NOAA Ocean Acidification Program

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Outline

• Science of Acidification
• Drivers
• Program Structure
• NOAA’s research portfolio
• Other agencies: NSF, USGS, EPA, NASA, State
• Next steps
Observed Ocean Acidification

Figure modified courtesy of Richard Feely (NOAA PMEL) reproduced from Doney, *Science* (2010) and Dore et al., *PNAS* (2009)
pH Distribution in Surface Waters

from the NCAR CCSM3 model projections using the IPCC A2 CO$_2$ Emission Scenarios

Feely, Doney and Cooley, *Oceanography* (2009)
Aragonite (\(\text{CaCO}_3\)) Saturation State

Modeled aragonite saturation state in world’s oceans.

\(<1 = \) undersaturation

When saturation state drops below 1, it becomes difficult for many shelled organisms to maintain their shells.

Feely et al 2009
Change in Aragonite Saturation with CO₂

- Saturation state declines across all latitudes
- Undersaturated conditions appear for aragonite in high latitudes in next decade for A2 scenario

Steinacher et al., *Biogeosci.*, 2009
In terms of calcification rates, a range of sensitivities and responses to OA have been experimentally determined precluding a simple narrative.

Figures provided courtesy of Joanie Kleypas (National Center for Atmospheric Research)
Pacific Northwest oyster emergency

- Failure of larval oyster recruitments in recent years
- Commercial oyster hatchery failures threatens $100M industry (3000 Jobs)
- Low pH “upwelled” waters a possible leading factor in failures

Update: NOAA working with Gov. Gregoire on Blue Ribbon Panel to synthesize findings and develop adaptation strategies
The purpose ... is to present a consensus research strategy for NOAA to advance the understanding of the impacts of ocean acidification and to address related challenges to local and national ecosystems and communities.
"Development and coordination of a comprehensive interagency strategy to:
(a) Monitor and conduct research on the processes and consequences of ocean acidification on marine organisms and ecosystems;
(b) Establish a NOAA research and monitoring program on ocean acidification;
(c) Establish a program at NOAA for assessment and consideration of regional and national ecosystem and socioeconomic impacts of increased ocean acidification research adaptation strategies and techniques for effectively conserving marine ecosystems as they cope with increased acidification."

Federal Ocean Acidification Research and Monitoring (FOARAM) Act of 2009
NOAA National Ocean and Great Lakes Acidification Research Plan

Monitor trends

Ecosystem Impacts

Model changes & responses

Develop adaptation strategies

Conduct education and outreach
NOAA Current and Potential Resources

- **Oceanic and Atmospheric Research (OAR)**
  - OA Program Office (HQ)
  - Observing, modeling and technology development (PMEL/AOML)
  - QA/QC for laboratories/universities (PMEL/AOML)
  - Coral reef research and monitoring (AOML)
  - National Sea Grant College Program: extramural research, communication, extension (300+ agents)
  - Climate Program Office: Office of Climate Observation and Carbon Cycle Program
  - Earth System modeling (GFDL )
  - Great Lakes Research (GLERL)

- **NOAA’s Fisheries Service (NMFS)**
  - Species specific experiments on commercial or recreational fishery species or their food/prey including primary producers (NEFSC, NWFSC, AFSC)
  - Coral reef research and monitoring (PIFSC)
  - Building shared-resource mesocosm infrastructures (NEFSC, NWFSC, AFSC)
  - Fishery Impacts modeling (NEFSC, NWFSC, AFSC)

- **National Ocean Service (NOS)**
  - U.S. IOOS Program Office and Regional Associations: OA is one of the current seven HIGH priority observing foci
  - Coral Reef Conservation Program
  - Biogeochemical and Ecosystem OA Impacts Modeling– extramural program - FY 12 RFP (NCCOS)
  - NCCOS Laboratories
  - National Marine Sanctuaries: Research and outreach plans for sanctuaries
  - National Estuarine Research Reserves: Adding pH to monitoring programs
  - Arctic Program

- **National Environmental Satellite, Data, and Information Service (NESDIS)**
  - NODC: Data Archives
  - Coral Reef Watch
  - Satellite sensing of phytoplankton blooms
Ocean Acidification Observing

- Fixed site observing platforms
- Ships of opportunity
- Repeat hydrography and dedicated OA cruises
- Biogeochemical Modeling
- New technologies
31 total moorings
20 CO₂ moorings; 11 OA moorings
14 open ocean, 12 coastal, 5 coral reef

NOAA PMEL Mooring Network

Supported by NOAA’s Office of Climate Observation (OCO), NOAA’s Ocean Acidification Program, and a variety of partners
Gulf of Maine OA Mooring

