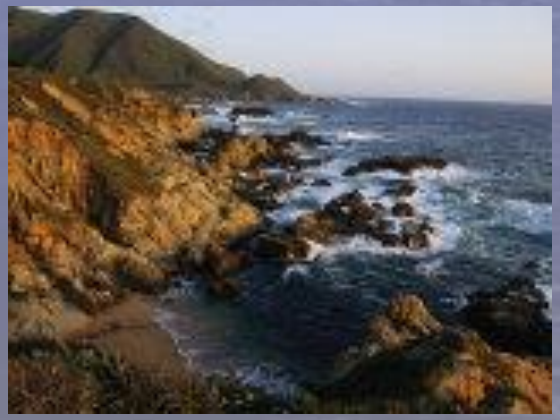
Phillip Taylor

Acting Division Director
&
Head of the Ocean Section

Division of Ocean Sciences

What is in store for our oceans, our coasts, the species, the ecosystems and the human systems built upon these resources?



Impacts of Ocean Acidification on Coral Reefs and Other Marine Calcifiers

A Guide for Future Research

Report of a workshop sponsored by

NSF NOAA USGS

JA Kleypas . RA Feely . VJ Fabry
C Langdon . CL Sabine . LL Robbins

Present and Future Impacts of Ocean Acidification on Marine Ecosystems and Biogeochemical Cycles

Report of the
Ocean Carbon and Biogeochemistry Scoping Workshop
on Ocean Acidification Research

Authors:
V. J. Fabry, C. Langdon, W. M. Balch, A. G. Dickson, R. A. Feely, B. Hales, D. A. Hutchins, J. A. Kleypas, and C. L. Sabine

Ocean Acidification

PROGRAM SOLICITATION
NSF 10-530

National Science Foundation

Office of Polar Programs
Division of Antarctic Sciences
Division of Arctic Sciences

Directorate for Geosciences
Division of Ocean Sciences

Directorate for Biological Sciences

Letter of Intent Due Date(s) ***(required)*** (due by 5 p.m. proposer's local time):

March 29, 2010

Full Proposal Deadline(s) (due by 5 p.m. proposer's local time):

April 26, 2010

FOARAM

The Federal Ocean Acidification Research and Monitoring Act

FOARAM passed in the House of Representatives and Senate respectively on 3rd and 19th March 2009.

The Act authorizes appropriations for NOAA and NSF for ocean acidification research for fiscal years 2009, 2010, 2011, and 2012, at $14 million, $20 million, and $27 million, and $35 million per year, respectively.

Establishes an interagency committee to develop an ocean acidification research and monitoring plan.

Establishes an ocean acidification program within the National Oceanic and Atmospheric Administration

Joint Subcommittee on Science and Technology, JSOST

Interagency Working Group on Ocean Acidification, IWG-OA

First action:

Initial Report on Federally Funded Ocean Acidification Research and Monitoring Activities and Progress in Developing a Strategic Plan (completed this spring)

Second action:

A Strategic Research Plan for Ocean Acidification (due spring 2011)

Strategic Research Plan- our Outline

Executive Summary

Introduction and Background

Legislative Mandate and Report Process

- Monitoring of Ocean Chemistry and Biological Impacts (Theme 1)

- Research to Understand Responses to Ocean Acidification (Theme 2)

- Modeling to Predict Changes in the Ocean Carbon Cycle and Impacts on Marine Ecosystems and Organisms (Theme 3)

- Technology Development and Standardization of Measurements (Theme 4)

- Assessment of Socioeconomic Impacts and Development of Strategies to conserve Marine Organisms and Ecosystems (Theme 5)

- Education/Outreach & Engagement Strategy on Ocean Acidification (Theme 6)

- Synthesis of Data and Information Products (Theme 7)

Budget Requirements by Agency

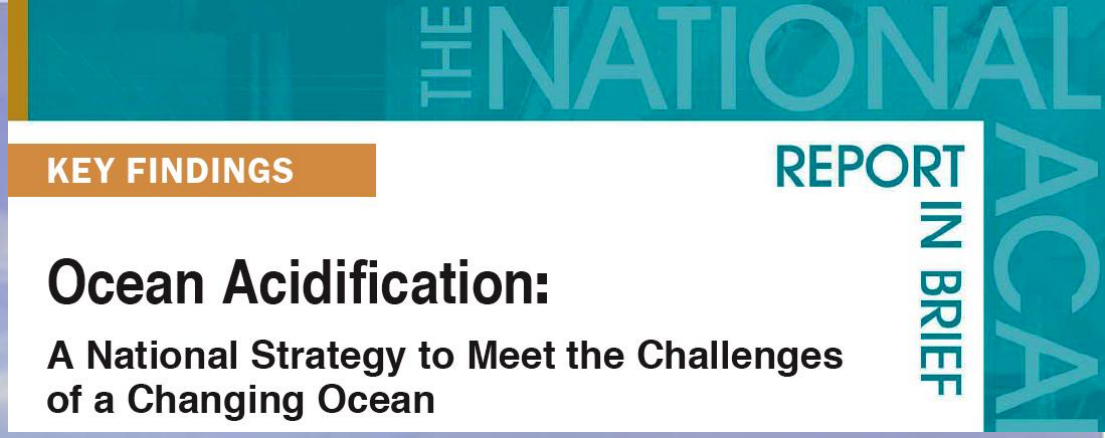
Appendix I: Agency Programs Involved in Ocean Acidification Research

