Atlantic Oceanographic and Meteorological Laboratory

Ocean Chemistry and Ecosystems Division

March 2014

Disclaimer

Cover photograph: Florida Bay (courtesy of Christopher Kelble)

The Ocean Chemistry and Ecosystems Division

The Ocean Chemistry and Ecosystems Division (OCED) is an interdisciplinary team of scientists working in support of NOAA's mission to understand our oceans and coasts, aid conservation and management of marine ecosystems, and predict changes to these valuable resources. We focus on the forces and stressors that cause ecological responses and work on scales spanning from the local to the global. The Division works on a variety of important topics including the global rise of oceanic CO_2, the ability of our ecosystems to support marine life, the safety of our coastal waters, and the health of coral reef ecosystems here and across the globe. Projects fall under these general themes:

- *Carbon Program: Understanding the ocean's role in removing excess carbon dioxide caused by the burning of fossil fuels.*
- *Ocean Acidification: Understanding the process of ocean acidification and the consequences to marine life.*
- *Coral Reef Research: Assessing environmental changes and the local and global consequences to coral reefs.*
- *Ecosystem and Coastal Oceanography: Managing coastal resources based on an understanding of the ecosystem as a whole.*
- *Land-based Sources of Pollution: Assessing the impacts of land-based sources of pollution flowing into the coastal ocean.*
- *Molecular and Environmental Microbiology: Development and application of molecular assays and sensors to quantify and diagnose the sources of microbial contamination and to track changes in microbial diversity and function.*

OCED conducts projects in an integrated fashion and in close collaboration with our partners (intergovernmental, academic, international, and NOAA). The OCED team includes scientists from the Rosenstiel School of Marine and Atmospheric Science (RSMAS) and the Cooperative Institute for Marine and Atmospheric Studies (CIMAS) of the University of Miami and institutions that include nine of South Florida's and the Caribbean's premier universities. The scope and direction of research is guided by strategic plans developed by NOAA as a whole and by NOAA's Office of Oceanic and Atmospheric Research (OAR). The following pages provide brief descriptions of OCED's research projects and associated personnel. For additional details, please contact the relevant investigators.

National Oceanic and Atmospheric Administration (NOAA)
Atlantic Oceanographic and Meteorological Laboratory (AOML)
Ocean Chemistry and Ecosystems Division (OCED)
4301 Rickenbacker Causeway, Miami, Florida 33149
305-361-4380 http://www.aoml.noaa.gov/ocd

OCED Staff and Administration

Dr. James Hendee, Director (Acting)
Dr. Thomas Carsey, Deputy Director
Dr. Kelly Goodwin, Strategy Execution and Evaluation
Mr. Esa Peltola, Budget
Ms. Emy Rodriguez, Division Administrative Assistant

Research Scientists

Natchanon Amornthammarong	CIMAS/UM
Leticia Barbero	CIMAS/UM
Thomas Carsey	NOAA
Geoffrey Cook	CIMAS/UM
Ian Enochs	CIMAS/UM
Maribeth Gidley	CIMAS/UM
Kelly Goodwin	NOAA
Lewis Gramer	CIMAS/UM
Kevin Helmle	CIMAS/UM
James Hendee	NOAA
Rubin van Hooidonk	CIMAS/UM
Paul Jones	CIMAS/UM
Kelly Kearney	MBF/UM
Christopher Kelble	NOAA
Derek Manzello	NOAA
Denis Pierrot	CIMAS/UM
Xaymara Serrano	NRC
Christopher Sinigalliano	NOAA
Jack Stamates	NOAA
Richard Wanninkhof	NOAA
Jia-Zhong Zhang	NOAA

Research and Operations

George Berberian	CIMAS/UM
Joseph Bishop	NOAA
Renee Carlton	CIMAS/UM
Robert Castle	NOAA
Michael Doig	NOAA Corps
Charles Featherstone	NOAA
Charles Fischer	NOAA
Pamela Fletcher	NOAA
Betty Huss	NOAA
Michael Jankulak	CIMAS/UM
Graham Kolodziej	CIMAS/UM
Rachael Kotkowski	NOAA Corps
Esa Peltola	NOAA
Michael Shoemaker	NOAA
Kevin Sullivan	CIMAS/UM
Lindsey Visser	CIMAS/UM

Administration

Emy Rodriguez	NOAA

CIMAS/UM: Cooperative Institute for Marine and Atmospheric Studies, University of Miami
MBF/UM: Marine Biology and Fisheries, University of Miami
NOAA Corps: NOAA Commissioned Corps Officers

Index of Project Pages

*POC: Point of Contact.

GOSHIP Repeat Hydrography/CO_2 Inventories

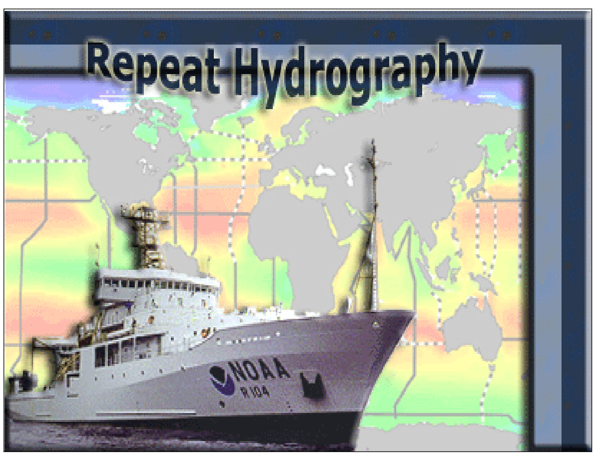
POC: Jia-Zhong Zhang

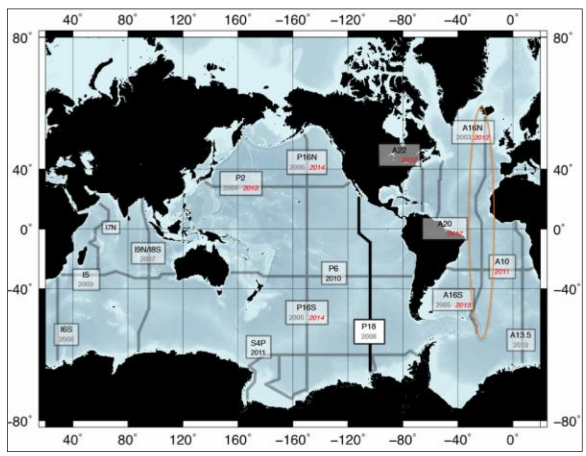
The International Global Ocean Ship-based Hydrographic Investigations Program (GOSHIP, http://goship.org) is a multi-disciplinary international program that occupies selected trans-basin sections on decadal timescales to document changes in heat, fresh water, carbon, nutrients, oxygen, and trace gases in the ocean. The work is executed in each major ocean basin by NOAA and NSF funded-investigators using NOAA and UNOLS vessels (see graphics of cruise track below). Ship-based hydrography remains the only method for obtaining high-quality, high spatial, and vertical resolution measurements of a suite of physical, chemical, and biological parameters over the full water column. The foci are to quantify increases in anthropogenic carbon content and natural and climate induced changes in chemical and hydrographic features in the ocean to determine:

- The distributions and controls of natural and anthropogenic carbon.
- Uncertainties in global fresh water, heat, and property budgets.
- Ocean ventilation and circulation pathways and rates using chemical tracers.
- The variability and controls in water mass properties and ventilation.
- The changes of a wide range of biogeochemically and ecologically important properties in the ocean interior.

Major discoveries to date have been the accurate determining of heating of bottom water and a small increase of carbon in the deep ocean. The program has also quantified increases of CO_2 in surface and intermediate water and its effect on ocean acidification.

A key aspect of the program is open and rapid dissemination of data for utilization by the community at large. Program details can be found at www.go-ship.org and datasets are available at: cchdo.ucsd.edu/ and cdiac.ornl.gov/oceans/.





Left: NOAA R/V Ronald H. Brown is used for the NOAA component of the repeat hydrography effort.
Right: The sections occupied in the 2004-2015 time frame as part of the US program jointly sponsored by NSF and NOAA.

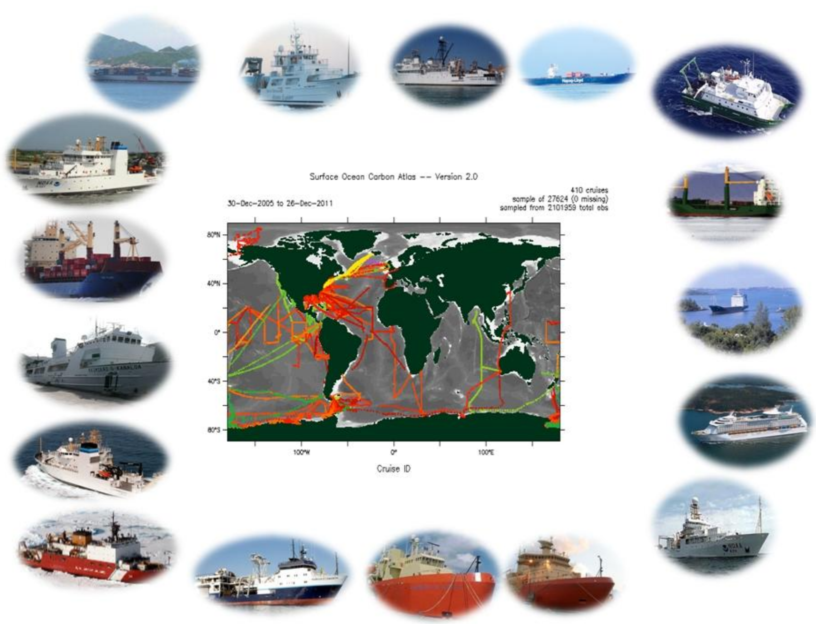
Quantifying Sea-Air CO_2 Fluxes Using Surface Water CO_2 Measurements from Ships of Opportunity

POC: Denis Pierrot

The global ocean takes up approximately one quarter of the anthropogenic CO_2 released each year but the patterns of uptake and release of CO_2 by the ocean vary in time and space. To quantify the fluxes on seasonal and regional scales NOAA operates the largest automated measurement campaign of surface water CO_2 from ships of opportunity in the world (SOOP-CO_2) (see graphic below). The data have been used to create the iconic global ocean sea-air flux maps under leadership of T. Takahashi of LDEO/Columbia U. The objectives of this sustained effort are:

- Produce CO_2 data at sufficient accuracy to constrain sea-air CO_2 fluxes to 0.2 Pg C yr^{-1}.
- Facilitate capacity building through instrumentation and data reduction guidance to attain a global network of SOOP-CO_2.
- Create CO_2 flux maps and related data products.

The data from our group and four other groups sponsored by NOAA's Climate Observation Division of the Climate Program Office is provided to the lab of Dr. Takahashi for incorporation in his global dataset. Furthermore, we provide our data to the Surface Ocean Carbon Atlas (www.socat.info), a group endorsed by the International Carbon Coordination project (www.ioccp.org), and work with this effort to provide expert input on instrumentation and data acquisition. We have also helped to design and develop a state-of-the art automated surface water CO_2 instrument produced by General Oceanics, Inc. which is used worldwide.



Ships utilized in the SOOP-CO_2 effort and their track lines over the past years.