**Original CO₂ mooring data**

CO₂ mooring data:
- CO₂
- O₂ in equilibrated air

**New OA mooring data**

OA mooring data:
- CO₂
- pH
- SSTC
- optode O₂
- fluorescence
- turbidity

New sensors provide insights into the influence of biology on short-term variations in ocean carbon chemistry.
AOML and NMFS: First surface water CO$_2$ data from NOAA ship *Henry B. Bigelow*
The WCOA2011 Cruise on the R/V Wecoma is designed to delineate the extent and magnitude of the exposure of West Coast ecosystems to “acidified” conditions and to study the links between acidification and hypoxia along the coast.
Carbon Wave Glider

- PMEL
- Measurements: T, S, pH, pCO₂
- West Coast
Impacts Research and Modeling

- Fishery Science Centers
- Coral Reef Monitoring and Assessment
- NCCOS/NOS Ecosystem Modeling RFP
- All involve extensive collaboration with external partners
Northeast Fishery Science Center

- Phytoplankton
- Finfish
  - Summer and Winter Flounder
  - Black Sea Bass
  - Sturgeon
  - Juvenile Scup
- Atlantic Surf Clam with WHOI
- Ecosystem Impact Modeling
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Northeast Fisheries Science Center
Northwest Fishery Science Center

- Bivalves
  - Geoducks
  - Pacific oysters
  - Olympic oyster
  - Pinto abalone
- Crustaceans
  - Copepods
  - Krill
  - Dungeness Crab
- Rockfish
- Market squid

- pH monitoring in Puget Sound as relevant to fishery species
- Ecosystem impact modeling
Southwest Fishery Science Center

- Retrospective analysis of the CalCOFI data
- Working closely with Scripps PIs to analyze biological data from CCE buoys off Point Conception
Alaska Fishery Science Center

- Managed Crab Species
  - Red, Blue and Golden King Crab
  - Tanner
  - Multiple life stages
  - Growth and survival
  - genomics

- Alaskan corals
- Fish
  - Pacific cod
  - Walleye pollock
Coral Reef OA Monitoring Portfolio

• Coral Reef Conservation Program began funding OA research activities in 2007
• Ocean Acidification Program joined in 2011
• Partnering in 2012 – 2014 and beyond
• Coordinated with the National Coral Reef Monitoring Plan (NCRMP)
• Two main focus areas:
  – Atlantic Ocean Acidification Test Bed
  – Pacific Islands surveys
Atlantic Ocean Acidification Test-bed

Provide data rich observing environment uniting satellite-based regional monitoring with high-resolution near-reef time-series observations.

Nexus of federal and academic monitoring and research to conduct intercomparison studies and develop advanced techniques to monitor coral reef community response and feedback to OA.
Pacific Islands FSC: CRED

- Carbonate chemistry monitoring in Pacific Islands
- Autonomous Reef Monitoring (ARMs)
  - Investigate invertebrate diversity
- Calcification Acidification Units (CAUs)
  - Assess long term trends in carbonate accretion and assess spatial patterns
  - First retrievals in 2012
- Coral Coring (collaborating with Anne Cohen, WHOI)
  - Growth rate of corals
Autonomous Reef Monitoring

Figure 6: Ship-board ARMS processing
Federal Coordination

• Interagency Working Group on Ocean Acidification (NOAA – Lead, NSF, USGS, BOEM, EPA, DOS, DFW, NASA)
• Interagency Strategic Research Plan: In Review
• Coordinating data management and RFPs
• Participation in international efforts via the Solas-Imber OA Working Group (Dick Feely, Rik Wanninkhof)
• Department of State: Rio +20
• Participation in the Oceans in a High CO2 World III International Symposium in Monterey, CA in Sept 2012 with Dr. Lubchenco as keynote speaker.
NSF

• Integrated across 3 directorates and 5 programs

  – Ocean acidification interconnected to oceanic biology, chemistry, physics, and geology.

  – Predicting the consequences of ocean acidification on ecosystem health and function.

  – Interpreting the geologic record to reveal the history of climate change and the assemblages of organisms that have risen, persisted, or declined, as the earth system has evolved.
Regional coastal saturation and pCO$_2$ linked to habitat
Florida & Caribbean

2010 cruise
2011 cruise

Historic coastal pH, salinity, and temp
FL Shellfish beds

Calcifying organism response
lab and field process studies

Integrated approach to understanding impacts of ocean acidification & carbon budget from estuary to shelf
Next steps for NOAA

• Build out coastal and open ocean **observing** system
• Establish Atlantic/Pacific coral reef OA **monitoring** portfolio and implementation plan
• Continue **experiments** on identified species of concern
  – Provide academic community with access to facilities
• **Model/Forecast** Species, Ecosystem and Economic Impacts
• Develop and coordinate **outreach and education** message
  – OA web page
  – Leverage skilled educators within NOAA
  – Work with NGOs
• Create standard **data** protocols and manage/serve data
• **National Program Office**: Feds and academics
  – Exploring models for this
• **International Coordination**
  – International Observing Network
  – International program office
Questions?