Appendix II: Case Studies – Regional Approaches to Ocean Acidification Monitoring and Research

We have ample scientific inputs of a general nature:

- **Royal Society** Report, 2005
- NSF, USGS, NOAA joint workshop on coral reefs – 2008
- **European Science Foundation** Position Paper 2008. *Impacts of Climate Change on the European Marine and Coastal Environment – Ecosystems*.
- **Ocean Carbon Biogeochemistry (OCB)** Program workshop report 2009: Present and future impacts of ocean acidification on marine ecosystems and biogeochemical cycles.
- **Oceans in a High CO_2 World 2009**: IGBP, SCOR, IOC, IAEA
- **Annual Review of Marine Science** 2009
- ***The Guide to Best Practices in Ocean Acidification Research and Data Reporting***, 2009: EPOCA, IOC, SCOR-ICSU, OCB and the Kiel Excellence Cluster "The Future Ocean".
- OCB Program Office – continuing community facilitation of discussion and planning.
- **International cooperation and collaboration**: EPOCA, BioACID, new UK NERC program, IMBER-SOLAS committee
- **NRC Report** (2010)

A synthesis of all this input is in the recent National Research Council report.



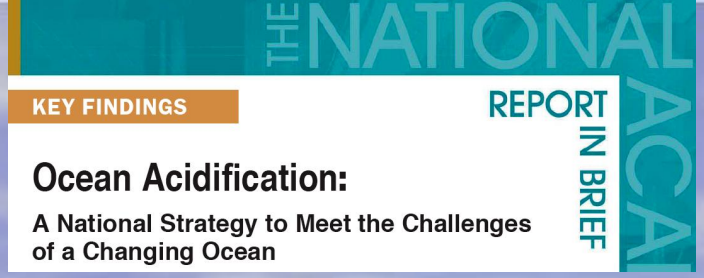
The easy part:

The ocean takes up carbon dioxide ….

as the gas dissolves in seawater it forms carbonic acid ….

this decreases the concentration of carbonate ions and increases bicarbonate in the water…

Ocean chemistry is changing at an unprecedented rate in our history.



Changes in seawater chemistry are expected to affect marine organisms that use carbonate to build shells or skeletons.

It is currently not known how various marine organisms will acclimate or adapt to the chemical changes resulting from acidification.

More information is needed to:

- ♦♦ understand the chemical and physical processes affecting acidification in coastal waters;
- ♦♦ understand the physiological mechanisms of biological responses;
- ♦♦ assess the potential for acclimation and adaptation;
- ♦♦ investigate the response of individuals, populations, and communities of species.
- ♦♦ understand the ecosystem-level consequences, including the implications for biogeochemical cycles
- ♦♦ investigate the interactive effects of multiple stressors;
- ♦♦ understand the socio-economic impacts and the decisions that must be made for mitigation and for human system adaptation.

The supporting needs are articulated strongly

A **global network of chemical, biological and ecological observations** to monitor changes in ocean conditions attributable to a lowering pH.

Support for infrastructure for this science: development of **standards for measurements**, systems **for data collection and archiving** to ensure that data is accessible and useful into the future.

International cooperation, coordination and collaboration.

Sustained support.

Strategic Research Plan – where we are now

Inputs of a more specific nature and geared to specific missions:

- **individual agency discussions and research planning are ongoing; multi-agency cooperation and coordination – local to federal.**

- **recommendations of the external Task Force on Ocean Acidification of the Ocean Research and Resources Advisory Panel (ORRAP). Scientists, NGO's, Foundations, ….**

- **direct engagement of stakeholders in industry sectors, managers, NGOs, Foundations.**

On the way toward setting priorities of actions and articulating the budget needs to accomplish the program

Monitoring of chemistry and biological impacts in coastal and open-ocean regions (in situ and satellite-based) to characterize marine ecosystems, changes in marine productivity, and changes in ocean chemistry.

- From current efforts in global surveys, to ocean time-series (HOT, BATS, LTERs), to the future of OOI, Argo, and glider surveys

Research to understand the species-specific physiological responses of marine organisms, and to develop environmental and ecological indices that track marine ecosystem responses.

Modeling to predict changes in the ocean carbon cycle as a function of carbon dioxide and atmosphere-induced changes in temperature, ocean circulation, biogeochemistry, ecosystem and terrestrial inputs. Also modeling to determine impacts on marine ecosystems and individual marine organisms.

Technology development and standardization of carbonate chemistry measurements on moorings and autonomous floats

Assessment of socio-economic impacts

Development of adaptation and mitigation strategies to conserve marine organisms and marine ecosystems, and to sustain the people and industries these support.

