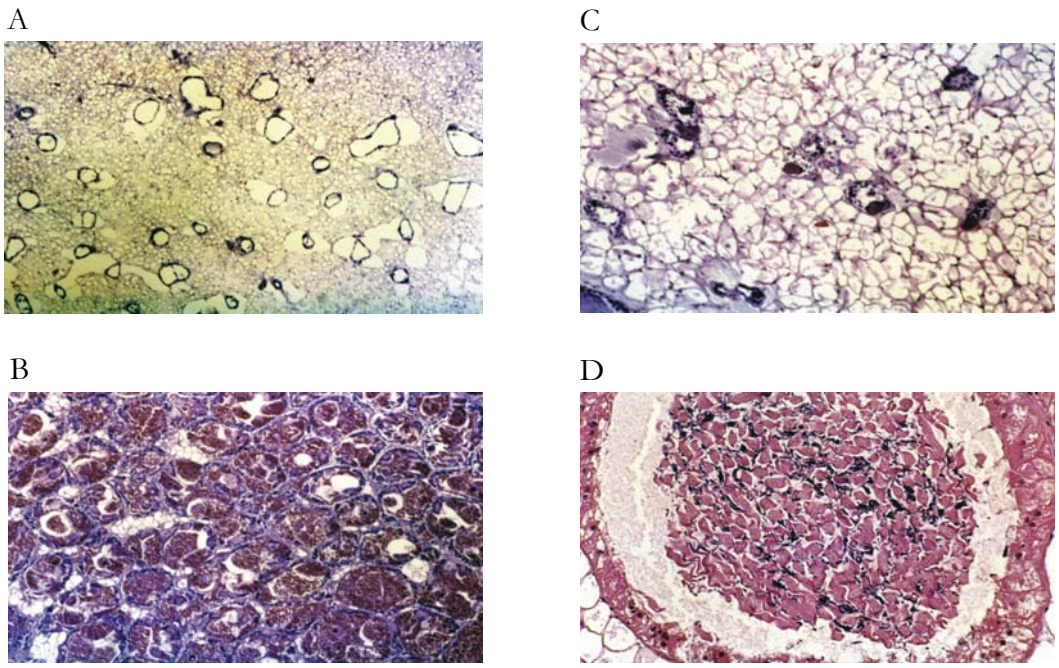

Figure 2. Photomicrographs of the gonads of resident nearshore and resident offshore queen conch (*Strombus gigas*). **A:** resident nearshore female, no tissue, and <25% gametogenic tissue. **B:** resident offshore female, ripe, and >75% gametogenic tissue. **C:** resident nearshore male, early development, and <25% gametogenic tissue. **D:** resident offshore male, ripe, and >75% gametogenic tissue. Adapted from Delgado et al. 2004.

Environmental conditions may also directly impact reproductive condition. These may include poor habitat (Madrones-Ladja et al. 2002), diet (Madrones-Ladja et al. 2002), or food quality (Le Pennec et al. 1998). Furthermore, low dissolved oxygen concentrations (i.e., hypoxia) have been shown to disrupt reproductive function in fish populations (Rudolph et al. 2003).

In 2004, the Florida Fish and Wildlife Conservation Commission's Fish and Wildlife Research Institute began a project with the University of Florida and NOAA's National Centers for Coastal Ocean Science funded by the U.S. Environmental Protection Agency with the goal of examining endocrine disruption in adult queen conch. This will be accomplished by examining vitellin in the blood of conch. Vitellin is a naturally occurring protein that may be induced by exposure to certain xenobiotics. After the tools are developed to quantify the vitellin in conch blood, we will test whether there are differences in vitellin levels between conch found in the nearshore and offshore regions of the Florida Keys. Further tests can then determine the chemical(s) or environmental condition(s) that may be negatively impacting conch reproduction in the nearshore, coastal zone and may help lead to the development of management strategies that safeguard the function of critical ecosystems in South Florida.

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Episodic Nutrient Transport to Florida Coral Reefs

Steven Miller

From: J.J. Leichter, H.L. Stewart, and S.L. Miller. 2003. Episodic nutrient transport to Florida coral reefs. *Limnol. Oceanogr.* 48: 1394-1407.

Abstract

This study documents the changes in nutrient fluxes associated with internal tidal bores arriving on Florida Keys coral reefs and points to biological use of subthermocline nitrate brought onshore by this mechanism. Internal bores on Conch Reef, Florida Keys, are associated with concentrations of 1.0–4.0 μmol L^{-1} nitrate (NO_3) and 0.1–0.3 μmol L^{-1} soluble reactive phosphate (SRP) and onshore flow velocities of 0.1–0.3 m s^{-1}. The arrival of internal bores causes 10–40 fold increases in nutrient concentrations and 1–2 orders of magnitude increases in nutrient flux relative to ambient, nonbore conditions. The magnitude and duration of cool-water nutrient transport events increases significantly with increasing depth on reef slopes. In June 2001, the gradient of increased exposure to subsurface water with depth corresponded to increased percentage of N and $\delta^{15}N$ and decreased C:N ratio in a common benthic macroalga, *Codium isthmocladum*. Internal tidal bores are widespread throughout the Florida Keys reef tract, with cool-water episodes influencing reefs up to 10%–25% of the time during summer months and with significant variability among years. Estimated inputs of nitrogen and phosphorus by internal tidal bores to Florida Keys reef slopes are as much as 40-fold larger than published estimates of inputs to near-shore waters from waste water and storm water runoff. Internal tidal upwelling represents an important, previously underestimated, episodic source of nutrients on the Florida Keys reef tract. In order to assess nutrient availability in this system accurately it is essential to understand natural sources of high-frequency variability.

Conclusions

Recognition of the highly complex, naturally varying nutrient availability in this system, as well as the strong potential for similar effects in other locations, supports the view that it is unrealistic to expect simple concentration thresholds such as 1.0 μmol L^{-1} NO_3 to cause phase shifts to algal dominance on coral reefs (Bell 1992; Lapointe 1997; Hughes et al. 1999; McCook 1999). Further, the possible signal of anthropogenic nutrients reaching the Florida Keys reef tract is likely to be small relative to the large fluctuations in background concentrations and thus very difficult to detect. Periods of strong internal tidal upwelling may explain rapid algal growth including reported blooms of *C. isthmocladum* (Hanisak 2001) on Florida reefs, and it appears likely that natural availability of nutrients, including high-frequency nutrient pulses, is sufficient to support significant growth of macroalgae in this system (Hanisak and Siemon 2000). Considering the natural availability of nutrients in this system, it seems much more likely that recent increases in macroalgal cover and changes in community composition on Florida reefs are related to factors such as herbivory, changes in water clarity, sedimentation, and coral diseases (all of which may have anthropogenic components) than to direct anthropogenic nutrient inputs. However, this does not rule out the possibility of important effects related to anthropogenic nutrients reaching the reef tract. Although Szmant and Forrester (1996) found no evidence in Florida Keys reef tract sediments of anthropogenic nutrient enrichment, there is widespread consensus that conditions on the Florida Keys reefs and back reef environments have changed dramatically in recent years and that anthropogenic activities are a major cause (e.g., Porter and Porter 2002 and papers therein). The data presented here clearly suggest that natural inputs of nitrogen and phosphorus during strong bouts of

internal tidal upwelling would swamp out the possible signal of anthropogenic nutrients reaching the reef tract. However, there also are significant periods between pulses of upwelling and long periods particularly in October–December in each year when internal tidal upwelling is minimal. One consequence of anthropogenic nutrient inputs may have been subtle alterations in baseline nutrient concentrations and shifts toward a situation of more continuous, chronic nutrient availability in a system naturally characterized by large but highly episodic inputs. It is also reasonable to speculate that warming of surface waters associated with climate change may have, and/or could in the future, lead to increased water column stratification. A possible effect could be an increase in the number of internal bores reaching Florida reef slopes and significant increases in reef slope nutrient availability. The physical processes observed here are likely to occur on other reefs adjacent to strong, relatively shallow thermoclines and in proximity to mechanisms of internal wave generation such as strong alongshore currents and tidal exchange over abrupt shelf topography (Baines 1986; Wolanski 1994). Frequent bouts of strong internal tidal upwelling with associated low temperatures and significant nutrient input are probable contributors to the less-than-optimal conditions for scleractinian corals in the Florida Keys reflected in relatively low rates of reef accretion during the last 2,000–4,000 yr (Shinn et al. 1989). Periods of intensified upwelling, such as those observed in May–August 2000 and June–July and September 2001, are likely related to regional-scale oceanographic variability associated with the Florida current (Lee et al. 1985, 1994). At long temporal scales, changes in processes that control high-frequency upwelling such as water column stratification and the trajectory of coastal currents may result in significant changes in reef nutrient dynamics. At more immediate temporal scales, with the increasing need to understand rapid ecological change on coral reefs comes a critical need to evaluate and understand high-frequency oceanographic forcing mechanisms and their consequences for these and other complex marine ecosystems.

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Coral and Seagrass Habitats

Moderator: Brian Keller

EPA/NOAA Coral Reef Evaluation & Monitoring Project

Carl R. Beaver, Walter C. Jaap, James W. Porter, Jennifer Wheaton, Michael Callahan, James Kidney, Selena Kupfner, Cecilia Torres, Shannon Wade , and Dustin Johnson

The Florida Keys National Marine Sanctuary (FKNMS) and Protection Act (HR5909) designated over 2,800 square nautical miles of coastal waters as the FKNMS. In cooperation with NOAA, the U.S. Environmental Protection Agency and the State of Florida implemented a Water Quality Protection Program to monitor seagrass habitats, coral reefs and hardbottom communities, and water quality. The Coral Reef Evaluation and Monitoring Project (CREMP) sampling strategy and methods were developed in conjunction with EPA, FKNMS, Continental Shelf Associates, and the Principal Investigators in 1994. The major criteria for coral reef monitoring included Sanctuary-wide spatial coverage, repeated sampling, and statistically valid findings to document status and trends of the coral communities. The results were intended to assist managers in understanding, protecting, and restoring the living marine resources of the FKNMS.

Forty sampling sites were selected using a stratified random sampling procedure (U.S. EPA EMAP) and permanent station markers were installed. Annual sampling began in 1996 and has continued through 2003. Three additional sites were selected and stations installed in the Dry Tortugas in 1999. In 2002, additional sampling techniques were incorporated including a bio-eroding sponge survey, an expanded stony coral disease survey, and a stony coral population abundance survey.

Results are reported for regions defined as Upper Keys (north Key Largo to Conch Reef), Middle Keys (Alligator Reef to Moser Channel), Lower Keys (Looe Key to Smith Shoal), and Tortugas (Dry Tortugas to Tortugas Banks).

Sanctuary-wide from 1996 to 2003, for a total of 105 stations, the number of stony coral species declined at 76 (72%) stations, increased at 15 (14%) stations, and remained unchanged at 14 (13%) stations. A decline in the number of stony coral species was recorded in all habitat types. In 2003, offshore deep and patch reef stations had the greatest numbers of stony coral taxa with 17 and 16 species, respectively. Hardbottom stations had the fewest number of stony coral species, averaging nine species per station. Between 1996 and 2003, the number of stony coral species decreased at 25 of 30 (83%) stations in the Upper Keys, increased at one station, and remained unchanged at four stations. In the Middle Keys, the number of stony coral species decreased at 18 of 29 (62%) stations, increased at seven stations, and remained unchanged at four stations. In the Lower Keys, the number of stony coral species decreased at 33 of 46 (72%) stations, increased at seven stations, and remained unchanged at six stations.

In 1996, coral disease was observed at only five stations Sanctuary-wide. By 2002 coral disease was observed at 102 stations. Incidences of stony coral disease were reported for 95 stations in 2003. Specifically, in 2003, "White" disease occurred at 72 stations, "Other disease" was recorded at 89 stations, and Black Band disease was recorded at seven stations (Fig. 1).

Sanctuary-wide, mean percent stony coral cover declined from 11.9 in 1996 to 7.4 in 1999, a decline of 38%. The greatest change occurred between 1997 and 1999 when mean percent stony coral cover declined from 11.3 to 7.4 (significant at $p = 0.03$, Wilcoxon rank-sum test). The changes observed between 1999 and 2003 were determined to be statistically insignificant. Sanctuary-wide, stony coral

cover has not changed significantly since 1999. In 2003, mean percent stony coral cover Sanctuary-wide was 7.2 (Fig. 2).

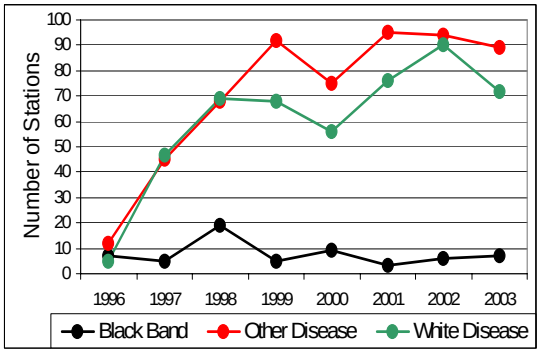

Figure 1. Incidence of coral disease 1996-2003.

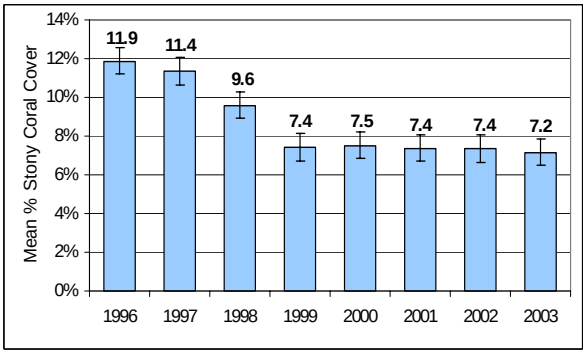

Figure 2. Mean % coral cover Sanctuary-wide 1996-2003.

From the inception of the project in 1996 through 2003, 57 (55%) stations had a significant decrease in stony coral cover, 39 (38%) stations showed no significant change, and only seven (7%) stations had a significant increase. Evidence of this loss and partial recovery can be seen in Figure 3, which shows a catastrophic loss of *Acropora palmata* colonies at Western Sambo Station 2 after hurricanes Georges in 1998 and Irene in 1999. Although the majority of stations had a significant decrease in percent coral cover over the first four years of the project, between 1999 and 2003, mean percent coral cover remained unchanged at 70 (68%) stations, increased at 19 (18%) stations, and decreased at 14 (14%) stations.

Also in 2003, functional group data showed the benthic community was composed of 64.5% substrate, 12.6% octocoral, 11.1 % macroalgae, 7.2% stony coral, 2.2% sponge, 2.0% zoanthids, and 0.5% seagrass Sanctuary-wide.

Beginning in 2002, a series of mid-water and coral mucus samples were examined for presence of human enteroviruses commonly found in sewage. Human enteroviruses were detected in coral mucus from two Upper Keys sites (El Radabob and Conch Reef), one Lower Keys site (Jaap Reef), and, surprisingly, one Tortugas site (Black Coral Rock). In addition, enteroviruses were detected in the mid-water samples from Black Coral Rock and Western Head off Key West (Lower Keys). It is unknown if the source of these pollutants is local or the result of remote transport. Additional analysis is planned for 2004, and may help define the source of this pollution.

From its inception, the CREMP has documented long-term changes in the status and trends of coral reefs throughout the 2,800-square-nautical-mile FKNMS. The cessation of rapid decline documented in the early stages of the project is encouraging. However, there is a general consensus that multiple stressors acting at local, regional, and global scales are continuing to have negative affects on coral reefs in the Florida Keys and elsewhere. The CREMP will continue to collect data relative to benthic habitat condition at the 40 sites in the Sanctuary and Dry Tortugas.

The CREMP was expanded in 2003 with the addition of ten sites in Miami-Dade, Broward, and Palm Beach counties through funding from the Florida Department of Environmental Protection

and the U.S. Coral Reef Task Force. The expanded CREMP is the only comprehensive, long-term coral monitoring program in Florida.

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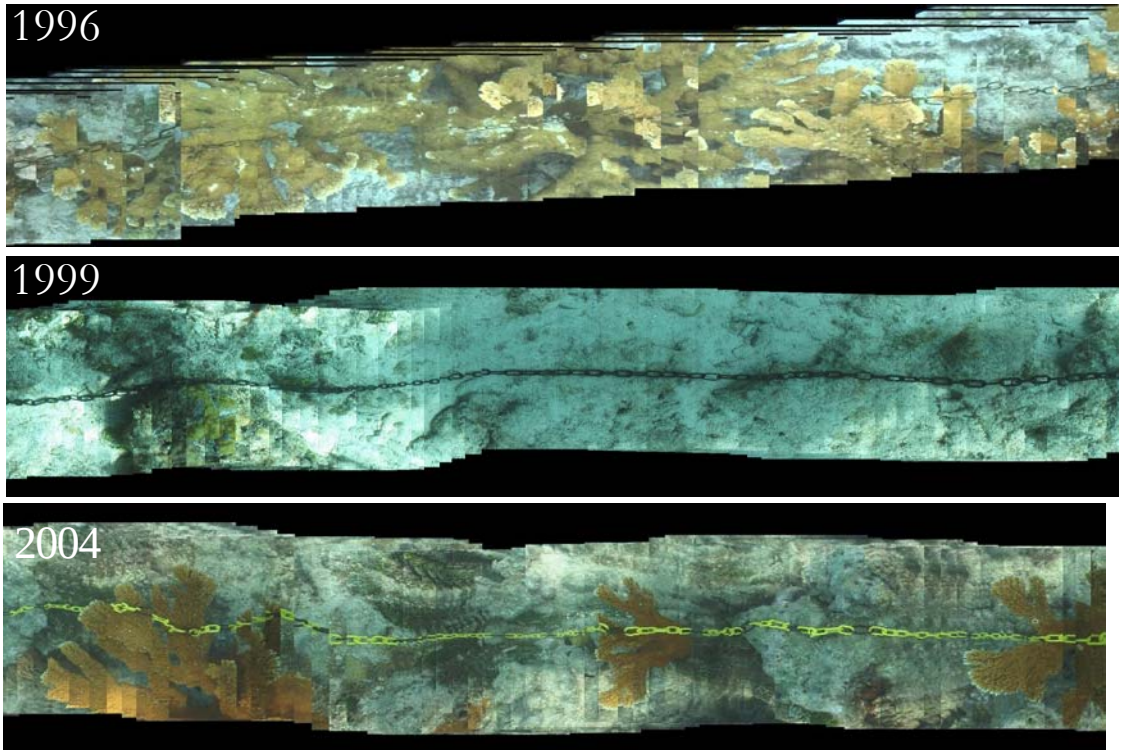

Figure 3. Photo mosaics of Western Sambo Station 2 showing catastrophic decline in *Acropora palmata* after hurricanes Georges in 1998 and Irene in 1999 and subsequent partial recovery into 2004.

Assessment and Monitoring of Florida Keys and Dry Tortugas Coral Reef and Hard-bottom Habitats

Steven L. Miller, Mark Chiappone, Leanne M. Rutten, and Dione W. Swanson

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Slide Presentation Narrative

Introduction

This slide presentation was put together for the Florida Keys National Marine Sanctuary (FKNMS) Connectivity Meeting held in Key West, Florida, during August 2004. The following narrative outlines the basic goals of the UNCW assessment and monitoring program in the FKNMS, including the Dry Tortugas, and the major results obtained on the status of reef and hard-bottom habitats sampling in the region conducted from 1999-2001. The work is carried out by scientists from the Center for Marine Science, University of North Carolina-Wilmington (UNCW), and the Rosenstiel School of Marine and Atmospheric Science-University of Miami (RSMAS).

Program Objectives

When the FKNMS zones were established, there was a desire on the part of Federal resource managers to be able to assess changes that might occur due to protection from fishing, one of the primary agents of coral reef decline worldwide. This program was born out of the need to assess and monitor the structure and condition of coral reef benthic organisms throughout the Florida Keys marine environment, including the Dry Tortugas, with an initial focus on changes within the Sanctuary's no-take zones designated in 1997. The no-take zones include Sanctuary Preservation Areas (SPAs), Special-use Areas/Research Only (RO), and Ecological Reserves (ER) designed to minimize user group conflicts, provide scientists with control areas for evaluating fishing effects from other human impacts to the marine environment, and protect contiguous habitats, respectively. The goals of the UNCW assessment and monitoring effort are three-fold:

- To assess the community structure and condition of reef benthos at multiple spatial scales, with particular reference to the no-take zones, but also inter-reef, among habitat type, and among region variations.
- To track the dynamics of coral reef benthos to assess changes due to protection from fishing within the zones, but also changes due to larger-scale factors, such as regional water quality phenomenon.
- To complement fishery-independent reef fish surveys with "fine-scale" or detailed habitat information, to facilitate experimental and modeling efforts for evaluating essential fishery habitat.

However, the FKNMS zones, even including the Tortugas North and South zones designated in 2001, represent only about 6% of the total area of the Sanctuary. Thus, there is also a need to determine the condition of benthic coral reef resources outside of the zones, necessitating a larger scale approach that considers regions in the FKNMS (upper Keys, middle Keys, etc.), multiple

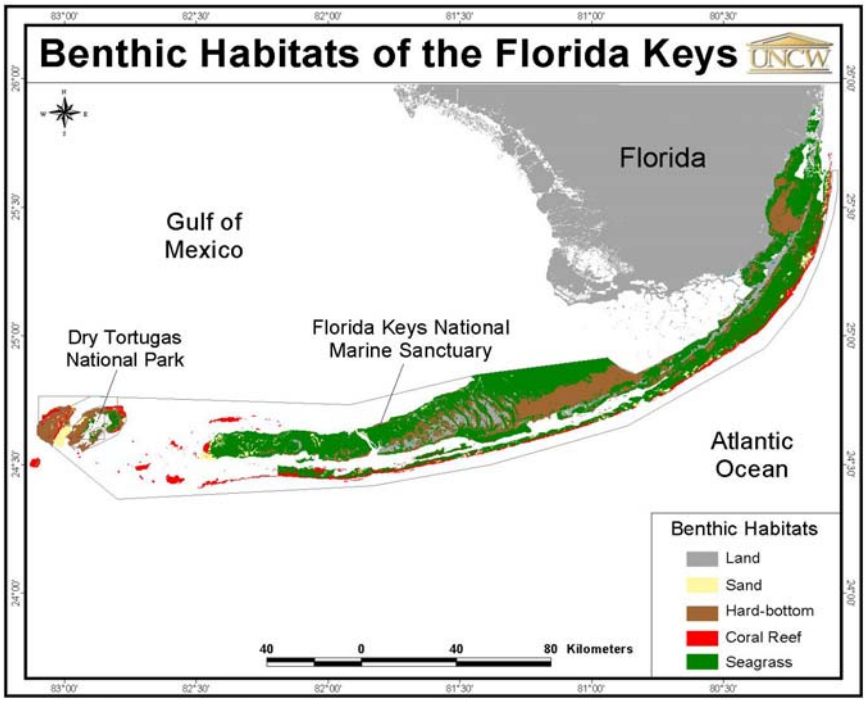
habitat types that form a mosaic of hard-bottom and coral reef habitats from nearshore to offshore of the reef tract, as well as comparable habitats inside and outside of the zones.

Protected Zone Assessment

Assessing and monitoring changes that occur on the sea bottom to a variety of benthic organisms (e.g., corals, gorgonians, sponges, algae) in the FKNMS zones is one facet of the UNCW program, placed against a backdrop of attempting to determine the status and condition of hard-bottom and coral reef habitats throughout the Florida Keys. There are a number of challenges to determining the effects of the no-take zones on benthic coral reef organisms. First, the no-take zones were not randomly placed, but instead are heavily concentrated along the reef tract and encompass most of the well developed spur and groove reefs. This was done largely to separate recreational fishing from snorkeling and diving activities, and is where most of the SPAs are sited. However, comparable reference areas (i.e., sites open to fishing) are sometimes difficult to find to compare to the zones. Second, most of the no-take zones include more than one benthic habitat type (e.g., spur and groove, rubble, hard-bottom) that necessitates a sampling program that considers multiple habitat types. Third, the zones comprise a relatively small percentage of the total hard-bottom and coral reef habitat area in the FKNMS, which raises the issue of not only what is happening within the zones, but changes that occur in the larger system that are not protected from hook-and-line fishing for finfish and trap fishing for spiny lobster. Fourth, baseline data on the status and condition of benthic resources was not available for most reef sites prior to the implementation of the zones. Finally, because of the long history of intensive exploitation of reef fishes and invertebrates in the Florida Keys, scientists are not exactly sure how these small reef areas will respond to protection from fishing. There are several hypotheses for how benthic coral reef organisms may respond to protection from fishing: herbivory by fishes may decline due to increased predation from more and larger fishes in the zones, leading to increases in algae; sea urchins may decline due to increased predation from more and larger fishes in the zones; the zones may experience decline simply because corals tend to be more abundant at the onset due to the non-random placement of the protected areas, etc.

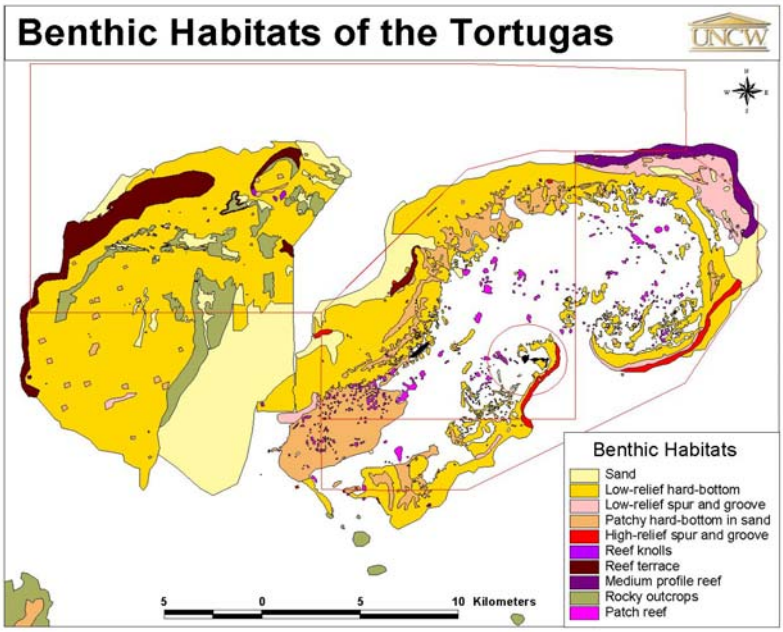
Benthic Habitats of the Florida Keys

Anyone who has spent time underwater in the Florida Keys is well aware of the mosaic of benthic habitats that occur from nearshore of the islands to deeper water along the reef tract. This mosaic includes soft-bottom (sand and seagrass) and hard-bottom habitats that provide food and refuge for hundreds of species of invertebrates and fishes. The map shown here highlights several patterns: (1) coral reef areas, while a focus of much of the tourism and management in the FKNMS, comprise a very small percentage of the total benthic habitat in the region; and (2) much of the south Florida shelf remains to be adequately mapped. Mapping is an integral part of the reef fish and benthic assessments that are undertaken because the area of different habitat types is used to estimate the sizes of populations of different organisms. One of the hallmarks of the UNCW program is our focus on a suite of different hard-bottom and coral reef habitat types.



Benthic Habitats of the Dry Tortugas

The UNCW assessment and monitoring effort has also include fieldwork in the Tortugas region of the Sanctuary. The map shown here included pre-existing maps developed by NOAA and the State of Florida, together with new information collected in 1999 and 2000 to fill in the gaps. Even so, one can see that large areas of Dry Tortugas National Park are still not adequately mapped.

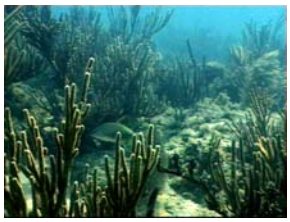


Classification of Hard-bottom and Coral Reef Habitats

An important feature of the UNCW program is our attention to multiple habitat types that occur in the Florida Keys. Not only do the zones encompass multiple habitat types, but the larger system is dominated by large swaths of low-relief hard-bottom and deeper reefs that traditionally were not sampled by earlier assessment and monitoring efforts.

Hard-bottom Types

Patchy hard-bottom
- Keys fore reef
- Tortugas region



Low-relief hard-bottom
- Nearshore Keys
- Fore reef
- Tortugas region

Rocky outcrops
- Deeper fore reef
- Tortugas region

Low-relief spur & groove
- Keys fore reef
- Tortugas region

Coral Reef Types

Patch reefs
- Hawk Channel
- Tortugas region

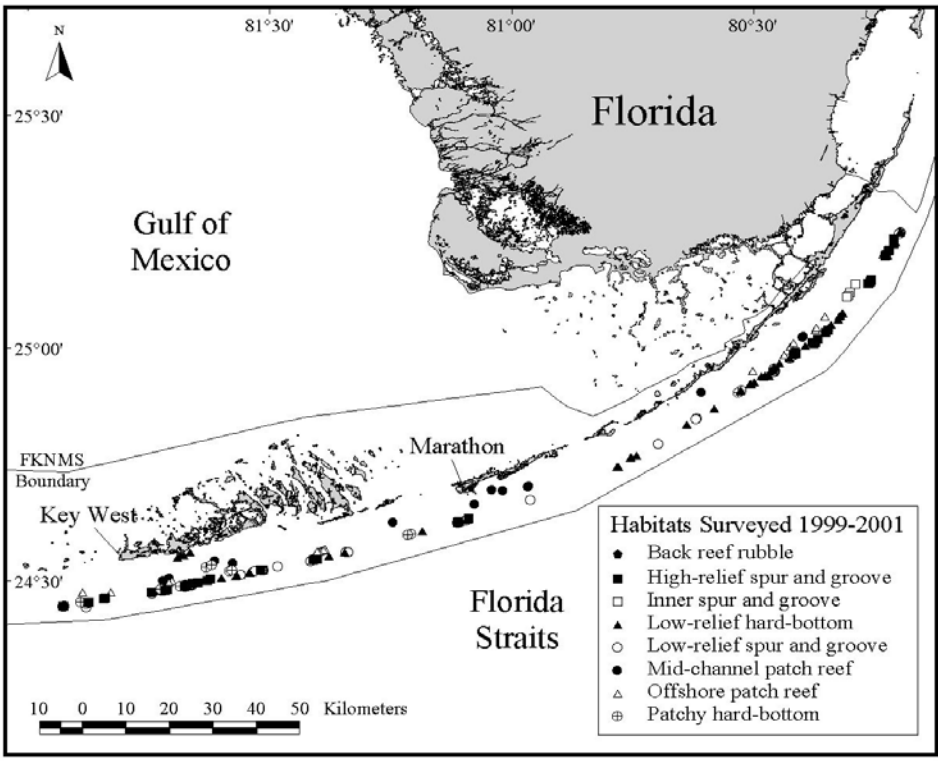
Medium-profile reef
- SW Florida Keys
- Tortugas region

High-relief spur & groove
- Keys fore reef
- East Dry Tortugas NP

Reef terrace
- Tortugas region

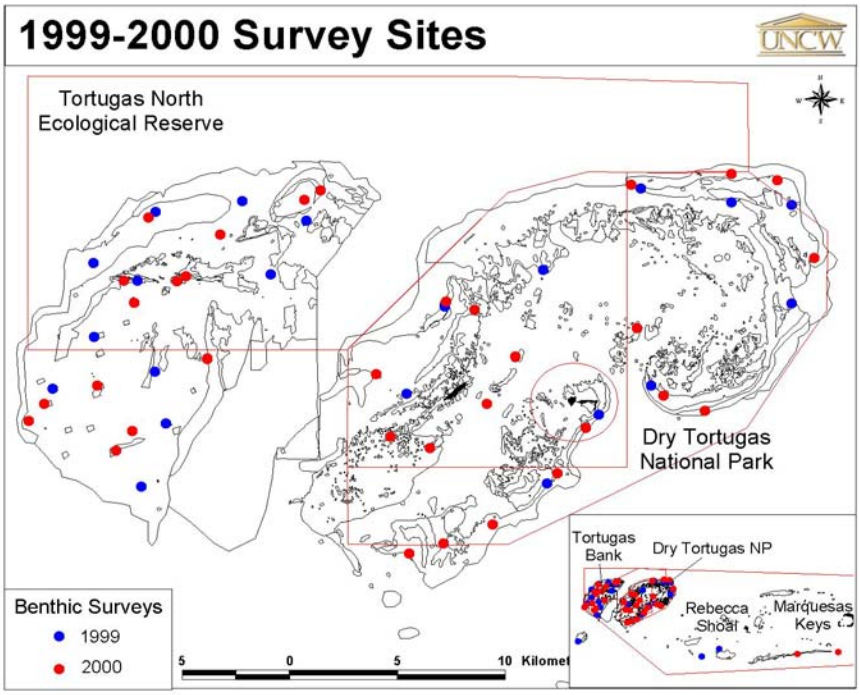
UNCW Survey Locations in the Florida Keys during 1999-2001

This map shows the spatial distribution of sampling locations from northern Key Largo to southwest of Key West that were surveyed for the abundance and condition of benthic coral reef organisms. All told, the UNCW survey effort included 80 sites surveyed during 1999, 45 sites during 2000, and 86 sites during 2001. Additional fieldwork was accomplished in 2002, 2005, and 2006.



UNCW Survey Locations in the Dry Tortugas during 1999-2000

This map illustrates the spatial distribution of sampling location in the Tortugas region that were surveyed for the abundance and condition of benthic coral reef organisms during two 3-week research cruises in 1999 and 2000. Survey locations not only included Dry Tortugas National Park, but also several locations on the Tortugas Bank, which was relatively unexplored as of 1999 when this program began. The Tortugas Region offers an important comparison area to the rest of the Keys, as coastal development and fishing pressure are not as intensive compared to the rest of the archipelago.



Benthic Survey Methods

The UNCW assessment and monitoring program measures a suite of variables to determine the abundance, size, and condition of benthic coral reef organisms. Before getting into the water, mapping information on the distribution and coverage of habitat types is used to allocate sites by habitat type, regional sector, and location within and outside of the zones. Global Positioning System (GPS) points are generated for each site. Once at the site, a three- to four-person team is deployed in the water with transect reels, rules, pencils, and slates. Four pairs of 25 m transects are deployed at each site, labeled as 1A, 1B, 2A, 2B, etc. Along four of the primary transects (A), coverage is determined every 25 cm to yield 100 points per transect. Digital video along a 0.4 m swath is also taken along the primary transects. The number of species of stony corals, gorgonians, and sponges is determined on all four primary and secondary transects. Gorgonian density and height distribution using four size classes (< 20 cm, 20-50 cm, 50-100 cm, > 100 cm) are measured along transects 1A and 2A, as are coral density, size, and condition. The condition measurements include an assessment of competition between corals and other taxa, and the extent to which interactions cause tissue damage or mortality. Juvenile corals (< 4 cm maximum diameter) are assessed along transects 1A and 2A by randomly sampling ten 0.68 m x 0.45 m quadrats along each transect. Urchin density and test diameter, as well as the density of incidental marine invertebrates are assessed on all four primary and secondary transects.

25 m transects for benthic cover

- In situ linear point-intercept
- Video and still photograph archive

25 m x 0.4 m belt transects

- Species richness (coral, sponge, gorgonian)
- Coral and gorgonian density
- Juvenile coral density and size
- Coral size and condition
- Urchin density and size
- Marine ornamental species density
- Substratum topography (vertical relief, slope, depth)
- Gorgonian height distribution
- Density, length, and impacts of lost fishing gear

Rapid Assessment Methods

Most of the information is collected underwater on pre-formatted slates, allowing for relatively rapid data entry and summary analysis that does not require a lot of time once the fieldwork is completed. However, the level of information collected underwater requires a team experienced in identifying the major groups of algae and species of sponges, gorgonians, stony corals, and other benthic invertebrates that are sampled for presence-absence, abundance, size, and condition. In 2001, we additionally assessed density and predation by the flamingo tongue snail (*Cyphoma gibbosum*), by noting the number of individuals, gorgonian prey, and gorgonian height on all transects deployed. We have periodically conducted surveys of fishing gear and other marine debris by surveying 1 m on each side of all primary and secondary transects. Noted are the type of gear, dimensions (typically length) to the nearest centimeter, whether the debris is biologically fouled or clean, and the number of sessile invertebrates impacted by the debris that are causing tissue abrasion and/or mortality. In situ measurements of topographic complexity along the four primary transects are undertaken to

provide an assessment of substratum angle, maximum vertical relief, and the coverage of different relief categories along 0.4 m x 25 m swaths.