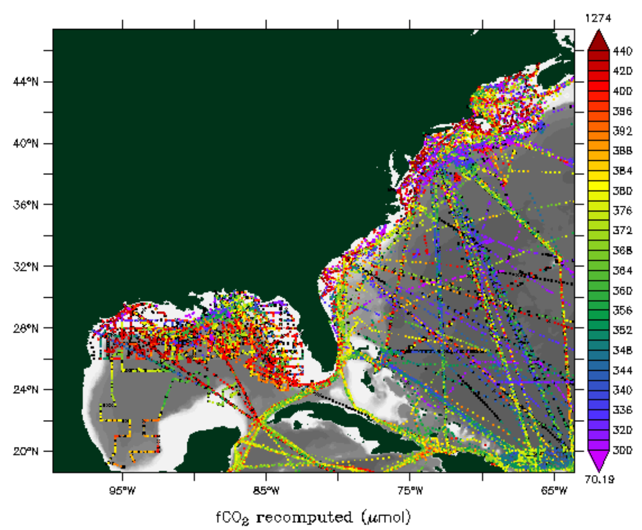
Oceanic, Coastal and Estuarine Ocean Acidification Observing Networks: North Atlantic Ocean, East and Gulf Coast

POC: Leticia Barbero

In this project we are developing the North Atlantic Ocean, East and Gulf Coast ocean acidification (OA) observing system in response to the requirements of the Federal Ocean Acidification Research and Monitoring (FOARAM) Act. The observing system will be used to determine patterns and trends in key geochemical indicators of ocean acidification. The observing network of the East and Gulf Coast is based on the following elements:

- Surface water measurements using autonomous systems on seven ships of opportunity (SOOP-CO_2) (see figure below).
- Dedicated Gulf of Mexico and East Coast Carbon (GOMECC) cruises with surface and subsurface measurements from the NOAA R/V *Ronald H. Brown*. This will improve process level understanding of the controls on ocean acidification.
- Moorings with autonomous instruments to determine the rapid temporal changes and causes thereof.
- Continued development of the observing system with new instrumentation and protocols.

AOML leads the SOOP-CO_2 effort and the dedicated research cruises along the East and Gulf coasts. PMEL and academic partners maintain three moorings that are an integral part of the effort. The scientific component includes analysis of total alkalinity and dissolved inorganic carbon samples taken from the SOOP and mooring efforts. Data reduction, quality control, and data management of the large data sets are a critical component of the observing system. This is done in coordination with S. Hankin of PMEL and H. Garcia of NODC. Data products and algorithms to extrapolate the OA indices in time and space will be developed as part of the effort.

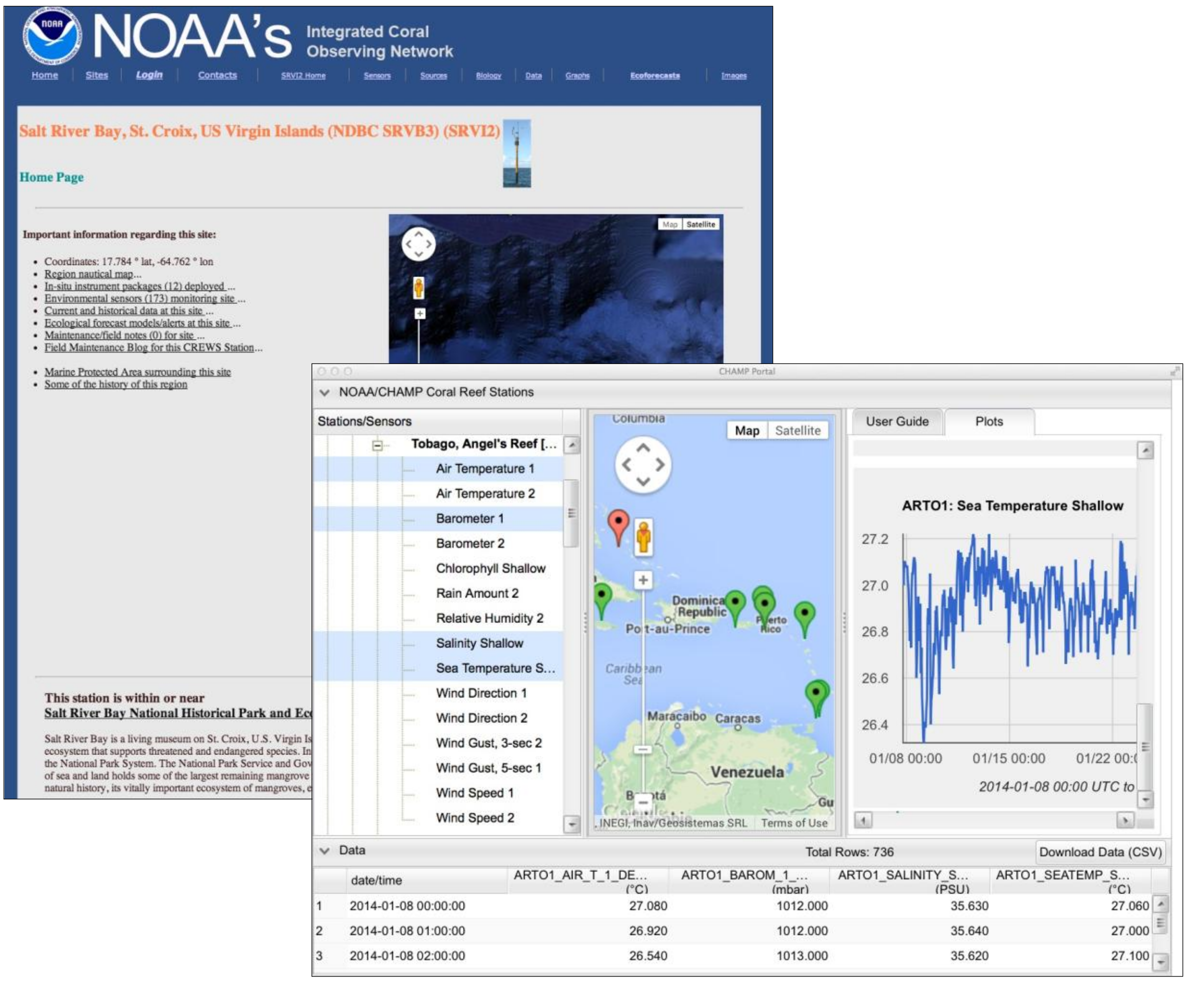


Cruise tracks of all the ships under the AOML SOOP-CO_2 effort that are contributing data in support of the OA observing system.

Integrated Coral Observing Network

POC: James Hendee

The Integrated Coral Observing Network (ICON) is a web presence that highlights the integration of satellite, in situ, modeled, and other sources of meteorological and oceanographic data in near real-time, for the purpose of eliciting ecological forecasts for coral bleaching and oceanographic events (e.g., onshore flux), with the capability to extend to other marine environmental events (e.g., fish and invertebrate spawning, migrations, etc.). These ecological forecasts (or "ecoforecasts") are aimed at informing policy and enforcement decisions, and furthermore require field validation, thus providing a focal point for ongoing collaborations between NOAA, academic partners, and coral reef Marine Protected Area managers. The ICON program currently monitors over 120 coral reef sites around the world. Plans are underway to greatly expand this number of monitored sites.



Two views of data and information output from the ICON Ecological Forecast web site.

The Coral Reef Early Warning System

POC: James Hendee

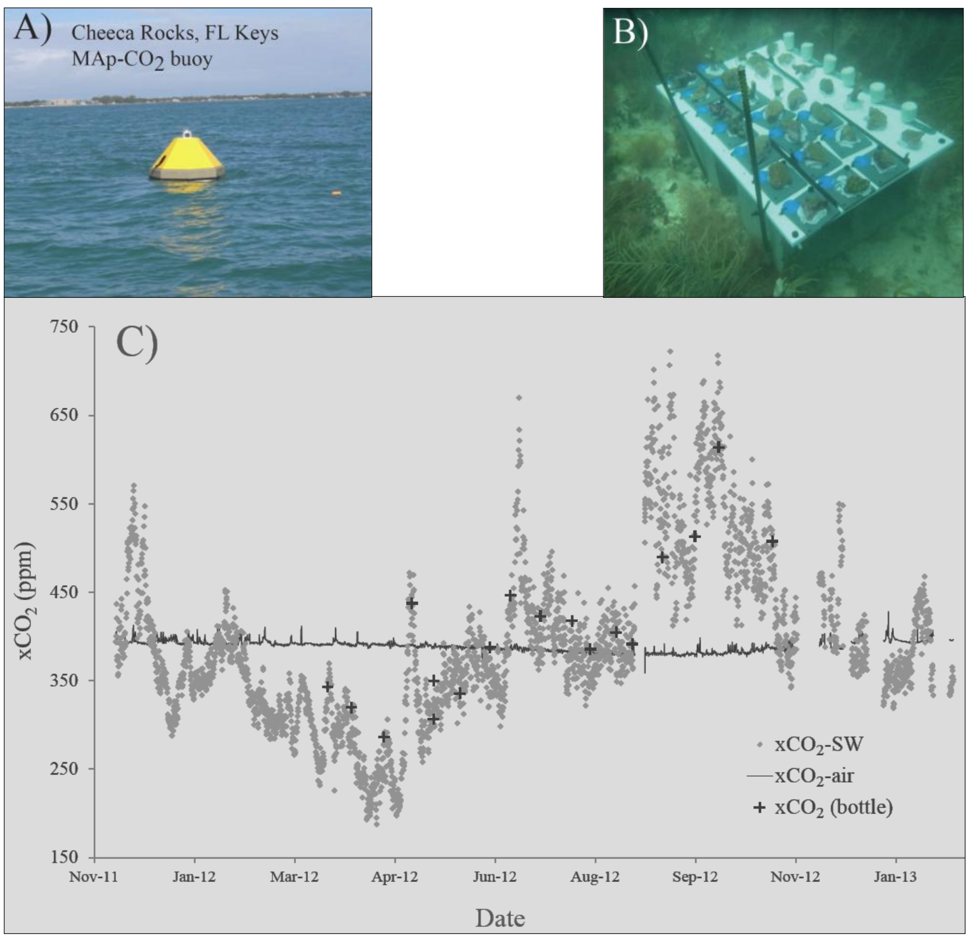
The Coral Reef Early Warning System (CREWS) was originally the AOML-developed software that now forms the basis of the ICON data integration and ecoforecasting system. The software system was developed at the same time robust environmental monitoring stations were being engineered and deployed for coral reef ecosystems. The stations came to be called “CREWS stations” and are currently deployed in Puerto Rico, St. Croix, Port Everglades (Florida), Cayman Islands, and Saipan, but have also been deployed in Jamaica (destroyed by hurricane), and the Bahamas (decommissioned). Six new CREWS stations are scheduled for deployment throughout the Caribbean (Belize [two], Barbados, Trinidad and Tobago, and the Dominican Republic [two]) as part of a collaborative effort with the Caribbean Community Climate Change Center headquartered in Belize.

Clockwise, from left: A CREWS station at La Parguera, Puerto Rico; a MAP-CO2 buoy, deployed by CREWS and PMEL personnel; installing meteorological instruments at the CREWS station in Little Cayman, Cayman Islands; installing a CREWS station at Lao Lao Bay, Saipan.