Education & Outreach on ocean acidification

NOAA - new and continuing

- Caribbean ocean carbon chemistry monitoring through assimilation of satellite and in situ data established in FY 2009

- Ocean acidification observing network established in FY 2010

- Coral reef test beds established in FY 2010

- Technology for carbon measurements on moorings is under development.

- Organism response studies are underway

NOAA - new and continuing

- Some ocean acidification-related data are made accessible and preserved by NOAA.

- Working on future access to other ocean acidification data and information both within NOAA and in collaboration with existing partnerships, such as the Department of Energy (Carbon Dioxide Information Analysis Center)

- NOAA Ocean Acidification Program Office is being established

- NOAA Implementation Plan for Ocean Acidification Research is in preparation

NSF **The past few years ($6 M / year):**

1. What are the impacts of **changing pH upon marine chemical phenomena**:

2. What are the impacts of elevated seawater CO_2 and decreased pH upon **marine organisms and their physiological adaptation**, on **species genetic diversity**, **on community structure, and ecosystem processes** of coastal, open ocean, and deep water systems?

3. In today's oceans, **what are the major drivers impacting seawater acidity and alkalinity?**

4. **What does the geologic record reveal** about the relationship between seawater pH and carbonate ion levels, marine species and their evolution,

5. Can changes in **the physical chemistry of the ocean affect other parameters in the water column, e.g., particle aggregation**?

6. What are some existing and potential **observational, experimental, and theoretical approaches** for studying past, present, and future trends in O, A?

NSF **2010 - Climate Research Initiative ($12-15 M / year):**

- **molecular and cellular biology, physiology, marine chemistry and physics, ecological sciences, paleoecology, and earth system history**

- diverse approaches for research (observational systems, experimental studies, theory and modeling.

- the research challenges:
  - Ocean acidification involves fundamental **geochemical phenomena** that are highly interconnected to oceanic biology, physics, and geology.
  - Predicting the consequences on ecosystem health and function requires knowledge of how a shifting geochemical landscape will affect **basic biological processes**.
  - Ocean acidification **may affect the function of ecosystems** through direct impacts on ecosystem members (e.g. life history, behavior and physiology) and their interactions, including food web structure, biotic interactions, and biogeochemical cycling.
  - The **geologic record reveals the history** of climate change and the assemblages of organisms that have risen, persisted, or declined, as the earth system has evolved.

EPA

Review of pH water quality standard

Coral Reef Biological Criteria Development

–Develop methods and approaches to support water quality criteria authorized by the Clean Water Act

Coral Reef Ecosystem Services Research

–Develop tools to support broader consideration of socioeconomic benefits of coral reefs in actions taken in coastal zones and watersheds

Effects of CO_2 on corals (laboratory- proposed)

Socio-economic cost of ocean acidification (proposed)

NASA

Ocean acidification research is embedded with the umbrella of understanding the **ocean carbon cycle and associated biogeochemical processes**.

Efforts to get at productivity and ecosystem change with species or group-based remote-sensing.

MMS, now BOEMRE

- Biogeochemical Assessment of the North Aleutian Basin Ecosystem

- Deep-sea Corals – Lophelia

USGS

Monitoring of ocean chemistry and biological impacts:

- Coral reefs
- Florida subtropical shelf ecosystems,
- Arctic Ocean - chemistry

Species specific physiological responses, development of environmental indices:

- Corals, forams, calcifying algae

Technology Development:

- low-through systems for the rapid measurement of CO_2 levels in water
- Supporting development of software for PC, MAC, and iphone app that will provide expanded capability and use of CO2Sys on various platforms (CO2Calc)

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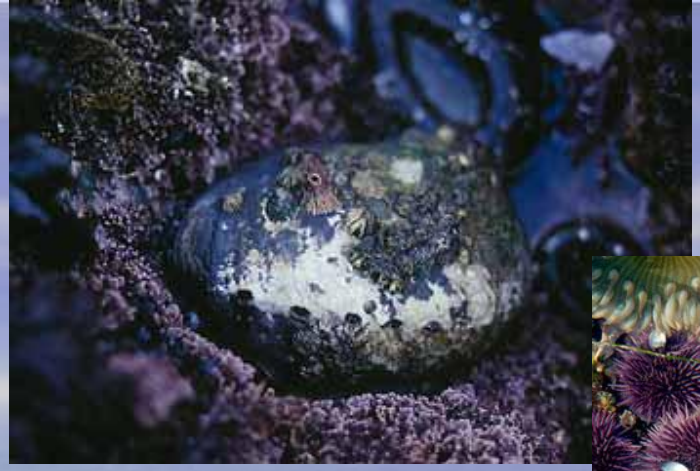

Across agencies, with state and local entities and non-governmental stakeholders, and also international partners, need:

-organizing and integrating research, observing, technology development

-much more engagement of stakeholders that have crucial economic needs to understand the impact of O-A

This meeting is one very important step that needs to be replicated and/or broadened in developing a national O-A enterprise.