Transect deployment | Digital video | Juvenile corals

Examples of Benthic Habitat Types Sampled

Illustrated here are a few of the many hard-bottom and coral reef habitat types that exist in the Florida Keys. Habitat types include mid-channel and offshore patch reefs, low-relief hard-bottom, high-relief spur and groove, rubble, and low-relief spur and groove.

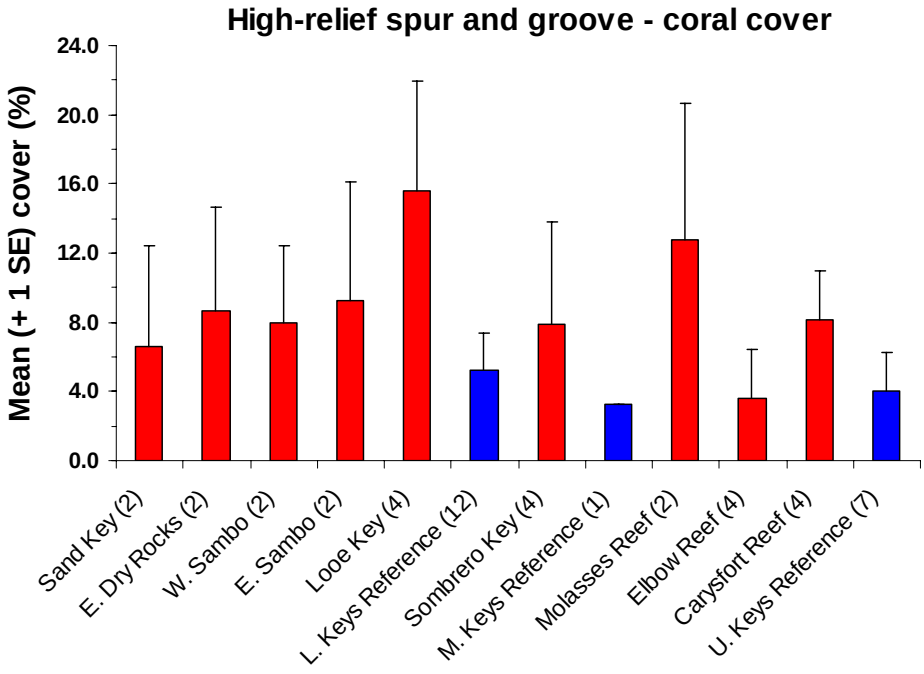
Cheeca Rocks patch reef | Sand Island spur and groove | Crocker Reef hard-bottom

Molasses Reef Sanctuary Preservation Area

Shown below is part of the high-relief spur and groove habitat at Molasses Reef SPA, one of the most popular SCUBA diving locations in the Sanctuary. Most of the SPAs are located in these types of well-developed reef areas and were designed to separate potential user group conflicts such as fishing and diving. Most of the well-developed spur and groove structures were built by elkhorn coral (*Acropora palmata*) several thousand years ago, but are now principally dominated by crustose

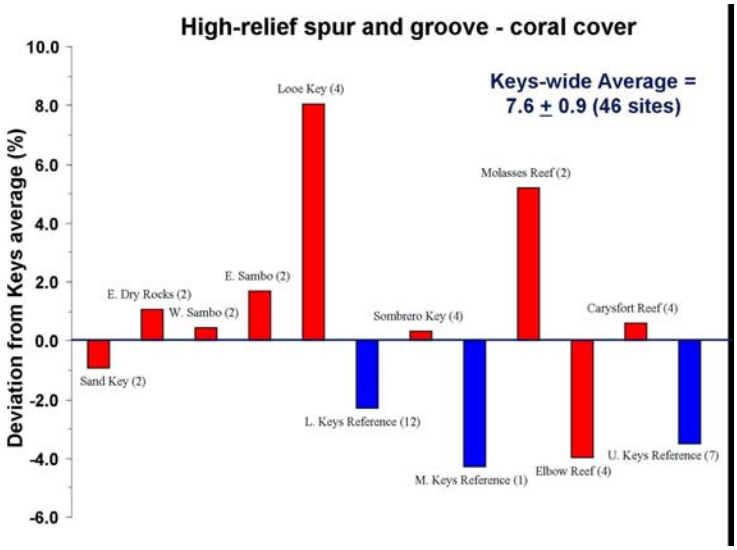
algae, colonial zoanthids (*Palythoa*), smaller corals (*Porites astreoides*, *Agaricia agaricites*), and gorgonians such as sea fans; a few *A. palmata* colonies are present in this image (left-center).

Coral Cover on High-relief Spur and Groove Reefs in the Florida Keys in 2001



Examining percent cover of stony corals (Milleporina and Scleractinia) on shallow spur and groove reefs from northern Key Largo to southwest of Key West sampled during the summer of 2001, several patterns emerged. First, fully protected marine zones, most of which are SPAs, had greater coral cover than corresponding reference areas open to fishing. This is the result of the non-random placement of the zones that encompass some of the best coral areas along the main reef tract. Second, even among no-take zones, there was substantial variability in coral cover, ranging from ~4% to ~16%. Third, overall coral cover was relatively low compared to how much coral covered the reefs historically, probably the result of storms, disease, and bleaching. Most of the corals in this habitat type were no longer *Acropora palmata*, but instead smaller colonies of *Porites astreoides* and *Agaricia agaricites*.

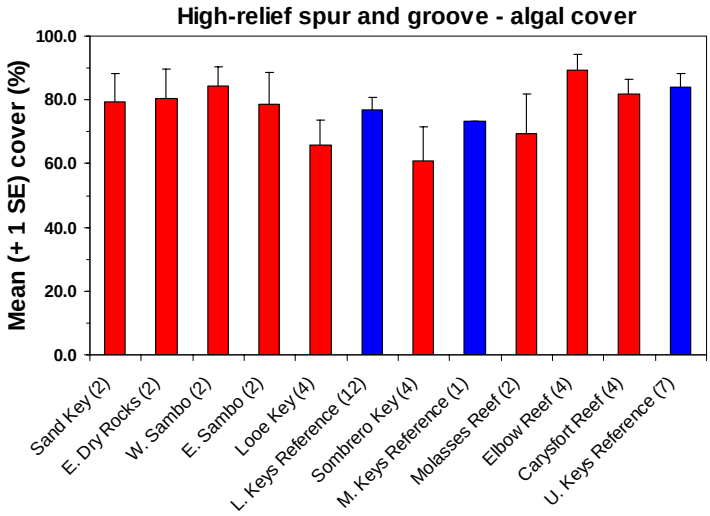
Spatial Variations in Coral Cover on High-relief Spur and Groove Reefs in 2001



Data on coral cover from individual fully protected marine zones and corresponding reference areas were compared to the overall Keys-wide average coral cover for the shallow (< 8 m) high-relief spur and groove habitat. Not surprisingly, most of the no-take zones were above the 2001 Keys-wide average of 7.6%, while corresponding reference areas were below this average. However, not all of the zones were similar in terms of total cover, illustrating the significant reef-to-reef variability inherent in the Florida Keys ecosystem.

Algal Cover on High-relief Spur and Groove Reefs in the Florida Keys in 2001

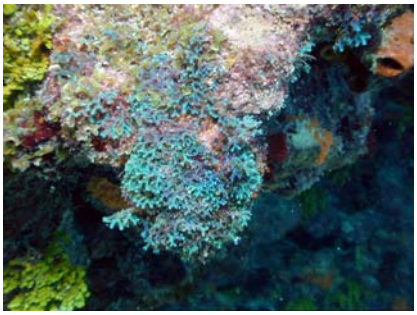
In contrast to corals, algae were obviously the dominant components of the sea bottom in this habitat type, covering as much as 90% of the available substratum at some sites. However, what these data do not reveal is that most of the algal cover in this habitat type consisted of filamentous algal turfs, crustose coralline algae, and calcareous algae such as *Halimeda*, all of which are generally indicative of relatively high grazing intensity and low nutrients.



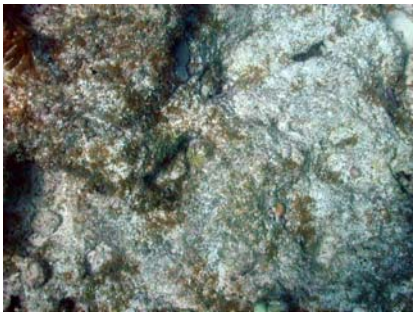
Dominant Algae on Offshore Spur and Groove Reefs

Shown here are examples of the dominant types of algae on offshore spur and groove reefs in the Florida Keys. Most of these dominant algal groups are characteristic of environments with high grazing pressure and/or strong wave energy.

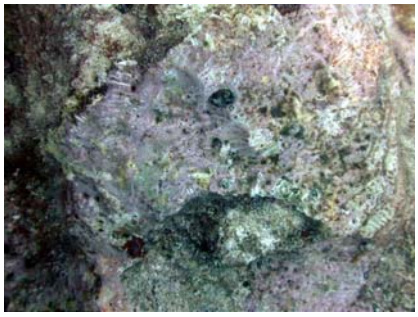
Halimeda opuntia



Dictyota bartayresi



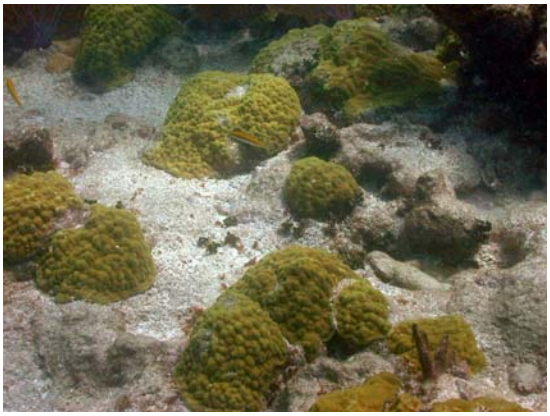
Algal turf



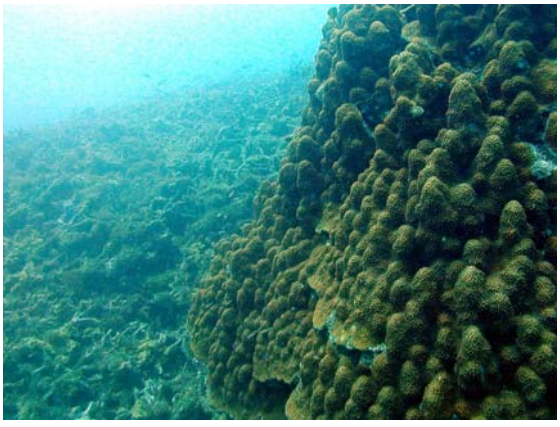
Crustose corallines

Coral Reproductive Strategies

Population assessments of corals in the Florida Keys need to take into consideration the different reproductive strategies employed by these organisms. Corals can be divided into life history groups based upon how fast they grow, how resistant their skeleton is to damage, how they reproduce (externally or internally), the extent to which a species relies upon asexual reproduction, and how successful larval recruitment is from the plankton. An apparent shift can occur in disturbed reef systems when older, slower growing and more massive corals are replaced by smaller, faster growing, "weedy" species. In the Florida Keys, the well-developed offshore spur and groove reefs where most of the no-take zones are located are now dominated by "weedy" corals such as *Agaricia agaricites* (left, below) and *Porites astreoides* (right, below). The life cycles of these species include brooding larvae (internal development), smaller colony size, faster growth, and higher adult mortality.

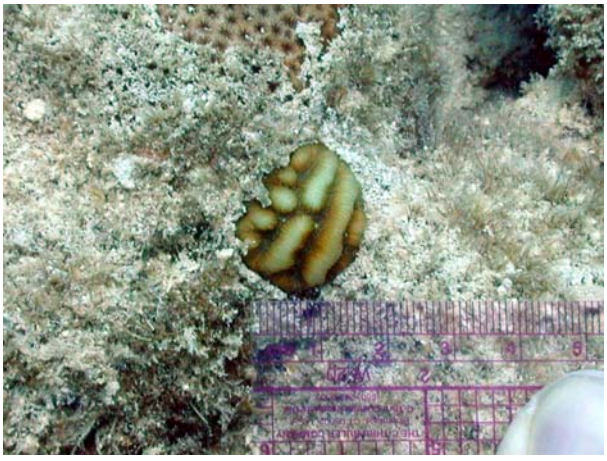


In contrast, patch reefs in Hawk Channel and closer to shore tend to be dominated by massive head corals of the genera *Diploria* (left, below), *Montastraea* (right, below), and *Siderastrea* (not shown). The life cycles of these genera include broadcasting larvae (external development), larger colony size, generally slower growth, and lower adult mortality; these also are major reef builders. These patterns have implications for how coral populations may change and provide insights into the factors that affect current distribution and size patterns of species.



Juvenile Stony Corals

An assessment of coral populations in the Florida Keys should also consider the species and densities of small (< 4 cm) diameter corals. These juveniles represent those corals that have settled from the water column (whether internally or externally developed relative to the parental corals), metamorphosed, and reached a size that is visible underwater (usually 0.2 cm and greater). Thus, the density of juvenile corals represents an integrated measure of all of these processes and provides insights into the factors that affect the ability of coral populations to maintain themselves and recover from disturbance.



Diploria strigosa

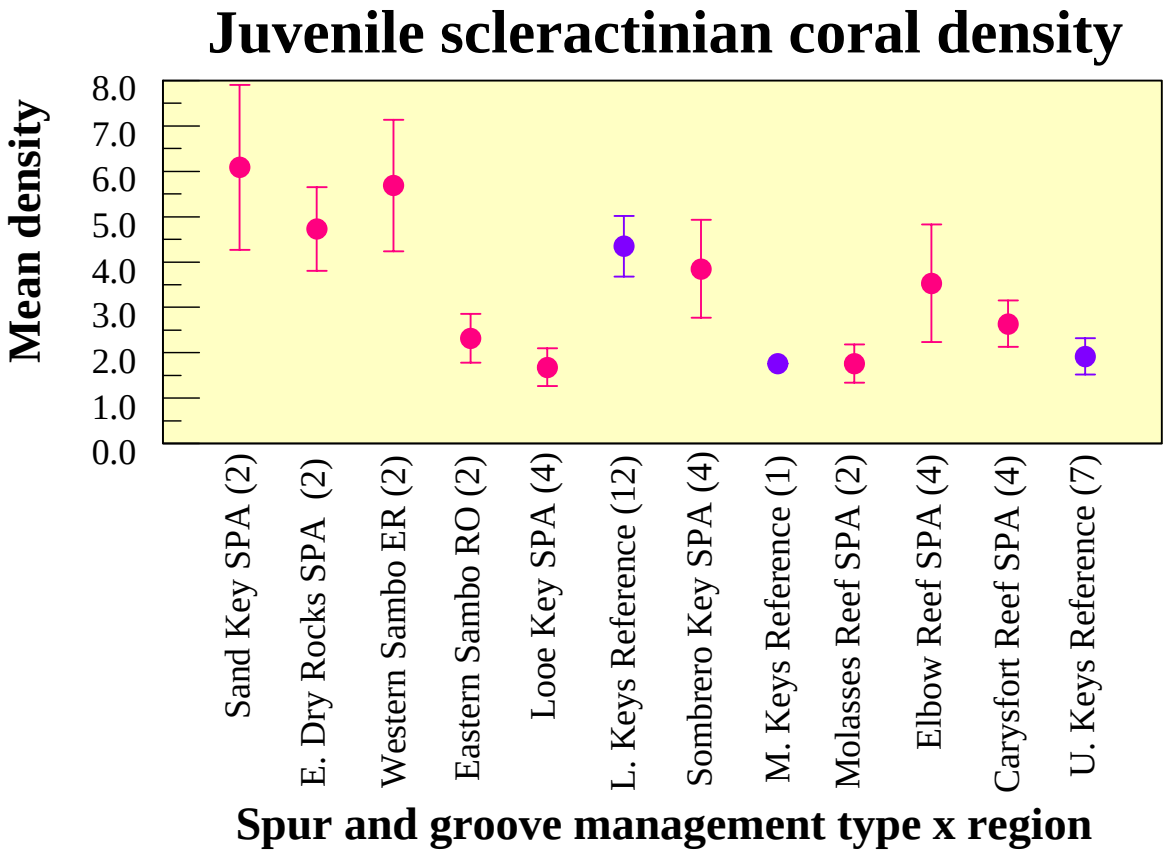
Dichocoenia stokesi

Diploria labyrinthiformis

Siderastrea radians

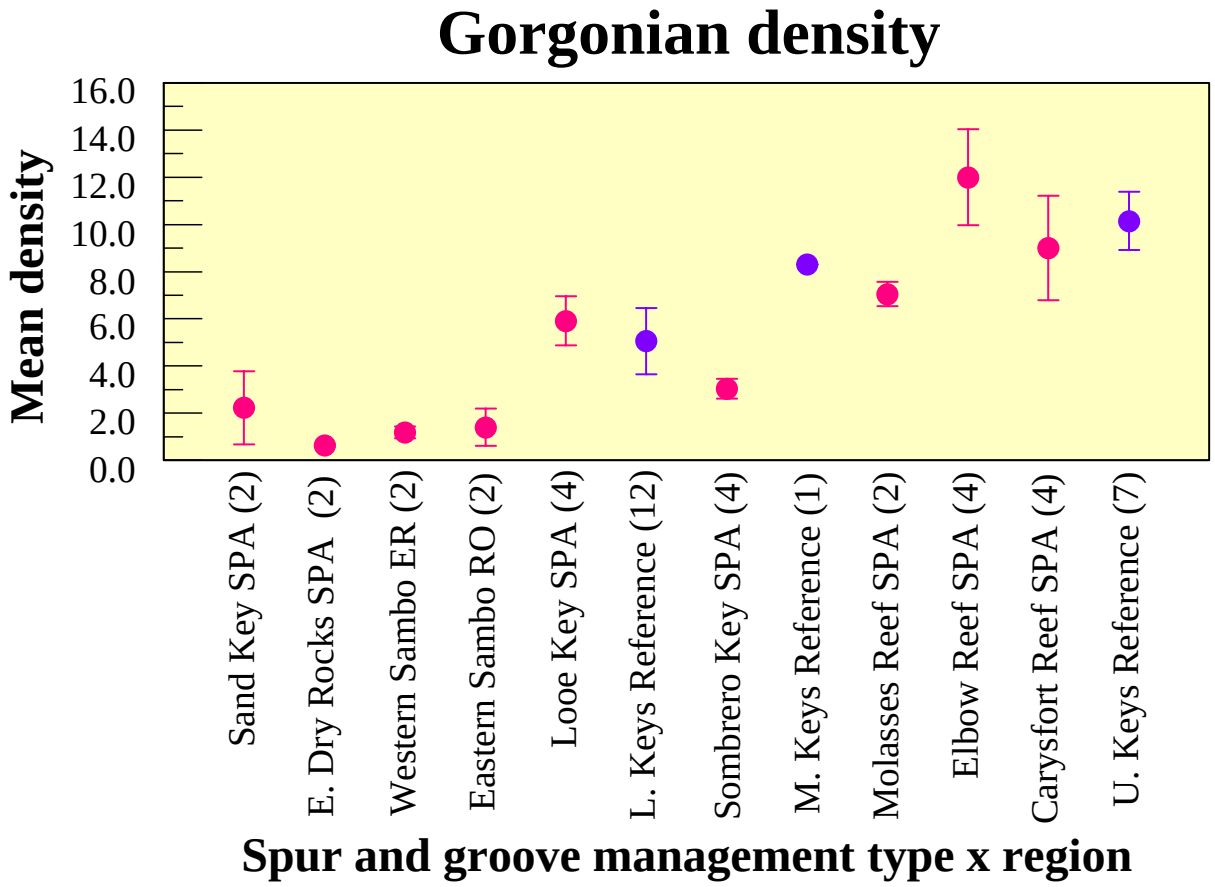
Juvenile Scleractinian Coral Density on High-relief Spur and Groove Reefs during 2001

Densities of juvenile (< 4 cm maximum diameter) scleractinian corals measured among several high-relief spur and groove reefs in the Florida Keys during the summer of 2001 showed several patterns. First, juvenile coral densities varied greatly among individual reefs, again implying that a large-scale approach that considers multiple sites is needed to capture the inherent spatial variability in the Florida Keys. Second, juvenile coral densities varied between fully protected zones and reference areas, with no clear pattern relative to protection level. Third, densities in this habitat were relatively low compared to other habitat types and especially compared to other areas in the wider Caribbean. Most of the juvenile corals in this habitat type were small colonies of species that brood their larvae, such as *Porites*, *Favia*, and *Agaricia*, instead of the massive reef framework builders.



Gorgonian Density on High-relief Spur and Groove Reefs in the Florida Keys in 2001

Anyone who has snorkeled or dived on Florida Keys reefs and hard-bottom habitats knows that gorgonians, which include sea fans, sea rods, and sea whips, are dominant. In fact, in most Florida Keys habitats, gorgonians are usually two to three times more abundant than the hard corals. Shown here are data on mean gorgonian densities on offshore high-relief spur and groove reefs in the Florida Keys sampled during 2001. It is evident that there was substantial inter-reef variability, with densities ranging from ~1 colony per m^2 to over 12 colonies per m^2, and no clear trend between fully protected zones and corresponding reference areas. These data also indicate that there were significant regional variations in gorgonian densities in this habitat type, with lower Keys sites exhibiting much lower densities than upper Keys sites. We are not sure why this regional variation occurs, but we do know that while gorgonians were dominant on upper Keys reefs, they appeared to be replaced by the colonial zoanthid *Palythoa* on lower Keys reefs.



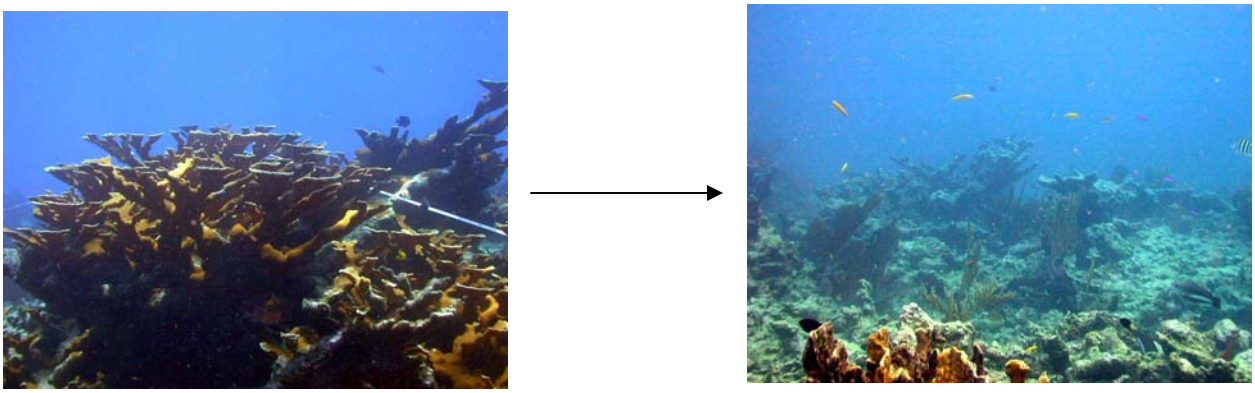
Eastern Sambo Research Only Area

This underwater photograph at Eastern Sambo Reef, offshore of the island of Boca Chica, indicates the general structure of high-relief spur and groove reefs in the lower Keys region. Note the dominance by the colonial zoanthid *Palythoa* and the near absence of gorgonians. This reef, like other similarly structured reefs in the Keys, was primarily built by elkhorn coral.

Elbow Reef Sanctuary Preservation Area
This underwater photograph at The Elbow, offshore of Key Largo, indicates the general structure of high-relief spur and groove reefs in the upper Keys region. Note the dominance by gorgonians, especially the sea fan *Gorgonia ventalina*, and the fire coral *Millepora complanata*. This reef, like other similarly structured reefs in the Keys, was primarily built by elkhorn coral, although this species is now relatively rare on most offshore spur and groove reefs.

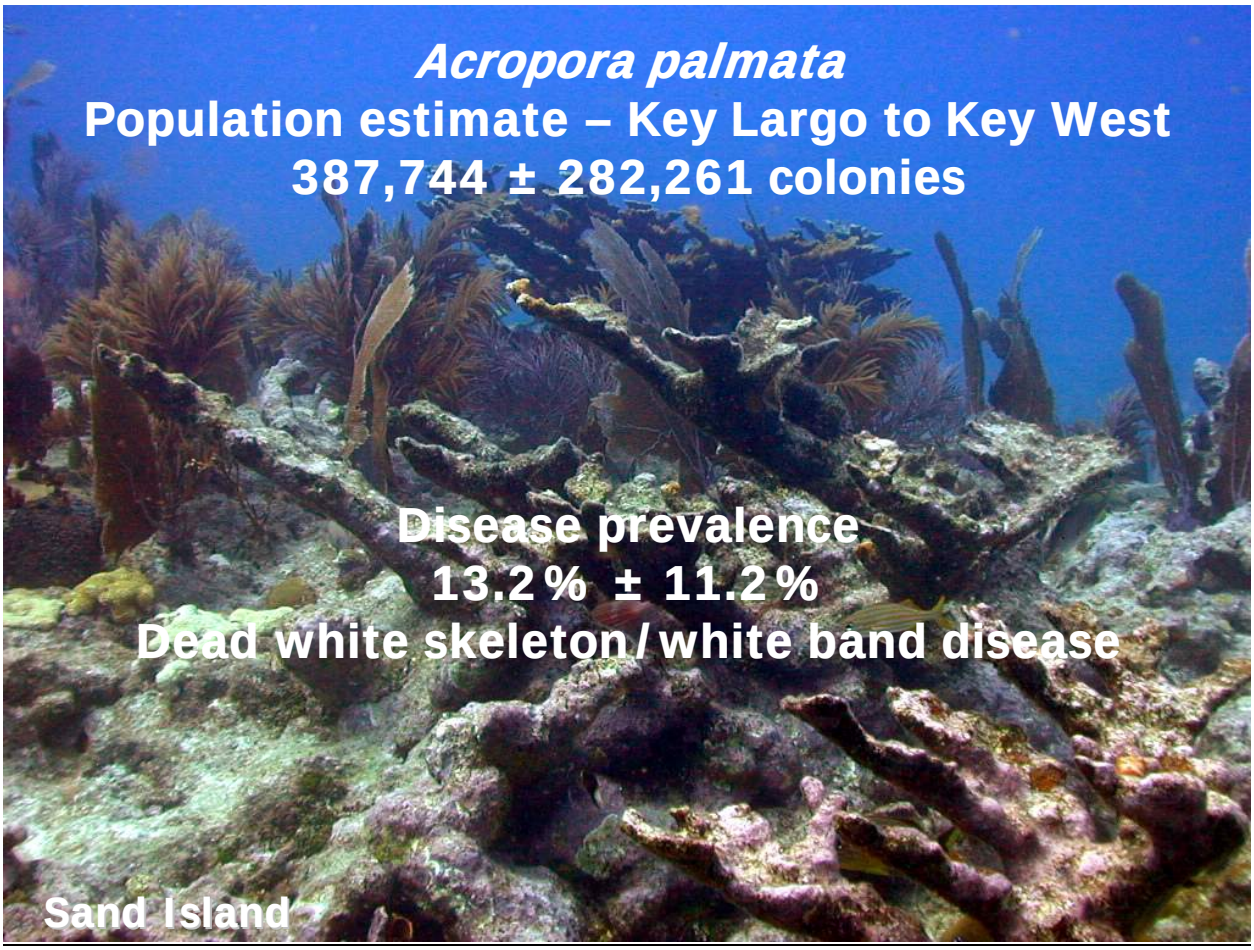
Historical and Present Status of Elkhorn and Staghorn Corals

People who have snorkeled or dived in the Florida Keys know that significant changes have occurred to corals and other marine organisms relative to the 1950s and 1960s. Significant among these changes are the well-documented declines in the abundance of elkhorn (top) and staghorn corals (bottom), two species that are important reef framework builders in the Florida Keys and throughout the Caribbean. However, dramatic declines in populations of these corals have occurred during the past 25 years, principally due to storms and disease. Disease is of particular importance, especially white band disease, because it has affected populations far removed from local human activities, suggesting that the declines in the Florida Keys are part of a Caribbean-wide decline. In any event, this has implications for the future of many Florida reefs, as the major framework builders are not significantly reduced and have been replaced with gorgonians, *Palythoa*, algae, and smaller corals.



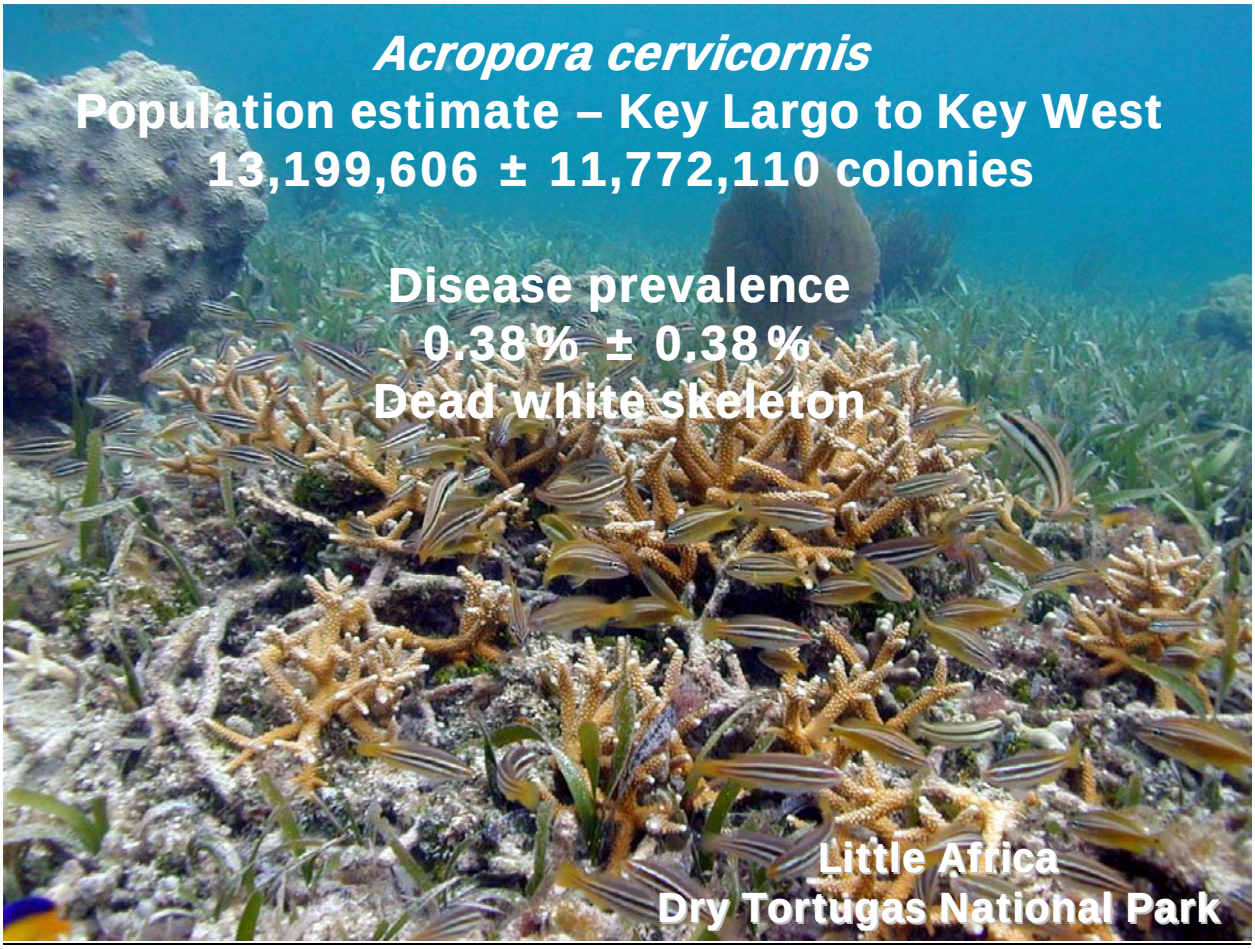
Population Estimate for Elkhorn Coral in the Florida Keys

The stratified sampling design employed by our program, using habitat-based mapping, allows for the construction of population estimates for a variety of benthic coral reef organisms. Detailed surveys of the offshore reef tract in 2001, focusing on high-relief spur and groove reefs and patch reefs, allowed us to derive population estimates for both elkhorn and staghorn corals. Shown here are the population estimates for elkhorn coral (*Acropora palmata*) throughout the Florida Keys. This is an important step in assessing a population. The disease prevalence estimates are a concern because elkhorn coral is relatively rare compared to what it used to be, but in addition, extant colonies are being affected by disease-like conditions. However, it is encouraging that large stands of elkhorn coral can still be found at sites such as Sand Key SPA, Sand Island, Elbow Reef SPA, and South Carysfort Reef.



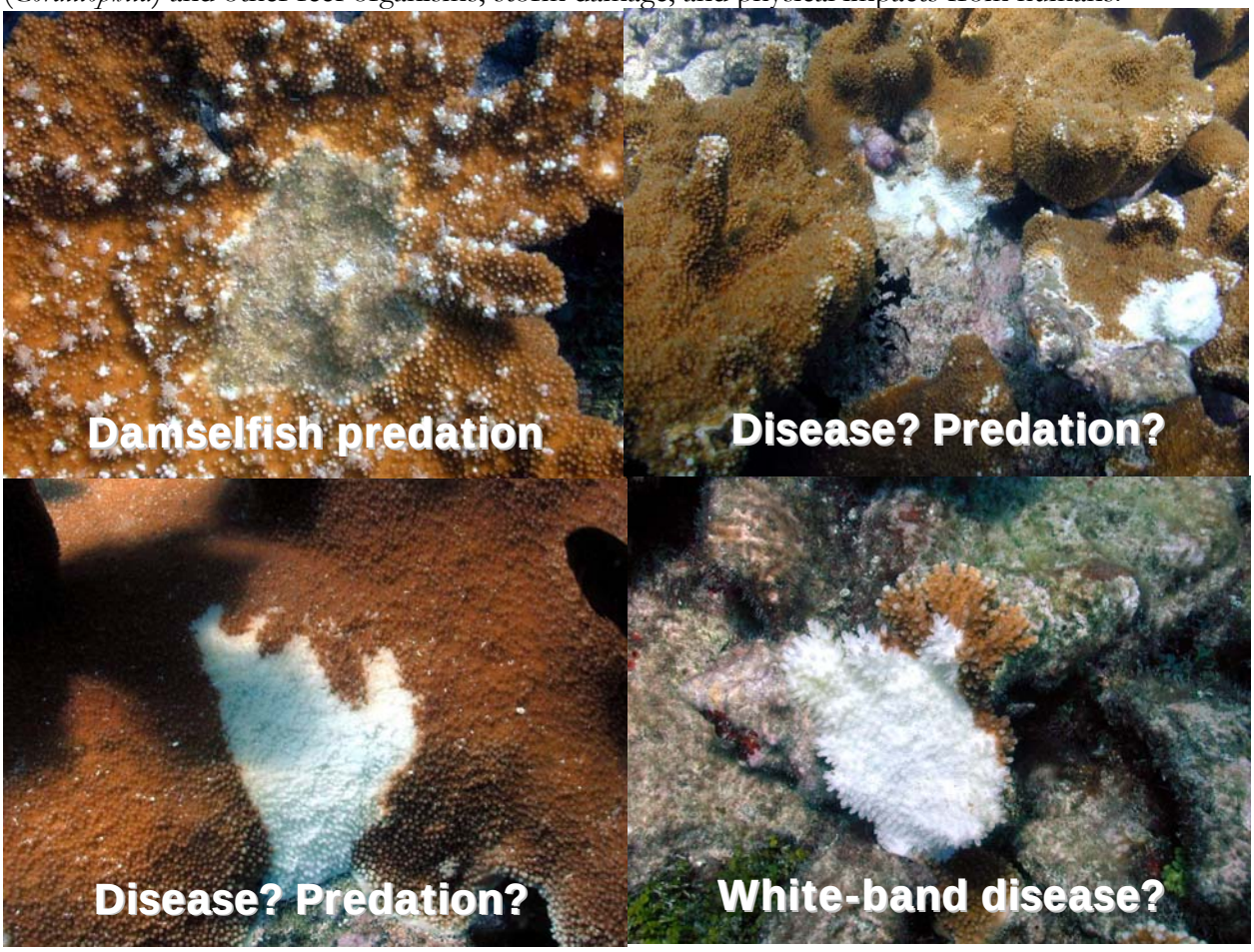
Population Estimate for Staghorn Coral in the Florida Keys

Similar population abundance estimates were developed for staghorn coral (*Acropora cervicornis*) after the summer 2001 surveys. Shown here are the abundance and disease prevalence estimates throughout the Florida Keys. Relative to elkhorn coral, staghorn coral is more abundant, occurs in more diverse habitats such as patch reefs and low-relief hard-bottom, and appears to be less affected by disease-like symptoms. However, only small patches (< 10 m diameter) are usually found. The large stands that historically occurred at 10-15 m depth on the fore reef of many lower Keys bank reefs (e.g., Sand Key, Sambos) are gone, but we are encouraged that this species is still present at many sites, albeit in relatively low densities.