National Coral Reef Monitoring Plan and Ocean Acidification Program

POC: Derek Manzello

OAA's Coral Reef Conservation Program (CRCP) has recently initiated the National Coral Reef Monitoring Plan (NCRMP) to measure the status and trends of the nation's coral reef ecosystems. At AOML, NCRMP, in partnership with NOAA's Ocean Acidification Program (OAP), is monitoring the status and trends of climate change and ocean acidification (OA) on U.S. coral reefs. In addition to long-term physical and chemical monitoring, this project is also monitoring the ecosystem impacts of OA over time. The primary ecosystem impacts being monitored at select sites include reef metabolic performance (net ecosystem calcification, net community productivity), species-specific rates of coral growth and calcification, bioerosion, high-resolution and digitally archived annual benthic characterizations, reef framework cementation and architectural complexity, and biodiversity of cryptofauna. This work incorporates the Atlantic Ocean Acidification Test-Bed (AOAT), which, in collaboration with academic and other governmental partners, tests and improves current and newly developed methodologies to understand and interpret the effects of OA on coral reefs.



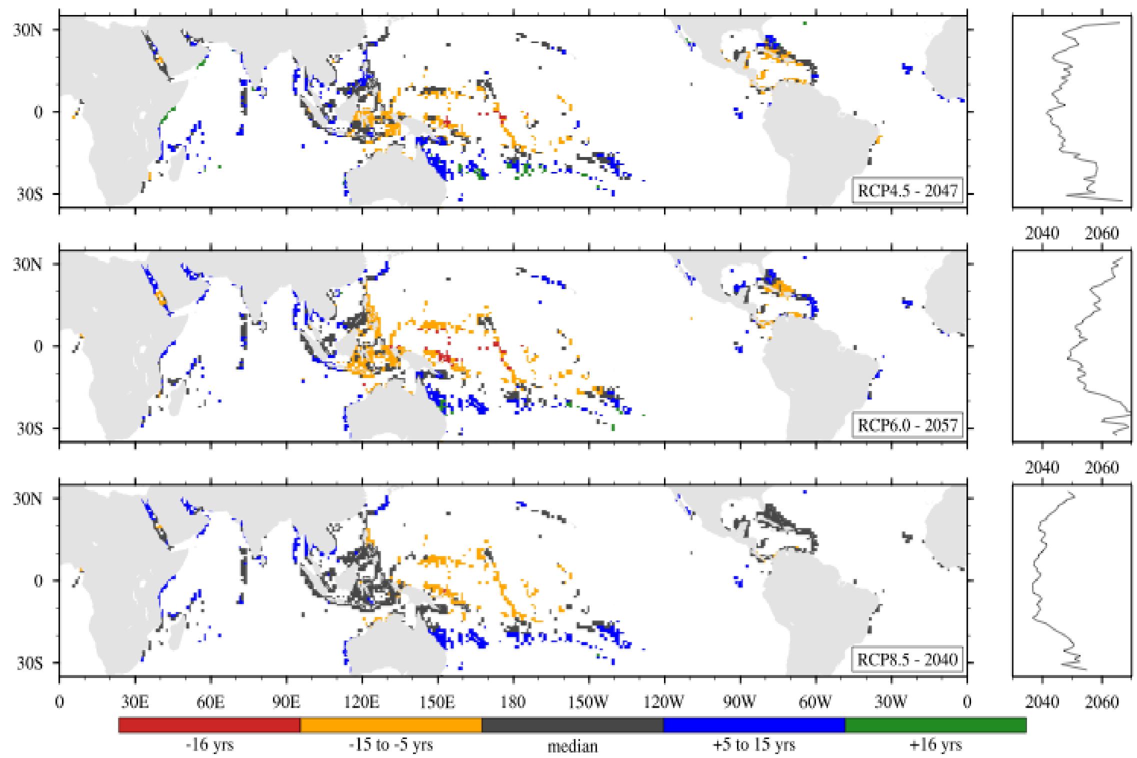
A: Moored-autonomous pCO$_2$ (MAp-CO$_2$) buoy at Cheeca Rocks, Florida Keys. The MAp-CO$_2$ buoy measures CO$_2$ in air and seawater. B: Coral samples being measured for growth rates. C: Annual cycle of air and sea pCO$_2$ at Cheeca Rocks from Dec 2011 to Jan 2013.

Global Modeling and Coral Bleaching

POC: Ruben van Hooidonk

Coral reefs face two potentially devastating threats from climate change. Ocean acidification reduces growth and resilience, while rising temperatures cause bleaching and mass mortality. Using state-of-the-art, fully-coupled climate models, both the stresses of bleaching and ocean acidification on coral reefs are analyzed globally. When these model results are combined with empirically-derived thresholds (species specific tolerances), powerful projections of local reef futures can be made.

Assuming carbon emissions remain on their current path, the results show that most of the world's coral reefs (74%) are projected to experience coral bleaching conditions annually by 2045. However, there is great spatial variability in the onset of annual bleaching.

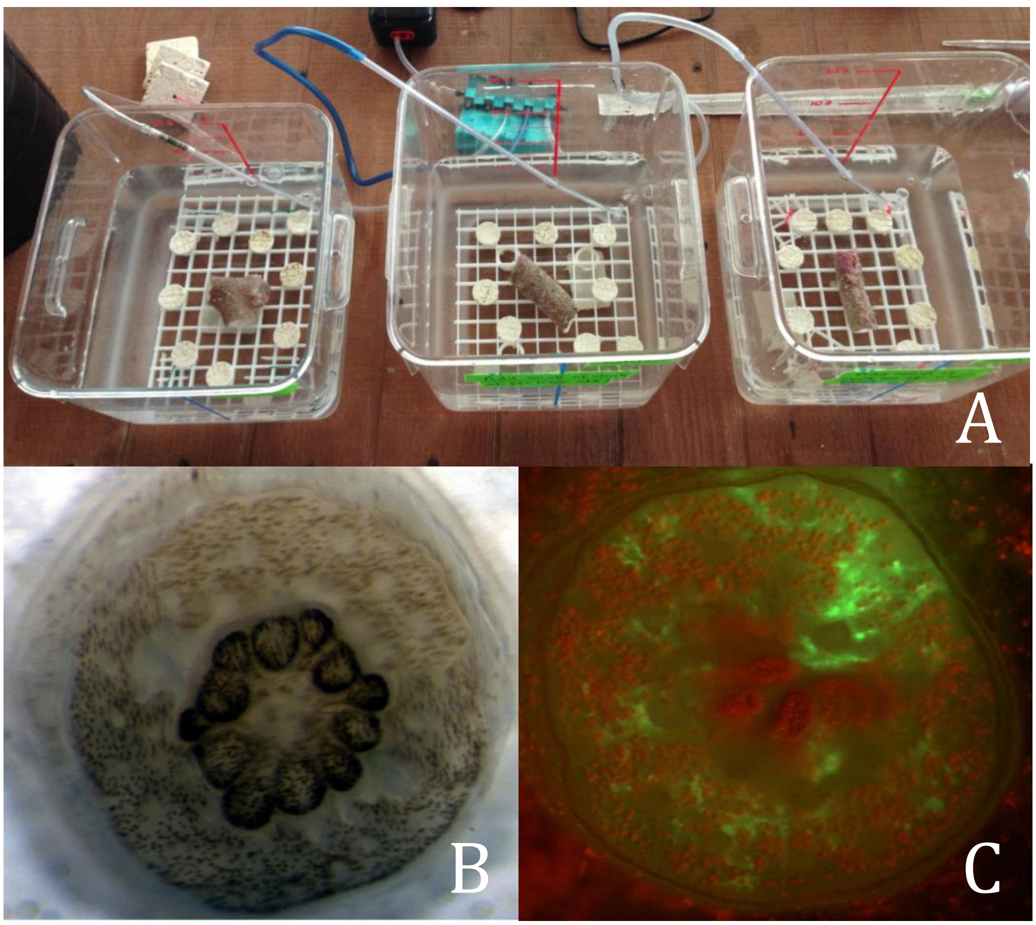


Global projections of the year annual bleaching conditions start for all reef locations. On the left, maps for three emission scenarios (RCPs) show the years that reef locations start to experience bleaching conditions annually (color scale); median values are shown next to the RCP labels. Zonal means are shown on the right.

Synergistic Effects of Eutrophication and Elevated Sea Surface Temperatures in Caribbean Reef Corals

POC: Xaymara Serrano

Recent evidence suggests that corals which regularly experience poor water quality conditions seem less resistant to thermal stress. This research aims to assess the thermal sensitivity of newly settled recruits of two Caribbean reef corals with contrasting life-history reproductive strategies (*Orbicella faveolata* and *Porites astreoides*), after exposure to various nutrient levels (including levels ecologically relevant). An array of molecular and ecological techniques will then be applied to: (1) quantitatively monitor how coral recruits change the density of their symbionts in response to changes in nutrients and how these changes subsequently affect thermal tolerance; (2) assess how bleaching susceptibility may depend on the genetic identity of the coral or its algal symbionts; and (3) monitor the photosynthetic efficiency of nutrient-enriched coral recruits (reduction in photosystem II quantum yield) prior to, during, and after thermal stress.



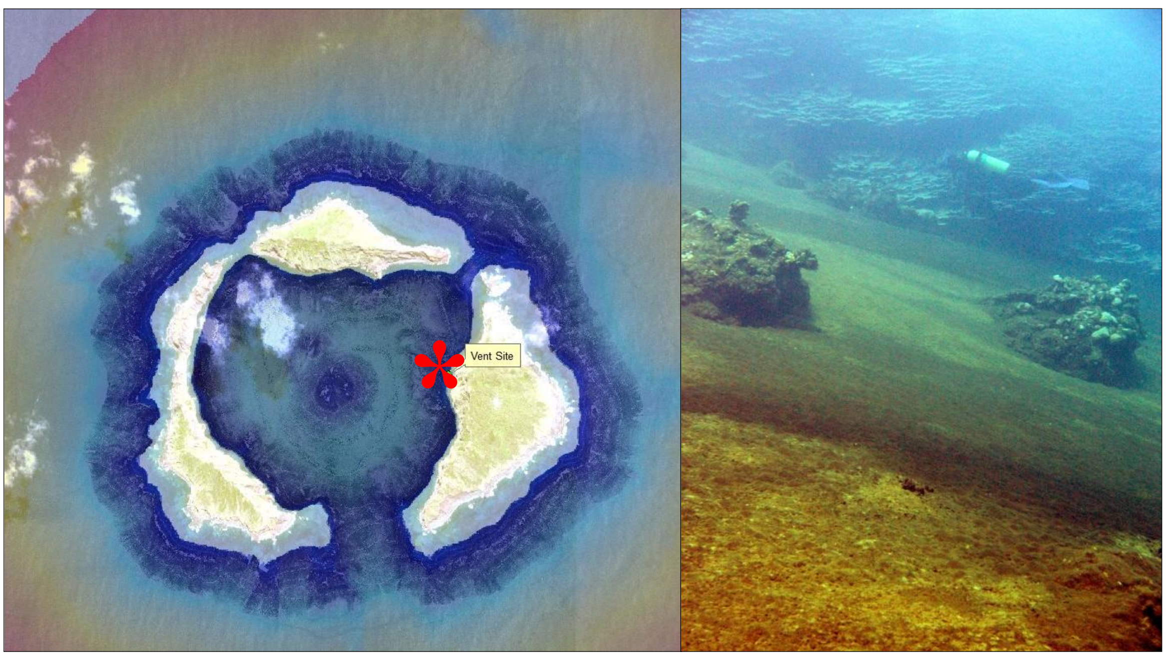
A: Coral recruits (in settlement tiles) exposed to two different nutrient levels (5 and 10 µM NO3) and control conditions. B and C: Coral recruits after exposure to 10 µM NO3 for 3 weeks and observed in the microscope with (C) or without (B) fluorescence. Algal symbionts can be seen as brown (B) or red (C) spots in the photographs.