Impacts to Elkhorn and Staghorn Corals

There are several biological and physical factors that may impede the ability of elkhorn and staghorn corals to re-establish their former prevalence on Florida Keys reefs. Among these are continued disease such as white band, patchy necrosis, and white pox, as well as predation by snails (*Coralliophila*) and other reef organisms, storm damage, and physical impacts from humans.

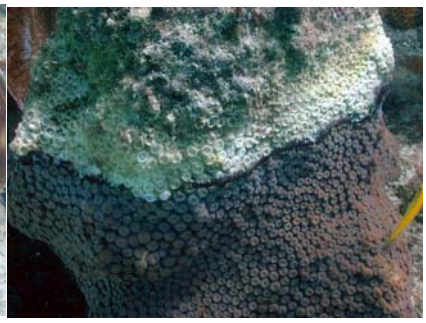


Coral Diseases

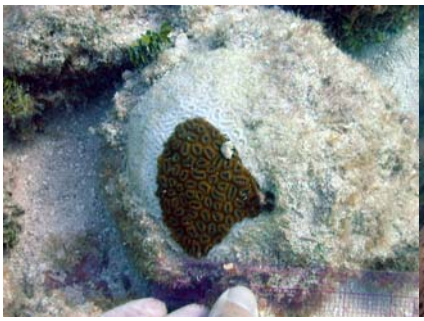
Reports from reef areas throughout the world over the past 20 years indicate that the number and prevalence of diseases has increased dramatically. The etiological agents involved and the causes of the increased prevalence of diseases are still not well understood, but are considered to be one of the primary factors that has caused changes to Florida Keys reefs. Shown here are some of the diseases or disease-like symptoms that affect Florida Keys corals.

White band?

Black-spot disease

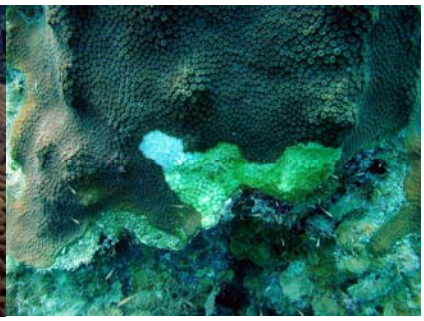


Black-band disease



White plague type II

Black-band disease



Unknown

Prevalence of Coral Diseases in the Florida Keys

The following are summary data that provide a general overview of disease prevalence estimates obtained from our program's large-scale sampling of the Florida Keys since 1999:

- 204 sites were sampled between 1999 and 2001
- 7,587 colonies (39 taxa) were sampled
- 125 colonies (1.65%) exhibited one of six signs of disease
- 85% of disease conditions were dark spot and dead, white skeleton of unknown cause(s)
- 22 of the 39 taxa exhibited one of six signs of disease
- There were no significant habitat or regional variations
- Disease prevalence generally was 1-3% among habitat types and regions

Reef-building corals in the Florida Keys can be affected by any number of disease-like conditions, such as any one of the band diseases, spots, and tissue necrosis. Most species appear to be susceptible to at least one of these disease-like conditions, but overall prevalence was relatively low. Specifically, we have consistently found that 1% to 2% of all scleractinian corals measured in a particular year are experiencing a disease-like symptom. During 2001, we were encouraged to find very few incidences of bleaching from the areas surveyed and disease incidence in the habitats was

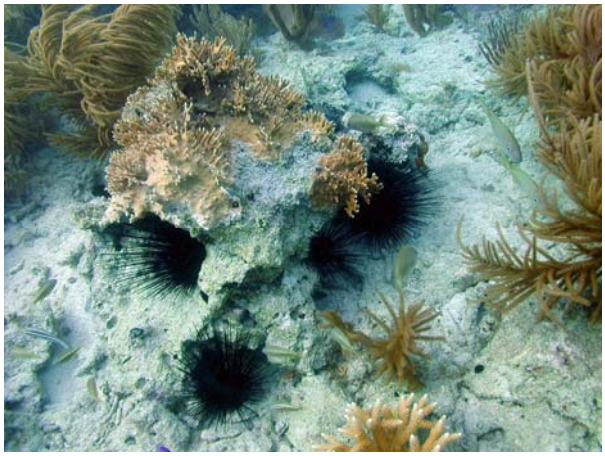
very low. Of the 2,665 scleractinian corals assessed, only 49 (1.8%) exhibited signs of disease. Disease conditions noted were:

- Dead white skeleton noted on several species, including *Porites astreoides*, *Siderastrea siderea*, *Stephanocoenia michelini*, *P. porites furcata*;
- Dark spot condition, noted primarily on *S. siderea*, but also *Agaricia agaricites* and *A. humilis*;
- Yellow band disease;
- White plague type II, noted on *Dichocoenia stokesi*, *A. humilis*, and *A. agaricites*;
- White band disease, noted on *Acropora palmata*; and
- Decaying tissue/skeleton, noted on *S. michelini*, and possibly indicative of shutdown reaction.

The percentage of scleractinian corals with signs of disease varied among habitat types as follows: mid-channel patch reefs (2.5%), offshore patch reefs (2.1%), high-relief spur and groove (1.7%), and low-relief hard-bottom (1.5%). No incidence of black-band disease was recorded from any of the colonies assessed.

Urchin Density and Size Patterns in the Florida Keys

One of the factors that has led to dramatic changes in Florida Keys and wider Caribbean reefs was the mass mortality of the long-spined sea urchin, *Diadema antillarum*, in 1983-84. The cause of the mortality was a water-borne pathogen that presumably originated near the Panama Canal and spread rapidly throughout the Caribbean basin. Populations in the Florida Keys were impacted by a second die-off event, similar to the first, in the early 1990s that further depressed population levels. However, the implication for reefs in the Florida Keys was probably not as dire because we have relatively healthy herbivorous fish populations, unlike those in the Greater and Lesser Antilles, for example. So, even with the mass mortality of this urchin species, there has probably been at least some compensation by fishes that continue to keep many habitats well grazed of macroalgae (see algae data, above). Since 1999, we have sampled for urchin density and test size at hundreds of sites in the Florida Keys and Dry Tortugas. While six species can be found in hard-bottom and reef habitats, *D. antillarum* is still relatively rare. Specifically, densities of this urchin still remain about an order of magnitude lower than historical data prior to the 1983-84 mortality event. Despite this pattern, we have found several locations, including the Dry Tortugas, with large (3.5-5 cm test diameter) *D. antillarum*, with clear effects of grazing on the substratum. Many other sites have relatively high densities of other species. The factors that may be impeding the recovery of *Diadema* may include insufficient adult densities to produce enough larvae, poor recruitment, and high post-settlement mortality due to inadequate habitat and/or predation.



Diadema antillarum

- Poor recovery since 1983
- Low densities in all habitats
- Dominated by recruits
- Poor survivorship
- Locally high densities in Tortugas

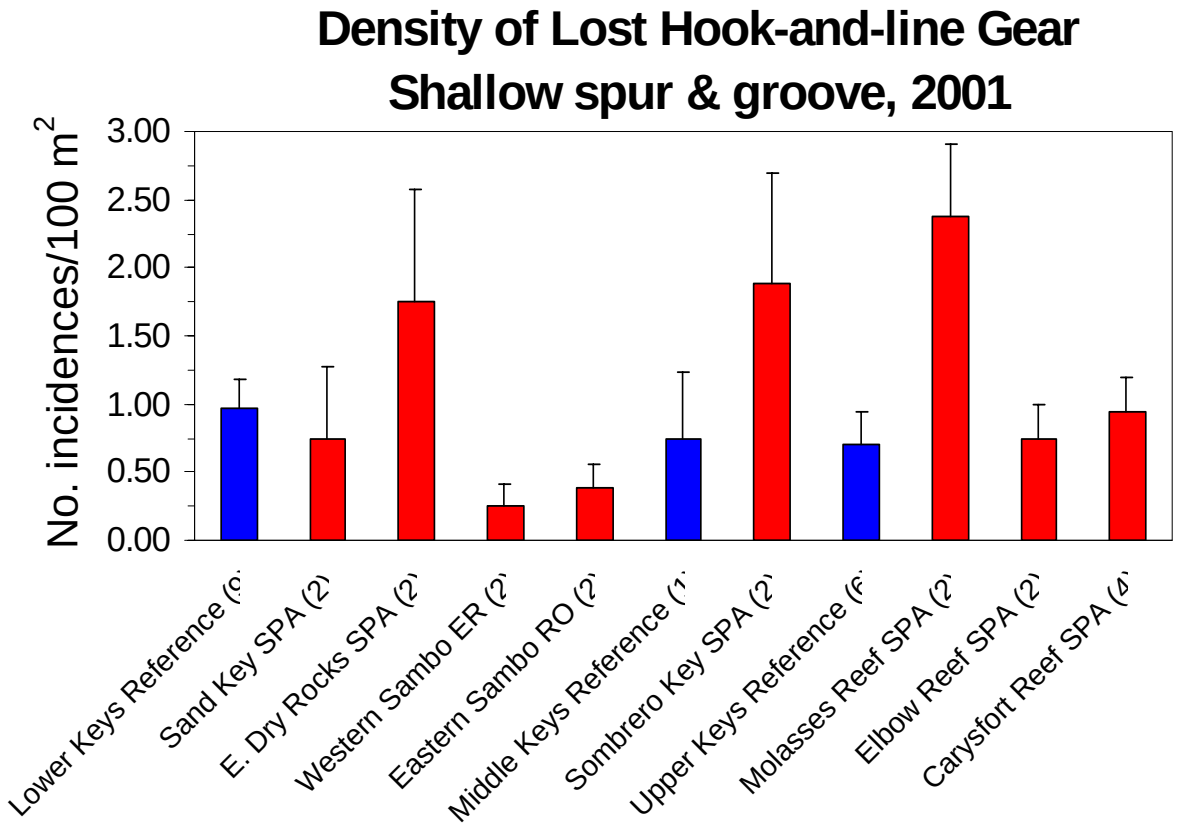
Echinometra and *Eucidaris* (shown here)

- Poor compensation by species other than *Diadema*
- Similar historical distribution/density patterns
- Shallow fore reef appears to be well grazed by fishes

Amount of Hook and Line Fishing Gear on Spur and Groove Reefs during 2001

Periodically we have sampled the amount of marine debris and have noted the type, amount, and biological impacts. With literally hundreds of thousands of lobster traps deployed per year, the thousands of recreational and commercial fishing trips, and the shear numbers of people on the water, it probably comes as no surprise the amount of debris that can be found on the bottom. Based upon results from 2000, we assumed when we made assessments in 2001 that relatively little fishing gear would be found throughout much of the shallow (1-6 m) fore reef, especially within the fully protected zones that are closed to fishing. We were surprised at the amount of marine debris, represented mostly by hook-and-line gear that was recovered, even within the fully protected zones. The majority of the debris was hook-and-line gear, represented by monofilament, wire, leaders, hooks, lead weights, and even a fishing pole, followed by remnant lobster/crab trap debris, including rope, wood slats, buoys, and cement. From all 86 sites representing a total survey area of only 25,200 m^2 during the summer of 2001, we recovered more than 0.5 km of hook-and-line gear and trap rope. Of the 349 m of hook-and-line gear recovered from the fore reef, 112 m (32%) was recovered from fully protected zones. In fact, many of the fully protected zones surveyed yielded some of the greatest densities of hook-and-line gear in the Sanctuary. While most of the gear within the zones was biologically fouled, clean or freshly lost hook-and-line gear was recovered from Sand Key SPA (7.4 m), Sombrero Key SPA (29.06 m), and Carysfort/S. Carysfort SPA (1.86 m). Most of the gear found on mid-channel and offshore patch reefs was lobster trap debris, especially buoy lines. However, several patch reefs near Molasses Reef Channel (near Three Sisters) and White Banks/Dry Rocks had significant quantities of hook-and-line gear. We also were able to assess the number of organisms impacted by debris, specifically abrasion and tissue mortality to sessile marine invertebrates. On the fore reef alone (63 sites), we noted 319 incidences of damage to fire coral, stony corals, gorgonians, sponges, and the colonial zoanthid *Palythoa*. Not surprisingly, most damage

was caused by hook-and-line gear on the fore reef, especially to gorgonians, and secondarily to fire coral and sponges. We recognize that lost fishing gear and other debris is probably a relatively minor factor affecting Florida Keys reefs; however concerted efforts need to continue to remove this material due to the cumulative effects that may occur.



Gorgonian-dominated Hard-bottom in Dry Tortugas National Park

This slide narrative has illustrated some of the patterns that have emerged from the large-scale sampling of benthic coral reef organisms in the Florida Keys, with a particular focus here on the high-relief spur and groove fore reef habitat. However, it is also important to point out that other habitat types, such as this low-relief hard-bottom site in the Dry Tortugas, are equally if not more important in terms of area coverage in the Sanctuary. In addition, many of the patterns observed in one habitat type are not universal. For example, we have noted relatively healthy coral assemblages and abundant urchins in other habitats.

Mid-channel Patch Reefs in the Florida Keys

One habitat type of particular interest in the Florida Keys are patch reefs, which are distributed from close to shore to the seaward edge of Hawk Channel. Literally thousands occur from Biscayne National Park southwest to the Dry Tortugas and are notable for their diversity in physical and biological structure. While dramatic changes have been documented on offshore reefs in the Florida Keys, the patch reef environment is characterized by significantly greater coral densities, coral cover, and coral colony size, despite existing in an environment often characterized by low visibility and flocculent sediments. Of interest to scientists are the factors responsible for the persistence of high coral cover reefs located relatively close to shore. Perhaps these habitats are a source of new corals to other areas of the Florida Keys. In any event, Federal and State resource managers should consider additional protection for patch reefs, as most are not within zone boundaries and represent what are probably the best remaining coral assemblages in the Florida Keys.

Status of Seagrass Beds in South Florida

James W. Fourqurean

Project Overview

The general objective of seagrass monitoring in the Florida Keys National Marine Sanctuary (FKNMS) is to measure the status and trends of seagrass communities to evaluate progress toward protecting and restoring the living marine resources of the Sanctuary. The scope and depth of this monitoring effort are without precedent or peer for seagrass ecosystems throughout the world. Specific objectives are: 1) To provide data needed to make unbiased, statistically rigorous statements about the status and temporal trends of seagrass communities in the Sanctuary as a whole and within defined strata; 2) To help define reference conditions in order to develop resource-based water quality standards; and 3) To provide a framework for testing hypothesized pollutant fate/effect relationships through process-oriented research and monitoring. In order to meet these objectives, we have developed these goals for the project:

- Define the present distribution of seagrasses within the FKNMS
- Provide high-quality, quantitative data on the status of the seagrasses within the FKNMS
- Quantify the importance of seagrass primary production in the FKNMS
- Define the baseline conditions for the seagrass communities
- Determine relationships between water quality and seagrass status
- Detect trends in the distribution and status of the seagrass communities

To reach these goals, four kinds of data are being collected in seagrass beds in the FKNMS:

- Distribution and abundance of seagrasses using rapid assessment Braun-Blanquet surveys
- Seagrass productivity of the dominant species of seagrass in the FKNMS (*Thalassia testudinum*) using the leaf-mark and harvest method
- Seagrass nutrient availability using tissue concentration assays

These data are being collected at three different types of sites within the FKNMS:

- Level 1 Stations: Sampled quarterly for seagrass abundance, productivity and nutrient availability. These stations are all co-located with Water Quality Monitoring Project stations (Fig. 1)
- Level 2 Stations: Randomly selected locations within the FKNMS, sampled annually for seagrass abundance and nutrient availability. Each year, new locations for Level 2 stations are chosen.
- Level 3 Stations: Randomly selected locations within the FKNMS, sampled annually for seagrass abundance. Each year, new locations for Level 3 stations are chosen.

We are assessing both inter-annual and intra-annual trends in seagrass communities. The mix of site types is intended to monitor trends through quarterly sampling at a few permanent locations (Level 1 sites) and to annually characterize the broader seagrass population through less intensive, one-time sampling at more locations (Level 2 and 3 sites). In addition to the monitoring activities, we take advantage of the vessel time needed to collect the monitoring data to also conduct manipulative experiments that help us understand spatial patterns and temporal trends in the monitoring data.

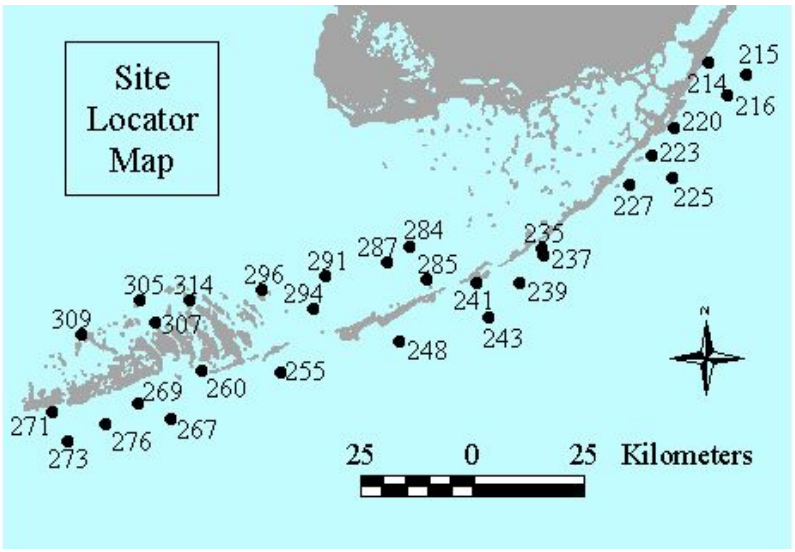


Figure 1. Location of the 30 Level 1 seagrass status and trends monitoring sites in the FKNMS. Site numbers correspond to water quality monitoring locations.

Project Accomplishments FY 2004 (October 2003 – September 2004)

The significant changes in seagrass communities at the permanent Level 1 stations that we reported last fiscal year continue to be present after an additional year of sampling. These changes are consistent with model predictions of nutrient-induced changes of these systems. There may be reasons for these observations that are unrelated to human activities in the region, but the spatial pattern of changes and the agreement of the changes with models of the system suggest that there is regional-scale change in nutrient availability that is causing changes in seagrass beds over a wide portion of the FKNMS.

In 2004, we resurveyed 251 Level 2 and Level 3 stations that were last visited during the summer of 1997 (Fig. 2). Preliminary analyses indicate that there are no large-scale spatial trends in the abundance of the dominant benthic plant types between the two years.

In general, nutrient addition to aquatic environments shifts the competitive balance to faster-growing primary producers. The consequence of this generality in seagrass-dominated environments is that seagrasses are the dominant primary producers in oligotrophic conditions. As nutrient availability increases, there is an increase in the importance of macroalgae, both free-living and epiphytic, with a concomitant decrease in seagrasses because of competition for light.
Macroalgae lose out to even faster-growing microalgae as nutrient availability continues to increase: first, epiphytic microalgae replace epiphytic macroalgae on seagrasses; then planktonic microalgae bloom and deprive all benthic plants of light under the most eutrophic conditions.

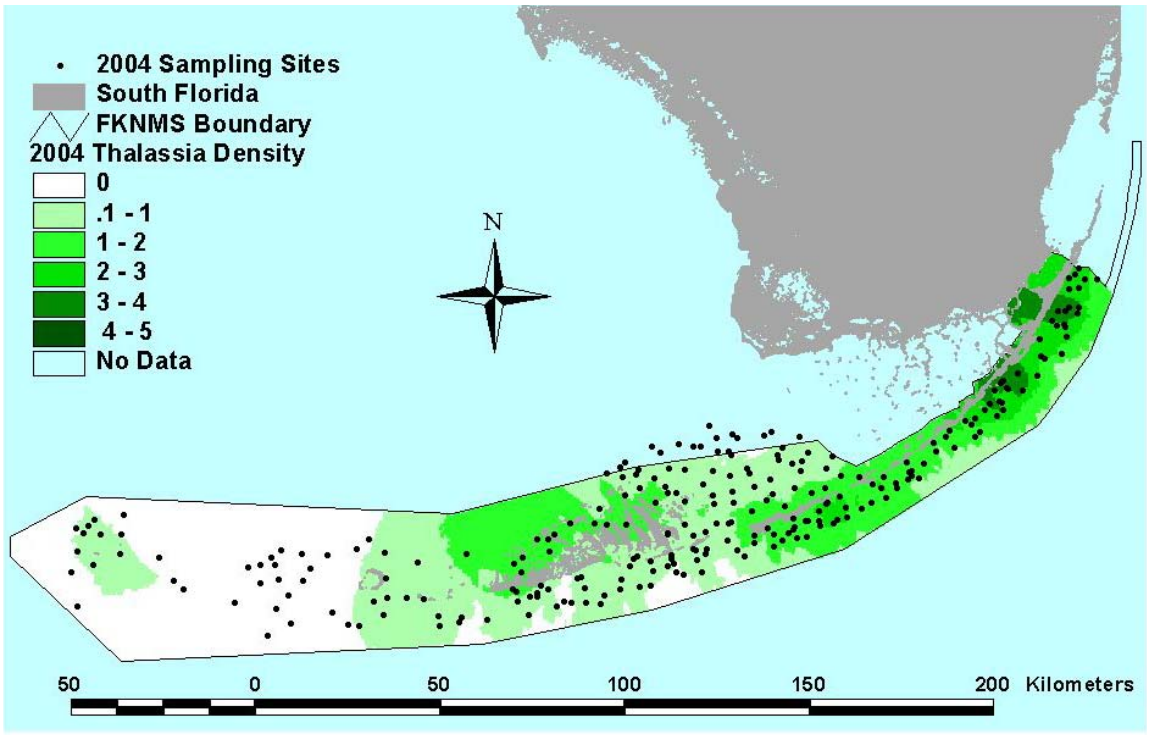


Figure 2. *Thalassia testudinum* distribution map from the 2004 Level 2 and Level 3 monitoring data.

The South Florida case is more complicated than the general case described above because there are six common seagrass species in South Florida, and these species have different nutrient and light requirements, and therefore have differing responses to eutrophication. Large expanses of shallow marine environments in South Florida are so oligotrophic that biomass and growth of even the slowest-growing local seagrass species, *Thalassia testudinum*, are nutrient-limited. At this very oligotrophic end of the spectrum, increases in nutrient availability actually cause increases in seagrass biomass and growth rate. As nutrient availability increases beyond what is required by a dense stand of *T. testudinum*, other seagrass species will out-compete it (Fig. 3). The relative importance of the various primary producers, then, can be used to assess the trophic state of the community.

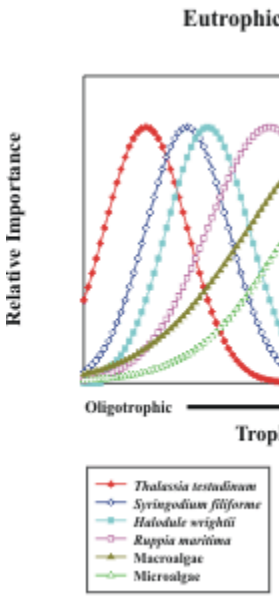


Figure 3. Conceptual model showing the change in importance of primary producers as nutrient availability increases from low (oligotrophic) to high (eutrophic).

Each species in the species dominance-eutrophication gradient model (Fig. 3) can potentially dominate over a range of nutrient availability and the model predicts a change in species dominance as nutrient availability changes. These changes are not instantaneous, however. Field evidence suggests that species replacements may take place on a time scale of a decade or more. It is desirable that we be able to predict the tendency of the system to undergo these changes in species dominance before they occur, so that management actions can be taken. Tissue nutrient concentrations can be monitored to assess the relative availability of nutrients to the plants. For phytoplankton communities, this idea is captured in the interpretation of elemental ratios compared to the familiar "Redfield ratio" of 106C:16N:P. For the seagrass *T. testudinum*, the critical ratio of N:P in green leaves that indicates a balance in the availability of N and P is approximately 30:1, and monitoring deviations from this ratio can be used to infer whether N or P availabilities are limiting growth of this species. *T. testudinum* is likely to be replaced by faster-growing competitors if nutrient availability is such that the N:P ratio of its leaves is approximately 30:1. A change in the N:P ratio in time to a value closer to 30:1 is indicative of eutrophication (Fig. 4).

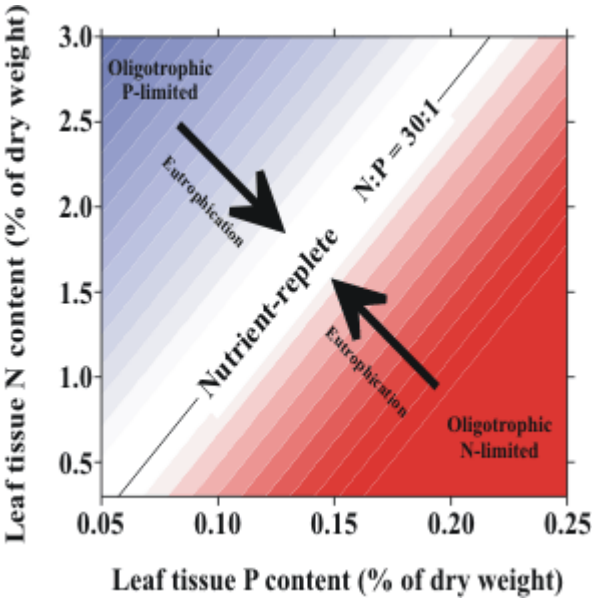


Figure 4. Conceptual model indicating how elemental ratios of seagrasses respond to increasing nutrient availability.

These models lead directly to a definition of trends likely to be encountered in the seagrass communities of South Florida if humans are causing regional changes in nutrient availability because of alterations to quantity and quality of freshwater inputs to the marine ecosystem: 1) regional eutrophication will cause N:P ratios of seagrasses to approach 30:1 from higher or lower values indicative of oligotrophic conditions; and 2) regional eutrophication will cause a shift in species dominance in South Florida seagrass beds. The first responses to eutrophication will be evidenced by an increase in the relative abundance of fast-growing seagrass species (*Halodule wrightii* and *Syringodium filiforme*) at the expense of the now-dominant, slow-growing *T. testudinum* (Fig. 3). At later stages of eutrophication, macroalgae and microalgae will become the dominant primary producers.

Our monitoring data indicates a large spatial gradient in the N:P ratios of *Thalassia testudinum* across the Sanctuary, with N:P ratios predicting nitrogen limitation in the offshore parts of the Sanctuary and predicting phosphorus limitation in nearshore areas (Fig. 5). These predictions based on our conceptual model (Fig. 4) were tested experimentally, and during this fiscal year, we published the results of an experiment that proved that offshore seagrass beds in the FKNMS were limited by nitrogen availability, while nearshore seagrass beds did not respond strongly to nutrient addition (Fig. 6; Ferdie and Fourqurean 2004). We also have completed experiments investigating the role of grazing fish in controlling the distribution of seagrasses in the seagrass beds adjacent to coral reefs in the FKNMS.

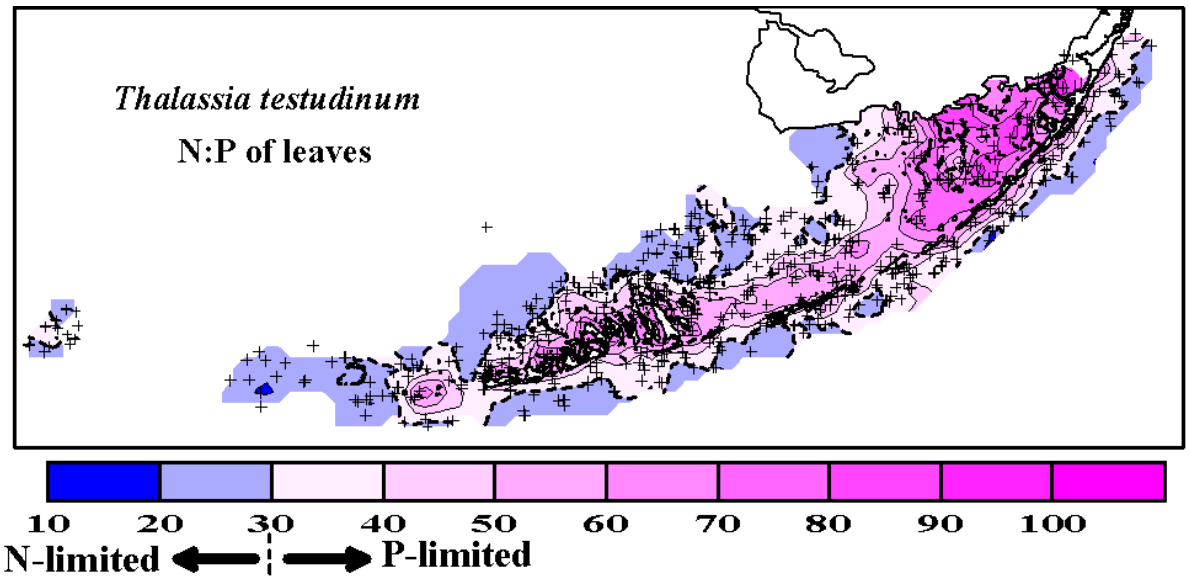


Figure 5. Distribution of N:P of *Thalassia testudinum* leaves.

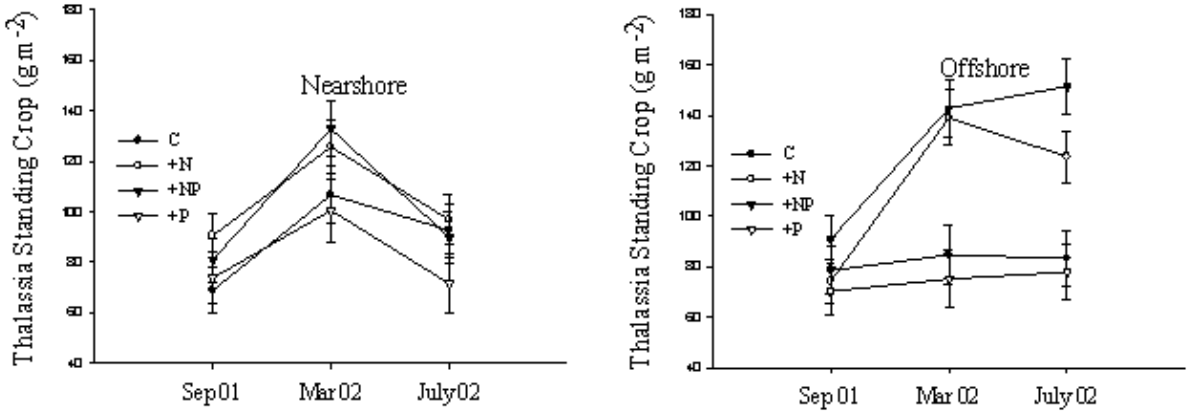


Figure 6. Response in *Thalassia testudinum* standing crop to nutrient additions at nearshore and offshore sites.

At four nearshore Level 1 sites in the FKNMS, there has been an increase in the relative abundance of macroalgae over the period 1995 - 2004 that is consistent with increased nutrient availability. At none of these has there yet been a decrease in seagrass abundance, but our conceptual model predicts that increases in fast-growing macroalgae should precede decreases in seagrass abundance (Fig. 3). One example, from site 235 offshore of Lower Matecumbe Key, shows how macroalgae have steadily increased in abundance over the monitoring period (Fig. 7). In addition to these sites where relative abundance of primary producers has changed, at four more Level 1 sites there have been long-term shifts in the ratio of nitrogen to phosphorus in seagrass leaves that are consistent with increases in nutrient availability (Fig. 8).

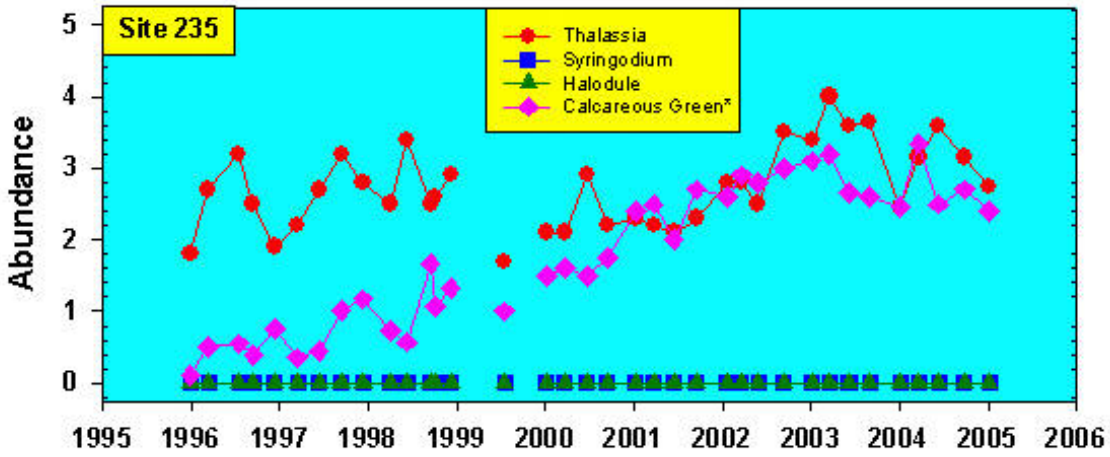


Figure 7. At Level 1 station 235 (see Fig. 1 for location) there has been a slow and consistent shift in species abundance, with faster-growing macroalgae becoming more abundant over the time period. This change is consistent with model predictions of the consequences of increases in nutrient availability.

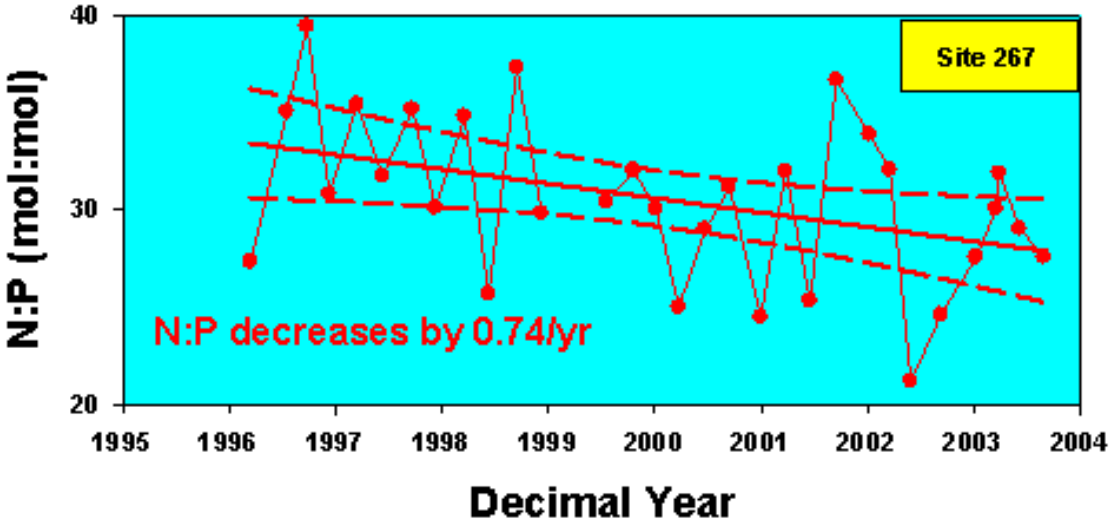


Figure 8. At Level 1 station 267 (see Fig. 1 for location) there has been a slow and consistent shift in N:P ratios from values consistent with P limitation toward values indicating an increase in phosphorus availability.

The sites that showed changes consistent with increased nutrient availability were not randomly distributed across the Sanctuary - rather, all of these sites were relatively close to shore in the Middle and Lower Florida Keys (Fig. 9).

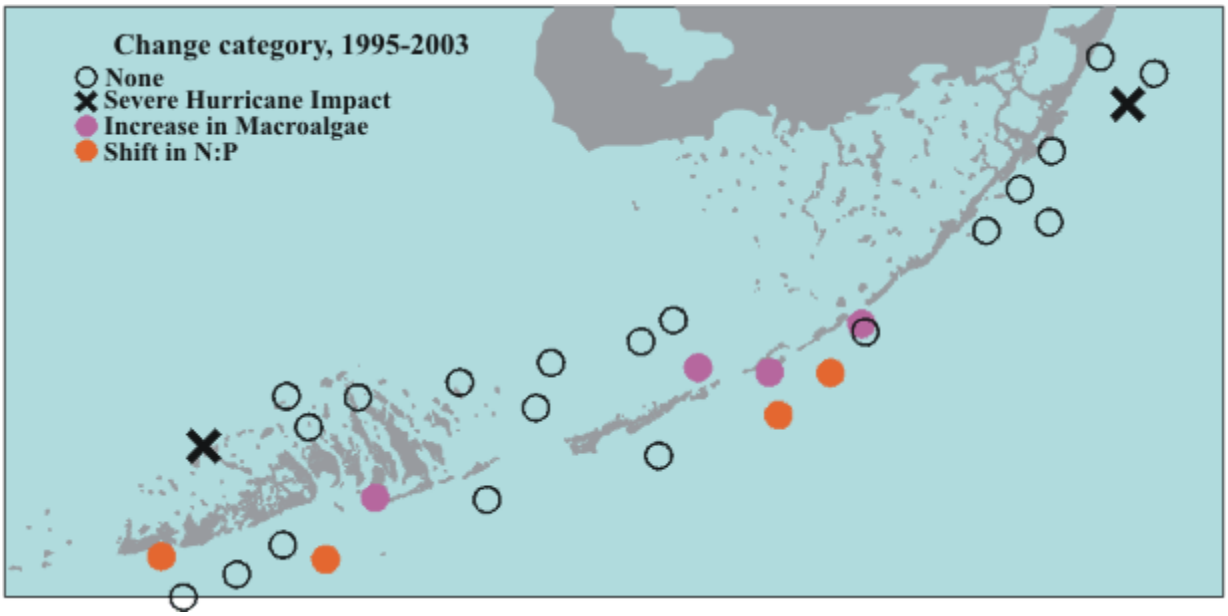


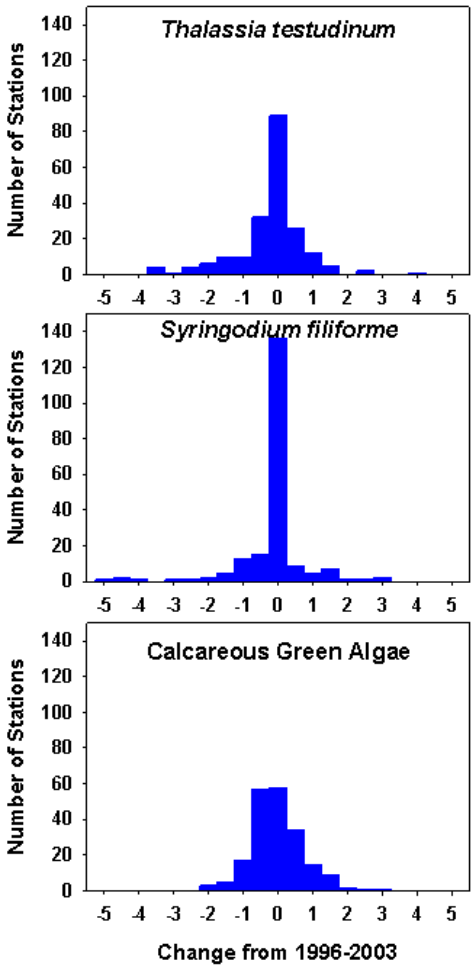
Figure 9. Long-term changes in seagrass beds at the Level 1 sites.

The lack of any such changes in the Upper Florida Keys suggests that the factor driving the observed changes is not present across the entire Sanctuary, so factors acting at the global scale (like global warming or coastal overfishing) are not likely responsible for the observations. In addition to Level 1 sites that are exhibiting changes that are consistent with long-term increase in nutrient supply, two additional sites were severely impacted by hurricanes over the course of the monitoring period.

Resurveying the Level 2 and Level 3 sites revealed no spatially consistent patterns in changes in relative abundance of seagrass communities from throughout the Sanctuary. The mean changes in Braun-Blanquet density for the major taxa for the period 1997-2004 were not significantly different from zero (Fig. 10), but there were some locations that had large differences between 1997 and 2004. Whether these changes were real changes in benthic communities or artifacts caused by small-scale spatial heterogeneity is currently being investigated. There were some areas, like around Islamorada, that showed declines in *Thalassia* in a large area contiguous with Level 1 permanent sites that exhibited changes that are consistent with eutrophication (see Fig. 11 for spatial pattern of change and Fig. 9 for Level 1 site summary). However, other regions of apparent change were not consistent with the patterns seen at the permanent sites. In FY 2005, we will resample an additional 272 sites that were surveyed in 1998 and an additional 94 sites in the Gulf of Mexico.

Our surveys have provided clear documentation of the distribution and importance of seagrasses in the FKNMS. The seagrass bed that carpets 80% of the FKNMS is part of the largest documented contiguous seagrass bed on earth. These extensive meadows are vital for the ecological health of the FKNMS and the marine ecosystems of all of South Florida. Maps of spatial distributions can be found on the web or DVD.

Figure 10. Frequency distributions of the changes in Braun-Blaunquet density for the three most common taxa based on revisiting 202 sites in 2003 that were originally surveyed in 1996. The mean change in density for all three taxa is not different from zero.



Our permanent monitoring sites have provided valuable data on the inter- and intra-annual variability of seagrass cover and abundance. Time series of species composition, seagrass productivity, nutrient availability and physical parameters can be found for each permanent monitoring site on the web site or the DVD. There have been some striking trends in the seagrass communities at these permanent sites: seagrasses were lost completely at 3 of the 30 sites during hurricanes over the last four years. At the remaining 27 sites, benthic communities are relatively stable. There are no common trends across the sites in seagrass cover or community composition. This can be interpreted to mean that there are no regional trends in the health of the seagrass beds represented by the permanent monitoring sites that can be detected with the six years of monitoring data. But, manipulative experiments in seagrass beds in South Florida demonstrate that the time course of the response of seagrass beds to eutrophication is on the order of decades, and we do not understand completely the interaction humans have with the natural dynamics of these systems. These 30 sites should continue to be monitored on a quarterly basis.

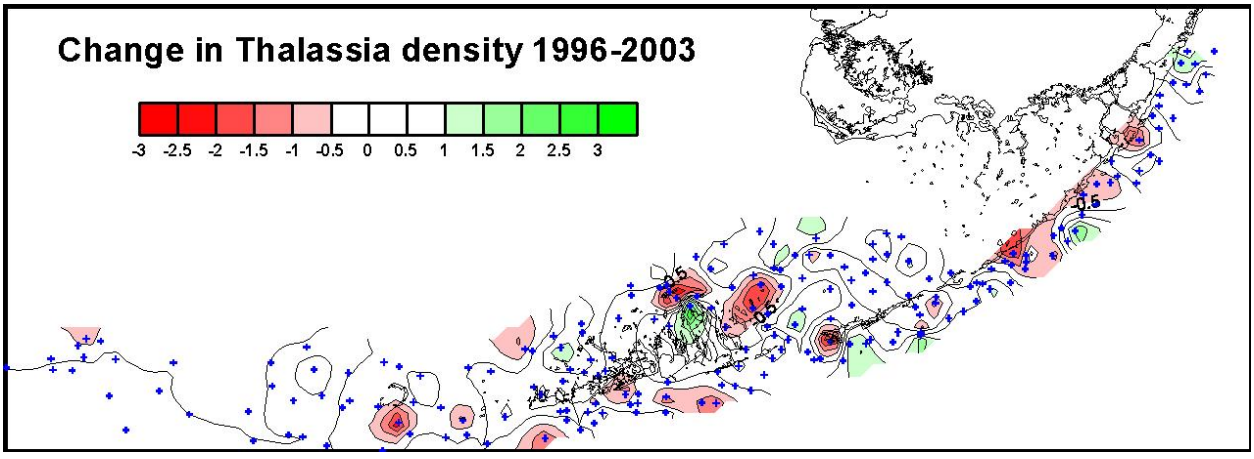


Figure 11. Spatial pattern of changes in Braun-Blanquet density of *Thalassia testudinum* at Level 2 and Level 3 sites surveyed in 1996 and revisited in 2003.

Detailed analyses of the monitoring data have led to 17 publications in the peer-reviewed scientific literature. These publications address aspects of the functioning and status and trends of benthic

communities, and lay the groundwork for forecasting future anthropogenic impacts on this ecosystem.

Acknowledgments

Michael J. Durako (University of North Carolina at Wilmington) and Joseph C. Zieman (University of Virgina) are Principle Investigators and Susie P. Escorcia (Florida International University) is the Project Manager of the South Florida seagrass program. This data report represents the dedicated work of many people. Craig Rose, Alan Willsie, Brad Peterson, and Leanne Rutten led the field collection efforts and spearheaded the compilation of the data report; Meredith Ferdie, Dottie Byron, Virginia Cornett, Sean Meehan, Kevin Cunniff, Segio Ruiz, Bryan Dewsbury, Travis Thyberg, and Anna Armitage collectively put in the thousands of hours in the field and laboratory that went into the collection of these data. The field work was conducted under permits FKNMS-2003-036 from the FKNMS, FDEP permit number 1587, FDEP Parks and Recreation. Contracts: NOAA - NA16OP2553/NA04NOS4780024; EPA X97468102-0.

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Plenary Presentation:
Building Resilience into Coral Reef Management

Rod Salm and Elizabeth Mcleod

In light of widespread coral reef degradation and the increasingly severe impacts of large-scale climate-related thermal bleaching, people began asking whether there is anything we can do to conserve coral reefs. The greater skeptics among these even ventured to ask "why bother trying to conserve coral reefs when events that are beyond our control will undermine our best efforts?" In this paper, we will consider the challenge posed by large-scale, emerging threats of this century, such as climate-related coral bleaching, introduce resilience as a possible strategy to address the challenge, exemplify this with the approach being taken in Palau to underscore that there is room for optimism, and suggest some specific actions that managers can take to build resilience into their programs, putting this into the context of the Florida Keys wherever possible.

The Challenge

Large-scale coral bleaching events have increased in intensity, frequency, and geographic distribution in the last two decades (Wilkinson 1998, 2000). The 1998 El Niño Southern Oscillation (ENSO) event and 1999 La Niña caused mass coral bleaching of unprecedented proportions worldwide and near complete loss of live coral at some sites (Goreau et al. 2000). Bleaching is the response of corals to many forms of stress, but is particularly severe and widespread when caused by thermal stress (unusually high seawater temperatures) combined with the intense solar radiation that usually accompanies warming during these calm, clear, cloudless conditions.

We now recognize that climate-related bleaching events pose a serious global threat to coral reefs (Goreau et al. 2000; Westmacott et al. 2000; Salm et al. 2001), raising concerns about appropriate response strategies (Hughes et al. 2003). Marine Protected Areas[1] (MPAs) have been identified as one of the most effective tools for conserving reefs and related marine systems (Lubchenco et al. 2003; Palumbi 2003). However, protected area managers must incorporate climate change as well as increasing human pressures into their conservation strategies, or MPAs may not be able to safeguard biodiversity effectively. Networks of MPAs, including no-take areas, have been identified as a critical way to protect coral reefs from human stresses.

Reason for Optimism

Despite the widespread bleaching-related mortality of coral reef organisms, particularly following the 1998 El Niño, it is rare for living corals to be completely eliminated from a section of reef. Even in the most severe cases, some coral communities appear to be more resistant (i.e., they don't bleach) or more resilient (i.e., they bleach and may die but recover quickly) to bleaching (Salm et al. 2001; West and Salm 2003; Salm et al. in prep). A recent analysis of bleaching reports (Wilkinson 2000) indicates that there is a wide variability in bleaching intensity, species affected, depth, and geographic distribution, and how much mortality a bleaching event causes. After widespread mortalities from

[1] MPAs are interpreted here in the internationally accepted context, which is broader than often applied in the USA: Any area of intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment (Kelleher 1999).

bleaching events have occurred, reefs also differ in their ability to recover through growth and expansion of surviving corals or the settlement and recruitment of new corals.

A variety of environmental and biological factors appear to influence the differences in responses to bleaching among various coral communities, making some communities more resistant or resilient to coral bleaching. These include factors that: 1) reduce temperature stress (e.g., local upwelling areas); 2) increase water movement and flush harmful toxins (e.g., narrow channels with strong currents); 3) decrease light stress (e.g., high island shading); 4) harden corals to adverse conditions and develop stress tolerance (e.g., regularly stressful environments where corals are already adapted to stress, such as reef flats where corals are exposed to the air at low tides); and 5) favor conditions that enhance recovery potential (e.g., high herbivore populations to graze back algae and maintain suitable substrate for settlement of coral larvae, low incidence of disease) (Salm et al. 2001; Salm and Coles 2001; West and Salm 2003). Sites where these factors reliably occur would make good candidates for MPA selection and the investment of conservation effort and funds.

Reduction of temperature stress

There is emerging evidence that vertical mixing of deeper cool waters up through the water column effectively cools the heated surface water and reduces thermal stress to corals (Done et al. 2003; Wooldridge and Done 2004). Tidal-driven and ocean currents can thus prevent temperature anomalies occurring within some coral zones, during times when regional heat stress is generally widespread. Following the 1998 El Niño, areas of local strong vertical mixing protected central Indonesian reefs from severe bleaching (Goreau et al. 2000; Salm et al. 2001). For example, at Komodo National Park and Nusa Penida Island in Indonesia, there was a clear vertical mixing effect of strong cool currents. At these locations, there was little or no bleaching or temperature related mortality in corals following the 1998 event. Other reefs also had lowered mortality due to the cooling effects of local upwelling: the outer reefs of Alfonse, St. Francois, and Bijoutier atolls in the Seychelles, Western Zanzibar, and certain areas in the Maldives (Goreau et al. 2000), and some outer reefs in the Great Barrier Reef following a 2002 heat wave (Berkelmans et al. 2004; Wooldridge and Done 2004).

Strong currents and flushing

Flushing by strong currents, even if the water remains warm, may also protect corals to some degree, apparently working by removing free radicals that are a toxic byproduct of bleaching in corals (Nakamura and van Woesik 2001). In laboratory experiments, these authors demonstrated that *Acropora digitata* suffered high bleaching mortality under low-flow conditions, and none under high-flow conditions. While field evidence for this effect is weak, there have been observations in Palau and Indonesia that clearly demonstrate synergisms at work. At several sites in Palau[2] where corals had died on reef slopes below 2-4 m, reef flats and shallow reef crests with strong currents showed much higher coral survival.

[2] Lighthouse Reef flats, reefs in Malakal Channel and at the Pincers, patch reef east of Ebiil Channel off NW Babeldaob Island, Fantasy Island area reef flats (these later severely impacted by the crown-of-thorns starfish *Acanthaster planci*)

Reduction of light stress

Under ideal conditions, corals thrive at high light levels (Jokiel and Coles 1990). However, in combination with a second factor (i.e., increased temperature), high light levels can become a stress.

Shading: High north-south orientated islands can sometimes provide shading for corals during one or other half of the day, and undercut karst islands or coastlines often provide intensely shaded shelves on which corals can grow. Trees growing on the slopes of these coasts can further extend the shading effect seawards. The Rock Islands in Palau demonstrate well this effect of shading in reducing bleaching and related mortality.

Rock Islands in Palau (Photo by Jez O'Hare)

Shaded corals beneath overhang in Palau (Photo by Rod Salm)

At Nikko Bay, in particular, one of the most diverse permanent monitoring sites of the Palau International Coral Reef Research Center, corals in shaded areas survived well during the 1998 bleaching event that, elsewhere in the vicinity, caused major coral mortality.

Screening: Suspended particulate matter in the water column may also protect corals naturally adapted to these conditions by screening them from destructive high light levels. On silty and often turbid fringing reefs on the inner Great Barrier Reef, coral cover can approach 100% over large areas (Stafford-Smith and Ormond 1992). In parts of the Rock Islands and sheltered bays off Babeldaob, Palau, *Porites rus* and *Porites cylindrica* succumbed to bleaching and died in clear water areas, but survived in naturally cloudy water. Turbidity may also have contributed to lower mortality following the 1998 bleaching event in the Gulf of Kutch, southwestern Sri Lanka, Mahé (Goreau 1998a, b), along the 18-foot break inside the barrier reef in the Florida Keys National Marine Sanctuary (B.D. Causey, pers. ecol.), and inside the lagoon of Alfonse atoll (Goreau 1998c; Goreau et al. 2000).

Screening by suspended particulate matter (Photo by Rod Salm)

Reefs in such naturally turbid waters are often overlooked by MPA managers, who focus their attention on the clearer water reefs favored by tourists. But these reefs merit greater representation in conservation programs as they may demonstrate greater resilience to bleaching events relative to reefs in clearer waters.

Stress tolerance

A history of regular exposure to severe conditions (Brown et al. 2000; Dunne and Brown 2001; Coles and Brown 2003) also appears to acclimatize corals to cope with anomalous excursions in light and temperature. This includes corals in habitats exposed to intense solar radiation (Brown et al. 2000) and/or high temperatures (Craig et al. 2001; Jokiel and Coles 1990; Marshall and Baird 2000). Corals on reef flats that emerge at low tide are exposed to conditions of heating, desiccation and rainfall. Such prior exposures have been suggested as explanations for lower bleaching susceptibility recorded for corals in some inner reefs and lagoons relative to the same coral species from deeper waters (Hoeksema 1991; Salm et al. 2001; West and Salm 2003). The central Indian Ocean in 1998 provides another example. Here, there was localized survival of corals in reef flat and lagoon areas (Spalding et al. 2000), probably reflecting the wide ambient variability in light and heat in these habitats.

Exposed corals (Photo by Rod Salm)

Thus, reef flat and lagoonal coral communities should not be overlooked in management plans or reef conservation. Indeed, reef flats will be the coral habitat most affected by sea level: given a strong supply of coral larvae, a rise in sea level could allow for successful recruitment and growth of a greater variety of corals than are currently found on some reef flats (Done 1999).

Coral community type

It is unlikely that the above factors acting alone can explain differences in coral survival during bleaching events. It is more probable that these factors interact to different degrees to favor growth of specific coral community types.

Coral species with rapid growth rates, thinner tissue, and branching forms, (e.g., *Acropora* spp., *Stylophora* spp., and *Pocillopora* spp.) tend to bleach sooner and more severely than slow-growing, massive corals with thicker tissues (e.g., *Porites*, *Goniopora* spp.) (Gates and Edmunds 1999; Loya et al. 2001). However, even in a specific location, different colonies of a coral species can vary greatly in their susceptibility to thermal stress (Marshall and Baird 2000; Smith and Buddemeier 1992).

In one study of three hard coral genera, *Acropora* spp. Showed the most severe bleaching, *Pocillopora* spp. Showed intermediate bleaching, and *Porites* spp. Showed the least bleaching (Hoegh-Guldberg and Salvat 1995). It was the corals that showed the fastest growth and metabolic rates (*Acropora* spp.) that were the most susceptible. All *Porites* spp. Colonies recovered from bleaching, while *Acropora* spp. Did not recover well. Here, mass bleaching quickly changed the dominance relationships by decimation of a major component, the branching corals. A similar change in community structure was observed in Okinawa (Loya et al. 2001). Community shifts away from branching corals might have negative impacts on these ecosystems, as many fish and invertebrate populations are obligate associates of intact branching corals (Goreau et al. 2000).

Strong and diverse coral settlement and growth are good indicators of the resilience of a site for its corals. Strong recruitment is measured by both the number and the cover of small coral colonies established in an area since a prior disturbance. The chronology of recovery is often reflected in the presence of different, well-defined sizes of corals. It can be argued that such recruitment is also a proxy measure of local reef "health"; i.e., suitability of the substrate for coral settlement and of water quality. The 'sources' of larvae that recruited may be some kilometers upstream, and themselves need to be identified and protected in MPAs to ensure strong and rapid recovery of the downstream 'sink' reef. It is likely that these source coral communities have survived because of one or more of these factors reduce the risk of bleaching at the site. Full protection of these "resistant" or low risk coral communities in MPAs is essential, whatever the underlying reasons for survival.

What Can MPA Managers Do?

MPA managers, accustomed only to addressing direct and usual threats related to fishing and tourism, for example, find it difficult enough to address the impacts of coastal development and inland activities, and may consider climatic sources of environmental stress totally beyond their sphere of influence. This perception is reinforced when even well managed reefs in the remotest MPAs (e.g., Ngeruangel atoll in Palau and Aldabra atoll in the Seychelles) succumb to a climate related bleaching event. However, there are some direct actions that MPA managers can take immediately, even as the scientific understanding improves. Salm et al. (2001) proposed that it might be possible to mitigate the negative impacts of bleaching on coral reef biodiversity in two broad ways:

1. Identify and protect from direct anthropogenic impacts, specific patches of reef where local conditions are highly favorable for survival generally, and that also may be at reduced risk of temperature-related bleaching and mortality (i.e., coral assemblages with a high level of "resistance");

2. Locate such protected sites in places that maximize their potential contribution to the recovery of damaged or vulnerable reefs that are connected through larval dispersal.

The Nature Conservancy developed a "Resilience Model" to assist conservation planners and managers build resilience into coral reef MPAs (Fig. 1).

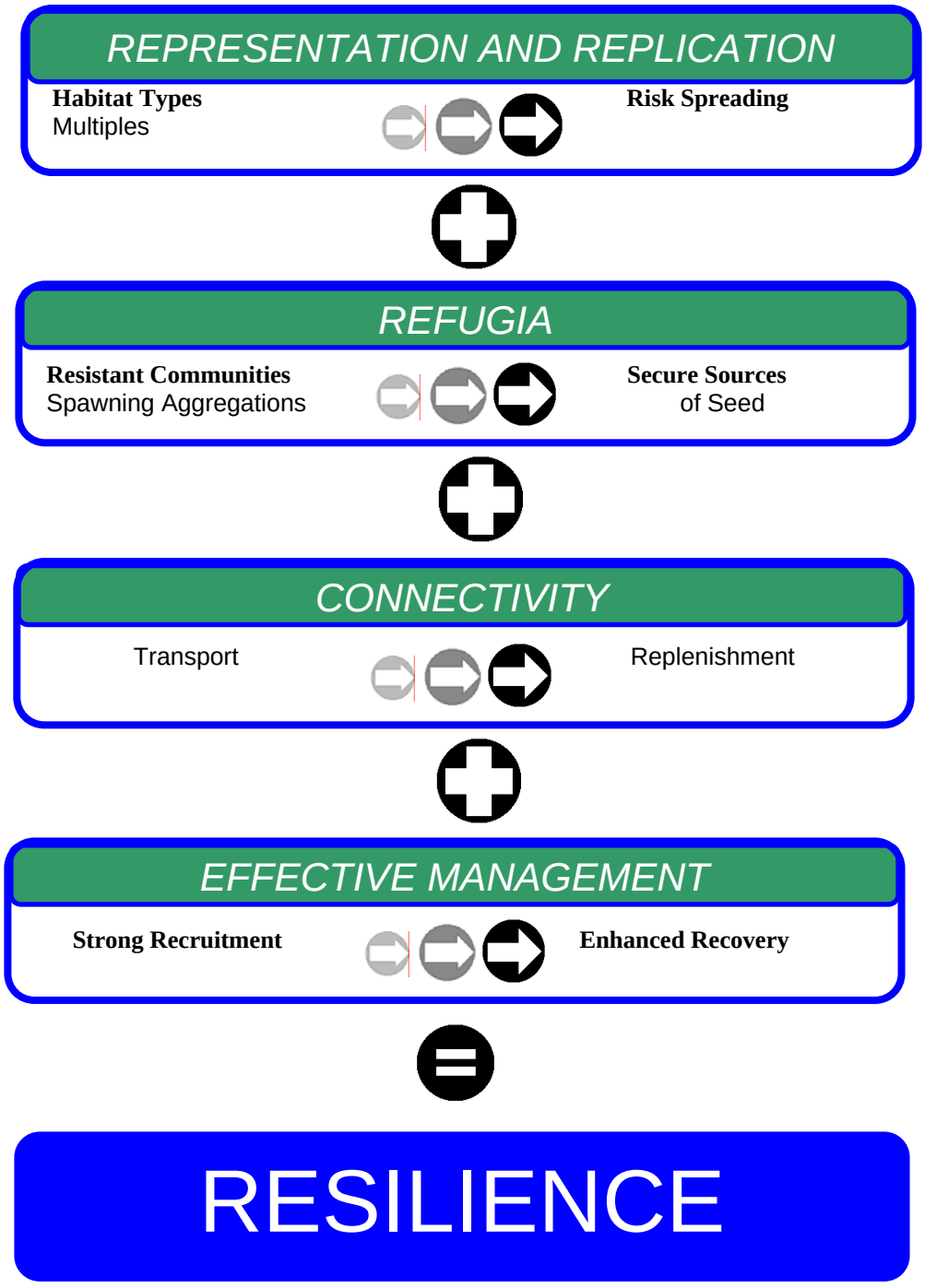


Figure 1. TNC Resilience Model.

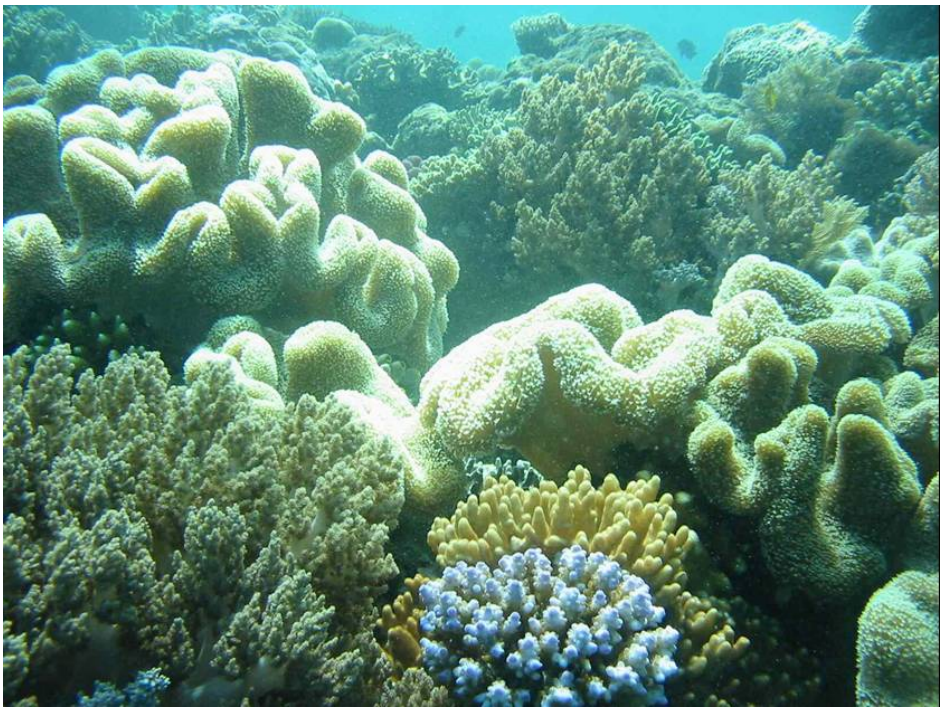
The components of the model and their application to MPA network design are described below. The most effective configuration would be a network of highly protected areas nested within a broader management framework. Such a framework might include a vast multiple-use reserve managed for sustainable fisheries as well as protection of biodiversity. The ideal MPA system would

be integrated with coastal management regimes to enable effective control of threats originating upstream, and to maintain high water quality (e.g., Done and Reichelt 1998).

1) Representation and Replication

Manager's action: Protect multiple examples of a full range of reef types, seeking to represent the area's total reef biodiversity. Replication within each type reduces the chance of any one type being completely compromised by an unmanageable impact such as a major bleaching event.

To fully represent regional biodiversity within protected areas, the range of reef types protected should include samples of offshore reefs (barriers, atolls) in areas with greater and lesser wave energy and exposure to trade winds, mid-shelf reefs (patch and fringing reefs) where these exist, and inshore fringing and patch reefs in sheltered locations. For long, linear coastlines, samples of all these reef types should be selected at regular intervals along the coast and reef tract. Wherever possible, multiple samples of each reef type should be included in MPA networks or larger management frameworks, such as multiple-use MPAs or areas under rigorous integrated management regimes. This approach also has the advantage of protecting essential habitat for a wide variety of commercially valuable fish and macroinvertebrates.



Representation: different coral habitats support different elements of biodiversity
(Photo by Rod Salm)

Key to achieving representation is a good classification scheme that shows the distribution of different reef types and further categorizes them by biodiversity. These reef types can then serve as surrogates for species diversity or resource and use values in determining representation. Presently, ~10% of reefs in the Florida Keys are fully protected. Studies and policies around the world are increasingly suggesting that up to between 30 and 50% of reefs should be fully protected to ensure full functioning and survival of the coral reef system (Hoegh-Guldberg and Hoegh-Guldberg 2004).

Certainly, an increase in fully protected reefs to 33%, as was recently decided for the Great Barrier Reef, would be a good place to begin building coral reef resilience in the Keys.

2) Refugia

Manager's action: Identify and fully protect coral communities that can serve as refugia and thereby reseed and facilitate the recovery of other areas that are seriously damaged by bleaching.

Through analyzing local environmental factors that contribute to coral community resistance and resilience, managers can identify areas of cooling, shading, screening, stress tolerance, and strong currents, as described in the preceding section (West and Salm 2003; Salm et al. in prep.). The compilation of these data in the Keys would help managers identify reefs that either do not bleach or that do bleach and recover with minimal mortality and low incidence of disease. Examples of both these types of reefs should be protected and included in fully protected zones.

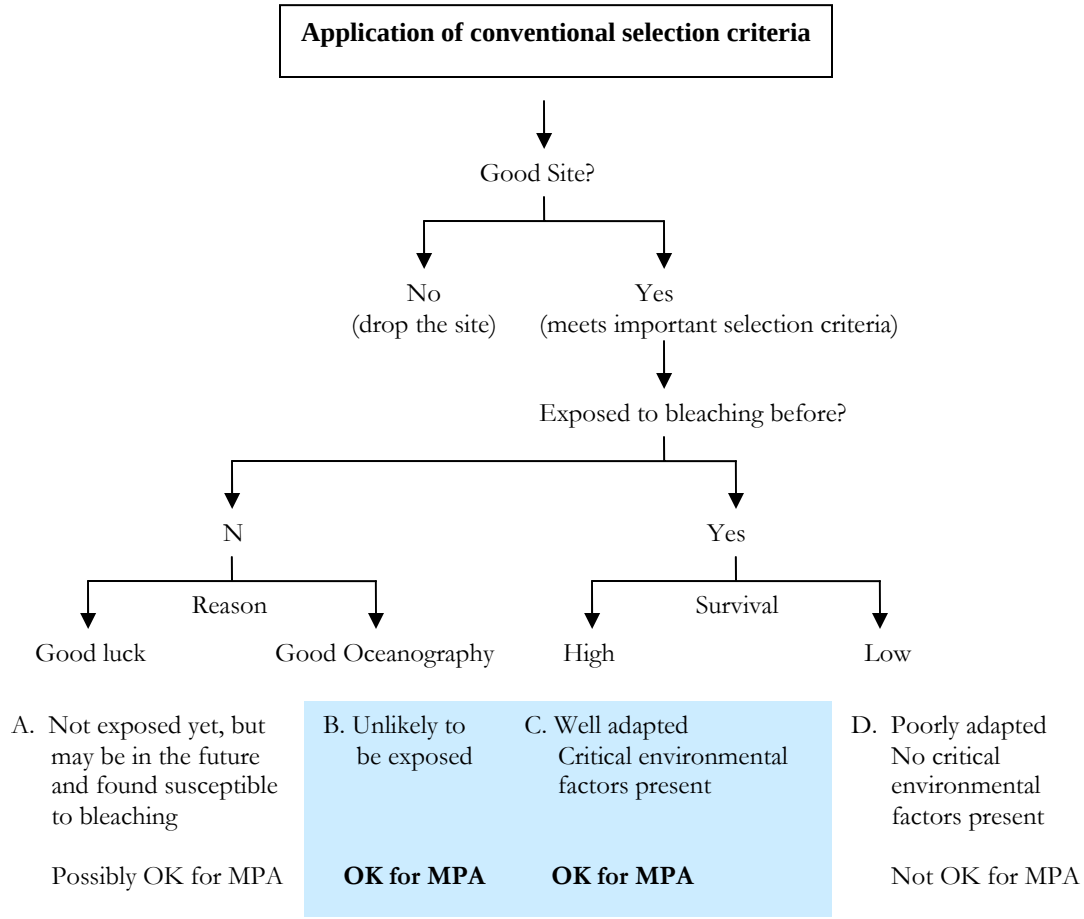
It is possible for managers to apply the following assumption as a shortcut to identify refugia sites that have a high probability of surviving bleaching events: corals that have survived a previous known bleaching event have a higher probability of surviving a future one, especially if they have a wide size frequency distribution indicating regular recruitment and survival over long time periods. The decision tree (Fig. 2) will greatly facilitate narrowing down the options for new MPA sites. It starts from the presumption that criteria for MPA selection have been agreed and applied to select candidate sites with high biodiversity value. Based on their response when tested by elevated temperatures, these candidate sites are then appraised for their survivability in the context of global warming.

3) Connectivity

Manager's action: Identify patterns of connectivity among source and sink reefs, so that these can be used to inform reef selection in the design of MPA networks and provide stepping-stones for larval dispersal, over longer time frames.

'Connectivity' describes the natural linkages among reefs that result from the dispersal and migration of organisms by ocean currents. In addition to hydrodynamic factors (speed, direction, and pattern of currents), the strength of connectivity depends on the abundance and reproduction potential of source populations, the life spans of their larvae, and the spawning sites and movement patterns of adults. Connectivity is thus a key driver of the strength and reliability of the replenishment of biodiversity on reefs damaged by natural or human-related agents. Ideally, to maximize a damaged site's chances of recovering from a bleaching event, it should have a bleaching-resistant site upstream of it to supply its larvae.