Rare Reefs in an Ocean Acidification Hotspot at Maug Island, CNMI

POC: Ian Enochs

Maug Island, CNMI (Commonwealth of the Northern Mariana Islands) is one of the few places in the world, possibly the only location in US waters, where CO_2-rich gas from subterranean sources naturally increases seawater acidity for surrounding reefs. The purpose of this project is to use unique equipment previously designed and built at AOML to spatially and temporally characterize the carbonate chemistry of this important ecosystem and to pair these data with benthic cover. This information will increase awareness and understanding of one of the rarest US reef ecosystems and will allow scientists and managers to understand how ocean acidification will alter ecosystem health and productivity.

We will utilize unique custom instrumentation developed at AOML to measure gradients in carbonate chemistry in real time. The Mobile CO_2 Analyzing Tool (M-CAT) will be used to create high-resolution maps of the carbonate chemistry surrounding the Maug Island site. In order to characterize temporal dynamics, high resolution SeaFET pH loggers, ECO-PAR loggers, and a Pro-Oceanus pCO_2 instrument will be deployed along this spatial gradient. Collaborating partners from the CNMI Division of Environmental Quality's (DEQ) benthic monitoring team will help to characterize reef community structure in the impacted area. The synthesis of these spatially-linked data will allow inferences into the impact of ocean acidification on reef ecosystems.



Left: GIS basemap of Maug Island with depth and multibeam data overlayed. Vent site indicated with red asterisk. Right: Photograph showing vent site in foreground and a diver investigating reef framework in the distance (courtesy of C. Young, NOAA CRED).

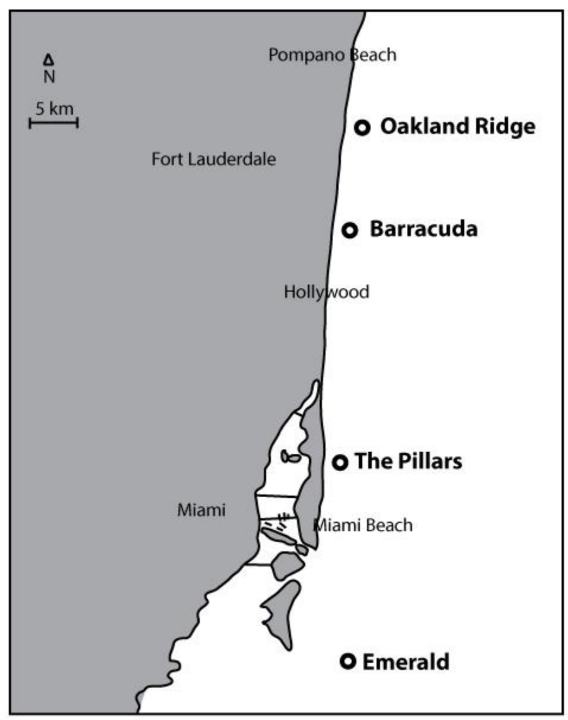
Influence of Nutrients on Southeast Florida Reefs

POC: Ian Enochs

There is strong evidence that nutrient enrichment can affect the benthic composition of a reef ecosystem, and the mechanisms behind nutrient-associated reef degradation are numerous. For example, high nutrient levels can influence calcification and reduce skeletal density, decrease coral growth, reduce the reproductive success of certain coral species, and directly increase coral mortality. Furthermore, elevated nutrient concentrations may lead to algae out-competing and overgrowing coral colonies. These physiological and ecological responses underscore the need to understand the nutrient dynamics in South Florida and to determine how spatial gradients and seasonal fluctuations influence the health of these important reef ecosystems.

Supplementing ongoing and planned coastal monitoring efforts organized by NOAA-AOML, this project involves monitoring multiple sites at each of four reefs. It generates target species biometric data using the EPA Stony Coral Rapid Bioassessment Protocol and the Periphyton Rapid Bioassessment Protocol to assess nuisance algal growth. SCUBA surveys are conducted four times per year (over two years), to capture seasonal fluctuations in benthic community composition.

Analysis of reef corals and algae includes the calculation of univariate community parameters such as abundance, density, species richness, and diversity. Furthermore, coral condition is quantified including percent live tissue and presence of bleaching. These types of data will be regressed against gradients in nutrient concentration in order to identify significance and develop models of community response to stress. Additionally, size-frequency distributions of common coral species will be analyzed to assess the relative longevity and recruitment success of coral populations at each study site. Populations skewed towards larger size-classes of corals reflect low recruitment yet long-lived colonies, whereas those populations with higher than expected frequencies of small size class colonies are expected to have higher recruitment and higher than expected mortality of older corals. With this type of analysis we can use existing population structure to make inferences on present and past stressors influencing benthic cover.



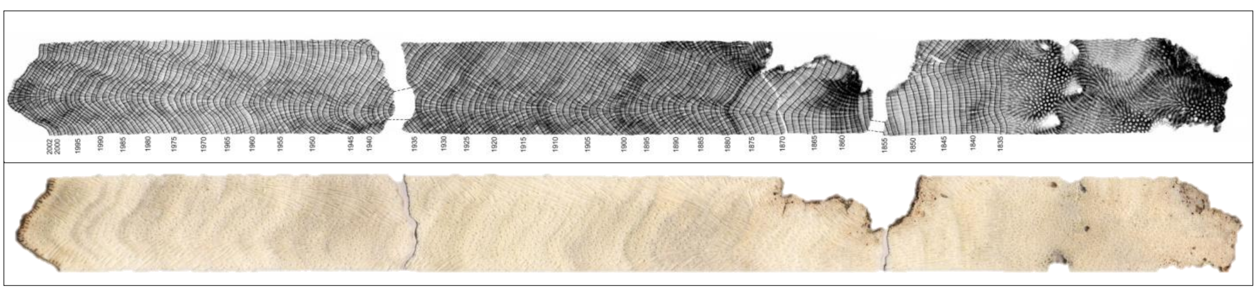
Coral reefs off Broward and Miami-Dade Counties.

Coral Sclerochronology

POC: Kevin Helmle

The field of coral sclerochronology is akin to dendrochronology, or the study of annual rings in trees. Sclerochronology uses annual skeletal growth bands to reconstruct historical records of coral extension, density, and calcification along with skeletal geochemical records to reconstruct environmental, oceanic, and climatic change (see full description in Helmle and Dodge, 2011). These annual and subannual skeletal records are ideal for establishing long-term (century-scale) time series which enable retrospective monitoring of baseline means, variability, and temporal change (Helmle et al., 2011). Using historical growth records in conjunction with geochemical proxy records of environmental variables such as sea surface temperature, sea water pH, salinity, productivity, and nutrients, it is possible to identify past changes associated with global warming, ocean acidification, and land-based sources of pollution along with the associated changes in coral growth.

Ongoing projects include coral growth and geochemical analyses of coral cores from the Atlantic Ocean Acidification Test-Bed sites at La Parguera, Puerto Rico and in the Upper Florida Keys. The aim is to reconstruct past changes in seawater pH along with coral growth and calcification to identify the extent to which ocean acidification has occurred in near-reef waters and whether it has exerted a limiting control on coral growth and calcification. Coral skeletal records are being utilized for retrospective monitoring of the possible impacts from coastal inlets and outfalls by measuring growth rates before and after construction. Sclerochronology is also being applied to basic coral biology and ecology whereby a size, age, and growth rate model is being developed to further our understanding of possible recovery rates, population dynamics, and influence on habitat equivalency analysis.



Coral X-radiograph (top) and skeletal slab (bottom). Annual density bands are apparent on the X-radiograph as alternating light and dark bands, each of which represent one year's growth as indicated by the annual chronology (marked at 5-yr intervals) between the two images.

Ecosystem Restoration, Assessment, and Modeling (ERAM)

POC: Christopher Kelble

The Ecosystem Restoration, Assessment, and Modeling (ERAM) research group examines the holistic, integrated ecosystem status and potential future condition using a broad range of scientific tools from observations through end-to-end ecosystem models. The goal of all projects in ERAM is to provide scientific information to resource managers in a manner that is useful, ensuring that resource-management decision-making is science-based. This transfer to management focuses on providing the products needed to inform ecosystem-based management (EBM) decisions and ensure resource managers are aware that their decisions should be evaluated in the holistic integrated ecosystem context rather than only evaluating the response of the single sector being targeted. ERAM projects aim to understand the ecosystem effects of tropical and subtropical coastal ecosystems to the myriad of natural and anthropogenic pressures they currently face and evaluate the ecosystem response to potential management actions.

A view of Florida Bay.

<u>Current projects being conducted by ERAM include:</u>

1. *Gulf of Mexico Integrated Ecosystem Assessment (GoM-IEA)* – provides the scientific syntheses, analyses, and models necessary to inform EBM throughout the Gulf of Mexico.
2. *Marine and Estuarine Goal Setting project (MARES)* – develops a science-based consensus about the defining characteristics and fundamental regulating processes of a South Florida coastal marine ecosystem that is both sustainable and capable of providing the diverse ecosystem services upon which our society depends.
3. *Juvenile Sportfish Research in Florida Bay* – determines how Everglades restoration and climate change will affect economically and ecologically vital sportfish species within Florida Bay.
4. *Integrated Models for Evaluating Climate Change, Population Growth, and Water Management (i.e., CERP) Effects on South Florida Coastal Marine and Estuarine Ecosystems (iMODEC)* – couples ecological, physical oceanographic, and climate models to predict the potential effect of climate change and restoration scenarios on the ecology of Florida Bay.
5. *South Florida Project (SFP)* – monitors the physical, chemical, and biological oceanography of South Florida's coastal ecosystem and develops indicators for water quality.

Gulf of Mexico Integrated Ecosystem Assessment (GoM-IEA)

POC: Geoffrey Cook

Humans have long enjoyed a broad spectrum of benefits from the sea termed ecosystem services. Providing sources of seafood, opportunities for recreation, and avenues for transportation and commerce are just a few of the many ways we depend on our oceans. Healthy ocean and coastal habitats also provide protection from storms and the threat of climate change. They serve as buffers to pollution and other stresses. To this list we can add newly emerging prospects for renewable energy from wind, tides, and ocean currents. Because of a desire to live near these benefits, we now face a burgeoning human population concentrated in coastal areas. As a result, the diverse ways in which we take advantage of the services provided by our oceans and coasts carries risk as these demands escalate. It is clear that in order to protect human communities dependent upon our coasts and seas we must first protect these ecosystems. To meet this need, a worldwide movement has emerged that places Ecosystem-Based-Management (EBM) at the center of our approach to safeguard marine ecosystems and their benefits.

To effectively implement EBM requires tools that make science-based EBM tractable to resource managers. The GoM-IEA will fill this need by providing the scientific products and analyses required to inform EBM. The GoM-IEA recognizes the necessity to maintain ecosystem sustainability and services; therefore, it focuses upon cross-sectoral analyses that investigate the tradeoffs among and between services and sustainability. To accomplish its objectives effectively, the GoM-IEA is a wide-ranging collaboration within NOAA and with outside NOAA partners in the Gulf of Mexico. AOML's contributions include the development of methodologies to conduct integrated risk and scenario analyses that will be used to assess cross-sectoral trade-offs and to inform management decisions that aim to minimize the risk to ecosystem services and sustainability. For use in these and other analyses in the GoM-IEA, AOML develops qualitative, semi-quantitative, and dynamic holistic ecosystem models.