It is important for managers to develop an understanding of how and where the larvae of corals and other reef related species are distributed. Some reefs may be sufficiently large to be self-seeding. Others may rely on reefs up current to provide their seed. Thus identifying source and sink reefs and linking them into a MPA network is critical to enable surviving reef communities to aid in the recovery of others that have succumbed to one or another threat.



(modified from Done, 2001)

Figure 2. Decision tree to aid MPA site selection.

Where protected areas are surrounded by intensively used lands and water, buffer zones are commonly established to provide a transition zone of partial protection. Such buffer zones will become increasingly important for coral reefs as sea level rises, potentially expanding the extent of some shallow water habitats for reefs and mangroves. As warm tropical waters extend polewards, it may be timely to begin modeling future connectivity patterns. This would help guide planning of MPA configurations in light of possible expansions in latitudinal distributions of coral communities that presently are restricted by existing temperature ranges.

4) Effective Management

Manager's action: Manage reefs for both health and resilience, and monitor multiple indicators of the effectiveness of current actions as the basis for adaptive management.

Effective management is fundamental to the success of any conservation effort and the daily business of managers' work. While management activities focus mainly on addressing direct proximate threats, such as those resulting from destructive forms of fishing or recreational use, pollution from various sources on land and at sea, and those linked to coastal development, mining,

or oil and gas prospecting, there is the need to plan for impacts resulting from beyond the manager's field of influence. This calls for actions to ameliorate the impacts of such threats as climate related coral bleaching and hurricane damage.

Managers can also help strengthen the science underlying resilience, by encouraging or supporting dedicated research programs and by tailoring existing monitoring programs to address issues of bleaching resistance, determine connectivity patterns, and accommodate a rapid response to a bleaching event. A rapid response mechanism allows us to track the bleaching impact and to measure and interpret the response in light of different factors that might explain the different levels of mortality and recovery.

Expanding the area of tropical seas managed for biodiversity conservation increases the impact on people's activities, access, and resource uses. Effective management therefore also needs to address the socioeconomic impacts of both coral bleaching itself and of the conservation strategies introduced to counteract its impacts (Salm et al. in prep.). Poverty reduction and sustainable development strategies become the cornerstones of effective MPA management in many locations. Partnerships are the key to both conservation and sustainable development. For example, only through partnerships with local communities could managers hope to rehabilitate damaged sites by such actions as removal of crown-of-thorns starfishes or other coral predators, restriction or reduction of fishing of herbivores, prevention of destructive practices, control of tourism impacts, improvement of water quality, and physical removal of macro-algal mats that are inhibiting coral settlement, survival, or growth. Only through the existence of influential partnerships among government agencies and the private sector could protection of coral reef resources be used as the leverage to bring about control of land-based sources of pollution. To engage communities in such ways, there is a clear need for managers to develop strategies that are attuned to local priorities and needs, with useful productivity and resilience of the reef resource system among those needs. These strategies should include incentives to local fishers to protect key species that support reef resilience.

Is there more managers can do?

The Caribbean reefs provided a valuable lesson in reading warning signs that signaled future reef collapse. Loss of herbivorous fishes, loss of macro-fauna, a shift from fish-dominated herbivory to echinoid-dominated herbivory, destructive overgrazing and bioerosion by food-limited sea urchins, and reduced coral recruitment all indicated significant ecosystem changes that depleted the resilience of reefs (Bellwood et al. 2004). Managers must pay attention to ecosystem shifts and incorporate targeted responses to mitigate these shifts in order to maintain reef resilience.

Manage water quality: Managers can manage water quality by addressing sources of pollution, especially nutrient enrichment of water, which creates conditions that favor algal growth and prevent coral larvae from settling. To manage water quality effectively, managers must link their MPAs into the governance systems of adjacent areas, as well as controlling the pollution sources within their own boundaries.

Manage functional groups (herbivores): Steneck and Dethier (1994) defined a functional group as a collection of species that perform a similar function, irrespective of their taxonomic affinities. Some areas have more species in each functional group; thus they have functional redundancy. Reef communities with functional redundancy may have a better chance of recovery, if a species is lost from a functional group.

The issue of how to respond to competition between algae and corals for space to settle and grow is challenging. One way managers can respond is to regulate herbivore fisheries so that herbivores – especially fishes, are able to keep the algae in check. Bellwood et al. (2004) defined three functional groups of herbivores that play complementary roles in preconditioning reefs to facilitate coral recovery: bioeroders, grazers, and scrapers. Bioeroders are important because they break down stands of dead coral which provide transient substrates for coral recruits. Grazers assist ecolonization of coral larvae following mass coral mortality by keeping the coral substrate clear of overgrowth and shading by macroalgae (Nyström et al. 2000; Bellwood et al. 2004). Scrapers reduce the development of algal turfs which can trap sediments smothering coral recruits and inhibiting recovery. Bioeroders, grazers, and scrapers are critical herbivores required to maintain reef resilience, and managers will need to monitor these populations and take measures to regulate fisheries before they show signs of depletion.

Surgeonfishes are important algal grazers
(Photo by Rod Salm)

In parts of the Caribbean, overfishing of herbivorous fishes created the opportunity for sea urchin populations to expand and fill the niche as key algal grazers. While this helped maintain suitable conditions for coral settlement and growth, resilience was compromised because the resulting dense urchin population facilitated the spread of disease leading to the urchin die-off, near total loss of herbivores, and phase shift to the algal-dominated state of today (Hughes 1994; Knowlton 1992).

Manage functional groups (predators): There are indications that corals which survive bleaching are weakened to the extent that they are susceptible to both disease (Harvell et al. 1999) and predators. There is no easy fix for disease so far, but predators, like the crown-of-thorns starfish, can and have been effectively removed when their populations explode following a bleaching event.

Crown-of-thorns starfish
(Photo by Rod Salm)

One of the greatest impediments to recovery of damaged coral areas is the pre-emption of the reef surface by carpets of algae; rates of algal production are too high relative to rates of export and consumption (e.g., Hughes 1987; Littler and Littler 1997; Williams et al. 2001). This type of negative effect can be a result of sequential fishing down the fish food web, including herbivorous fish species (Pauly et al. 1998; Pandolfi et al. 2003; Bellwood et al. 2004; Dulvy et al. 2004). For resilience in coral cover, there needs to be enough grazing by reef organisms to keep algal biomass on damaged reefs sufficiently low that corals can establish and flourish (Sammarco 1980; Hatcher and Larkum 1983; Steneck and Dethier 1994). In some circumstances, grazing rates can also be too high for corals to reestablish themselves. This can occur when top-level fish predators are fished out, causing populations of lower level grazers – notably sea urchins – to explode, eroding reef surfaces, and in the process, destroying small coral recruits (McClanahan 1997). Some intermediate level of grazing is therefore an important operational goal for coral reef management. Of equal importance to grazing, especially when coral reefs occur in enclosed waters, may be the reduction of runoff of nutrients that enhance the growth of seaweeds to the detriment of corals (Smith et al. 1981; McCook 1999).

Monitoring: Coral reef management needs to be responsive to issues and adaptive to learning; baseline data and monitoring provide an essential foundation for guiding decision making in both instances. Not only is there a need to monitor the ecological well-being of the reef, but also to define and monitor indicators of the effectiveness of reef-related governance measures and of reef-related socioeconomic trends (Pomeroy et al. 2004).

There is no substitute for real-time tracking of a bleaching event with field work. This helps managers understand the vulnerabilities of particular species and communities in different locations and identify those places where corals merely bleach, as opposed to those where the corals die (Marshall and Baird 2000). For this, a good baseline and understanding of the natural fluctuations in coral communities are essential. Retrospective surveys and follow-up studies of the spatial patterns of individual coral reef bleaching events in relation to the pattern of heat stress as recorded from satellites can be an effective means of assessing the response and vulnerability of particular coral communities at that time (Arceo et al 2001; Berkelmans et al. 2004; Wooldridge and Done 2004). However, retrospective studies done long after the event are not always easy to interpret, as other factors (e.g., hurricane damage, disease, and crown-of-thorns predation) may obscure the causes of mortality.

In the long term, there is concern that the effectiveness of MPAs and other management measures may be compromised by several other manifestations of climate change (Pittock 1999): changes in ocean chemistry (brought about by increasing atmospheric CO_2 levels – Kleypas et al. 1999); changes in salinity due to changed rainfall and runoff regimes (Pittock 1999); and changes in hydrography (sea level, currents, vertical mixing, storms, and waves). Managers can help build knowledge through the accumulation of long-term monitoring data-sets and use this knowledge to guide decisions about the design and management of MPAs in a future, changing environment. The results of such research and monitoring programs also provide managers with an improved basis for recognizing truly bleaching-resistant sites for protection and for informing decisions relating to realization of the conservation goal.

Manage adaptively: Emerging global threats, like climate related coral bleaching with all of its unknowns, require us to respond adaptively. We are entering a period of rapid change and need to

build change into our strategies. We should be rethinking our paradigms, and considering MPA boundaries that are flexible in space and time, including ones that are designed to expand or contract, or that have seasonal or other fixed time limits. Our strategies should be flexible too, so that we can change zone designations and levels of protection as changing conditions indicate.

Integrated management: We should try harder to integrate our management with that of surrounding areas, particularly as concerns land and water use that might exacerbate the level of threat to our target reefs. Nesting coral reef conservation programs in broader management frameworks, such as integrated coastal management, makes good sense – especially in island nations where everything is essentially coastal.

Is this enough?

Yes, it probably is if we are concerned only about the location of reefs in our lifetimes, but probably not if we think beyond this century. We need to expand our horizons and think both long term and globally. Many reef managers around the world plan in one- to five-year timeframes. Their strategies are generally reactive in response to proximate threats – not proactive in anticipation of change. However, reef distribution has expanded and contracted over hundreds of thousands of years. How do we deal with this? We should be planning our coral reef conservation activities to anticipate change and help coral reefs survive longer timeframes that are measured in decades and centuries. This will mean including in our planning where to position protected reefs so that they are able to seed new areas as seas warm and cold water barriers to coral reef distribution expand away from the tropics. For example, we can anticipate in time that corals will move north along the eastern seaboard of the U.S. mainland *if* there are healthy source reefs protected in the right places up current. There is some evidence for this from the re-establishment of staghorn corals (*Acropora cervicornis*) on the relict Holocene reef tract off Fort Lauderdale, where this species was an important reef-builder up until about 6,000 years ago (Vargas-Angel et al. 2003; Precht and Aronson 2004). *A. cervicornis* is also establishing itself on the Flower Gardens Banks in the northern Gulf of Mexico (Precht and Aronson 2004).

There are compelling reasons for conserving the reefs in the Florida Keys and for selecting the Florida Keys National Marine Sanctuary as a place to develop our global understanding of resilience and how to apply it to MPA design and management across the United States and the world. The extensive research and monitoring in the Florida Keys and the high levels of public visitation have generated a vast body of knowledge from which to draw information on the location of coral community types, which ones bleach and which do not, and possibly even why the communities respond differently. So there is the opportunity to make quick progress on application of all elements of the resilience model to protection and management strategies in the Keys. The Sanctuary is well placed to play a leading role in developing practical application tools and approaches both locally and globally to build resilience into coral reef management.

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Human Perspectives

Moderator: Heidi Schuttenberg

Connections Between the Tourism Industry, the Environment, and Society in the Florida Keys

Daniel Suman

Heidi Schuttenberg
Thank you very much. The first panel is going to look at the first list of criteria concerning how we value the reef and how that influences management. We have a wonderful panel that has changed just a bit. Our first speaker, Dr. Daniel Suman, is really one of the pioneers of looking at values for reefs and human perspectives on reefs. This has recently got a lot of attention internationally and Daniel has been doing this for a long time before that, and is going to bring a really rich and deep view to that discussion. He is a professor at the University of Miami, at RSMAS, and let's give him a welcome. [applause]

Daniel Suman
Thank you very much, and good morning. Congratulations to our Sanctuary and, of course, to NOAA for organizing this symposium. We think it is an excellent opportunity to get people together, and I also thank you, Heidi, for moderating the panel. I am going to provide a quick overview. I focus not entirely on coral reefs, but more on tourism in the Florida Keys, and connections and linkages between this industry and the environment and society. I think my general overview will provide a good introduction to Manoj Shivlani, who will be talking about the world he surveys and research that he has been doing for the last couple of years here in the Florida Keys, and to Peter Ilchuk from the Florida Keys Lodging Association. We are really happy to have him on our panel as well, talking about the good work, the good evolving work that the hotel industry is doing here in the Florida Keys. And then onto Stephen Frink, who will show us views of reefs, and hopefully changes that we see in time. That will help us, of course, to dedicate our efforts to making the situation better.

So, first of all I would like to look at the broader perspective of where we are here in the Florida Keys and in the wider Caribbean. Of course the tourism that we see in the Florida Keys is really a similar type of sun and sand and beach tourism that we see throughout the Caribbean. The differences, of course, are that here in the Florida Keys we have a road and a lot of mainland visitors as well as cruise liners and air traffic. So I think that the tourism pressure that we see in the Florida Keys is greater, perhaps, than in other island destinations, or even mainland destinations around the wider Caribbean.

Tourism is perhaps one of the world's largest industries. Coastal tourists amount to, perhaps, 600 million people throughout the world, and in the Caribbean, depending on how we cut the pie, perhaps between 30 and 50 million people. The Florida Keys is right up there, too, with perhaps 4 million visitors now because of the dramatic increases in cruise passengers that we have seen over the past few years, here in Key West. In the Caribbean, tourism is a major economic player, contributing heavily to the economies of Caribbean islands, and to our economy, providing a lot of jobs, as well. Throughout the area, despite the setback of a few years ago, we see a rapidly growing industry that is threatening the resource base.

Focusing in on the Florida Keys and Key West, let's look at some of the connections between this industry and the economy. From Bob Leeworthy's work and his group at NOAA, we know that

almost 3 million visitors spent perhaps 13 million person-days in the Florida Keys, and this data is almost 8 or 10 years old. It has increased perhaps 25% since then, and we have tourists who visit Key West as their final destination. Key West alone has about half of the hotel rooms and half of the restaurants in the Florida Keys. There has been a significant change and dramatic increase in cruise passengers, from 250,000 cruise visitors 10 years ago to over a million, a more than 300% increase in the last 10 years, with some interesting social and environmental impacts, perhaps, from this industry. Now the number of cruise visitors here, to Key West, compares certainly with the major cruise destinations throughout the Caribbean: Puerto Rico, the Virgin Islands, and Jamaica. We know from our surveys that tourists are involved in water–based activities – snorkeling, diving, recreational fishing, spending time on the beaches, and viewing nature and wildlife. Other survey data from the NOAA group, from the state of Florida, and some of the counties indicate that we have high numbers of people visiting the reefs, both natural and artificial in the Florida Keys. They are involved in typical reef activities, as you would expect. That survey, as well as one that Manoj Shivlani did, estimated that the number of people diving on Florida Keys reefs ranges between 600,000 and 800,000 people per year – diving and snorkeling.

So tourism is the major economic engine of the Florida Keys, accounting for over a million dollars spent and about half of the employment in the county. The reef activities themselves are responsible for creating 10,000 jobs. We have a dynamic and economically very important activity which is driving the economy of the county, and the political engine and interests of the county as well. From the NOAA work we know that tourists are satisfied; of course they are perhaps not aware of Shifting Baselines [laughter]. They are satisfied with the water, the amount of living coral on the reef, and the diversity of fish. But this NOAA research indicated that there were significant declines in the satisfaction in those critical areas and of course aquatic conditions, but overall, even in the most recent survey, the satisfaction ratings were high.

I want to mention some really fascinating research that Joe Schittone did when he was a student at Miami. Joe now works at the sanctuary program's national office in Silver Spring, MD. He looked at the evolution of tourism in the Florida Keys, and I just want to let you know that this is another connection to other interests. Commercial fishing has been an important activity in the Florida Keys for hundreds of years, beginning with sponges and turtles, and evolving to shrimp and fish and lobsters and stone crabs. In the Lower Keys the activity centered at Key West Bight. Other economic activities: salvaging, commercial shipping, and the military have had their rises and falls in the Lower Keys, but the city of Key West and the county really began to think about tourism as an answer, as all of south Florida did, in the 1930s. Joe points out in his manuscript this really interesting evolution of Key West Bight as the seafood companies, supporting facilities, and fishing operations were pushed out of the Bight because of rising land values, and have essentially moved to Stock Island. Perhaps rising dockage fees have been the major factor behind this. The city eventually acquired this waterfront area and began leasing it to new tenants who could pay the higher rents, so now we see the charter fleets, dive boat operators, sail charters, sight-seeing vessels, and sunset cruises in Key West Bight. And the county and the city have major policies oriented toward increasing the activities of this sector.

The potential environmental impacts of tourism are great. Luckily, in many aspects I think the Florida Keys are doing well compared to Caribbean island economies. We do have problems of anchoring, groundings, and diver contacts. Some research indicates that one diver during one day may contact, either by dragging, touching, brushing up against, or a tank hitting a reef, 10 times during a dive. Recreational boating has a number of impacts that we are all familiar with: anchoring,

groundings, propeller scars and seagrass beds, and waste disposal issues. Fishing, which we have talked about in the last few days, often can lead to over-harvesting of renewable resources, reducing abundance, decreasing average sizes, and altering age distribution and species composition. Damage from fishing gear is another impact: abandoned traps and equipment, and trawls on reefs and the sheltered areas. Perhaps also the increase in tourism has led to an increase in demand for local seafood products, which again in some situations can lead to over-fishing. The infrastructure for hotels and resorts results in major land-use changes and habitat damage during the construction phase and the operation of these facilities. Sediments are mobilized during construction and increasing sediment loads and transport to nearshore lagoons and offshore areas, which of course, as we have mentioned in the last few days, can cause increased stresses to coral reefs. Some of these also generate large amounts of solid waste.

Throughout the Caribbean, sewage systems do not operate efficiently, and in many cases are non-existent. Perhaps between 80 and 90% of resorts have adequate sewage treatment. Marinas result in dredge and fill, and may alter sediment transport and destroy important coastal habitats. Tourism throughout the Caribbean demands the 10,000-foot runway to bring in passengers from Miami, as well as piers and roads that may alter hydrology. In some cases beach alterations may result from tourism as a result of beach replenishment of shoreline protection structures or dune alteration. And cruise liners themselves have their own impacts because of the way they generate gray water and black water, and also the solid waste that they generate and the resulting disposal.

Social impacts may be great, as well. Throughout the Caribbean as well as here in the Florida Keys, increased congestion, population density, replacement of traditional uses as Joe mentioned in his paper, and the displacement of commercial fishers here in Key West to Stock Island with the increase in the tourism industry. In other situations we may have decreased beach access as a result of hotels and resorts, and fishing may be banned from certain areas, certain beach areas. Of course, there are many benefits: the economic benefits from tourism, the employment benefits, the revenues to governments, the development of important infrastructure, and in some cases the feedback to an increasing environmental awareness and understanding of the local population. But the basic issue of course is sustainability. Is this a sustainable activity throughout the Caribbean and in the Florida Keys?

We see some decrease in satisfaction with the environmental product, with the environmental amount of use, and certainly throughout the Caribbean and here in Key West in the Florida Keys an increase in mass tourism. Of course this inevitably leads to decreased and diminished environmental amenities, and could result, has resulted in some places in the Caribbean in a tourism spiral, the tourism death spiral. The tourism industry and local policy makers, local decision makers, and local governments need a recipe for suitable policies for sustainable tourism development. There needs to be an integration of tourism and tourism planning into the broader sector of planning, through integrated coastal management, or applying more aggressively restoration and environmental mitigation. Another approach is increasing the effectiveness of coastal and marine protected areas and adopting or recommending best management strategies for this sector, for the tourism sector.

Many best management strategies already exist through international and national environmental groups, and governmental agencies, as well as international organizations. It is time to increase the acceptance and use of best management practices for the tourism sector here in the Florida Keys. So, the final words that I have are that we can see coastal resources as "capital" that will provide interest through rational use and interest that benefits the tourism industry. Without a rational use,

without a wise and rational use of the resources, we will begin to erode the capital base, which will diminish the interest that the county and the Caribbean region as a whole obtain from the resource base. Thank you. [applause]

Remarks: The Lodging Association of the Florida Keys and Key West

Peter K. Ilchuk

Heidi Schuttenberg
Thanks very much. If you have been with us a the past couple of days, you know our normal format is to hold questions until the end and then have all the speakers come up to a panel; however, we are going to break the rules briefly for our next speaker because he has to leave immediately following his talk. So we will allow one or two questions after the presentation by Peter Ilchuk. Peter is the President of the Florida Keys Lodging Association and the former head of United Way for Monroe County.

Peter Ilchuk
As the head of the lodging industry in the Florida Keys, I could focus on many aspects of our business of serving our visitors and how it relates to the Florida Keys National Marine Sanctuary. I will focus, however, on two key items that I believe have a potential for negative impacts on both the Sanctuary and the lodging business. But first some history.

Our predecessor organization, the Key West Hotel & Motel Association, was one of the earliest supporters of creating a National Marine Sanctuary for our offshore waters. We took a strong position of support in the very first scoping hearings. This was in contrast to most of the Keys business community that was adamantly opposed to the Sanctuary concept. Why?

Our industry recognized that our livelihood depended on beautiful waters filled with wonderful sea life and a healthy offshore coral reef. While our guests booked rooms with us for our great lodging hospitality, their vacation experience was dependent on their finding new adventures fishing, diving, snorkeling, or sailing in and on our offshore water resources.

Unlike the rest of Florida, we cannot advertise fabulous Keys beaches. We are on top of an old coral rock formation. We do, however, have great year-round sun in a tropical environment and America's only living coral reef six miles off shore. Our nearshore waters also offer a wonderful window on a fascinating marine environment for even the most timid adventurer. Our advertising and marketing thus prominently features the unique and beautiful aspects of the marine world that surrounds us and the excitement a day of sailing, snorkeling of fishing can bring. The National Marine Sanctuary was critical to preserving that resource and, if you will, our marketing tool!

In the late 1980s, the lodging industry also was among the first to raise concerns over the growth of visitor numbers. We recognized that TOO many tourists would destroy the very thing our visitors came down to see. We were then and are still today advertising the Keys as an easy going, laid back, and relaxed place to visit with unique natural resources, attractions, and dining and shopping experiences. That was what our visitors wanted and we had to make sure it stayed that way.

Thus, in Key West in 1988, we urged the elimination of all transient zoning from the code except to grandfather in those sites already transient. Of course, we were accused of trying to eliminate competition; however, our desire was to preserve the uniqueness that attracted our visitors and to limit the impacts too many visitors and residents could have on our natural resources as well as our historical and cultural assets. Unfortunately, we were not successful then, but subsequently transient unit growth controls were incorporated in both the City and County land use plans.

In the early 90s, we fought the trend toward attracting spring breakers in March, at that time the biggest month of the year for lodging. Spring breakers were NOT the type of visitor that was compatible with our message or our product. Working with the City to assure strict enforcement of our laws, we managed to bring that so-called event under control. Unfortunately, March continues to be problematical with many of our traditional visitors shying away during the perceived spring break weeks. Many of our hotels do not accept guests under 25 unless accompanied by a parent.

In the early 90s, the cruise industry started to grow exponentially. What started out as a form of transportation was morphing into a vacation experience unto its own. This again was threatening our natural resources, stirring up the bay bottom in the ship channel and harbor and thus threatening our reef and muddying the good fishing in nearshore waters. It also was adding congestion to our downtown area that belied the easy going atmosphere of Duval Street. And it was changing the quality of our retail from artisans and specialty shops to t-shirt shops, chain outlets, and other American generics. We have not been successful in this area and today we see a million or more cruise passengers enter our port. We continue to urge limits on this market.

We also fought to prevent large numbers of day trippers coming to the Keys, particularly on day bus tours converting Key West to an attraction on view from a bus window. The City of Key West has wisely put limits on that activity.

I would suggest that the lodging industry and those concerned about protecting our offshore waters and reefs are natural allies. A strong lodging industry that can educate our visitors when they arrive and provide the financial resources to the community to support preservation is in your best interests. And the lodging industry will continue to support the efforts of the National Marine Sanctuary and other programs such as the Nancy Foster Eco-Discover Center at the Truman Annex Waterfront.

Now, let me outline two threats I see to our mutual efforts to preserve and protect the natural water resources of the Florida Keys.

Regional planners expect the Homestead/Florida City area of South Dade to go from the current population of 42,000 to 462,000 by 2050. Tens of thousands of building permits are already active in the area, and that does not include a planned major development with 6,000 homes as well as hotels and shopping at the junction of Card Sound Road and Route One, the entry to the Keys. That proposed project is outside of the development boundaries for South Miami-Dade, but there appears to be political momentum to approve it.

All those new residents will want to drive down Route One, a short 30 minute jaunt, to enjoy the Florida Keys. It's a federal and state highway. We cannot bar them from doing that. And they will want to visit a State Park, John Pennekamp, already one of the busiest in the State. And, of course, they will be going out on the water.

Unlike guests in our hotels, who generally use local attractions operators to access the waters and reef, these folks will be on their own in their own boats. They will not be educated about how to protect the corals or encouraged to release their catch.

It is impossible not to believe that these numbers will not have a major negative impact on our Florida Keys natural resources. And by creating a major congestion point at the entrance to the Keys, it also will have a major negative impact on our lodging industry.

We must join together to push for stricter limits on the unbridled growth occurring in the South Miami-Dade area. In addition to the negative impacts I have outlined, this area is the major source of drinking water for the Keys and South Miami-Dade. Massive development could well destroy the water table upon which hundreds of thousands of residents rely. And it will adversely impact our efforts to restore those areas of the Everglades, also essential to the preservation of our Keys reef and nearshore waters.

The other major threat I see to our Keys resources and industry is the increasing numbers of people who are buying homes in the Keys as a second or vacation home. While this might seem at first an attractive prospect, it is an insidious threat to the well being of the Florida Keys and all its resources. Here's why.

State and local government depend on the revenues generated from lodging properties and their guests to commit the financial resources necessary to environmental protection and sensitive land acquisition. Nineteen of the top 25 taxpayers in the Florida Keys are hotels. We and our guests contribute more than 60% of sales tax revenue. Half of the 4th cent of bed tax paid only by lodging guests goes toward the purchase of environmentally sensitive lands, saving them from development. Lodging properties also are the primary payers into sewer and solid waste systems. As an industry, we strongly supported the effort of the City of Key West to install the highest standard of wastewater treatment facilities in the country. We now treat our wastewater to near drinking water standards before disposing of it down a deep injection well. We also strongly supported additional assessments on property owners, largely our hotel properties, to provide for an advanced stormwater treatment system in Key West to prevent pollution of nearshore waters. We have much work still to be done in the rest of the Keys. Where will the financial resources come from if the major property tax and sales tax payers are removed?

Yet that is what will happen if more homes are purchased for second homes by wealthy outsiders seeking their piece of paradise. First, they are removing more and more residential properties from the permanent resident housing stock. We are now not only finding it hard to house lower-income service workers, but it is becoming increasingly difficult to hire nurses, executive secretaries, public safety personnel, school teachers, and even doctors. In the lodging industry we are seeing a growing exodus of our mid-level managers. These are the folks who have been around for years, own their own home, and form the backbone of the community. They serve on the boards of community associations and service organizations. They are the volunteers for social services agencies and community projects, such as shore cleanups and installing mooring buoys. They are selling out to big bucks investors and second home seeking billionaires and moving elsewhere where the cost of living is more affordable for raising families.

So in keeping with the topic of your conference, I hope I have outlined a few of the ways there is a connectivity between the lodging industry and those in the marine sciences field concerned about preserving the Florida Keys National Marine Sanctuary. And we must stay connected if we are to accomplish our mutual goals of preserving and protecting the Florida Keys and its natural resources for future generations. Thank you.

Discussion

Deb Shaw: This was the first time I have heard you speak, Mr. Ilchuk, and I am reassured by your comments because from a distance I have been concerned about the lodging industry and I am a biologist. The question I have is, in the Marathon area we have a tendency to take small, old motels that were probably single guests in a room, and we are now redeveloping them into suites. I have heard people say, how many people are going to be accommodated in these larger suites, and I have a fear that we are finding a way to pack more people in to what used to be a very small, little hotel. I am hoping that there will be sewage treatment with these redeveloped businesses, but could you just comment please on how we seem to be cramming more people in, and am I right to be concerned, or am I being a little hysterical?

Ilchuk: Oh, you'd better be a little hysterical [laughter]. A lot hysterical, basically. I have heard a lot of people asking about that – the changes, the increase in the size, traditionally in the Middle and Upper Keys. Most of the hotel units were 600 square feet or less – standard hotel rooms. There is a major trend in the entire industry to go into a suite concept or larger units. People want, and demand, when they travel, more space. They want a kitchen facility, they want all of these extra benefits that they have come to associate with the lifestyle. This is particularly true of the environment in the Keys, which is generally a much more upscale market that we have to adhere to. We have to do that because the costs of doing business simply are much higher here. So I don't think you are necessarily going to see, because you have three bedrooms you are going to have six people, or eight people, or ten people. Or that it is necessarily going to escalate the number of people coming into the marketplace. It is a world trend, and nationwide and also in the change of ownership, where people are going to condos that are being rented out, hotels that are actually condo-izing their hotel; they don't necessarily change the nature of the hotel. This is what is happening in Cheeca Lodge. So this is a trend nationwide, as Americans feel that vacationing is their birthright, also having bigger hotel rooms is practically a birthright.

Question: I want to know if you have any recommendations for how those of us in the science and education community could better reach your customers and educate them?

Ilchuk: Actually, we spend, here in the Keys particularly, a lot of our tourism dollars on educating our customers. If you look at some of the ads that we put on to promote tourism, and we advertise around the country, our videos and other media, we talk about the coral reefs, but we also talk about being careful about them at the same time. So at the same time we are saying "Come on down," we are also starting a message about protecting the resource that you are coming to visit. And we work very closely with Reef Relief, and our industry works closely with those people who are out there, putting up the buoys, doing the management to keep that education resource going. We just have to constantly keep getting the message across and advertising and of course the person-to-person contact that we get. But I think the science and education community also have to help us with the people that are outside of the media, such as South Florida, to educate them about how their impacts of construction and expansion will have a tremendous impact on this resource down here, even if we stopped everything.

Question: How does your organization think that the eventual opening of Cuba to U.S. tourists will change tourism in the Florida Keys?

Ilchuk: Well, we compete against destinations throughout the Caribbean already. We compete against Cuba now, although not with the American visitor, but with foreign visitors. Cuba right now

is more of a downscale tourist market, and is not the type of tourism that we are seeking here in Key West. More mass tourism and 747 trucks coming in; it's a competition. Right now, our greatest threat for tourism in the Florida Keys is what is happening south of Cancun. Cancun has been abandoned to mass tourism, but the development of a more eco-friendly tourism south of Cancun, the condo-type development, that is putting in 15,000 units right now; it's very accessible by air. We are having some problems getting people by air. Richer people like to fly in – they don't like to drive. That is affecting us much more than Cuba.

Question: How can you promote tourism that is more upscale? Because that is one of the issues that is usually raised down here, that perhaps we should be looking at wealthier tourists?

Ilchuk: We do have wealthier tourism, as you might say, but because the cost of doing business here for hotels is so extraordinary – there is not a single person in the lodging industry that is making minimum wage. We will pay $9-10 to start because we are competing against everything else and we have to put that money in. One of the best jobs is as a housekeeper, where you make about $10-12 an hour, you get out in six hours; they have done the work and they have the tips. The promotion? Our whole marketing effort is toward the upscale visitor. We look at $100,000 household income, we go after media markets to attract them, and this goes again to the type of lodging. They are not going to come to a 10-room mom-and-pop of 400 square feet. They are looking for higher quality of accommodations – we have to provide that, and we have to provide a high level of customer service to do that. And to do that, we need housing for our workforce, and that is another problem.

Question: How do you feel about enlarging the airport in Key West and doing away with the rather quaint facility that is there now?

Ilchuk: About 10 years ago was the last time we replaced "that quaint facility." We do need to replace it, it's inadequate. I have had a lot of ideas from my friends within our community about the airport and its runways. I don't know whether improving the airport and improving the runway and bringing in the RJ jets that are coming in now, is going to increase tourism. Thirty percent of our visitors fly into South Florida, but only 9% end up flying into the Keys. Some of them can drive to the Upper Keys from the Miami Airport, but a large percentage has to drive down to get here because of the lack of air service. I would like to shift that to air and then make sure they know they don't need a car when they get here.

Question: What is your opinion of the cruise ship industry and how that industry is impacting the marine resources here in the Keys?

Ilchuk: I am just checking – do we have any Congress people here? [laughter] Our industry has not only suggested you need to control the number of lodging units, you need to control the source of other visitors as well. Not only the cruise ship industry, the other visitors coming in – are they going to be day trippers, or overnight visitors and the day-tripping bus visitors and so-on and so-forth. You can't keep putting more people on an island that is advertised as easy-going, laid-back, relaxed, unique shops, restaurants, etc., and then get up in the morning at your $359 a night hotel and you find a large structure blocking the sunrise, 10,000 people at your doorstep, and a Burger King across the street. [applause]

Diving and Snorkeling in the Florida Keys

Manoj Shivlani

I am going to focus on diving and snorkeling in the Florida Keys as a retrospective over the last 10 years – what's been happening. There are a number of studies that have been looking at diving and snorkeling and looking at how that has changed over time in the Florida Keys. Specifically, I am interested in looking at three aspects of diving and snorkeling. One is the sheer numbers themselves. The second is the economics behind diving and snorkeling and the third is resource perceptions, because all of these feed back into how sustainable the industry is down here. Finally, I am going to end up with some management recommendations.

The importance of diving and snorkeling in tourism cannot be understated; it is one of the fastest growing sectors. NAUI last year issued about 1.5 million certifications; these are new people going into the water. Thirty percent of the persons who came down here to the Florida Keys, as Daniel mentioned before, go into the water, either as a diver or a snorkeler, so there is significant usage of the resource. The other aspect of diving and snorkeling is partly due to the fact that condition of the use itself is tied to the resource. First, water clarity and quality will affect the visitor experience. Marine life and benthic habitats will affect the wilderness experience, and consumptive activities will be affected by the resource base. So that makes it an ideal industry to study how well management is taking place.

What do we know about diving and snorkeling in the Florida Keys National Marine Sanctuary? What we know can be divided up into two components. The first is the tourism base itself and the residents who use the resource and the second is the industry itself. I put this slide in because this is what people come to see. Obviously water clarity makes a *big* difference, and that is one of the focuses of my talk. There have been a number of studies that looked at diving and snorkeling, and I can make these available for those of you that are interested. Obviously, when we give these talks, we try not to focus on the studies, but there are a number of researchers who have been working on this, especially Bob Leeworthy, Grace Johns, Daniel Suman, and myself.

The first thing we want to look at are baseline conditions. Baseline conditions are those conditions that existed before the Sanctuary was put into place. So far, the baseline conditions are 1995-96, and thankfully we actually completed our first study of the dive industry in 1996, so we have excellent baseline information. The 31.3% of 3 million visitors to the Florida Keys that year entered the water, via a dive or snorkel trip, 80-85% of all divers and snorkelers actually visited one of 18 SPAs, which are the Sanctuary Preservation Areas, and 70% of all dive trips the dive operators told us about in 1995 ended up in one of the 23 designated no-take zones within the Sanctuary.

The use we found in the Florida Keys National Marine Sanctuary is very variable – it is not the same throughout – and that makes a big difference in terms of how to manage the resource. In the Upper Keys, for instance, which is the upper graphic over here, you will note that there are series of numbers from 1-12, and none of them are shaded very differently; however, in the lower graphic you will notice that the numbers are shaded differently where #6 and #3 are darker than the rest of the numbers. What this shows is that in the Upper Keys, dive operators tend to shift their trips around quite easily because of the availability of habitat and dive sites, whereas in the Lower Keys

they are focused on two main dive sites, Looe Key to the east and Western Sambo to the west. So any management that is going to be done has to take into account the regional perspective.

The other aspect that studies have looked at is economics. In terms of economics I want to focus first on investment and expenditures. Looking at divers and snorkelers, Grace Johns et al. looked at the numbers of visitors to natural and artificial reefs in South Florida, and they found that 2.5 million person-days were spent in Monroe County. If you analyze the use-value, which is a willingness to pay, which I will talk about shortly, it comes to about $50 million, and the regional impact is $1.7 billion, and this is looking at 2001. A lot of this data is pre-9/11, but the numbers have come back up in the past year, especially. For the dive industry we found, with 62 and 75 dive operations in 1995, that the average investment, and there is a high variance in this, but the average investment per operation, is about $300,000. You can see the number of trips taken is quite large – about 30,000 trips – for at least those persons that we spoke to, and that was extrapolated to about 540,000 divers and snorkelers. Years ago, in 1996, this led to an annual revenue of $18 million.

If we look at willingness to pay, using what is known as contingent valuation methodology, which is where you go up to somebody and ask them: How much would you be willing to pay to go diving? Or how much would you be willing to pay if we closed this area? What we find within the industry first, in 1995, is that there is a low level of support for user-funded maintenance programs, the way they exist in Bonaire and Saba. Only 13% were in favor of this. We did find though, that by 2001, persons who were being surveyed who were actually using the reefs were willing to pay $9.87 more than what they were paying to visit the reef. We followed that up using a 2003 study, which found that for a single site, persons were willing to pay $9.61 and when you went to two sites, they were willing to pay more than that - $10.19. The additional value, the use value that they are willing to pay to protect reefs, no-take zones particularly, was about $20 per person.

We will look at resource perceptions, which are again very important, because perceptions tie into people's willingness, they tie into how well they support management. If you look at some of the resource perceptions, first looking at diver and snorkeler resource perception, you will see the positive views in terms of how well the zones have performed in terms of the number of fish, the type of fish, the size of fish, and other resource indicators. They have positive views on social crowding issues. Most people we spoke to in the last study we did said that they have no problem with spacing, even in the most heavily dived sites, and this is a credit more to the operators than the users themselves, who tend to space out effort accordingly.

The third thing that we found, and the most important thing, the point that I'm going to stress today, is that water clarity is an emerging and important issue. In the two most recent studies, experienced residents reported declining water quality and visitors reported that water clarity conditions did not meet their expectations, and the next graphic shows this in more detail. If you look at the purple bars being what people expected to see, versus what they did see, which would be the blue bars, being observed, and create a comparison index, you will notice that the comparison index shows that the observed conditions for large fish, and the amount of fish, met the expectations for most divers and snorkelers. However, the comparison index also shows that observed water clarity conditions did not meet expectations, so the zones are working at one end, but they're not working at the other. There is a break in terms in of the effectiveness, and people can perceive this.

The next group of perceptions that we looked at are dive operator perceptions, and these are based on the 1995 study. The first is that there are poor levels of support for any sort of user-based funding program, but there is a high level of support if that use is passed on to the user, versus the industry. The second thing that we found is that the industry on the whole supports the Sanctuary, and is strongly behind its management plan, so there is a base here that can be utilized and worked with. And thirdly we found that there is industry-wide recognition that diving and snorkeling are indeed not non-consumptive activities, do have some impacts, and therefore there is strong support for mooring buoys.

So, what have been our major findings? The first thing is that the zones are working, as perceived by users, in terms of increasing the number, size, and types of fish, as well as other resource indicators. The second major finding is that, according to users, the Sanctuary and its no-take zones need to focus on water clarity, and this is true not only from our study, but from Johns's study, back in 2001, so there is corroborating evidence for this. And finally, the third finding is that the dive industry is efficient in spacing out its efforts, so many of these issues that look at dive capacity for sites are not really an issue down here in the Keys, because the dive operators are doing a good job in spacing out their effort. However, the important thing to keep in mind is that there is a high turn-over within the industry, so it is not something that research can guarantee will continue into the future, because competition increases as new people come in.

There are, of course, information gaps, and I have identified two important ones. The first one is that the impact of diving and snorkeling on marine resources is poorly understood. There have been studies done, sporadically, but nothing systematic. Which is – What are the direct impacts? How are the corals being impacted? As Daniel mentioned, 10 persons, or 10 hits per day – What does this mean into the long term? And secondly, what are the indirect impacts – How many persons can these reefs hold? We have background information from Barker and Roberts and other studies that have been done elsewhere, but nothing has been done here. Related to that, what is the social carrying capacity, How many people can other people have around them? Is there a threshold? And if so, are we reaching it?

The other information gap is more difficult to get to because it is looking at the linkages, the economic linkages between diving and snorkeling and the environment in the Florida Keys National Marine Sanctuary, specifically, What is it worth, in terms of dollars, to have water clarity and quality, healthy resources in terms of sustainability, of industry, of tourism? And secondly, do visitors perceive the same conditions that biological monitoring reveals, that is, are we seeing the same thing, and how is that related to the willingness to pay, and their willingness to return?

Finally, with that I will come up with five different management recommendations. I could come up with a lot more, but I think that these are the ones that need to be focused upon most immediately. The first is to involve the dive and snorkel community in research. I know this is done currently, for example, that the Reef Environmental Education Foundation does a great job with this. If it could be expanded, you could not only get free information, but you would also get buy-in. The second management recommendation is to involve the industry in self-policing and management. Again, this is something that is done, and I am not saying that this is a problem. However, if you increase stability within the industry, you will increase self-policing and management, and the way to increase stability is to look at limited entry. Of course, limited entry is seen as a big issue, something that is taking away a person's rights, and so on and so forth. But in this case, if limited entry is introduced such that it brings in everybody, includes everybody, rather than being exclusionary, in terms of how

it is brought in is what I mean to say, it will promote stability, and it will help implement related protection matters. The fourth point is to consider reef rotations, where possible, and only as needed, and up to this point, from all the data that we have collected, from a social perspective, we do not find the need for this. Again, this is something that we are looking at sometime in the future, if it were the case. This is practiced in other parts of the Caribbean. Bonaire, for instance, closes off reefs after they reach a threshold. Is that something that we need to look at here? Of course, more research is required, but that is an option down the road. And fifth, and finally, most importantly, is to develop an integrated policy to manage reefs that can minimize the environmental damage and maximize economic benefits. I look at this more or less as a pilot.

The plan itself can include these special items: consider user fees that do not affect operator fees, which is to say, if you have an industry-wide standard of stability, you have a set number of persons, limited entry, then you can consider implementing user fees. If there is flux in the industry, user fees will not work. The second point is to implement a cohesive, industry-wide education program. If you want to have your visitors understand what the Sanctuary wants done, what management wants completed, you can best do that by having something that is standardized from Key Largo to Key West. The third point is to track visitor opinions to determine sources of decline. Now, these could be perceived sources of decline. Nevertheless, it's still very important to 'track', because they could be telling you what the science end, the natural science end is missing, or at least where information needs to be better told to users themselves. And finally, track all uses. Make sure that the area is not being burdened, either from a biological or from a social perspective.

So, with all of these management recommendations, put into effect hopefully tomorrow [laughter], no seriously, I am not going to be so I as to say that these aren't without their hurdles and their criticisms, they are, but what they represent is a way for the industry and for this tourism sector to move forward, maybe into the next generation, without incurring some of the impacts that are inevitable as more and more people start taxing a finite resource. Thank you. [applause]

Personal Reflections and Underwater Images of the Florida Keys

Stephen Frink

You are all scientists, and you speak of baselines. Thank you for that, thank you for my lead. I come to the Florida Keys with personal baselines. I guess the first significant one probably happened when I was in sixth grade, I dropped out. At that point some very forward-thinking conservationists created a marine preserve off Key Largo – John Pennekamp Coral Reef State Park happened in 1960. Now, that was pretty exciting because people were beginning to think that the marine resource was something that we should protect, so that was pretty exciting. Everglades National Park was happening at that point. At a time when people were dredging hard corals, other people were thinking of how to preserve them.

Another personal baseline occurred in 1978 when I came to town. I lived in Colorado at that time, I came diving in the Florida Keys, in Key Largo and I thought "Well, maybe a guy could make a living processing E6 film." We had a sanctuary in Key Largo at that time, and Looe Key a little bit later. But I did my math. I came to town and I saw that there were 500,000 divers that were going to dive Key Largo, and I figured half of those would be shooting film underwater. Certainly half of those would come to my shop and have them processed at $6 a roll, so I came to town. [laughter] And that never happened in life. My math was more like fuzzy logic.

I have been here since 1978. I have been very involved with diving in the local community, and I have also traveled the world. Gratefully. A big part of my business is commercial photography and I have been to all the tropical dive sites. I went to Palau for the first time in 1982. I was there in 1998 when that terrible coral bleaching occurred, so I have seen the good and I have seen the bad, and I have seen changes in our own home environment.

Part of what I do in the course of my business, once a year, I teach an underwater photo seminar, and this happened, coincidentally, last week. So I was tied up all last week teaching digital photography. Billy Causey called me a while ago and said "Will you come down and speak at this symposium?" And I thought well, this is a perfect opportunity for me to bring the latest images. I have been here since 1978, I have enjoyed this resource, I go to places like the Winch Hole where we have these massive forests of elkhorn coral, and I could show you that, but is that really the relevance?

I think the relevant thing is, what we have today, what we have to protect, what we have to promote to our tourists, what the dive operators are here serving people, day after day after day. And so to that end, this is a perfect opportunity, because I was on the boat for six days in a row, with 14 highly motivated people who wanted to take digital photographs in Key Largo. What I am going to do is to show you the fruits of their labors over the last six days, and then we'll talk about what we have to protect, and some of the things that have come forward in the course of your meetings this week. So we are going to go ahead, I am not going to interrupt their vision, but I'm going to let you share. [slideshow] This is all Sunday through Friday of last week, in Key Largo. OK, and I think that is our final image. [applause]

Thanks to my students for providing those images. It was a very inspirational week; it was fun to get in the water. We talk about the impacts that come from recreational divers, and always on the first

day of the seminar we talk to them about the importance of maintaining proper buoyancy control. Photographers are often the whipping boy for environmental damage, but these guys were very, very good. I think we are seeing a big change, particularly the more sophisticated customers like I had last week. There was something like $200,000 worth of digital cameras and housings and strobes sitting on two camera tables with 14 customers, all available systems, so people take this very seriously. We take photos all around the world, but when it comes to teaching photography, I come back to Key Largo, and why do I do that? First of all I get to stay at home and be with my wife and daughter, but most significantly we have water that is clear enough to take our photographs in. I wish we had better coral, and I applaud the efforts of all of you in this room to make that happen.

Water quality is a massive issue. I thought the stuff that Rod Salm spoke about this morning in terms of creating the seed, for example the Florida Keys National Marine Sanctuary could be perceived at a national level as the seed population for this whole eastern seaboard. I think that is a very dramatic benefit for all of us who live here, because we are going to have a better environment to begin with. So keep going guys, that is a very strong message. But you know what it is, it's that prescient vision that started in 1960, and it evolved since, with the Key Largo National Marine Sanctuary, the Looe Key National Marine Sanctuary, and now the whole Florida Keys National Marine Sanctuary in terms of preserving the natural resource. I remember when the boat captains used go out and had to triangulate to find out where the reef would be. But now we have mooring buoys and that's a whole other story. But that's another issue [laughter].

Nevertheless, the mooring buoys were a massive advantage to begin with, but I've got to say "Thanks" to Billy right here in public, because this whole concept of Sanctuary Preservation Areas is so good for our National Marine Sanctuary, and to provide these fish nurseries and to go out with a group of 14 people and to go on Molasses Reef. Did you see all those fish on Snapper Ledge? Now that actually is not a SPA, but I'm going to tell you, it ought to be, because the same day that we were out there, photographing schools of fish like that, we had spearfishermen and people collecting tropical fish on the same reef. So you do have those kinds of conflicts, and I don't know how you can satisfy everybody, and I'm not here – I had an opportunity to express an opinion, so I did it [laughter].

At any rate, SPAs are magnificent, you get out there, you can come in on a Civil War wreck to see – there is one image that I didn't show you because it wasn't a digital image and it didn't fit this. With a single closed focus with a wide angle with a 15 mm lens on the Civil War wreck, I have 14 lobsters in a frame. We are two weeks after the opening of lobster season, and if that were not in a SPA, those things would be gone, absolutely gone. Those are lobsters that are going to make baby lobsters, so that's a pretty cool thing! Anyway, that is my opinion, and I am very proud of our National Marine Sanctuary, I am very proud of our management personnel, and I congratulate the science, and I congratulate the vision. Thank you. [applause]

Panel Discussion

Schuttenberg: I would like to ask our speakers to go to the table at the front for some additional questions, of which I am sure there are many.

Question: This is for Daniel or Manoj. You both reported that there is a perception that there is a decline in water quality, or water clarity. I am wondering if you teased out the seasons, because in the winter you know we are driven by siltation, and in the summer we have more of a decline of the problems.

Suman: Correct. I think that those data were from two different six-month periods, one was the winter and the other was the summer and there was an average.

Shivlani: The Johns study was an average of a year. One of the things that we did with the other study – because there are two studies that show this, but I only talked about the one that we worked on. What we tried to do is equalize the clarity issue with sea state, as well as with the experience of the diver, so what you are seeing there is a snapshot, single statistic, which I guess could be manipulated. But there is a lot more behind it that we tried to use to corroborate, and seasonality, unfortunately was not used, but sea state was.

Question: One major concern that I have picked up on this week, because it has changed from the last time that I was in the Keys, is the major increase in cruise ships. The reason it concerns me is not just the numbers, but it is the change in the thought process, the demography, the whole approach. In the earlier data you had 30% of the people being involved in underwater activities. These are people, primarily, you can tell them there is a beautiful coral reef under you, they are going to believe it and they are going to go off and do what they're doing. And the amount of money they are bringing in is a driving force that could be going in the wrong direction in terms of preserving the natural resources here. I wonder what your thoughts are on the encroaching problem of this massive influx of money and power from a different source.

Suman: Actually I was thinking that power is something that Manoj would comment on [laughter]... regarding activities of cruise line passengers once they arrived in Key West. We were talking about that the other day.

Question: And how many do some kind of nature-based activity when they are here, compared to the general population, non-cruise line population?

Shivlani: I do not have numbers on that currently, but the group I work with is involved in the Quality of Life Study, looking at cruise ships down here in Key West. In fact our data collector is right here as well, but we are still doing the summer season, and I don't want to make any comments until we have all the data because it would be unfair. So maybe you want to check back in a year.

Sandy Walters: I have a question that has to do with diving impacts, but because I work closely with the cruise industry, I would like to clarify a couple of issues if I may, just very quickly. I am an environmental consultant for the harbor pilots and also have worked with the City of Key West on the subject, and I just wanted to mention a couple of really quick things that might clarify. The cruise ships that come to Key West for the most part are the higher-end ships that bring higher-end

visitors who don't worry too much about spending $300-500 at a high-end jewelry store. From what I understand, we will be collecting solid data on this, which of course will be very useful for us. Many of the dive and tour businesses in Key West, the nature businesses, do take visitors out to our resources. The number of vessels that you saw compared from 1993-2003, peaked in 2003 largely as a result of the 9/11 phenomenon, which had visitors wanting to stay within the United States. Those numbers are already starting to drop significantly, even before the Mole Pier was closed by the Navy for repairs. Cruise visitors do not drive cars and produce that associated pollution, and they don't flush nearly as many toilets as residents and people staying in hotels. The Sanctuary supported a highly environmentally conscious Navy harbor dredging project, which will cause a great decrease in harbor turbidity issues. The Florida Department of Environmental Protection will confirm that more water under the keel of a vessel at Pier B here in Key West resulted in less turbidity. Initial monitoring has found following cruise ships in the outer entrance channel more than an order magnitude drop in turbidity as a result of the dredging. So to answer my question concerning the dive industry, all of your management suggestions were focused on the industry. How can that relate to the day-tripper visitors who tow their own boats, and launch them at a ramp, and just goes piling out there to reefs without any contact with our professionals here who can give them education and direction?

Shivlani: You are talking about a different user group, the private boaters. There are other strategies that could be used, namely education and outreach, which are being used currently. Unfortunately, because they are not being taken out by a professional, there is really nothing that could be recommended within that scheme that would reach them.

Question: This is directed to all three of you, and also to Billy. Back in, I don't know, Billy could tell me a date, or many of you could, the referendum to accept the Florida Keys National Marine Sanctuary, the county-wide referendum, when was that – 1995?

Causey: I think it was 1996, November 1996. I will never forget that. [laughter]

Questioner: No, you won't. And at that point I think the citizenry was asked to vote in favor of or against the establishment of the Sanctuary. I am sure it was wordier than that, and the Sanctuary lost...

Causey: 53-47.

Questioner: In what many people view as a skewed vote, but I wonder for all of you who are assessed and surveyed and had your finger on the pulse of the populace in the Keys, tourist and resident alike, if we did that same referendum now, what do you feel would be the percentage for and against the Sanctuary? I would like to get Billy...

Frink: Since there is no science to your answer and it is purely postulation, I'm happy to postulate [laughter]. I think the big issue when the initial referendum happened was that individual rights were going to be eroded. That people weren't going to be able to salvage, they weren't going to be able to spearfish, they weren't going to be able to tropical fish, or live collect, they weren't going to be able to take pictures, they weren't going to be able to do a lot of the things. But I think the Sanctuary, with the concept of zonation, probably allayed a lot of those fears and the positive benefits from things that evolved like Sanctuary Preservation Areas, and the fact that now we have nurseries. People, I think, now are far more trustful of the Sanctuary, that it's not just a rights grab, that it's

something that is necessary to manage a fragile resource. I think people trust our Sanctuary, where they didn't before because there was distrust of the unknown. I really believe that's what it was. It was distrust of the unknown and you guys have earned our trust.

Shivlani: I would just add to that by looking at two different processes. The first was the zone designation process that took place in 1995 and contrast that with the Tortugas process. The latter went much more smoothly. There were obviously opponents of it, critics of how it worked, but the zone was passed unanimously, and is in effect today. So if that is a subset, some sort of a sub-sample, showing the level of support in at least part of the commercial industry, the commercial fishing industry, which was probably the most vociferous opponent of the Sanctuary, then you are seeing at least a slight shift.

Suman: I will guess at a number. I would think that a similar referendum today would be 3:1, maybe 75% supportive, that would be my guess.

Causey: And there is science that supports that now. Bob Leeworthy can account for that better.

Alison Gleason: My name is Alison Gleason, I am a graduate student at Duke University, and I was lucky enough to be a Lower Keys office intern over the summer, working on a somewhat parallel project in the kayaking industry down here. One of my study focuses was on educational materials within the tourism industry, and so my question would be for all three of you. Where do you place the bar for the educational materials? There is such a diversity of tourists out there. There are people who barely know how to swim and kayak and have never seen the ocean before, and then there are 20- or 30-year returning divers who have a great knowledge of the reef system and the mangrove systems. So if the responsibility were in the tourism industry to provide educational materials, what level – or how would you address the scope of the span of different skill levels and prior knowledge?

Suman: I would think that a sophisticated environmental education program based through the industry would, first of all, look closely at the audience, break out the different subsets, and develop materials that were focused toward the different users – as many as was feasible, given available funding.

Frink: The sophisticated consumer probably isn't going to pick it up anyway, so you might as well target your market to the people who are eager to learn. Obviously it has to be visually compelling anyway, and then you're going to have to craft a soft sell in there. I don't think you can hammer them with a lot of words; you're going to have to make them believe in the pictures, and speak to those that need education. The people on my boat last week didn't need environmental education, but I will say that they were universally surprised at how good the resource was. There is a perception that – I don't know who said it – somebody commented that there is a perception that there is perhaps 6% coral cover in the Florida Keys, and that's bogus. They didn't have a clue how good our waters are, they didn't have a clue as to the density of the marine life, and those were all happy surprises for those people. But if they're already here, they're going to have that surprise themselves once they step off the gunwale.

Shivlani: I would just add that the recommendation that I mentioned is that the education, at least the aspect that I wanted to focus on, the education be placed on what the Sanctuary is doing, what management is trying to get done, which does not necessarily affect, which is not affected by, rather, the experience of the user.

Male question: I guess I wanted to make a comment about what somebody had said before, you said that you really didn't – or there wasn't a way to help the private boaters know what's going on, and I just wanted to make a comment, that before you get a driver's license, you have to pass a test, and maybe for the private boaters, if you could maybe have some private education process before they get the boater's license.

H.T. Pontin: My name is H.T. Pontin and I've been diving down here in the Keys since 1960s, especially around Looe Key before there was a sanctuary and you people doing your studies. But I do have an important question that has not been answered. All your studies are based on the conditions today. Now for the last 30 years, the Florida Keys have been filling in, and we only have three foot tide range down here, so if we lost a foot and a half of that tide range, for example, would that affect all your studies and reasoning and everything else, because if that much less water comes over the reef four times a day you're going to clearly stop out. Thank you.

Shivlani: Well I would just say that our baseline, in terms of the industry is at least 10 years old, so it's not as of today. Unfortunately some of these studies weren't done in the past and we have to start somewhere and work with the baseline that we have. If you use anecdotal information, it can't really be corroborated, and besides it's not representative enough of the area. I would also add that one of the articles that's included in the pack that's given out deals with Jim Bohnsack talking about Shifting Baselines, and that's something that's very important to consider, not only from the natural perspective, but also from the social perspective. Baselines shift as well.

Cheva Heck: Manoj, I just want to note in regards to your recommendation about an educational program for the dive and snorkel operators in the Florida Keys, you and I haven't talked, but I think that's an excellent recommendation. In fact we're going on to our fourth meeting with local dive operators for something called the Blue Star Program which is Billy's idea, and slowly but surely trying to get it off the ground. The idea is that anyone that steps on a dive or snorkel boat in the Keys would eventually learn a basic amount of information about the Sanctuary, about the no-take areas, and how they can help protect the marine environment and be partners with us in that. The other thing that I have to ask you a question about is the relationship in your remarks between water clarity and the no-take areas. I'm not a marine biologist, I'm not an oceanographer, I've worked in the Sanctuary for seven years and I can't figure out how being a no-take area would affect the water quality. To me, that's a broader relationship. So I'm confused there, and would like some clarification.

Shivlani: The reason why you are confused is because I didn't explain it well. The study that we did was a paired-site study. It looks at no-take areas and compares them to open, or open-access areas and really the things that we're interested in looking at is whether divers and snorkelers perceived resource condition differences within open versus closed areas. So what they reported generally, for both open and closed areas, and I'm sorry I didn't point that out, is that water clarity is an issue – that the statistics shown there, the comparison index, is actually for all areas, both open and closed. Sorry about that.

Causey: I think I get the last comment and the last question. First, a comment. Manoj, your management suggestions are very insightful, excellent. There's two of those that we've implemented partially in the Tortugas Reserve, as a part of what we heard. One is that we have access by permit only, and it would prohibit all diving except by permit in Tortugas South, and so in Tortugas North

you can only access it by paper permit – by reporting permit, and that's going to give us the data that we think is going to help us start looking at changes to the resources with use. The other thing is that we went ahead and established a rotational system for our mooring buoys. We put in 36 locations and we've started really moving around between 18 and 24, different locations, with the monitoring of the sites where we're moving them from, and trying to see what kind of impact – we have a really clean slate to start with out there. My question is for you Stephen, and thank you for coming down, I don't know if you all know, he's a world-wide known photographer, he's been all over the world, and he comes back here to photograph fish. At a very crucial time when I was licking my wounds after the referendum, Skin Diver magazine came out with a before-and-after photograph, and it was Stephen's work, and it was phenomenal, and it made me feel a little bit better. I saw you had a number of artificial reefs, in fact I think you had the Spiegel Grove, would you just close and comment on what you think of artificial reefs and their importance for the dive industry.

Frink: OK, I'm glad to have an opportunity to speak on that. First of all, I was personally involved with the *Dwayne*, that was in 1987 and after going through the fund-raising and everything that happened with the *Dwayne,* I swore that I would never get involved again in an artificial reef project. Then, about four years later, I guess time heals all wounds, and we started to think We need one Bigger, Better. So Bill Herrigan, former National Marine Sanctuary manager, and myself and some of the local dive operators in Key Largo, probably over too many beers, started thinking that we ought to go back up to the Reserve Fleet in the James River and find a suitable vessel. So back, I guess it was probably in the late 1990s, we decided that the *Spiegel Grove* would be the appropriate thing for another artificial reef, and we went about doing that, it was a massive fund-raising effort, we did it through the private sector. I've got to say thank you very much to the Tourist Development Council for their support on that, because it was just such a big project. We started out thinking it was going to be a couple of hundred thousand dollars to acquire a shipwreck. I realize this isn't where you're going with the question, Billy, but I've got to say a bit about the history because it was a tough thing to live. We acquired the vessel, we hired who we thought would be good contractors; they weren't good contractors, they – you know, man, it's just a viper nest, once you get into trying to clean a ship for salvage, but in our case we got people who took the money that we paid them to take the steel and put it for salvage, and then said they were out of money, could we have more. We couldn't do it. We got a new contractor, we cleaned the vessel, we towed the vessel, in the end it was like seven to ten years of our life to finally, proudly get it on site and think we're going to have the thing exactly like happened with the *Dwayne* and we're going to have a ship upright like the Dwayne. Well, it didn't happen, you all know that, what happened with the *Spiegel Grove*. I guess we're not really here to talk about the trials and tribulations of putting a ship on the bottom, but what happened once it went on the bottom. There are biological issues, and again, I think these have been carefully documented, and I think Billy, I'd like you to speak on this, but there were baseline studies done about fish aggregation, so we knew what happened with coral reefs in proximity to the *Spiegel Grove*, and I know that REEF [Reef Environmental Education Foundation] is out there doing documentation after the *Spiegel Grove*. Now, I am told that there are far more species of fish on the *Speigel Grove* than there are even on the *Dwayne*. The *Dwayne's* been down since 1987 – do you know the exact number of species on the two ships? [no]. I think it's like 32 species of fish that live on the *Dwayne* and I think it's like 52 that live on the *Spiegel Grove*. I think a lot of it has to do with the luck of the draw, because the ship, when it did go down, it went down on its side, and it's kind of counter to the current, so there's significant upwelling from the Gulf Stream, and it ended up being a magnificent habitat for fish. Now, speaking of Sanctuary Preservation Areas, it would be very cool if we had a clean scientific study, so that we knew exactly how much fish would

come to an artificial reef, and what kind of species. But you have game fish that are going to come there because it's an oasis in the middle of the Gulf Stream, and that has to be attractive to an angler. I'm not saying that's good or bad, but it's not science anymore, because we have the right for people to take fish off that artificial reef, but for recreational diving aspect, I think you only have to look at the dive shops that can't really run, that may be in the Upper Keys – but the *Spiegel Grove* is too far to run, and they, there was – it was a detriment economically because the people in the Upper Keys, because it's so easy to drive five miles north to get on a boat that's going to go to the *Spiegel Grove* versus to be on a dive boat that's going to have to run 10 miles to get there. So it's a big deal. Was it a massive economic benefit to Key Largo? Yes, it was. Was it terribly fascinating in terms of the fish life that's accruing on the ship? Yes, it was. And you guys are going to have to do the scientific studies to tell us what does it mean when you sink an artificial reef in the Florida Keys, and I'm really looking forward to the benefits of that study.

Schuttenberg: Thank you very much. Let's thank our panel. [applause]

Keller: Thank you all very much. That was very interesting, in fact this whole morning has been so interesting and full of discussion that we're starting to run late, even by Keys standards, if that's possible [chuckling from panel] so what we're going to do is we're going to move right on into the next panel on Management Options and encourage you to take your individual breaks as your physiology requires [laughter] and just go ahead and get started, and I'm going to hand it over to Joanne to move this along.

Management Tools

Moderator: Joanne Delaney

No-Take Marine Reserves: Science, Values, and Choices for the Florida Keys National Marine Sanctuary

Cheri A. Recchia

The Florida Keys National Marine Sanctuary was designated in 1990, but the regulations implementing the final management plan were not issued until 1997. The Sanctuary was expanded in 2001 with the addition of the Tortugas Ecological Reserve (TER). The protections put in place are therefore still relatively new, particularly in the TER, but it is nonetheless reasonable and necessary to ask whether the Sanctuary appears effective in achieving conservation goals. For example, is there evidence that, overall, ecosystems are healthier inside the Sanctuary than outside? If one traveled in a submarine across the Sanctuary boundary, would there be any visible difference?

The answer to both questions appears to be no. To date, at a Sanctuary-wide level, the protections established have not been demonstrably effective in conserving healthy populations (abundance, structure, etc.), halting declines in biodiversity, protecting habitat, or protecting or restoring ecosystem functions. Threats to the marine ecosystems of the Florida Keys are numerous, and include several operating at regional, hemispheric, and global spatial scales. African dust, plumes from the Orinoco and Mississippi Rivers, dark water phenomena, harmful algal blooms, bleaching, and global climate change are a few such threats, and none of these can be addressed directly through actions taken within the Sanctuary.

However, there is reason to believe that the Sanctuary's ecosystems and the resources they sustain would be healthier, more resistant to these as well as local threats, and more resilient in recovering from impacts if the Sanctuary included adequate no-take marine reserves. No-take marine reserves are marine protected areas that are closed to all extractive uses, including to all fishing. Around the world, they are increasingly being employed as an essential marine conservation and resource management tool. However, less than 6% of the Sanctuary is designated as no-take reserves, and there is good reason to believe this is woefully inadequate if the Sanctuary is to conserve the resources it was designated to protect.

The substantial and growing scientific literature clearly demonstrates that well-designed and adequately enforced no-take reserves are singularly effective in increasing the size, diversity, and abundance of organisms, protecting habitat, and providing ecosystem-based protection within their borders. Research on dozens of sites around the world has shown that even though no-take reserves cannot directly counter threats from poor management practices on adjacent lands, distant air or water pollution sources, global climate change, or a variety of other adverse impacts originating outside reserve boundaries, they nonetheless produce dramatic improvements within their boundaries. Reserves are much more effective in this regard than are temporary, seasonal, or partial closures, all of which may confer important conservation or management benefits, but are not associated with equivalent long-term effects. For example, studies have demonstrated rapid return to pre-reserve conditions following re-opening of temporary closed areas.

Although some controversy remains, common sense, theory, and increasing scientific evidence also point to beneficial effects beyond reserve boundaries, for example, through increased fish catches. This may occur through fish traveling out of reserves into areas in which they may be caught, through movement of fish eggs or larvae into surrounding waters in which they settle and grow

larger until they may be caught, or both. In addition, there are increasing suggestions that reserves can lead to increased resistance and resilience of ecosystems, so that they are better able to withstand and recover from a variety of adverse effects, such as those arising from pollution, bleaching, and other threats.

In the Florida Keys National Marine Sanctuary, three types of zones are commonly cited as no-take reserves: the Ecological Reserves, consisting of the Western Sambo Ecological Reserve and the two areas comprising the Tortugas Ecological Reserve, the four Research-Only Areas, and the 18 Sanctuary Preservation Areas (SPAs). While the first two zone types are indeed no-take, all the SPAs allow baitfishing for ballyhoo, and four allow catch-and-release trolling. The SPAs may be producing significant conservation benefits, and indeed anecdotal reports are accumulating that some fish species are more abundant inside SPAs than outside, but they are not and should not be considered no-take areas, nor expected to generate equivalent benefits.

The total no-take area, consisting of the Ecological Reserves and the Research-Only Areas, is less than 6% of the Sanctuary. (The 18 SPAs are very small, collectively covering only 16.5 km^2, less than 0.02% of the Sanctuary, so do not much increase this percentage even if included). Scientific recommendations of the percent area that should be protected in no-take reserves to protect biodiversity and support sustainable resource use typically range from 20-30%, and recommendations in the 30-50% range are becoming more common. Experience from around the world and the best available scientific information clearly indicate that 6% is not nearly enough.

Establishing additional no-take reserves in the Sanctuary would incur both costs and benefits. The benefits of reserves are many. In addition to those discussed earlier, adequate no-take reserves also typically are healthier than surrounding areas, providing much needed natural laboratories and classrooms for science and education, so that it is possible to know and document what natural, healthy areas look like. We cannot measure the impacts of fishing, for example, if we do not have sufficient unfished areas for comparison.

These benefits, however, come at the cost of further spatial constraints on extractive human activities, including fishing. As a result, establishment of no-take reserves is currently quite controversial. The heated voices and polarized views on both sides of the issue are reminiscent of those that occurred in the Keys during the sanctuary designation process. Opposition to the Sanctuary was initially very strong, but was eventually largely overcome through a lengthy public consultation process, supported by concerted and successful efforts to inform the debate with the best available science.

Today, opposition to establishment of no-take reserves is strong among some interest groups. For example, some recreational fishing interests are seeking to advance "Freedom to Fish" legislation federally and in several coastal states. The typical formulation of the proposed legislation would prevent closing areas to recreational fishing unless there is a clear indication that it is the cause of a specific conservation problem and that no "less severe" conservation measure (such as size or bag limits, gear restrictions or seasonal closures) will adequately address the problem. The proposed legislation would further require that any recreational closure be the minimum size supported by the best available science and that the closure be reopened as soon as the problem is resolved. If passed, this legislation would demand a level of scientific proof of the need for reserves that is unprecedented among other management measures, and likely unachievable. It would also prevent closure of healthy areas, even if needed for science or other purposes. Had the Freedom to Fish Act

been in place at the time, it would likely have prevented the establishment of the Tortugas Ecological Reserve, as well as the Research-Only Areas, and may have resulted in SPAs that were open to all recreational fishing. Freedom to Fish legislation of this type has not yet passed federally or in any state, but its supporters remain active.

Today, those with an interest in the Florida Keys National Marine Sanctuary and its resources are faced with several choices. Will the needed attention on distant threats, whether African dust, Orinoco plumes, or global climate change, eclipse the equally needed attention to strengthening local protections afforded sanctuary resources? Should there continue to be fishing allowed in over 94% of the Sanctuary? Are those interests more important than implementing adequate no-take reserves, which are the most powerful, flexible, and proven tool for conserving species, habitats, and ecological processes?

Elsewhere in the world, choices are being made to limit all fishing in some places, restricting this type of use in selected locations in order to better conserve species, habitats, and ecosystems, and hopefully to improve fishing elsewhere. For example, after extensive ecological and socioeconomic analysis and public consultation, the Great Barrier Reef Marine Park has recently been rezoned, increasing the percentage of the park closed to all fishing from 4.5% to 33%. Beyond this, the Australian government is already working to complete a national, ecologically representative MPA system, including no-take reserves, in federal waters, and several states are implementing reserve systems in their waters. In New Zealand, the government is moving to protect 10% of waters in no-take reserves. Many other countries are following suit, including Kenya, Belize, and Chile. Indeed the U.S. is lagging behind many developed and developing countries in implementing marine reserves.

Finally, in the Florida Keys as elsewhere, it is really a question of values and choices. How do we want these world-famous reefs, the ecosystems of which they are a part, and the resources that are so critically important both ecologically and economically, to look and to function in 10 years, or in 50? What measures are we willing to take now to reverse the well-documented declines and set a path to recovery and long-term health and protection? There is no question: enforced, no-take reserves work. And reserves require closing selected areas to all fishing. The best scientific information clearly points to the conclusion that, although no-take areas are by no means a silver bullet, Florida Keys National Marine Sanctuary will not succeed in halting further species and ecosystem decline without additional, adequate reserves. What choices will we make?

Suggested reading:

National Center for Ecological Analysis and Synthesis. 2001. Scientific Consensus Statement on Marine Reserves and Marine Protected Areas. University of California, Santa Barbara. http://www.nceas.ucsb.edu/Consensus

National Research Council. 2000. Marine Protected Areas: Tools for Sustaining Ocean Ecosystems. Committee on the Evaluation, Design and Monitoring of Marine Reserves and Protected Areas in the United States, Ocean Studies Board, Commission on Geosciences, Environment, and Resources. Washington, DC: National Academy Press.

Sobel, J.A., and C. Dahlgren. 2004. Marine Reserves: A Guide to Science, Design, and Use. Island Press, Washington, DC.