Some of the many features of the Gulf of Mexico.

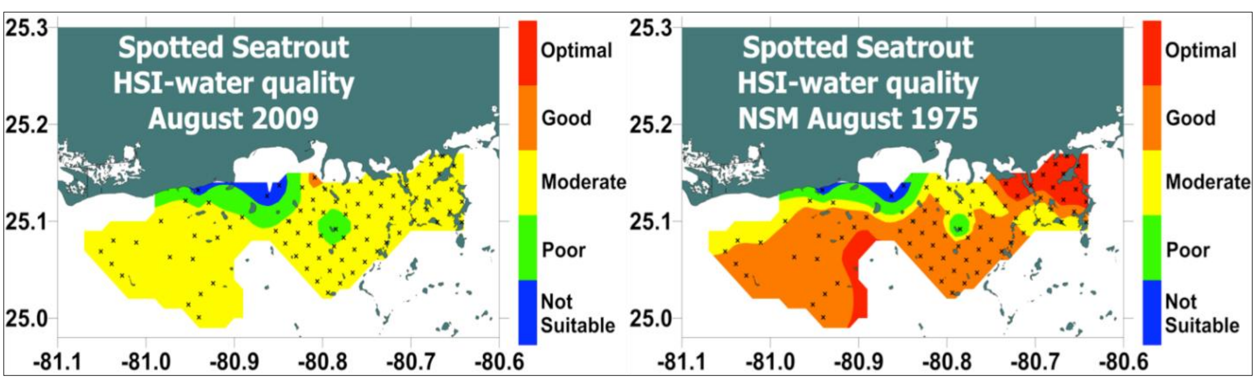
Juvenile Sportfish Research in Florida Bay

POC: Christopher Kelble

The saltwater recreational fishery adjacent to the Everglades generates approximately $880 million and greater than 6,000 jobs per year. This area includes Florida Bay, which not only supports a substantial recreational fishing industry within its waters, but also serves as a nursery ground for many of the adjacent commercial and recreational reef fishery species. These commercial and recreational fishery species within Florida Bay will be affected by Everglades restoration as it aims to restore Florida Bay to a less disturbed state by minimizing hypersalinity. One of the best indicators for estuarine health is spotted seatrout (*Cynscion nebulosus*). *C. nebulosus* is a good indicator because it spends its entire life within the bay in which it was spawned and is sensitive to fluctuations in water quality including salinity. Additionally, *C. nebulosus* is the second most commonly caught sportfish in Florida Bay, accounting for approximately 30% of all catch.

Chris Kelble aboard the R/V Whipray.

We have partnered with NOAA's Southeast Fisheries Science Center (NOAA/SEFSC) to investigate how juvenile sportfish in Florida Bay respond to water quality and habitat. This project conducts otter trawls to sample the juvenile sportfish populations, along with water quality and seagrass measurements in Florida Bay. The objectives are to: (1) develop reference conditions that can be used as a baseline to evaluate trends in juvenile spotted seatrout populations and quantify the impacts of Everglades restoration; (2) develop a juvenile abundance index (mean abundance and frequency of occurrence) and determine if annual differences in abundance occur among areas in the bay; (3) examine the relationship between juvenile spotted seatrout abundance, salinity, temperature, and seagrass and use this analysis to gain insights into the potential response of spotted seatrout to CERP; and (4) determine the salinity preference for other juvenile sportfish in Florida Bay.



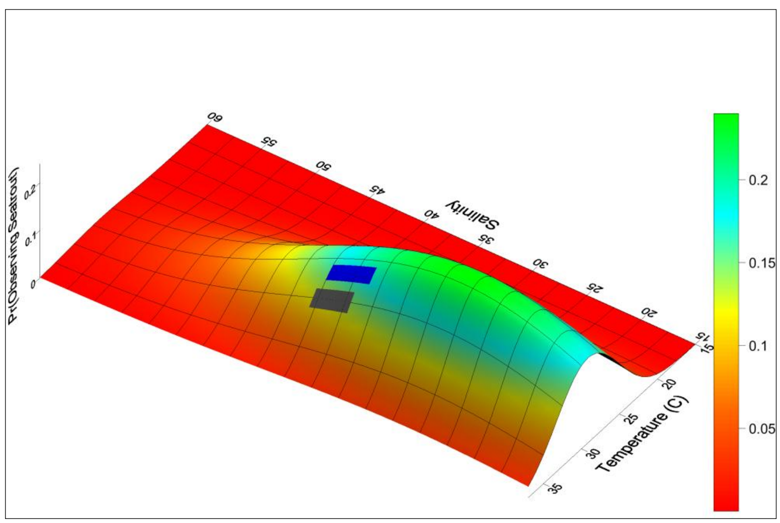
Spatial distribution of habitat quality for* C. nebulosus *calculated from observations in August 2009 (left panel) and from the NSM output in August 1975 (right panel). The NSM (Natural System Model) output from August 1975 represents what the HSI scores would have been in August 2009, if full restoration had been completed.

Integrated Models for Evaluating Climate Change, Population Growth, and Water Management Effects on South Florida Coastal Marine and Estuarine Ecosystems (iMODEC)

POC: Kelly Kearney

Global climate change will have profound implications for marine ecosystems, as well as the economic and social systems that depend upon them. Through this integrated, multidisciplinary project, we examine the effects of future climate and water management conditions on the sustainability of key commercial and recreational fishery species focusing upon Florida Bay, a major nearshore nursery ground for many fishery species. To accomplish this goal, we have assembled a diverse team with partners at NOAA's Southeast Fisheries Science Center (NOAA/SEFSC), the University of Miami's Rosenstiel School of Marine and Atmospheric Science, and Florida International University.

The physical oceanography, including temperature and salinity, is simulated with a nested high-resolution model of southwest Florida implemented with the Regional Oceanic Modeling System (ROMS). The circulation of the ROMS model presently is forced at the surface by the NCEP North American Regional Reanalysis (NARR) atmospheric model. We use CMIP5 climate model outputs for new simulations that will be coupled with ecological models to predict the impact of interacting climate change and water management scenarios on South Florida nursery habitat. ROMS case scenario output will be used as inputs into habitat suitability index (HSI) models, a mechanistic trophic model, and a connectivity model. Species modeled will be pink shrimp (*Farfantepenaeus duorarum*), spotted seatrout (*Cynoscion nebulosus*), and gray snapper (*Lutjanus griseus*), which support valuable South Florida commercial and recreational fisheries. The HSI models will predict how the interacting effects of climate change and water management alter suitable nursery habitat area available to target species. Relating recruitment strength to suitable habitat area will quantify population impacts. An expanded existing mechanistic trophic model for Florida Bay will examine trophic interactions among these species, allowing determination of how interacting water management/climate changes might affect populations of these species, their prey, or other target species. Simulation outputs will be used to produce decision support tools depicting the impact of these scenarios on the vulnerability and health of South Florida's marine ecosystem.



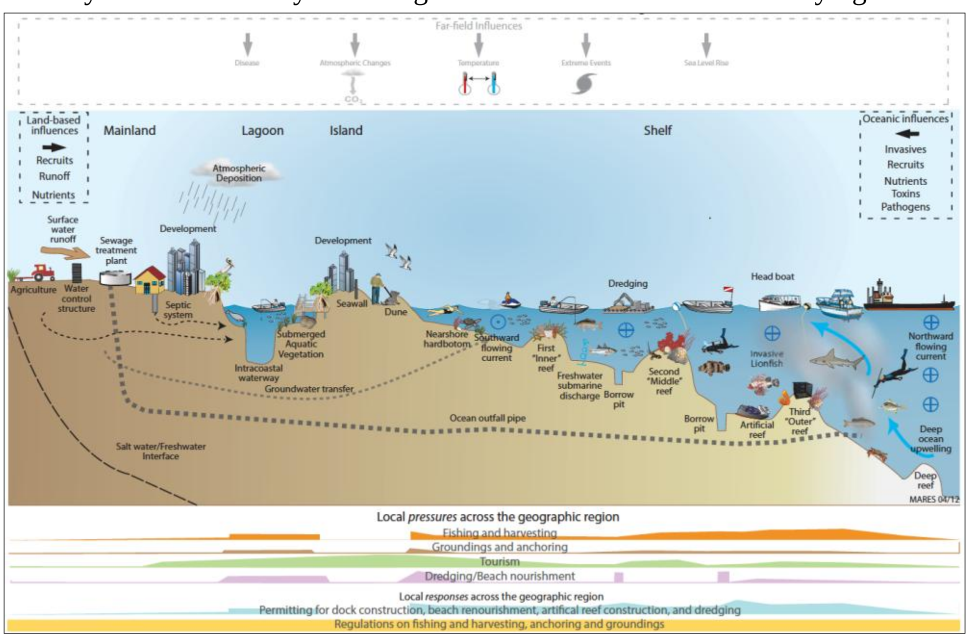
HSI model shows the current conditions for spotted seatrout in Florida Bay in blue and potential future conditions (1.5°C temperature increase and a 48 cm sea-level rise) in gray.

Marine and Estuarine Goal Setting for South Florida (MARES): A Testbed for Science-to-Ecosystem Based Management

POC: Pamela Fletcher

The coastal marine ecosystem is invaluable to the growth, development, and sustainability of South Florida. The underlying purpose of MARES is to focus and prioritize future research and to facilitate integrated adaptive management of South Florida's coastal marine ecosystem. MARES supports this purpose by developing a science-based consensus about the defining characteristics and fundamental regulating processes of a South Florida coastal marine ecosystem that is both sustainable and capable of providing the diverse ecosystem services upon which our society depends.

MARES represents a collaboration among academic scientists, federal and state agency experts, and non-governmental organizations working in close conjunction with federal and state environmental managers, private industry stakeholders, and interested members of the public. The first step in the formal MARES process is to convene the relevant experts from natural systems and human dimensions science, stakeholders, and agency representatives and charge them with developing a visual representation of their shared understanding of the characteristics and processes regulating and shaping each sub-regional ecosystem. The second step is to build upon these diagrams to develop Integrated Conceptual Ecosystem Models using an innovative model framework that incorporates information about the effects that people have on the environment and about the values that motivate their actions. The objective is to organize information about the relationship between people and the environment in a format that will help managers deal with the trade-offs they face by using "Attributes that People Care About" to focus attention upon "Who cares?" and "What do they benefit or lose from changes in their environment?" MARES models serve not only as a basis for synthesizing information but also for identifying societal and ecological indicators and knowledge gaps. The third step in the MARES process is to combine these indicators into a set of indices that can be incorporated into coastal ecosystem report cards that document trajectories towards or away from a sustainable and satisfactory condition.