Marine Zoning: A Management Tool in the Florida Keys National Marine Sanctuary

Billy D. Causey

Delaney: Thank you Dr. Recchia very much. We're next going to hear from Billy Causey.

Causey: I didn't tell you to be that provocative [laughter]. Ah, you can't get through this skin. Thank you. Cheri made some very good points, and you are going to see in my story – I am going to tell a very fast story about the Florida Keys, but I am going to give you some background. I have given this presentation all over the world, but I realized when I was going through it to start cutting out slides, that I don't think that I've given it right here in the Florida Keys.

We are a part of a system of national marine sanctuaries (Fig. 1), but I am really just going to be talking about the Florida Keys. I can't go around and name all thirteen sanctuaries and the resources, but just to know that we are part of a national network of marine protected areas, and we are currently working on what is going to rival the Great Barrier Reef Marine Park Authority, up here in the Northwestern Hawaiian Islands. Terry, you don't want to touch it.

Figure 1. System of 13 National Marine Sanctuaries and the proposed site at the northwestern Hawaiian Islands.

I am proud to say that we manage the Sanctuary through a co-trustee partnership with the state of Florida's Department of Environmental Protection, and the Fish and Wildlife Conservation Commission. You may have seen the Captain of our Sanctuary enforcement squad with FWC. Stand up, Captain Luher. Laurie Luher, she has been around the last three days paying attention to this, meeting. My partner Kacky Andrews is around here somewhere.

The Sanctuary is a 2,900 square nautical mile area, this entire blue line (Fig. 2), including this disjunct area around Tortugas South. The three national parks fall outside our boundaries, but we do have contiguous boundaries with them. The Sanctuary is a marine protected area. If you use the definition that Kelleher and Kenchington and DeVine used in 1991, it is a marine protected area, but as some of the movements – the Freedom to Fish Act, all of these movements, they turned the term marine protected area into a bit of a bad term, with a negative connotation. We have very clear legislation from Congress, and that is we will improve the conservation, management, and wise and sustainable use of marine resources, enhance public awareness and appreciation, and maintain it for future generations. Just like the Great Barrier Reef Marine Park Authority, you heard Elliott and his opening comments, or some of you did, we are a multiple-use management area. National marine sanctuaries allow continued commercial, recreational uses. One of our mandates is to facilitate to the

extent compatible with the primary objective of resource protection, all public and private uses of the resources. That is quite a challenge.

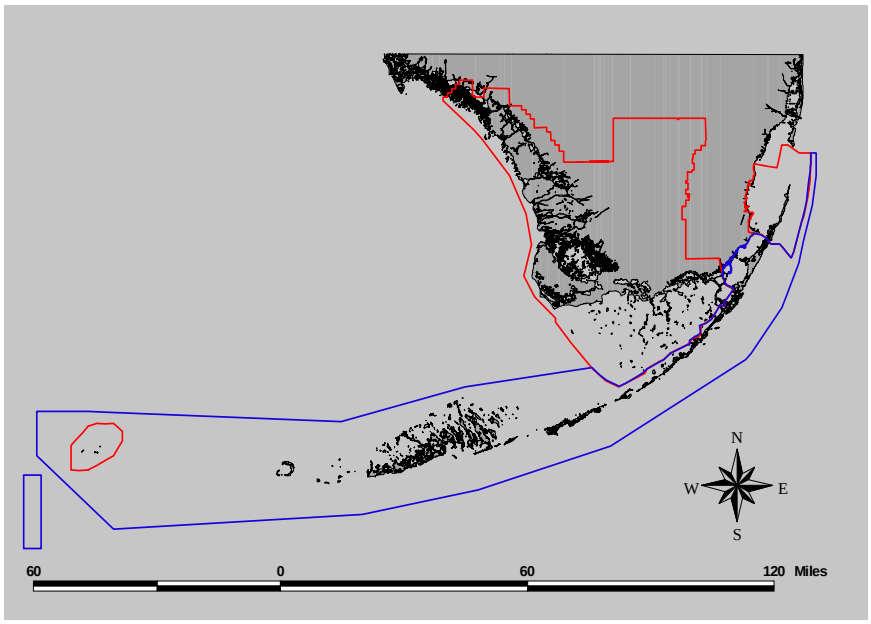

Figure 2. Diagram of southern Florida, showing the boundary of the Florida Keys National Marine Sanctuary (blue line), which surrounds most of the Florida Keys. Also shown are the Dry Tortugas, Everglades, and Biscayne National Parks (red lines).

My job today is to talk about management tools, and to embed in this presentation the kind of management tools that we have put in place to try to achieve that objective. This sanctuary gave us the first opportunity when it was designated to start looking at the full coral reef ecosystem, not just little islands out on the reef tract, but to look at the full range of the habitats and all of the species that exist in those areas. But we are not doing it in a vacuum, and this was the first sanctuary to totally surround a populated community. It was the first sanctuary to have a water quality protection program, directed by Congress, coming in at a time when we were already challenged by development and use of the resources, more and more impacts coming in and affecting our resources in various ways.

As you have seen, I am not going to spend a lot of time on the uses, but I have to lay the framework for where we are today, and how we got there. We do get over 3 million visitors every year and they spend 13.3 million visitor-days. In other words, one visitor might spend 5 days. They come in by a variety of ways. Someone asked about cruise ships. When I moved here there were no landings of cruise ships 31 years ago. Fifteen years ago, maybe one or two a month. Last year they had 526 landings alone in that one year. So we are getting a lot of people coming down to the Keys, including a lot of people pulling their own recreational boats. Terry, I don't think that is something you see out on the Great Barrier Reef, all those small 22-foot boats sitting out there on the reef tract. We have over 60 dive shops, 65 boat rental operations, and 35 bait and tackle stores.

Diving and snorkeling – you have heard the importance of that to the economy, locally. And of course as well as snorkeling and diving, recreational fishing is a very important part of our economy. A lot of people come down here now just to look, to drive around Key West and enjoy the various sites, but commercial fishing is our second largest industry as far as the economy is concerned. Our fishermen will land anywhere from $50-70 million worth of product every year on the docks. We have the eighth largest fishing industry in the United States here in the Keys. This is not without impacts. We have all sorts of impacts that come with the use of these resources. We get over 600 vessel groundings every year; those are on seagrasses, on corals, these are things that affect the Sanctuary.

It took us from 1991 to 1996 to develop a comprehensive management plan to manage the Sanctuary, and we incorporated in that plan 10 different action plans (Fig. 3). In 1997, in spite of, I wouldn't say in spite of, I would say on the heels of the referendum, we had the Governor and Cabinet with seven elected officials, partisan officials, who agreed for the Sanctuary to include State waters. The reason I said the numbers earlier, 53-47%, the Governor and Cabinet heard so much misinformation going on down here by the opponents to the Sanctuary, that they were just glad that we only lost by that percentage. [laughter] They thought we were going to lose with about 15-20% support.

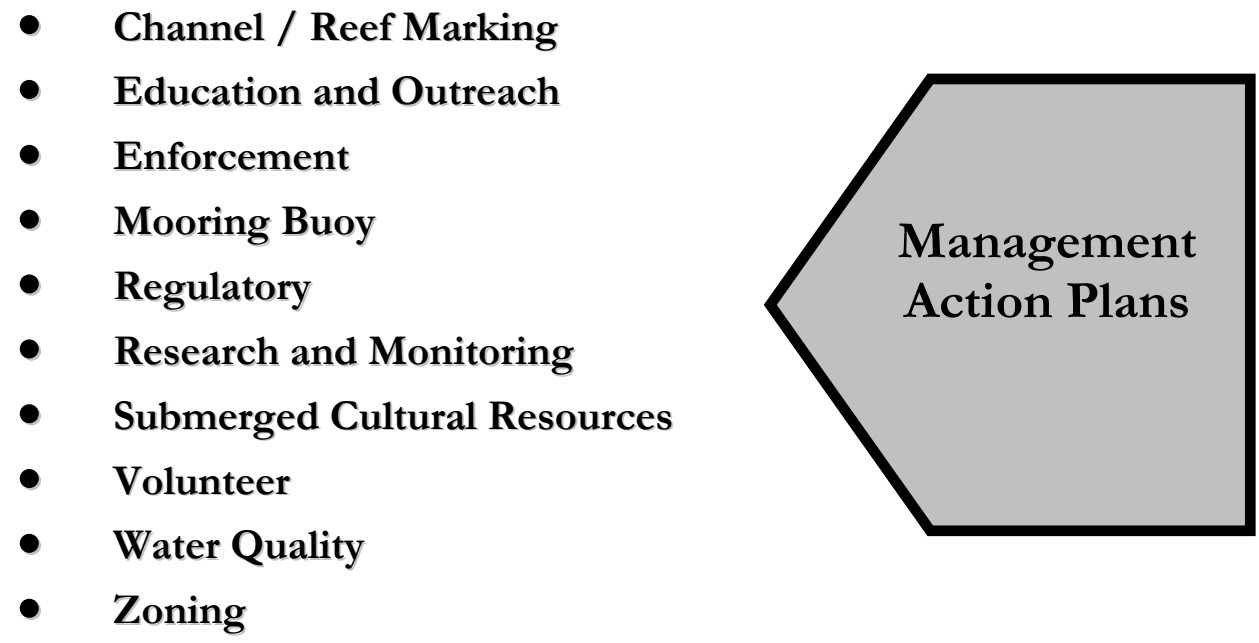

Figure 3. The 10 Action Plans comprising the Management Plan of the FKNMS.

Over 60% of the Sanctuary lies in State waters. We overlap four wildlife refuges, six state parks, three aquatic preserves, and two previously existing national marine sanctuaries. It is a very complex mosaic of management. In order to pull it all together, we had an inter-agency core group that helped us to develop the management plan. In order to help us develop this plan we brought together this nation's first sanctuary advisory council, a group of stakeholders from various occupations: scientists, commercial fishermen, recreational fishermen, a variety of people, educators, conservation groups, even treasure hunters to help us put together a plan. The plan came up with six major management categories, but the one that I really want to focus on is a management tool that we implemented here, called marine zoning.

This is how we defined marine zoning in our final management plan. I am not going to read that to you, but it is a concept that has been used around the world, and when we developed our draft management plan in 1995 the areas that were most controversial were three large, what we called "replenishment reserves" (Fig. 4). A twenty square-nautical-mile area in the Carysfort area, a nine square-nautical-mile area around the Lower Keys, and a 110 square-nautical-mile area around the Tortugas. When we put this plan on the streets, the advisory council drew every one of these lines. I

am not shifting responsibility; we used them for that purpose – 99% approval of this by the SAC. We hit opposition. What we realized is that sometimes you don't think about the uniqueness of the community where you are working, the people that live there, and in fact this whole thing, in the Keys and Key West is that we do have people who are individualistic in their thinking. But, Cheri, it wasn't easy to do this, and this was the worst day in my life, except for when my parents passed away, and that was to see George Barley and myself hanging in effigy as we arrived at a meeting. These things are not easy to do when you exclude people from the process, and clearly what we had done the first time around is not done a good job about thinking about all of the people that were in the Keys and who we were working with. We thought we were, but we didn't. What we ended up with in the final plan that came out in 1997 was one nine-and-a-half square-nautical-mile area (Fig. 5), but with a promise to come back and do something else in the future.

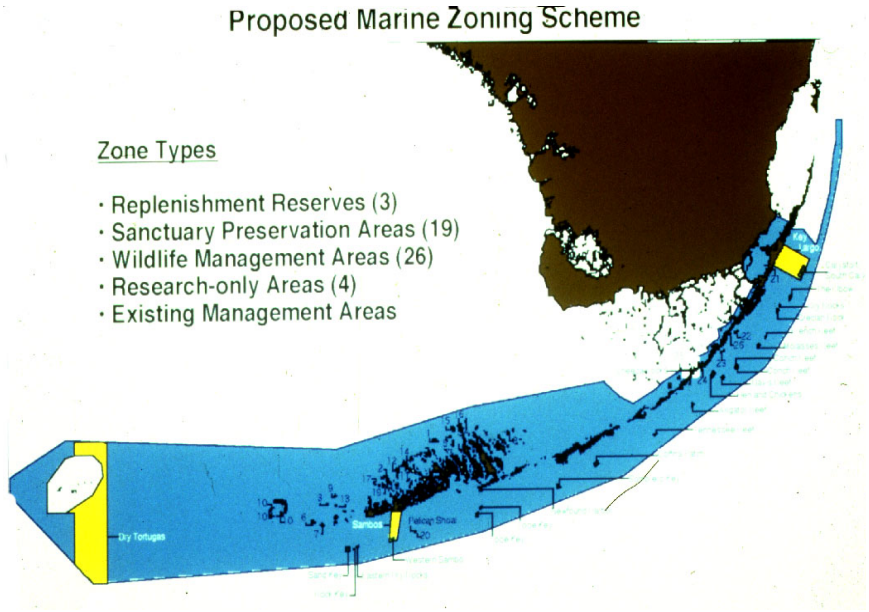

Figure 4. Map of the FKNMS from the 1995 Draft Management Plan showing the three proposed "replenishment reserves" (yellow areas).

Marine zoning is a versatile tool. We didn't develop it; we really copied a lot of what was done at the Great Barrier Reef Marine Park Authority. It is a multiple-use tool. It helps reduce conflicts. The Sanctuary Preservation Areas, and I will get into it – we have 18 of those. Those are not set aside for any fisheries management purposes, whatsoever. I guess if you're a blenny or a goby, it's your home, but those are set aside for visitor-use conflicts. I am going to go over all five of these different types of zoning, and I think I am going to have to hurry. We have 18 Sanctuary Preservation Areas that focus on top of the shallow reefs; these are the areas that are the greatest use. We capture 80-85% of the snorkeling and diving activity, except for the first two weeks of lobster season. These areas are critical for sustaining and protecting some important marine species, such as the small critters. When we talk about these for biodiversity purposes, they are great. I can tell you that many of the areas set aside in New Zealand were not much larger than even our smallest Sanctuary Preservation Area. We sometimes lose dimension when we start talking about percentage. The Sanctuary Preservation Areas focus our protection, and you can see here we have about 60-65% of the spur-and-groove reef formations, and the main thing is that we do protect a number of species that do not move very far. If you look at them along the map, they do look like little postage stamps, but you can imagine that is where 80-85% of the snorkeling and diving activity takes place.

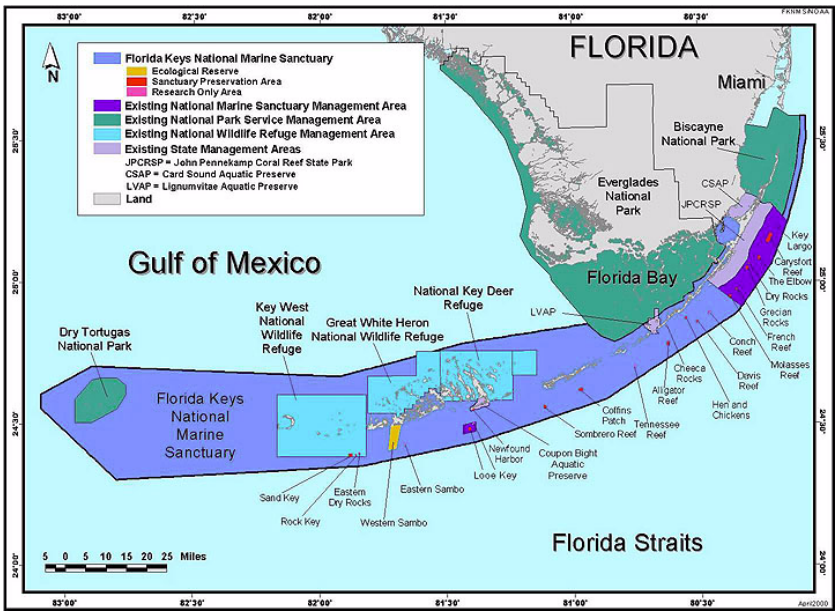

Figure 5. Map of the FKNMS in the final Management Plan (1997), showing the single Ecological Reserve at Western Sambo (orange area). Also shown are the 18 Sanctuary Preservation Areas, Existing Management Areas, and four Research Only Areas (Eastern Sambo, Looe Key, Tennessee Reef, and Conch Reef).

We also have four areas set aside to help monitor what is going on with uses. These areas are only accessible by permitted scientists that can go in and study them. We have two Sanctuary Ecological Reserves now. One of nine square nautical miles, and one of 151 square nautical mile, and I am just very quickly going to touch on those. These are areas of some the best remaining water quality, they encompass larger areas, and they provide natural spawning and nursery areas for a lot of the marine life where they lie. The one that we ended up with in the management plan in 1997 was the Western Sambo Ecological Reserve, and you can see we run it from onshore, we pick up the inshore patch reefs, all of this Hawk Channel reef system, the back-reef patch system, the reef flat and all the way out to the first 60-foot depth. The reason we stopped at the first 60-foot depth is that the fishermen that were on our advisory council wanted it to stop there at that first depth. We ended up there after a process.

I am going to go through very quickly what the Tortugas Ecological Reserve – we implemented that in July 1, 2001, and it covers 151 square nautical miles (Fig. 6). It is broken up into Tortugas North and Tortugas South. We had to deal with seven different jurisdictions to get them implemented; four of them had veto capability in the process. This is what it looks like, if you throw it over our habitat map, thanks to The Ocean Conservancy for this. Here is Riley's Hump, a very important fish spawning aggregation site, here is the Tortugas North, spectacular coral reef resources still in this area, this is the Research Natural Area that the Dry Tortugas National Park developed that will be implemented eventually [tittering]. Promise. If you look at Tortugas North and then look at the Western Sambo area, and then look at this slide, you can see why the fishermen really supported us tremendously in the Tortugas process. There are two counter-clockwise gyres, you saw some of this on the first day, if you were here for the oceanography presentations. There is the current between us and Cuba, along this very deep area, a series of counter-clockwise gyres or eddies spin off. The Tortugas gyre spins for a long period of time, in fact you can see right there that one of the drifters just stayed in that area. Anything spawning there is going to get distributed on up into the Keys and into the nursery areas, to the seagrasses. When the fishermen saw that data presented to them, they really bought into the Tortugas Reserve process.

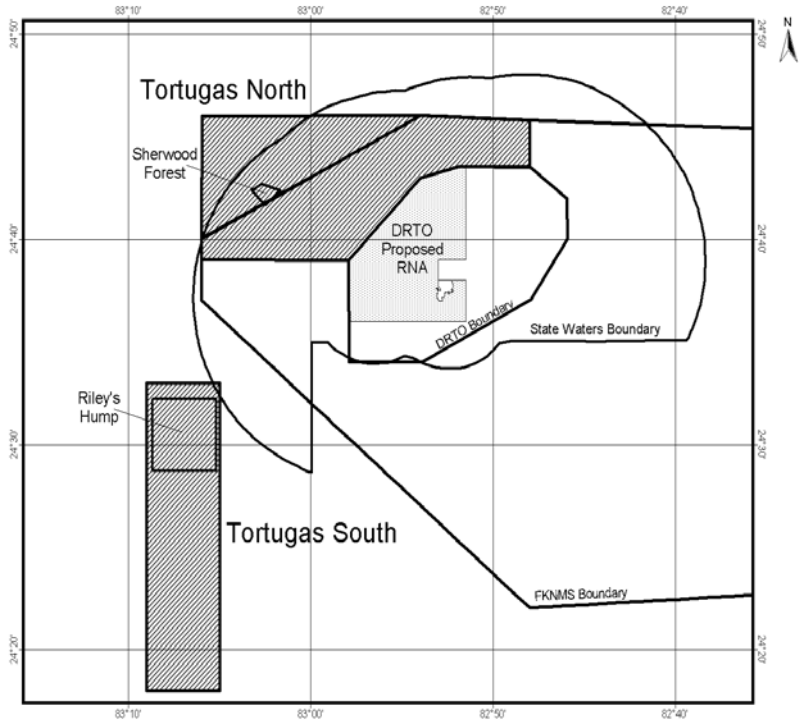

Figure 6. The Tortugas Ecological Reserve, which covers 151 square nautical miles and was implemented in 2001.

One of our stealth tools has been these Wildlife Management Areas. These are areas that primarily address the mode of access, recreational paths of access, and the flats fishermen have found that these areas are very positive. They have been supporting them, and in fact I was very glad to see this reporter came down in December or January, he was trying to find something controversial about the area, and in fact went back with a story on no-motor zones revive Keys fishing. He couldn't find a flats guide to say anything negative about them.

Existing Management Areas, this is a very simple tool. This is one that protects all of the other existing authorities that we overlap, including our own at the Looe Key and Key Largo areas. The zoning, as you look at the map now, you see the layout, the Existing Management Areas such as these Wildlife Refuges, we overlap, Pennekamp Coral Reef State Park, and then Looe Key and Key Largo National Marine Sanctuaries.

Tortugas 2000. We promised to come back and do something, but we promised to come back and do it right. We had a newly configured advisory council. We listened to our old advisory council, we made some changes in the make-up of the group, and we had some lessons learned from the first process, and those fell into four categories: participation, process, science, and jurisdictions. I am just going to speed through these work slides, you can read them for yourself, but participation was the big thing. That we involved the general public more, we maintained an integrated group, and we tried to include all of fisheries managers up front. The Sanctuary Advisory Council formed a working group to help us in the process, and this working group was very effective in helping us. In fact, we asked that they use an ecosystem approach, and they did such a good job that they added 60 miles to the reserve that was outside the Sanctuary boundary [titters]. Process: we tried to make it open, flexible; we tried to be as adaptable as we could. They came up with the ground rules, they listened, and they really listened to all of the stakeholders and tried to engage the public as much as possible. We had a lot of public meetings. Science was an important part of this, and it was science really that helped everyone, but I'm also talking about the socioeconomic sciences. You heard that presented today, but that is something that was a big gap in our previous process. We did come back with the science, and the working group heard from oceanographers, geologists, ecologists, biologists, divers, and fishermen. They heard oceanographers tell us about the special area, they had satellite tracking meters, information to go by, they had a lot of socioeconomic on-the-ground work.

Then we had to work with the jurisdictions – seven different jurisdictions, but we did get success. And in fact, consensus was what we ended up with, at the end of the game. Governor Bush and the Cabinet were the last ones to approve it, and the last two steps were the State – the State Fish and Wildlife Conservation Commission, and then the Governor and Cabinet. And this is what we ended up with, with the Tortugas Reserve, and the main thing, some of the summary here, is to involve stakeholder leadership, use the socioeconomic science, bring people into the process, don't exclude them. Utilize the process as precise and science-driven, but incorporate the best anecdotal information when necessary. We made Ph.D.s out of commercial fishermen. We told them that we felt that they were at that level.

Implementation: I am just going to touch on a couple of things in closing. Enforcement is critical. You heard Cheri say that you have to enforce these areas. We now have 17 enforcement officers in the Sanctuary. We have a captain, four lieutenants, we are actually changing that slightly, but it is in fact something that we are committed to. Is it working? Well, here are three of our buoys, right here. One, two, three. These boats are all fishing the line (Fig. 7). I was in the Tortugas two weeks ago, and saw the same thing, just like that. So I think enforcement does work. One thing I am going to leave, is a little philosophical thought that we have been doing this on land for a long time, and we are just starting to do it in the ocean. We need to do more of it. [applause].

Figure 7. Aerial photograph showing vessels fishing just outside the boundaries of a Sanctuary Preservation Area. The SPA marker floats are highlighted by the red symbols. [Photo credit: D. McClellan, NMFS]

How Acoustic Telemetry Might Be Used in MPA Design

Rodney Bertelsen

Delaney: Thank you, Billy; a good reminder for most of us that we have some pretty innovative management tools going on right here in our own backyard. Next we are going to hear from Dr. Rod Bertelsen with Florida Fish and Wildlife Research Institute.

Bertelsen: Formerly known as FMRI. I am going to talk from the science end of trying to provide information to managers, and give you a case study that we have been conducting in the Western Sambo Ecological Reserve, using sonic technology. You saw some tags on the first day (Fig. 1); I brought one along that I can activate if you want to hear what it sounds like. You just put it right up to your temple, and this one fires off every two seconds. The other items that we use a lot are these – the receivers that we put into the water (Fig. 1), and they're omni-directional, they listen in all directions for the sounds these particular tags make. These tags come in a wide variety of shapes and sizes. In our case we used the tag that was passed around on the first day, and we tag lobsters by affixing them to the top of the carapace (Fig. 1).

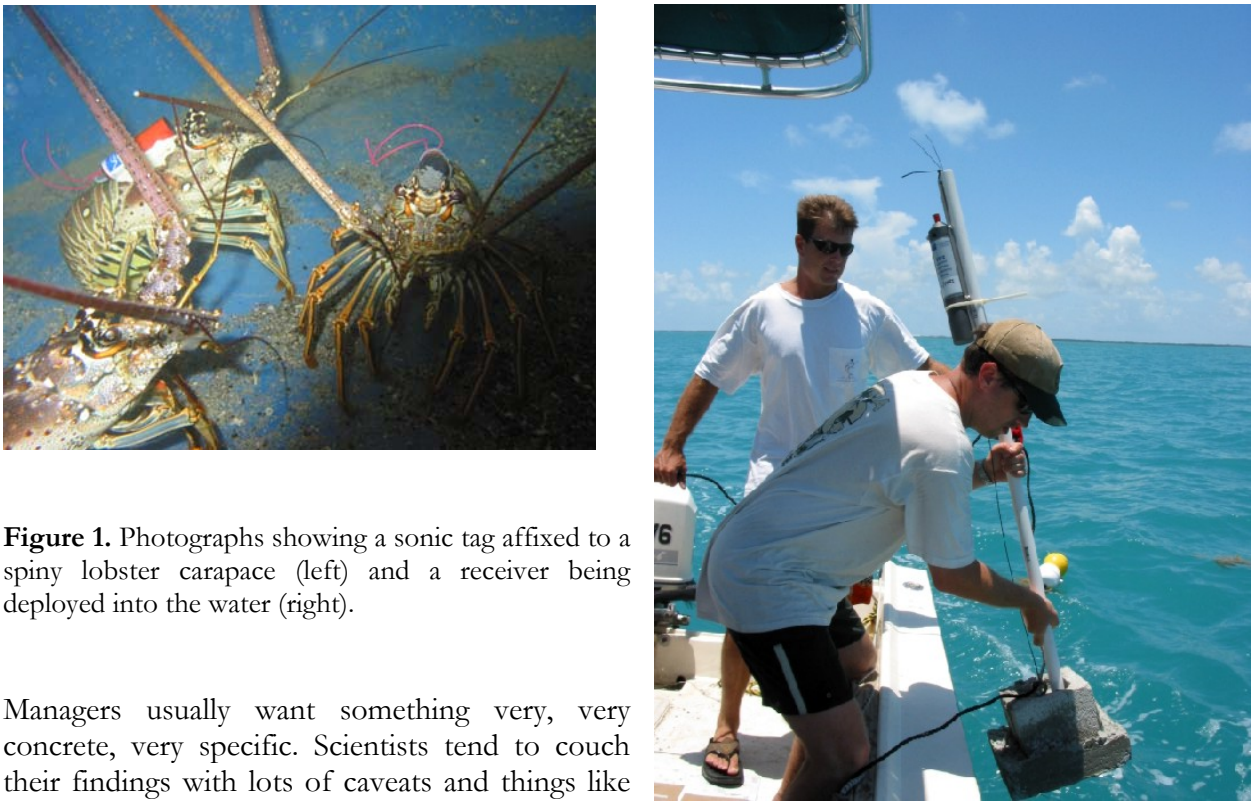

Figure 1. Photographs showing a sonic tag affixed to a spiny lobster carapace (left) and a receiver being deployed into the water (right).

Managers usually want something very, very concrete, very specific. Scientists tend to couch their findings with lots of caveats and things like that. To misquote Harry Truman, who might say something like "On the one hand my scientist tells me to do this, and on the other hand he tells me to do that. What this country needs is a good one-handed scientist." [laughter] What we may be able to do with sonic technology is to provide something a little more specific. Some of the questions about which we may be able to provide some information that managers want are: How many of these marine protected areas should we have? How large should they be? Where should we put them? What shape should they be? What contours, how far out should they go, and this sort of

thing. Acoustic telemetry can probably help us concerning what size they should be, depending on the types of creatures you are trying to protect, the suite of creatures or the ecosystem, and what shape or where we should put them. The two are kind of related, because we are going to tie habitat in with the creature's needs.

These are the principles that we used for our pilot study, and the study that we have just completed that involved tagging spiny lobsters. We put a sonic tag on their backs (Fig.1). We can tag them down to sublegal size, and we have tagged lobsters up to almost a five-inch carapace length, that we found in the Western Sambo Ecological Reserve. We put these receivers out into the water into a grid pattern (Fig. 2). In the pilot study it was 800 meters by 200 meters wide, in those patch reefs, in that mid-channel patch reef area. Our area is over here; the fore reef is out here. This is where the snorkel/dive trip is going to go. These are the patch reefs that are located along the channel, and we will be traversing that area, for those who are going on the field trip. This is the study that we just completed. We expanded the grid out; we had a few more receivers to put in the water and we moved them into more of a honeycomb pattern to get a little bit more coverage, and put four sentinel receivers out on the fore-reef (Fig. 2), because we discovered something pretty fascinating about these lobsters out in the channels.

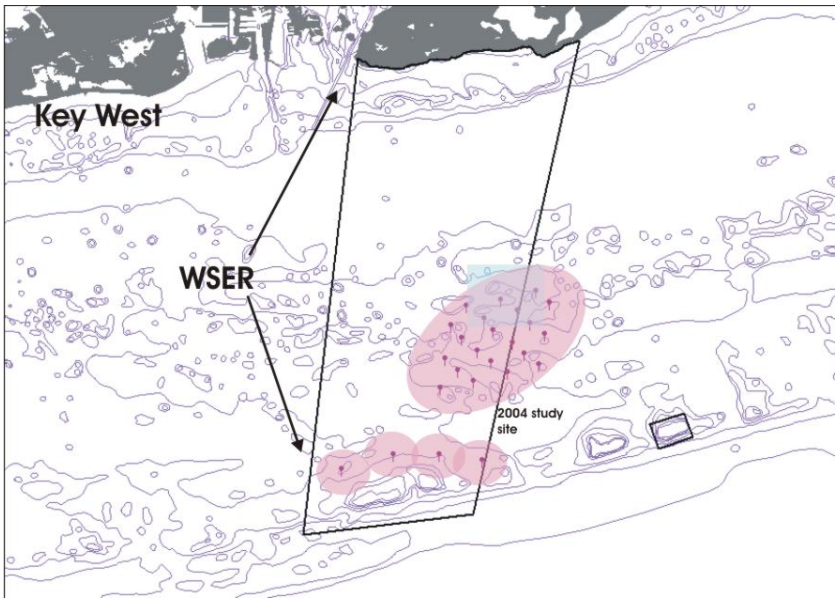

Figure 2. Diagram of the 2004 study site in and near the Western Sambo Ecological Reserve (WSER), showing the grid pattern (upper pale red oval) and the four sentinel receivers (lower pale red ovals).

These are some of the things that the acoustic telemetry used in this way can provide: How much territory do these animals take up, what do they need to exist in terms of space? We can also try and identify, if we have a good habitat map, how the lobsters are using the environment. Here are some home ranges from the study we just completed, which are still preliminary. One is a small, sublegal lobster – its carapace length is 68 mm; that is pretty tiny. You would know it was not legal-sized if you have experience in recreational fishing for lobsters. It took up quite a bit of area, and actually went and moved outside of the reserve, and back inside of the reserve, all the time, flip-flopping all over the place. This is a large male for the Keys-proper, an 84-mm male, and you can see that it used a decidedly smaller area. At 135 mm, this is a gigondo-male, especially for the Keys area, and it spent two months in an area that is smaller than these small specially protected areas.

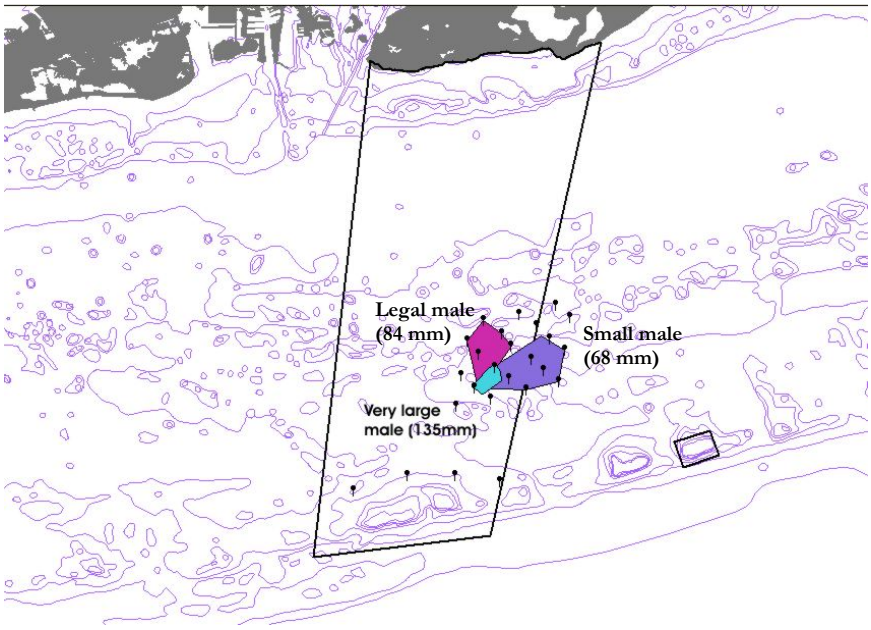

Figure 3. Diagram showing the home ranges of three male spiny lobsters: 68-mm carapace length (blue), 84 mm (red), and 135 mm (pale blue).

What we have found, looking at size structure across the Keys over the past few years, is that we are starting to see some large males showing up in some of these smaller protected areas, and this is probably the reason why: they are very localized. How do they use their habitat? We can trace the movements of these animals fairly specifically. When they are out in the open we know within about 10 meters of where that animal is located, by listening to the patterns of the pulses that are pinging off the different receivers.

This is a pretty large female that spent about seven weeks, the entire time of the pilot project, almost within the strip; she moved outside a couple of times, but most of the time within the strip. This was one of her favorite areas to den up during the day (Fig. 4). Lobsters hide during the day, and then they move around and forage at night. This female took off after night and then slowed down and spent a lot of time down in here. I suspect very strongly that is a foraging area (Fig. 4), and I would want to know more about what she was doing there. Here is a different pattern, on a different night; we looked at her from night to night. One time she went north, and went up in that direction, but she didn't seem to slow down much, she just kept trucking. Next we are going from July, almost a month later (Fig. 5). She had gone out of the area for a little while, and then all of a sudden she came zinging back to that same area, and then went back to den in one of her favorite spots.

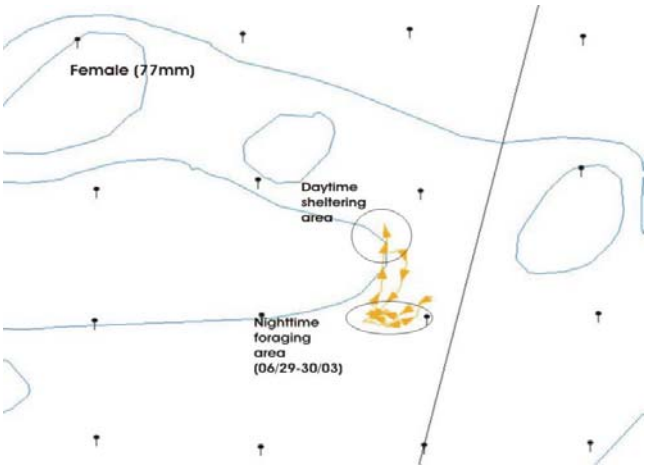

Figure 4. Diagram depicting movement of a female lobster between a daytime den and a presumptive nighttime foraging area.