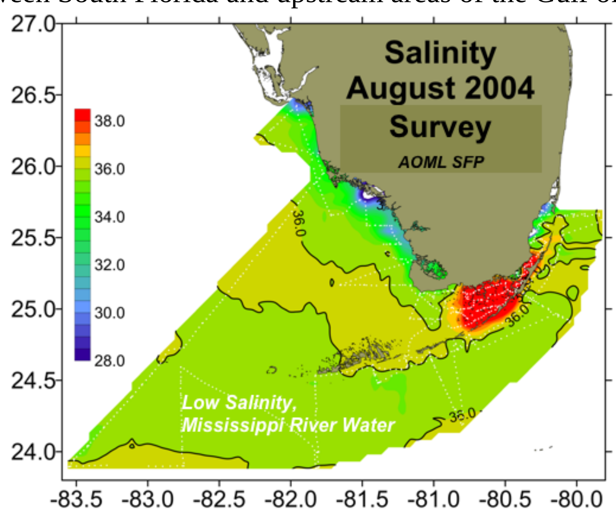
MARES infographic for Barrier Island ecosystems in southeast Florida shows the dominant pressures upon the key state components and human uses within the ecosystem.

The South Florida Project (SFP)

POC: Christopher Kelble

NOAA's Atlantic Oceanographic and Meteorological Laboratory has conducted regular interdisciplinary observations of South Florida coastal waters since the early 1990s. Field operations associated with this program have enabled scientists and resource managers to keep a watchful eye on the sensitive marine habitats found in the region and have served as a sentinel during periods when the ecosystem has been subjected to extreme events such as hurricanes, harmful algal blooms (HABs) and, more recently, oil spills. SFP has produced a comprehensive, long-term baseline regarding regional circulation, salinity, water quality, and biology for the ecosystem.

- SFP was originally designed to fulfill NOAA's responsibility to South Florida Ecosystem Restoration (SFER) and the ongoing Comprehensive Everglades Restoration Plan (CERP). To this end, SFP has been critical in the development of the water quality indicator for SFER, and SFP data are necessary to assess this indicator bi-annually as required by the SFER Task Force. This indicator assesses the impact of Everglades restoration on coastal algal blooms, a key concern raised by the National Academy of Science's Committee on Restoration of the Greater Everglades Ecosystem.
- SFP integrates data from environmentally and economically important areas, including three national parks (Biscayne, Everglades, Dry Tortugas) and the Florida Keys National Marine Sanctuary (FKNMS). Economic activity in the FKNMS alone was worth $6 billion and 71,000 jobs in 2001.
- SFP has played a critical role in examining the linkage between freshwater flow from the upstream Everglades and coastal ecosystem processes, including salinity distributions, phytoplankton blooms, zooplankton dynamics, and trophic structure, and has documented the linkage between freshwater run-off from the Everglades ecosystem and the FKNMS.
- SFP has documented the physical connectivity between South Florida and upstream areas of the Gulf of Mexico via the Loop Current system, and has defined the conditions that are favorable for a direct connection.
- SFP cruises have been able to adapt quickly to examine the ecological impact of highly publicized environmental events which have originated both locally (red tides, "black-water", and other HABs) and remotely (hurricanes and Mississippi River intrusions). During the summer of 2010, AOML SFP cruises were modified to survey for contaminants following the Deepwater Horizon oil spill.
- The AOML SFP provides a baseline spanning more than a decade for a critical region of the US coastal ocean. Its continuation is required if the impact of episodic extreme events or the long-term effects associated with climate change and ocean acidification are to be rigorously quantified and assessed.
- The AOML SFP cruises have resulted in 21 peer-reviewed journal articles, one M.S. thesis, three Ph.D. dissertations, and more than 30 conference presentations over the past decade.

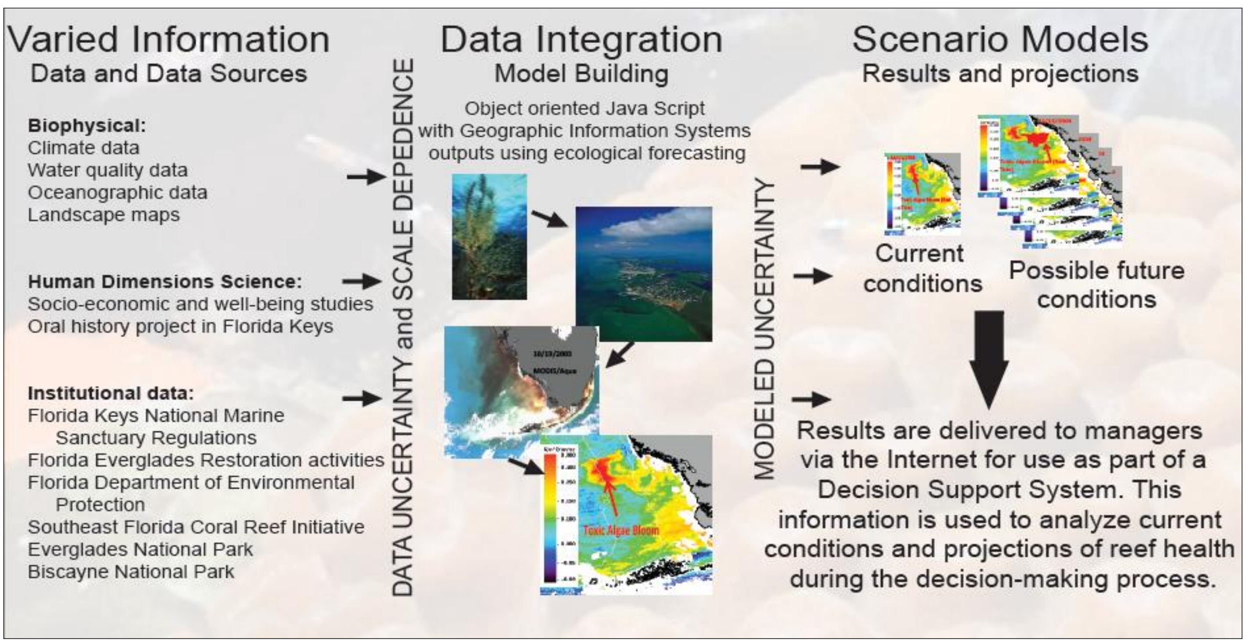


A salinity map of the AOML SFP study area is shown above for August 2004 (vessel survey track is represented as a white dotted line). This research cruise was adapted to document and quantify the presence of Mississippi River water in the Florida Straits and along the Keys reef tract.

Providing Real-Time Information for Marine Ecosystem Decision Support (PRIME-DS)

POC: Pamela Fletcher

Marine ecosystem management is a complex endeavor that requires decisions based upon timely evaluation of the best available indicators of ecosystem "health," ecological forecasts based upon current environmental trends, and possible socio-economic consequences of "good" and "bad" management decisions. Ecosystem "health" embraces (1) key processes operating to maintain stable and sustainable ecosystems, (2) zones of human impact not expanding or deteriorating, and (3) critical habitats remaining intact (Rapport *et al.*, 1998). A resource manager is rarely, if ever, well versed in these many fields of research and depends upon scientists and others to provide interpretations relevant to a manager's context in a timely and easily comprehensible way. After conducting a needs assessment survey of 15 South Florida marine resource managers, we determined that two of the clearest data and information needs were for water quality and climate change. Without "good" water quality, marine organisms may be more susceptible to challenges to organismal functioning (e.g., reproduction, growth, migration, respiration, etc.). An increasing rate of climate change becomes a challenge to ecosystems adapted to much slower environmental change. Our approach to supporting the decision process of South Florida marine resource managers is to provide data and information products identified in our needs assessment in as timely a fashion as possible and to incorporate their feedback into improving the quality of our reports. Iteration and close partnerships are the hallmarks of producing a timely suite of information products that evolve with the managers' needs and a changing coastal environment.



Environmental decision-making is a very complex process.

The Florida Area Coastal Environment (FACE) Program

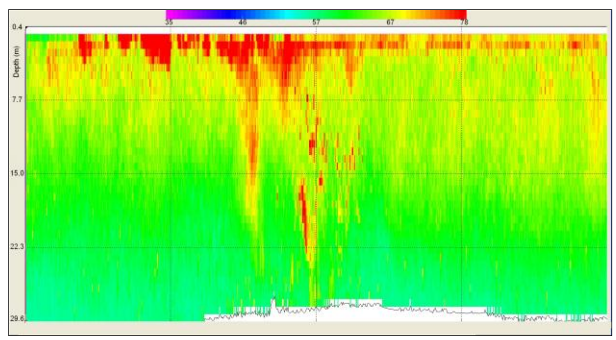
POC: Thomas Carsey

As a component of OCED's coastal environment focus, the Florida Area Coastal Environment (FACE) program was created in 2004 to obtain the scientific knowledge and long-term data needed to address key scientific issues of concern for environmentally compatible infrastructure operation, regulation, and coastal management on the southeast Florida coast (Miami-Dade, Broward, and Palm Beach counties). This program supports the key NOAA mission goal to protect, restore, and manage the use of coastal and ocean resources through an ecosystem approach to management.

The FACE project is primarily concerned with anthropogenic discharges in southeast Florida's coastal ocean. FACE field operations include a wide range of physical, biological, and chemical oceanographic measurements such as ocean currents, nutrients, acoustic remote sensing of plumes, microbiological monitoring, and coral reef health monitoring. These multi-year data sets are used to develop an overall understanding of the near-shore environment. While the anthropogenic contribution to the coastal environment is the only factor amenable to human control, a holistic approach including natural contributions is necessary for an accurate overall view.

The project has been involved in the measurement and fate of the flux of material from Southeast Florida's inlets and treated-wastewater outfalls, as well as assessment of natural contributions such as oceanic upwelling. Year-long surveys of the water quality off of Palm Beach and Broward counties, have been completed and a similar project off of Miami-Dade County is planned. A number of tracer studies, using natural and added tracers, have been undertaken at key inlets and outfalls. Current personnel on the project include Thomas Carsey, Jack Stamates, Charles Featherstone, Joseph Bishop, and NOAA Corps officers Rachel Kotkowski and Michael Doig. Further information is available on the project's web page, http://www.aoml.noaa.gov/themes/CoastalRegional/projects/FACE/faceweb.htm.

FACE scientists Cheryl Brown (left), Maribeth Gidley (center), and Lindsey Visser (right) recover water samples from a CTD sampling rosette on the NOAA R/V Hildebrand during the Broward County coastal water quality study in 2011.

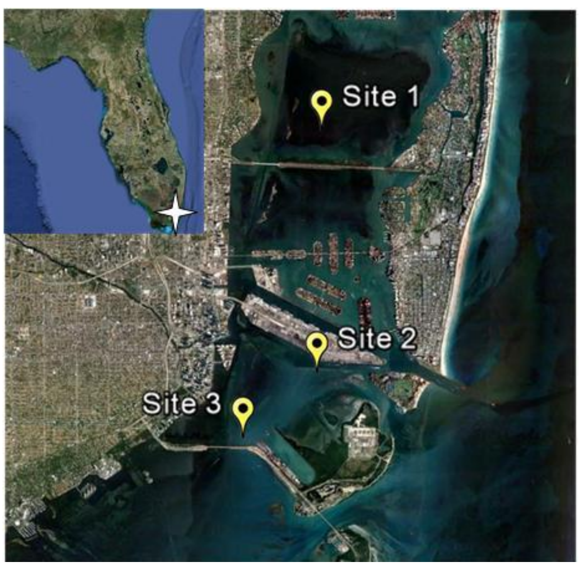


Backscatter image of the plume from the Broward treated-wastewater plant outfall during a tracer study conducted on 7-Nov-2011, as part of the Broward County coastal water quality study in 2011. The plume has been broken up by the presence of the nearby Gulf Stream. Horizontal axis is time along the track of the NOAA R/V Cable.

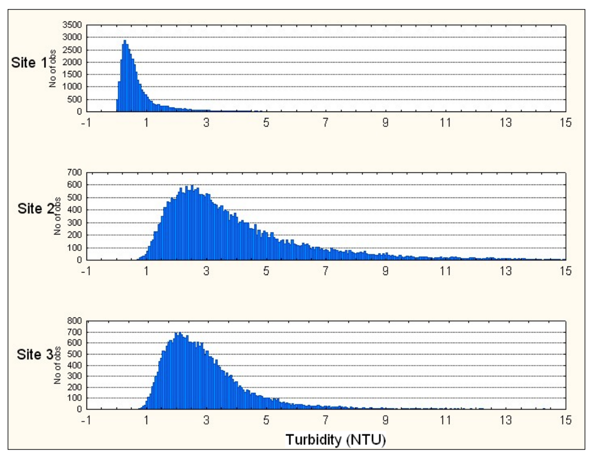
The Biscayne Bay Turbidity Study

POC: Jack Stamates

The Biscayne Bay Turbidity Study was undertaken to provide information about ambient turbidity levels at three locations in Biscayne Bay. In-situ instruments were used which provided data (turbidity, chlorophyll-a, colored dissolved organic matter (CDOM), temperature, salinity and current profiles) at high temporal resolution (15 min). Turbidity measurements were analyzed in conjunction with other environmental factors such as winds, current velocities, and phytoplankton populations to examine the effects of these factors on turbidity levels. A time-lapse camera system mounted atop the Four Season Hotel (240 m high) provided a year-long series of images of an area of Biscayne Bay. These images showed the development of visible turbidity plumes which then could be compared with data from the in-situ instruments. Water samples were collected and analyzed for total suspended solids, chlorophyll-*a* concentrations and microbial content. High resolution scanning electron microscopy images were generated from the water samples, allowing the identification and quantification of phytoplankton and other suspended materials. While this project was specifically conceived to provide information regarding turbidity levels and the variations thereof, the data and analysis may prove useful to others studying the waters of Biscayne Bay.



Location of the three Biscayne Bay Study sites.



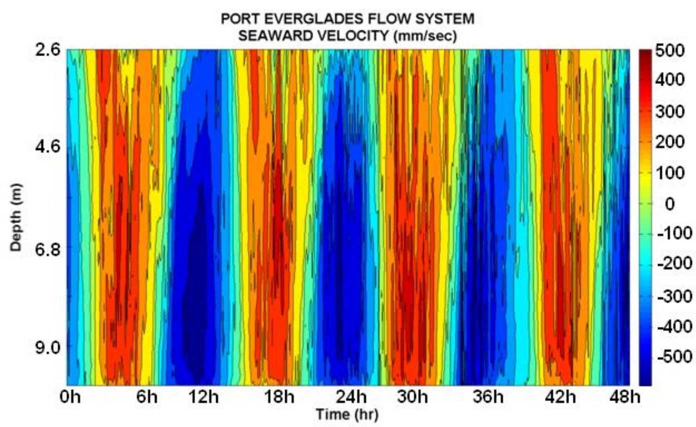
Histograms of one year of turbidity measurements at the three Biscayne Bay sampling sites.

South Florida Inlets as Land-Based Sources of Pollution

POC: Jack Stamates

This NOAA/CRCP-funded program seeks to estimate the flux of chemical and microbiological materials flowing through South Florida's inlets into the coastal ocean. The approach ideally is for (1) occupation of sampling stations at inlets and the adjacent receiving waters at regular intervals for a period >1 year, with analysis of samples for chemical, physical and microbial constitutes; (2) time series measurements of current velocities inside of the inlets using acoustic Doppler current profiling instrumentation; (3) measurements of key chemical and microbiological parameters in the inlets during sampling intensives that include ebb and flood tidal flows; and (4) time series measurements of nutrients and physical parameters in the Intracoastal Waterway that feed the inlets.

We have studied the Boynton and Port Everglades Inlets, and are currently studying the Boca Raton and Hillsboro inlets. These fluxes are viewed in the context of other key nutrient sources such as treated-wastewater outfalls and ocean upwelling, with the ultimate goal of developing a nutrient budget for the coastal waters of South Florida and the three reef tracts therein.



Above: Visualization of the flow through Port Everglades Inlet, as noted in legend at right (red denotes flood flow, blue is ebb flow) during a 2-day period. Note that at certain times, the flow was outbound at the surface and inbound at depth.

Left: Map of Florida showing key inlets.

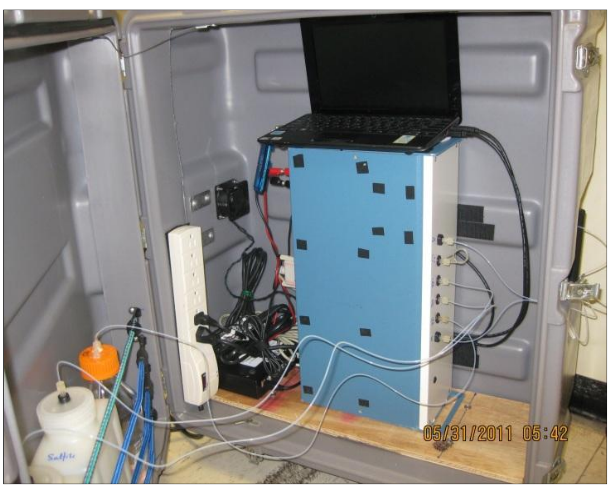
Development of an Autonomous Ammonium Fluorescence Sensor (AAFS) with a View Toward In-situ Application

POC: Natchanon Amornthammarong

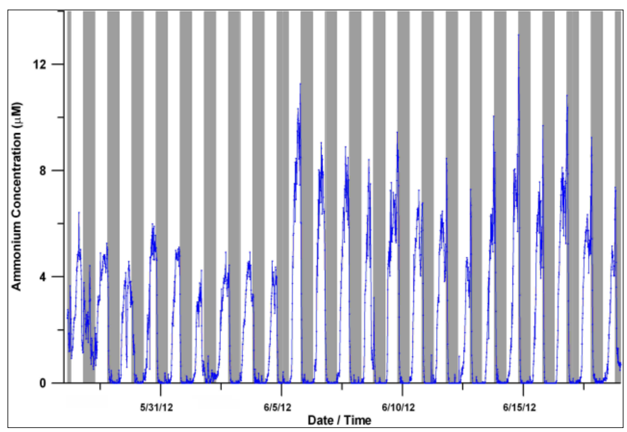
This project is funded by the National Oceanographic Partnership Program (NOPP) to develop a portable autonomous ammonium sensor. Such a sensor could be deployed for periods of up to a month aboard ships, moorings, or drifting buoys or used as a component in lowered or towed oceanographic instrument packages for vertical profiling. The technical objective is to develop a robust, relatively simple, inexpensive, low power and compact instrument with a detection limit in the nM range and a sampling frequency of at least six samples per hour. Robustness, simplicity, lower construction cost, lower power, and small size are all practical considerations for oceanographic application.

We have developed an autonomous batch analyzer for the measurement of ammonium in natural waters. The system combined previously described batch analysis and continuous flow analysis methods and a new mixing chamber. With its simpler design, the autonomous batch analyzer is robust, flexible, inexpensive, and requires minimal maintenance. The sampling frequency is ca. 8/hr, and the potential limit of detection is at nM levels, which is comparable to the most sensitive flow through or batch analysis methods previously described and within the design specifications set for our project. In addition, the system produces a calibration curve by auto-dilution from a single ammonium stock standard solution with the same accuracy as traditional manual calibration methods. This last aspect is particularly important for extended (one month or longer) in-situ deployments.

The instrument was field tested at several locations in South Florida coastal waters. Diurnal cycles and tidal influence were observed in the variability of ammonium concentration measured at different locations.



The autonomous ammonium instrument.



Production of ammonium from photochemical degradation of dissolved organic matter in mangrove fringed coastal pond water. Daily ammonium maxima, reaching 5-10 µM, were observed in the afternoon and decreased to below 0.1 µM during the night (shaded area) for 24 consecutive days. This is the strongest diurnal cycle of ammonium from the photochemical processes observed in natural ecosystems.

Development, Validation, and Application of Molecular Microbial Source Tracking Tools and Biosensors

POC: Kelly Goodwin, Christopher Sinigalliano

AOML participates in the development and testing of molecular technologies for the detection and enumeration of microbial contaminants in the marine environment, and provides field trials and test-beds for technologies developed by NOAA and its partners. DNA detection tools to identify sewage pollution, pathogens, and harmful algae are applied to recreational waters, beach sands, marine mammals, and coral reefs. Efforts in this area include inter-laboratory validation, inter-agency collaboration, stakeholder training, and technology transfer. Goals include faster water quality assessments to allow prompt public notification of swimming risk; development and application of assays that pinpoint contamination sources to guide remediation investment; direct detection of pathogens and harmful algae for risk assessment and automated in-situ detection of genetic signatures to increase monitoring capacity and decrease dependency on ship time.

AOML works to support the transfer of molecular tools to the private sector, academia, federal, state and local agencies, and to NGO environmental research groups. The Environmental Microbiology Program won the 2012 NOAA technology transfer award for the development of molecular Microbial Source Tracking (MST) tools to measure fecal contamination in the coastal environment by dogs and seabirds, and for its work in supporting the transfer, training, and use of these tools.

Student Intern Aditya Shetty using a quantitative real-time Polymerase Chain Reaction (qPCR) thermocycler. qPCR permits detection of fecal indicating bacteria more rapidly than traditional culture methods, and enables MST, which can identify the host source (e.g., human, bird, dog, cow) of the bacteria.

AOML microbiologists Kelly Goodwin and Chris Sinigalliano display their NOAA Technology Transfer Award for "for exceptional leadership in developing and transferring Microbial Source Tracking tools to identify coastal waters contamination sources and allowing city and county managers to devise mitigation strategies to restore water quality, decrease risks to human health, and preserve coastal economies."

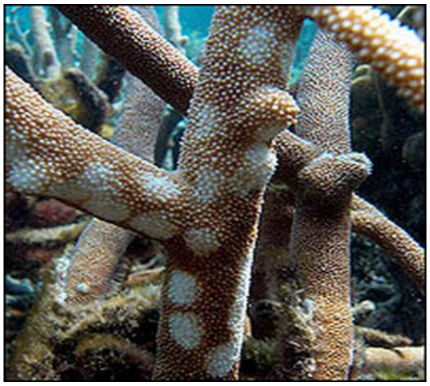
Microbial Water Quality Assessments to Support Coral Reef and Coastal Ecosystem Health

POC: Christopher Sinigalliano

Microbes help control the flow of energy and matter on the planet. They cycle nutrients, decompose pollutants, control the composition of the atmosphere, and produce bio-active compounds important to a wide variety of medicines and commercial products. Microbes also degrade water quality and cause infections in humans, protected species, and critical habitats. The AOML Molecular and Environmental Microbiology Program uses traditional microbiology and cutting-edge molecular techniques in conjunction with chemical and physical oceanographic measurements to help address management concerns regarding land-based pollution entering coral reef ecosystems and associated Essential Fish Habitat.

AOML Student Intern Sarah Greenhaus, aboard the R/V F.G. Walton Smith, filters and preserves coastal water samples for later molecular genetic analysis of microbial contaminants.