Another thing that we found out about these patch reefs, these inner channel patch reefs, is that the females that live in here, if they are reproductive age, go charging off to the reef when they are getting ready to lay eggs. A lot of the females that we have seen in the past years, egg-bearing females out on the fore-reef, a lot of those are temporary residents that we now know come from the patch reefs. Here is an animation, and this is going to show the movements of one particular female in the study that we tagged (Fig. 6). She took off. She had a large egg mass and she took off on the first night after we

tagged her, and she would come back and the yellow and the reds mean that this is day time, and the dark things – there she went. A week later she came charging back. She ended up over here on this patch reef during her first day back, then when it gets to night, she takes a little exploratory run, comes back to her patch reef, and then zings back over to her original home, where we tagged her, and then spent the day there. Two weeks later, here she is back in her favorite little spot. She dens up here during the daytime. And these are – she ran on full moons toward the reef, and she came back toward the new moon. Straight back home. They have very good homing instincts. They know where they are going and they know where they have been.

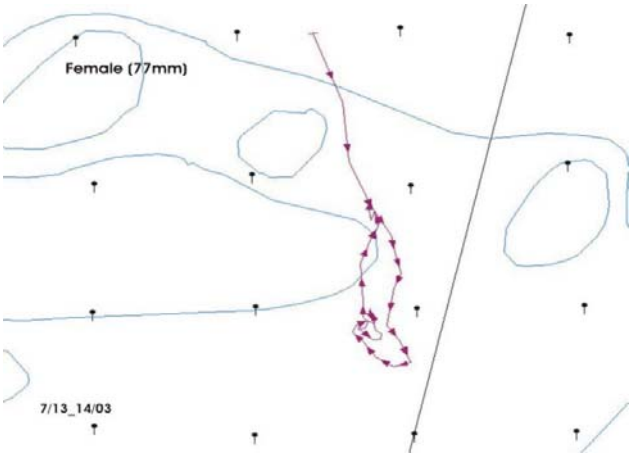

Figure 5. Diagram depicting movement of the same lobster shown in Fig. 4.

Just one other thing, on the study that we just did with the sentinel receivers that we put out on the fore reef, I can pretty much tell you with some confidence (there's my caveat) that female lobsters take a two-day trip to get out to that fore reef. They will make it about half-way, find a den somewhere, hole up during the day. We found some female lobsters when we were doing this last study, that were covered with mud and dirt and stuff, and they were on a patch reef that was surrounded with clean sand. They all had fresh spermatophores that they use to fertilize their eggs, and they had a huge egg mass, and so we knew that they were coming from closer inshore and that they were on the way out.

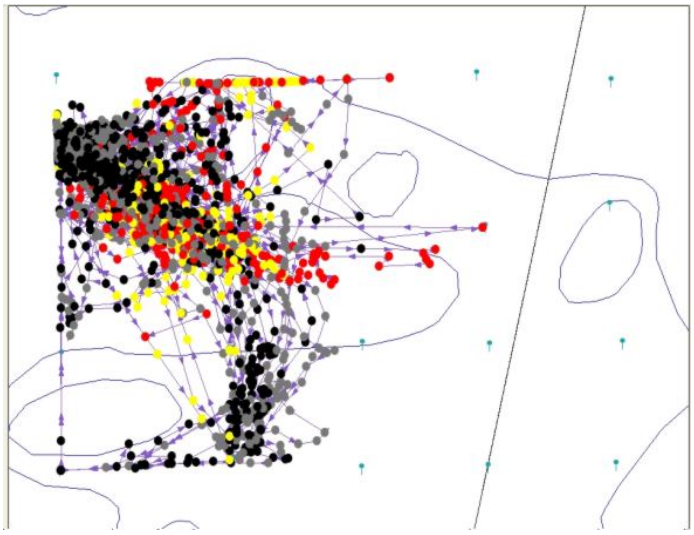

Figure 6. Diagram depicting several weeks of movements of a female lobster.

We have seen some tagging studies – this is kind of interesting with regards to the barracuda study, that had the barracuda show up on the Texas side, and then back in the Florida Keys, and that sort of thing. This is a fairly good-sized lobster that we tagged on one particular patch reef, near where that female was that I have been showing you, and a month later we also put an antenna tag on them. This was part of two studies going on, and the other study required us to go back and look for the antenna tags, and the same diver a month later goes into the water, finds this antenna tag, and the tag on the back of this lobster, just about in the exact same spot he placed it a month earlier. And what the next slide will show you is what that lobster was really doing (Fig. 7) [exclamations]. That diver came back up and said "This lobster didn't do a thing!" [laughter] You can see it is down here foraging, up in here foraging, lots of denning activity going on in the middle here. That lobster – and it went completely off of the strip – that is probably

the reason we expanded the grid, too, was to try and figure out how much territory these animals need.

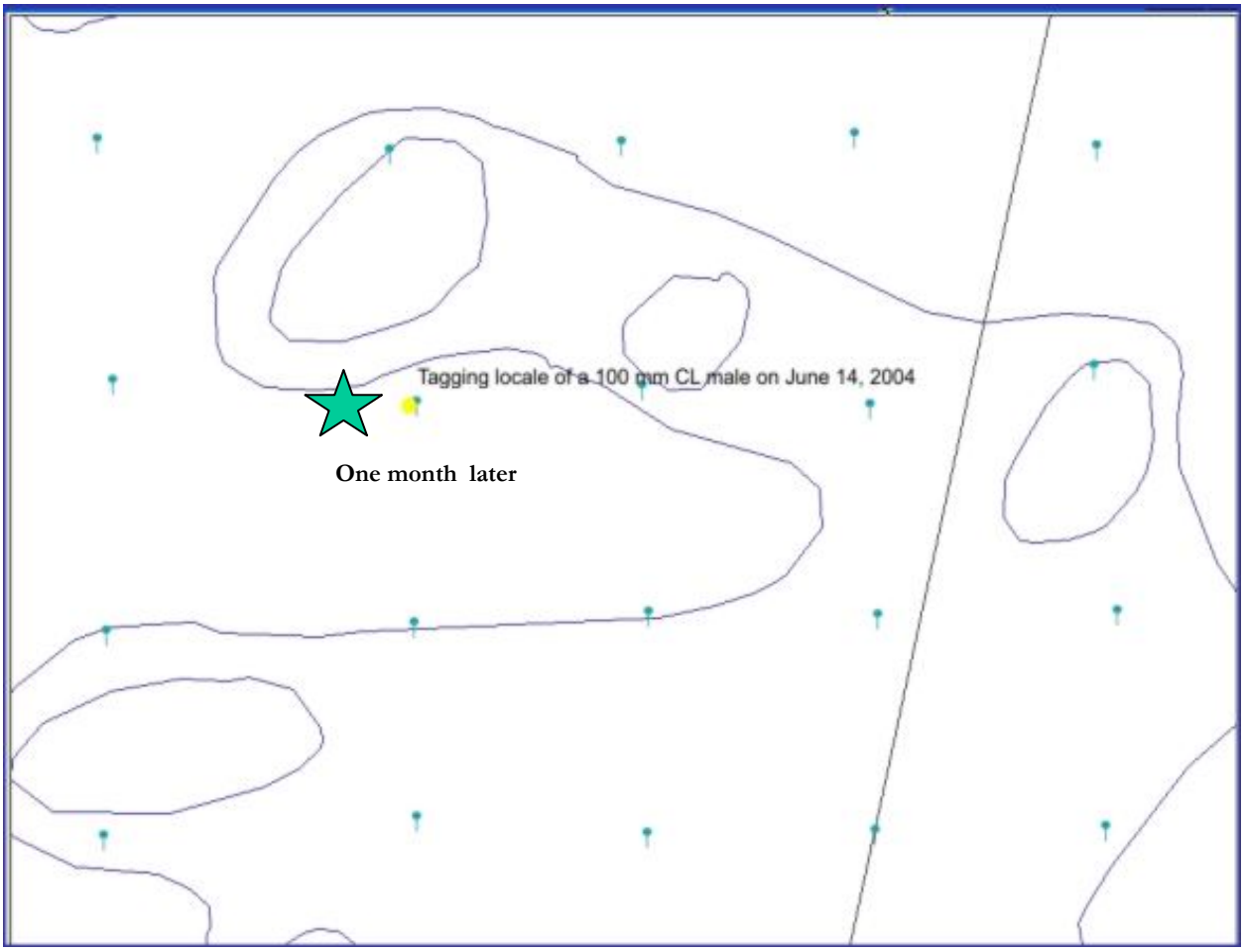

Figure 7. Diagram depicting position of a large male lobster in June 2004 (yellow dot) and one month later (green star).

So what is missing? Well to misquote Martin Moe, It's the habitat, stupid! [laughter]. We need to make a benthic habitat map so that we can correlate all of those dots and all of those motions and all of those home ranges with different habitat types, and once we understand that, and once we understand how those two are related, at least for lobsters, we can provide information to managers, specifically what they need in order to protect them. Thank you. [applause]. If anybody wants to listen to this tag at some time, let me know and I will fire it up.

Connecting Microbes to Management

Kimberly B. Ritchie

The Importance of Marine Microbes

Marine microbial processes are important to the overall health of the global ecosystem, but are largely underestimated. Life began in the oceans some 3.8 billion years ago as simple microbial life forms, creating the basis for the evolution of life as we know it today. It is currently estimated that there are 2 million species of bacteria in the oceans, but this number is likely to increase as our focus in marine microbial systems is expanded. As the earliest forms of life on earth, bacteria are able to exist in almost all environments throughout the biosphere. Studies over the past 100 years have shown that bacteria exhibit a tremendous diversity of metabolic capabilities and physiological attributes. One of the first vital global processes of marine microbes was the cyanobacterial production of oxygen in the atmosphere roughly 2.5 billion years ago. Despite decades of active scientific study, there remain large voids in our understanding of environmental microbial processes, especially in the marine environment.

Microbial Community Structures of Corals

Culturable heterotrophic bacteria associated with the surface mucopolysaccharide layer of corals form diverse communities that differ significantly from communities in the surrounding water mass. Living in a nutrient-rich matrix, bacterial populations are competitive and appear to be specific to the chemical environment in which they live. Recently it has become clear that there is a unique microhabitat or niche associated with corals and other marine invertebrates. Specifically, corals have a surface mucus layer populated with numerous commensal microbial species that appear specific to each host, actually reflecting the phylogenetic relationships among corals.

Bleaching is the loss, or degradation, of carbon-fixing zooxanthellae from otherwise healthy coral tissue. There is a significant shift in microbial community structure when corals become bleached. It is likely that, since qualitative changes (and often quantitative changes) have been reported in coral mucus during bleaching, the bacterial population change is a response to available carbon sources. Theoretical and observed consequences of environmental changes can also lead to the disruption of the 'normal' communities associated with healthy corals. We know that corals harbor a distinctive and species-specific set of microbial symbionts associated with the surface mucus layer and that these microbes undergo a shift to marine opportunistic bacteria when corals become stressed by bleaching.

Characterization of Keystone Species

All organisms, including marine invertebrates, are host to commensal microbes that live in healthy association with various tissues. These commensal microbes may vary, to a degree, from region to region, depending on water quality and biogeographical co-evolution of microbial associates. One good example is the mass die-off of the sea urchin *Diadema antillarum* in the early 1980s. Because the causative agent of this die-off is currently unknown, it is important to have a working knowledge of natural *Diadema* microbial associates in the Florida Keys. This may include a study cataloging the normal baseline, microbial communities for comparison in the case that *Diadem*a should become compromised in the future. This baseline information could add greatly to our understanding of the causative agents involved in future die-offs, by establishing a baseline of normal communities for comparison with diseased individuals. This was not possible with the mass die-off of 1983, as this

baseline of comparative data was unavailable. In addition, it is necessary to establish a set of region-wide rapid response procedures for the proper collection and handling of unhealthy specimens, applicable to any marine invertebrate, should another outbreak occur.

Some Management Questions

Inshore patch reefs and mid-channel reefs show higher resistance and/or resilience to bleaching and diseases compared to offshore shallow bank reefs and spur-and-groove reefs in the Florida Keys. Why are some corals more resistant to stress and disease than others? More specifically, *what role do bacteria play in normal host resistance to stress and disease?* A conundrum to addressing this issue is that the vast majority of environmental bacteria cannot be cultured in the laboratory. Many studies are now focused on baseline assessments of coral microbial communities based on molecular genetic analysis. This provides information on microbial associates that may never be available for culture in the laboratory. However, this approach leaves a critical void in our understanding of specific microbial processes. A solution is to look at a subset of constantly culturable microbial associates and study metabolic and protective processes in a laboratory setting. While not comprehensive, this provides an opportunity to study microbial processes associated with corals, and their surrounding environment, that would otherwise be missed.

From a management perspective, understanding how these microbial communities interact on healthy corals (and other keystone marine invertebrates) is a critical first step in understanding how and why these populations can become compromised. The establishment of a baseline microbial community of relatively *healthy* corals along the Florida Reef Tract is critical to knowing what has changed when corals become sick. This characterization can be accomplished in two different ways. First, culturable heterotrophic coral microbes can be identified via laboratory growth and characterization. A caveat is that the vast majority of environmental microbes are not culturable in current laboratory settings. However, a consistent subset of culturable individuals can be very informative because they are conducive to laboratory testing of microbial capabilities and processes that are likely to be important for coral health, but that are impossible to characterize using only phylogenetic analysis of total microbes. Second, total microbial populations associated with corals (including those not culturable in the laboratory) can be identified using genetic techniques. This type of analysis is labor intensive and expensive, and therefore not logistically suited for all reef organisms. This type of analysis, however, gives a comprehensive look at what type of microbes are present and may be best suited to the characterization of keystone reef corals or other invertebrates.

Misunderstanding Coral Stress and Disease

Current coral diseases, where pathogens have been identified, range from terrestrial fungi to marine bacteria. This suggests that the *putative* causative agents of marine diseases are much more complicated than just new invasive species. Do pathogens become pathogenic through a programmed adaptive process, or are they made pathogenic by the circumstances in which they end-up? If they become pathogenic, opportunistically or otherwise, then this suggests that bacteria are not the problem, but a symptom of a change in an environment making it more conducive to bacterial overgrowth or to microbial processes that trigger a chain of environmental effects. It is therefore likely that many different types of microbes can cause infection, given the opportunity.

One approach is to address the larger problem with as much interest as we address the one-pathogen paradigm. This includes not only addressing invertebrate symbiosis, but also water column or introduced microbes and their responses to environmental triggers. By learning more about the way microbes behave in their natural environment, in relatively *normal* situations and with the

addition of particular stressors, environmental data already being gathered can be integrated into a marine microbial processes model for the prediction of a potential for environmental degradation by opportunistic microbes.

Panel Discussion

Delaney: I would like to ask the four panelists to come forward please, take a seat and we will take some questions from the audience.

Gilman: My name is Sue Gilman. I am a citizen. I believe that I heard Dr. Salm say earlier today that diseased coral is not a problem in the part of the world where he works. Did I make that up? Is that correct? Is that interesting, I mean the fact that we have diseased corals and the coral there is not, is that interesting to science?

Causey: I will take a first shot at that and I think Terry will remember this, Rod probably will, but it seems like, anecdotally, it seems that things are happening in the Indo-Pacific about a decade, maybe a decade and a half, behind the trends that we follow in the Atlantic/Caribbean on coral bleaching and the appearance of diseases. We were having mass bleaching events in 1983, 1987, and 1990, and yet in Australia and the Indo-West Pacific, they had not had major bleaching events. We were on the heels of the 1990 bleaching event and, by the way, in between each of those bleaching events we had outbreaks of coral diseases. We had a workshop here in Florida in about 1991 and we brought in scientists from all over the world. Mark was one of the organizers of that conference and our colleagues from the Indo-West Pacific said this is a really nasty problem. It was an Atlantic/Caribbean problem at the time, and it was in 1992 I believe, Terry, when you had your first massive bleaching?

Done: There was some in the early nineties, but the big one was 1994.

Causey: The point being, that anecdotally, it seems like they are just starting to get some coral diseases showing up, and it is becoming more and more of an observation on the coral-list, and in the literature, that they are starting to see what we were seeing about 10-12 years ago. And if you look at what we saw in trends the other day, it almost seems like there is intensification spatially and temporally on these global impacts that we are seeing, and the corals are expressing those in diseases on the heels of stresses. Now, I can say that as a manager, but I don't think Kim is going to say that right now without more data.

White: David White with The Ocean Conservancy. Regarding marine reserves, we seem to be making – or were making a lot of progress with public dialogue and consensus on marine reserves, with a conference back in 1996 on marine reserves, sponsored by the state agencies, the Governor's Ocean Commission meeting in 1998, the stakeholder group with the Tortugas and the consensus agreement on that. This stands in contrast to the current state where the chairman of the Fish and Wildlife Conservation Commission has said in a public hearing that marine reserves go against everything the Commission stands for, and that the Memorandum of Agreement between the Fish and Wildlife Commission and the Park Service should not consider marine reserves as part of the fishery management plans for Biscayne National Park. There also has been the refusal so far of the National Park Service to even consider reserves or put them out for public review in Biscayne National Park as part of a general management plan. What happened? How did we go from building consensus and getting information on the table, and having a public dialogue about marine reserves, to a situation now where never again in the state of Florida will we even discuss marine reserves as part of ecosystem management in Florida state or federal waters?

Causey: Who is that for, David?

White: Anybody. [silence, followed by laughter from audience].

Recchia: I am pleased to be given this opportunity. Was it David – White? Was that? [laughter] Thank you for that question. I have to say that – I am frankly mystified by that because of course the Tortugas model is the one that is pointed to in Florida and around the country, and in fact, around the world, as a great stakeholder process. People have been saying – I have been working on marine protected areas for over a decade in Canada, in Australia, various sites around the world, and people always say that the most important ingredient for success with marine protected areas, including reserves, is effective public process. It's bringing the people together, putting in the science, the stakeholder perspective, involving everybody in the solution, which is the same thing that Billy was saying in his presentation earlier. And I think you can always look back and criticize some aspect of the Tortugas, learn how to do it better, but globally it is really pointed to as one of the first, best public processes. A similar process, in many respects, was undertaken in the Channel Islands, and a panel of scientists was directed to come up with a recommendation for marine reserves in the Channel Islands National Marine Sanctuary that would achieve two goals: conserve biodiversity and support sustainable fisheries. They did all kinds of studies. They assembled empirical data and they assembled as much data as they could get their hands on, frankly, and they came back with a recommendation of 30-50% and it needed to be representative and the other things that were talked about earlier today as basic principles. There was a complete breakdown of process that basically started then, and led to a lack of consensus at the end. There was consensus among many of the stakeholders in that process, but the recreational fishing members in particular violently objected to this kind of recommendation and distanced themselves effectively from the process. As a scientist, despite doing policy work now for a decade, I think I am still remarkably I. I think we just need to show them the data, and show them that these things work, and then everybody will say Oh, OK. Now we just need to work together to figure out how to do it. So, I guess that what I am wondering is, is what we are seeing is that people know things are bad and are so scared that they are afraid of the camel's nose under the tent, as one of my more colorful colleagues likes to say. They are afraid of the thin end of the wedge, they are afraid that groups like us really do want to shut down the ocean, or that if it starts it will get out of control, so we have to draw the line in the sand here. That's my best guess. It doesn't make sense to me, and I see it as counter-productive, at least I think that once we get an effective system of reserves in place, everything else will improve, including fishing. So my best guess is it is an ideologically based, fear-driven reaction that comes out of misunderstanding and mistrust – the kind of mistrust that was discussed earlier.

Causey: Thank you, Dr. Recchia, and if you don't mind, I'll just give a footnote on that. It's the boring part of what happens. It's the process, and I hate to talk process, but it is really critical, and that is what we learned the first time, some of our lessons learned. It's the participation and who you include in the process, and how you go about it. One of the bullets I had under process, and this is where we tend to fail up front, is when we come into the room with lines already on maps, and we're already starting to talk about how big, and then we come in and start asking people their opinions, and you immediately cut the communication. They become suspicious. They get polarized, and that was the lesson learned from the first time around. Up until the very last couple of meetings, I would not let them put lines on the maps, we wouldn't even talk about how big, and I can tell you what we ended up with was drawn up by the conservation community in one corner, sitting with the commercial fishermen, and they drew the line on that map and brought it to me, and had I spent a

year trying to pick out the best place, I could not have done a better job. So you can't over-estimate the importance of process. But what happened in California, and what my colleagues did in the Channel Islands was a tremendous effort to be all-inclusive. But what we have to realize, the story I just showed you here, what we did in the Tortugas was a culmination of over a ten-year process. What they tried to do in California was in two to three years. And I think it takes more time to get the information in front of people, it takes more time to build the trust, and to in fact be able to reflect that you are listening to those that are giving you the input. So it's process, process, process, and of course the science was critical.

Nancy Klingener: This is a question for each of you, and I am afraid it is going to involve some severe over-simplification, but I am going to ask it anyway. If you were to give us, and by that I mean all of us, a grade, at how we are doing at managing and protecting this ecosystem, (a) what grade would that be and (b) what is one suggestion you would have to improve that grade, and when I say "manage the ecosystem" I am not meaning How is Billy doing? How is Kacky doing? Because as far as I'm concerned we have two of the greatest resource managers in the country managing our Sanctuary. I mean how are all of us doing at protecting this resource?

Bertelsen: Well, with regard to Western Sambo, we have a very good grade there. The stated goals of this particular ecological reserve are being met, and in some cases exceeded, just for lobsters, for the fish formerly known as the jewfish [laughter], the corals and all of those sorts of things are doing very well. The jury is still out on the Tortugas Ecological Reserve. It's brand new – we haven't really had enough time. It takes about 5-10 years to start evaluating that one, but I am very pleased with what I am seeing in the Eastern and Western Sambos.

Recchia: I guess I would give a pretty good grade, maybe a B, on getting everybody together and really working these pretty effective and innovative inter-institutional management arrangements and so forth. I think the cooperative ties that have been forged among the various federal agencies and state agencies and everyone else are impressive. Having the Sanctuary Advisory Council and having those working groups,\ and that kind of process is impressive and a good model. I think the on-the-ground aspect, some things again are very good. I think a zoning approach is essential, and the Florida Keys was one of the pioneering sites for that technique, so again I think that's a good grade. I think the thing that causes my jaw to drop on a regular basis is – I am going to sound like a total broken record here – is the complete – the strength of the resistance to the concept of no-take reserves, which I just don't get, and it is not unique to the U.S. It's also seen in Canada, although perhaps in a less formal way. And I just don't understand that. I meant what I said in my comments earlier, which is the easy decision is to decide we need more of them, and we have to move forward. Let's get to the hard work of how we do that in a sensible, realistic and viable way. I would have to say, globally, I think the U.S. and the Florida Keys – the Florida Keys is a leader in the U.S., but the U.S. is lagging globally pretty seriously, and I would probably give a failing grade in that respect.
Ritchie: I can only speak about what I know, and I'm a microbiologist [laughter] but as far as my small baseline of data within the past eight months, I would give the Sanctuary down here an 'A' as far as working with scientists to get data to empower them to make decisions, and that's about all I can say.

Causey: Thank you, I will take that [laughter}. I would give some multiple grades. First, I think we have a 'B+' with the public here in the Keys, and the acceptance that we've gotten to with the public is important, and getting the public involved and focused on what's been going on has been a good grade. Our effectiveness, I would have to give us a 'C-'. And I would give it a 'C-' because we are

still having water quality problems, we're still seeing some resources decline, although we can celebrate some of what's happening in the fully protected areas, and some of the not-quite-so-fully protected areas. We are seeing some positive things, but still overall the trend continues to be downward. I think we are blessed in this corner of the world with 'A+' group of scientists, and we are blessed in this part of the world with an 'A+' group of educators that care about what's going on, and the room is full of them, particularly over here, today, and I think we have to give us as a community those positive grades – and over here [laughter] as far as educators and people that are involved, but definitely I think there are multiple things we have to grade ourselves on, but as far as the resources and what we need to do, we have a lot of work.

Delaney: Very thought-provoking question, Nancy, and can you join me in thanking our panel one more time. [applause].

Causey: That's right – I get to do the contingent surprise. Well, it may not be a surprise. First of all, I want to thank all of you. This has been an incredible audience, you all need a round of applause – let's applaud you [applause]. I want to thank each and every one of you, and I want to thank each and every one of our speakers. I am not going to go through each and every one of them, but those that are here, please hear my heartfelt thanks for coming from Down Under, for Way Over Yonder, to come and share with us your experiences. I also want to thank the Sanctuary team. I am blessed, and Kacky, my partner, we are blessed with some of the best, hardest working people in public service, and if you will, all of you, come up here that have been here, come on, we don't have much time, come on Robbie, come on Joanne, Nancy, Joanne we have something for you. [applause]. Heidi, where is Heidi? We'll give these to all of you if we can. Alright, and I also want to thank our Sanctuary Advisory Council. We have had some members stay here during the whole time. I recognized them the other day, but I want to thank all of you for staying with us and listening. We heard a lot about the connectivity of people who work, live, and play here in the Florida Keys and the coral reef environment of the Florida Keys. However, I want to stress over the last two-and-a-half days the importance of re-energizing the connectivity between managers and scientists. I feel like I am going away with a lot more information than I came with. I feel more blessed as a result of hearing from some experts from around the world, come and share with us. But I also want to emphasize the connectivity that we have made in reaching others. People kept asking over the last couple of days Is the right audience here? Are you getting your points across, do you think? And I want to say that I am very grateful that we have had members of the public come out, but I also want to say that we have had the Marine Resources Development Foundation – Art, you and your crew, thank you for bringing them down. We have had folks from SeaCamp here, we have had DeeVon Quirolo of Reef Relief here, and Michael, I had him earlier on my list, and we have also had all the folks from Mote Marine Laboratory, another science education facility, and I want to say "That's the connectivity." That's where it goes exponential, when we're taking the science and the management and getting it out to the public in various ways. I also want to thank the media that have been here. We have had some reporters here taking notes and getting the stories out, I haven't even had a chance to see all of them, but I just want to thank you, because that is connectivity between what you have been hearing and where we hope to go. Over the last two days we have attempted to demonstrate the connectivity, and you watched this down to the very last presentation, from the global sense, from the very remote sense, from satellite remote sensing techniques, down to the on-the-water, in situ, in the water monitoring, all the way down to microbial life, and the focus of this is that it is all connected, and all along the way we influence it in various ways. People influence it one way or the other all the way down to the microbial scale. I want to also stress that it is going to be in each of us, the solutions are going to lie in what we do after leave here, and the

messages we take home, and those we spread with our neighbors and other managers and educators, but it is going to be up to each of us to make a difference in the long term. From this conference Dr. Keller is going to be assembling a paper, a report, he has to do an annual report, and I think you're looking at this as already done, right? [Brian laughs heartily, then everyone else joins in]. So he is going to be assembling an annual report consisting of abstracts, but the bad news, we haven't told anybody this, but we are going to get some abstracts and put those together, but take this in a synthesized form and get that out to the public, and get it out to other managers and scientists. And I really want us to thank Fiona one more time. [face-reddening applause and hooting] Thank you once again, and Dr. Keller, do you want to add anything? We are adjourned, and those of you that are joining us for lunch, it's in front of the ballroom.

Concluding Remarks

Brian D. Keller and Fiona C. Wilmot

Was this colloquium successful at "connecting the dots" among science, people, and policy in the Florida Keys National Marine Sanctuary? Do we understand the complex coral reef ecosystem of the Florida Keys well enough to take additional management actions beyond those implemented in 1997 and 2001? If not, have we identified information gaps that need to be filled to help inform sanctuary managers? Or will we do little more than carefully document a coral reef ecosystem on the "slippery slope to slime" (Pandolfi et al. 2005)?

The Florida Reef Tract has lost most of its live coral over the past 30 years (see Gardner et al. 2003), has lost most of its grouper and snapper (e.g., Ault et al. 2005), lost most of its *Diadema* in 1983 and 1991 (Lessios et al. 1984; Forcucci 1994), loses most legal-sized spiny lobster each year (Cox and Hunt 2005), has lost most of its queen conch (Delgado et al. 2004), has lost most of its sea turtles, and is visited by millions of people every year (Johns et al. 2003). These are but some of the "shifted baselines" (Jackson et al. 2001) of the Florida Keys. Additional, anecdotal observations include widespread loss of crinoids (feather stars), loss of corallimorphs from some areas, loss of ornamental fishes such as rock beauties, and increased turbidity. Against this background of losses and changes can a marine protected area "turn things around" and help restore a more "naturally functioning" marine ecosystem? As Steven Miller showed in his plenary presentation (Shifting Baselines), we have a long way to go.

Cheri Recchia (Management Tools) may have summed things up pretty well when she observed that the level of protection provided by the FKNMS has not, to-date, been demonstrably effective sanctuary-wide, in part because many stressors operate on a larger scale than the sanctuary can manage, but perhaps also because stressors operating within the sanctuary are not yet adequately addressed. The factor that can be managed locally with considerable effectiveness – overfishing and other extraction of living marine resources – is presently done across only 6% of the sanctuary, and approximately 90% of this high level of protection is in the Tortugas Ecological Reserve, as discussed by Billy Causey (Management Tools). The rest of the fully protected zones within the FKNMS are mostly small Sanctuary Preservation Areas, which were designed to reduce human-use conflicts, not to protect large, contiguous areas of the ecosystem.

This spatial scale of protection probably is not adequate for restoration of heavily fished predator populations across significant areas of the Florida Keys, which is necessary to help re-establish a key ecosystem process – trophic cascades. As Terry Done discussed in his plenary presentation, the proportion of fully protected zoning within the Great Barrier Reef Marine Park recently increased from 4% to 33%. The U.S. Coral Reef Task Force set a goal of no-take protection of 20% of U.S. coral reefs by 2010 (http://www.coralreef.gov/), which seemed a bit radical several years ago but now seems rather conservative. For example, the largest marine protected area established to-date worldwide, the ~ 360,000-km^2 Papahānaumokuākea Marine National Monument surrounding the Northwestern Hawaiian Islands, will be a fully protected marine reserve in its entirety. This is an area as large as 36 Florida Keys National Marine Sanctuaries!

In addition to considerations of the spatial scale of protection is the time frame required for demonstrable changes within marine protected areas. For example, increased coral recruitment rates recently were documented in the Exuma Cays Land and Sea Trust in the Bahamas after 20 years of protection, associated with a net increase in herbivory by fewer, but larger parrotfish (Mumby et al. 2006, 2007). A similar time frame appears to apply in the Philippines for fishery benefits of a marine reserve (Russ et al. 2004). It may be difficult to maintain this level of patience with marine reserves in the State of Florida, the "Fishing Capital of the World," as discussed from various perspectives by the panel assembled by Jerry Ault (Connectivity between People and Marine Fishery Resources).

The sessions on regional connections and climate change highlighted the larger-scale phenomena that impinge on sanctuary management actions, which necessarily occur on a local scale. Frank Muller-Karger and colleagues (Regional Connections) noted the wide range of influences the FKNMS experiences: from freshwater discharges of the Everglades, rivers emptying into the western and northern Gulf of Mexico, and local oceanic circulation features to the significant impacts of the water and other materials carried from the Caribbean and Gulf of Mexico into the Atlantic by the Loop Current. Local-scale physical connectivity can bring negative influences such as blackwater phenomena (Chuanmin Hu and Frank Muller-Karger, Regional Connections) as well as the potentially positive effect of retention of larvae (Libby Johns and colleagues, Regional Connections). Interestingly, we learned from Tracy Villareal (Regional Connections) about connectivity between the eastern and western Gulf of Mexico, with an artificial reef "stepping stone" of 4,000 oil production platforms utilized by barracuda and other organisms.

Global climate change is exerting an unprecedented set of physical environmental influences and associated ecological changes that require us to re-think and modify some of our approaches to conservation, as outlined by Lara Hansen (Climate Change). These include protecting adequate and appropriate space, limiting all non-climate stresses, using adaptive management and testing strategies now, and reducing greenhouse gas emissions to slow the rate and extent of climate change. If this final recommendation is not undertaken with vigor, all other actions likely will be little more than "buying time."

It is imperative for resource managers to be aware of the influences of "externalities" such as regional-scale connectivities and climate change. Furthermore, it is fundamentally important to monitor ecosystems so that managers are aware of spatial and temporal patterns of variation even though we often do not understand their causes. For example, the long-term coral reef monitoring data set discussed by the late Carl Beaver and colleagues (Coral and Seagrass Habitats) shows the decline in cover of live coral in recent years based on 40 sites. Broader-scale assessments are being conducted by Steven Miller and colleagues across hundreds of sites, additional coral reef and hard-bottom habitat types, and inside and outside of fully protected marine zones, and have highlighted the significance of patch-reef environments for relatively healthy and abundant coral colonies. Kim Ritchie's research (Resource Conditions) is improving our understanding of the role of microbial communities within coral mucus for the health and susceptibility to diseases of various corals. The causes of marine diseases may be much more complicated than just new invasive species, and managers need the findings of this kind of research to help understand why coral

communities on patch reefs are doing so much better than on fore reefs. Ironically, most research on coral reefs has focused on the fore reef (but see Lirman and Fong 2007).

Monitoring of seagrasses is showing managers the value of these species and algae as an "early warning system" for signs of eutrophication. Jim Fourqurean (Coral and Seagrass Habitats) also discussed regional variation in these signs, showing that management actions within the FKNMS should be relevant – possibly additional wastewater treatment in the lower Florida Keys beyond the advanced treatment and deep-well injection that has been implemented in Key West. As Steven Miller discussed (Water Quality), upwelling can be a major source of nutrient inputs, at least along the outer reef tract, indicating that some patterns of variation in nutrient availability are not amenable to management actions. Furthermore, water quality monitoring described by Joe Boyer (Water Quality) noted likely advection of nutrients into the FKNMS by large-scale oceanographic processes as well as possible nitrogen fixation in shallow, nearshore environments, particularly along the Gulf of Mexico side of the lower Florida Keys. All these studies collectively highlight the inherent complexity of processes affecting nutrient availability and the difficulty of reversing the degraded water quality that appears to have developed over the years in the Florida Keys. As Stephen Frink (Human Perspectives) noted: "Water quality is a massive issue" in the Keys. It seems that human influences need to be managed on the scale of the Gulf of Mexico as well as in the Keys.

Nevertheless, the millions of people who visit the Florida Keys each year must think the water is just fine, based on the remarks by Daniel Suman (Human Perspectives). They most likely are not aware that queen conch cannot reproduce in nearshore waters, although offshore water quality favors their sex drive (Bob Glazer and Gabe Delgado, Water Quality). Nor do they know about the recently discovered virus killing juvenile spiny lobster (Mark Butler and colleagues, Resource Conditions) or the pressing need for restoration of Florida's coral reefs (Martin Moe and Ken Nedimyer, Resource Conditions). Visitors to natural and artificial reefs spent 2.5 million person-days in the Keys in 2001 (Manoj Shivlani, Human Perspectives). "Our nearshore waters also offer a wonderful window on a fascinating marine environment for even the most timid adventurer" (Peter Ilchuk, Human Perspectives).

Rod Salm's plenary presentation provided a ray of hope to coral reef managers by describing ways to apply the concept of resilience to management approaches The theme of resilience also appeared in Terry Done's plenary presentation about the FKNMS "sister system" in Australia and in Lara Hansen's talk (Climate Change); since the colloquium, the *A Reef Manager's Guide to Coral Bleaching* (Marshall and Schuttenberg 2006) has been published. In addition, Rod Bertelsen (Management Tools) discussed the use of acoustic telemetry to help guide the design of marine protected areas around patterns of utilization by animals such as spiny lobster. Finally, Kim Ritchie (Management Tools) highlighted the need for managers to understand the role bacteria play in coral resistance to stress and disease, which could lead to new management actions in the future.

We would like to conclude with a quote from Elliott Norse's keynote address, which provided a challenge to us all: "I have a sense that the Florida Keys National Marine Sanctuary is a microcosm of all of the problems we are facing and it will be – or it might be – the place where we come up with the solutions. I have a feeling that at least we have a fighting chance."

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