Microbial water quality assessments (MWQA) are used to evaluate the presence, abundance, transport, fate, and impacts of microbial contaminants in the marine environment. This work includes studies with the Florida Area Coastal Environment (FACE) program to assess land based sources of pollution to critical coastal habitats, such as coral reefs. People and coral can be affected by similar pathogens (for example Herpes virus and the bacterium *Serratia marcescens*), and many of the bacteria and viruses in sewage and septic discharge can cause disease in coral, while harmful algal blooms can also hurt coral health.



Some coral diseases, such as "white pox" shown here, are associated with land-based bacterial pathogens that can be transported to coastal waters by sewage, urban storm water, and coastal inlet discharges.

As a part of the NOAA Coral Health and Monitoring Program (CHAMP), metagenomic sequencing for bacterial, archae, algal, and fungal populations is performed on water samples from coral reefs, as well as from coral tissue and coral mucus samples. This work is part of a larger field program to assess water quality, to identify sources of microbial contamination, and to survey the coral benthos so that the microbiological stresses impacting coral reefs can be better understood and managed. In these studies, molecular methods, such as qPCR, are used to identify fecal indicator bacteria, host sources of fecal contamination, and a variety of pathogens (e.g., *Salmonella*, *E. coli* O157:H7, *Campylobacter jejuni*, *Staphylococcus aureus*, *Serratia marcescens*, adenovirus, norovirus, enterovirus).

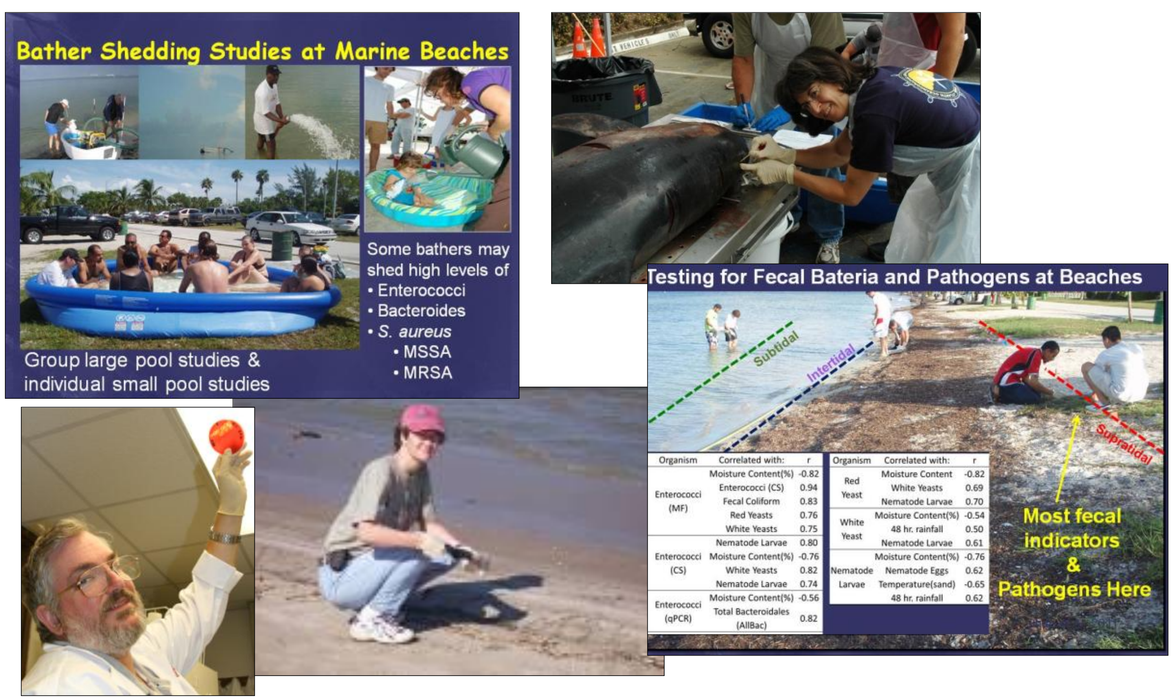
Microbiological Studies on Oceans and Human Health Interactions

POC: Maribeth Gidley

AOML has a robust, multi-institutional, collaborative program that is active in the larger national and international Oceans and Human Health (OHH) research community. Research focuses on the microbiological inter-relationships between our oceans and the health of ecosystems, marine animals, and humans. Investigations seek to better understand the environmental factors that control exposure of people and animals to microbial contaminants and harmful algal blooms (e.g., “red tide” caused by the dinoflagellate *Karenia brevis*). Efforts guide remediation investment, aid implementation of Total Maximum Daily Loads (TMDL), and support Quantitative Microbial Risk Assessment (QMRA).

Work includes participation in epidemiological studies at Florida and California beaches; shedding of bacteria by bathers; and surveys of pathogens in coastal waters and beach sand (such as *Staphylococcus areus*, including Methicillin-Resistant *Staphylococcus aureus* or MRSA). The persistence of microbial contaminants in environmental reservoirs such as beach sand, seaweed wrack, and marine debris is characterized. Other work includes watershed-level studies to understand the factors that contribute to chronically-elevated bacterial loads.

Marine mammal health reflects the state of our oceans and is a sentinel for human exposure. Work in this area includes investigation of bacterial pathogens from biopsies remotely taken from free-living and stranded marine mammals and research on the zoonotic transfer of pathogens between humans and marine animals. Work in this area has been used to devise improved protocols for marine mammal rehabilitation.



Clockwise from upper left: Poster on effect of bathers on beaches; Kelly Goodwin collects necropsy samples from a deceased dolphin; poster on beach pathogen study; Maribeth Gidley collects seaweed to test for microbial contaminants; Chris Sinigalliano displays a blood agar plate with staphylococci isolated from sand, showing that the bacteria are destroying red blood cells.

Microbial Diversity and Ecosystem Function of Marine Microbial Communities

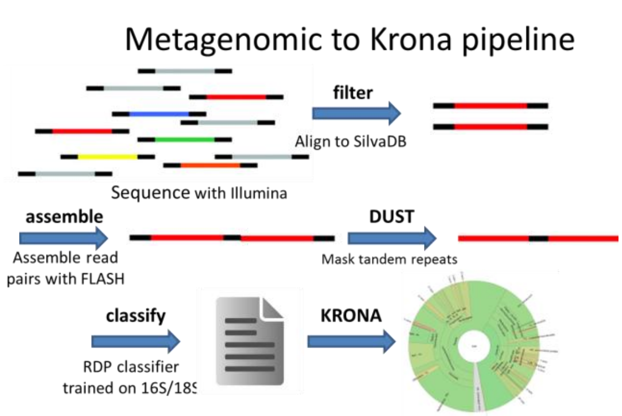
POC: Christopher Sinigalliano, Kelly Goodwin

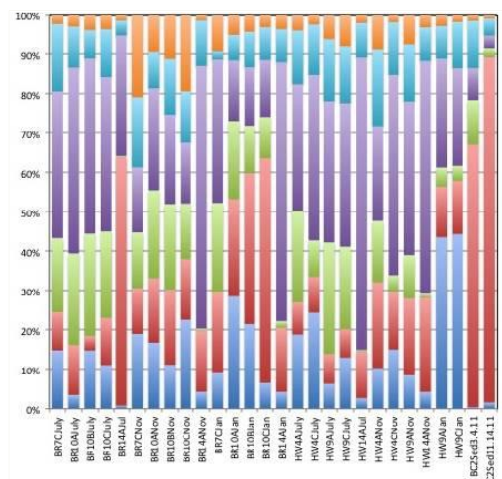
Microbes are fundamental to ecosystem function, and they serve as indicators of ocean change. However, microbial diversity and function represent one of the great data gaps in marine observations because, until recently, tools for direct investigation of microbial dynamics have been lacking. Metagenomics analyzes genetic material recovered directly from the environment. This approach overcomes the limitations of culture-dependent studies and enables direct exploration of the processes that regulate global biogeochemical cycles, food webs, and biological responses to environmental perturbations.

Electron microscope image showing a diversity of bacterial types. Only a tiny percentage of microbes have been characterized by culture. Metagenomics is revolutionizing our knowledge of microbial diversity and function.

We combine metagenomics with classical microbiology, ecology, and molecular microbial source tracking to elucidate baseline ecosystem function and community structure. Such work assesses the impact of changing environmental stressors such as degraded water quality, oil spills, harmful algal blooms, climate change, and ocean acidification on microbial dynamics.

In addition, metagenomic analysis is being used to reveal the metabolic capabilities of marine organisms living in extreme marine environments (Gulf of Mexico methane seeps) and to study ecosystem function in open ocean waters. These projects utilize next-generation sequencing and bioinformatics to discover and explore fundamental marine processes. The overarching goal is to improve understanding of ecosystem diversity and function to enhance assessment and stewardship of ecosystem services.





Left: Diagram describing bioinformatic methods using the Krona pipeline for taxonomic analysis on unassembled Illumina data from open ocean samples. Right: Metagenomic results from 454 pyrosequencing of seawater samples collected from South Florida wastewater outfalls, inlets, and a reef tract. Results in the "heat map" show a summary of taxa to the level of Order for the core microbiome (taxa that occurred in every sample and present at >50%). The different colors and lengths show the diversity and relative abundance of various bacterial groups. Bacterial dominance showed both spatial and temporal trends.

Research Mentorship in Environmental Microbiology: Training the Next Generation Workforce in Environmental Science

POC: Christopher Sinigalliano

NOAA-AOML in general, and the Environmental Microbiology Program in particular, hosts a wide variety of both long-term and summer internships for students of various ages ranging from senior high school students to post-doctoral fellows. These highly competitive educational opportunities provide student experiences with state-of-the-art training in oceanography, meteorology, and environmental science at an internationally recognized federal research laboratory in a location ideally suited for oceanic and coastal environmental research. In addition we conduct training workshops and visiting scientist opportunities for a wide variety of visiting researchers and collaborators who wish to learn our methods and techniques.

We have hosted research training opportunities for NOAA Hollings scholars, NOAA Nancy Foster Fellows, EPA interns, NSF REU interns, university student research assistants from a wide variety of academic institutions, high school summer interns, graduate research associates from a variety of universities, high school science teachers, NOAA-Smith College interns, NOAA-OHH interns, and NSF/NIEHS OHH Center interns, as well as students from many other research experience educational programs.

Clockwise from upper left: OHH Interns Lily Zhang and Heather Coit return to the R/V Walton Smith after a day of water quality sampling during an Oceans and Human Health research cruise; Undergraduate research assistant Jakob Bartkowiak collects near-shore beach water and sand samples to test for pathogens; Maribeth Gidley trains high school summer interns, graduate students, and post-docs about traditional culture isolation and screening techniques for Staphylococcus aureus on a cruise aboard the R/V Walton Smith; NOAA Hollings scholar and OHH intern set up automated water samplers at residential canals in the Florida Keys to track land-based sources of microbial pollution; Kelly Goodwin with NOAA/Smith College intern Wei Xin test for microbial contaminants at Cabrillo Beach in Los Angeles, CA; and NOAA Hollings scholar Frank Johnson pipettes qPCR reactions for a molecular microbial source tracking assay for human fecal marker in the AOML microbiology lab.

Ocean Chemistry and Ecosystems Division Publications: 2012-2013

(Names of OCED authors appear in capital letters)

Peer-Reviewed Articles

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