



# NOAA OCEAN ACIDIFICATION EDUCATION IMPLEMENTATION PLAN



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At left: NOAA Northwest Fisheries Science Center scientist works with a high-school intern on constructing an experimental system to study species response to ocean acidification. Credit: NOAA

## Executive Summary

Research shows growing evidence of the substantial impacts that anthropogenically released CO<sub>2</sub> is having on ocean waters and the organisms within it. Ocean acidification (OA) is a change in ocean chemistry (pH decrease, dissolved inorganic carbon [DIC] enrichment, decrease in carbonate mineral saturation state and carbonate ion concentration) resulting from the ocean's absorption of atmospheric CO<sub>2</sub>. It has implications for a wide variety of organisms: OA can make building and maintaining shells and other calcium carbonate structures difficult for some calcifying organisms, such as oysters, clams, sea urchins, corals and calcareous plankton, and can negatively affect non-calcifying organisms and structures (i.e., a fish's ability to detect predators and mussels' ability to attach to substrate via byssal threads). Federal legislation has identified a need to improve monitoring, research and education and outreach strategies related to ocean acidification. Using the strategy outlined in this plan, the NOAA Ocean Acidification Program ([OAP](#)), in coordination with other NOAA programs and collaborators involved in OA education, will lead an effort to help the public understand the complex issues arising from changes in ocean chemistry in response to OA.<sup>1</sup> The goals outlined focus on engaging audiences through regionally and locally focused innovative education and outreach programs. These goals can be extended to an international effort, reaching vulnerable communities and building upon existing programs and products that teach diverse audiences about this complex issue.

The following implementation goals and outcomes were created based on a foundation first outlined in the Engagement Strategy of the NOAA Ocean and Great Lakes Acidification Research Plan (April 2010):

**Goal 1: *Develop and conduct a comprehensive needs assessment of education and outreach programming and potential audiences***

**Outcome:** Strengths and weaknesses within ocean acidification education and outreach programs determined and novel target audiences identified

**Goal 2: *Prioritize and engage target audiences for ocean acidification education and outreach***

**Outcome:** Increased literacy in ocean acidification among students, stakeholders and the public

**Goal 3: *Match ocean acidification communication needs with existing research, education and outreach activities***

**Outcome:** Trained, knowledgeable scientists, educators and communicators able to network to broaden the effective distribution of OA science, education activities and communication tools

**Goal 4: *Develop innovative approaches for community involvement***

**Outcome:** NOAA and partner institutions identify and use innovative activities to encourage ocean stewardship through OA research, education and outreach

The NOAA Ocean Acidification Education Implementation Plan guides NOAA OA education and outreach collaborators to identify target audiences and assess the educational needs of populations potentially impacted by OA. From this information, the appropriate programs and products can be determined for each audience and OA education needs can be matched with existing NOAA education and outreach activities. Additionally, new activities needed to fill gaps will be developed by innovative and collaborative efforts within NOAA and other institutions involved with OA communication (i.e., non-governmental organizations [NGOs] and informal education centers [zoos, aquariums, and museums]). An integrated, coordinated effort will be necessary to support NOAA's mission and meet the requirements of the Federal Ocean Acidification Research and Monitoring (FOARAM) Act to better communicate OA and its impacts.

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<sup>1</sup> Ocean Acidification Program Website, [oceanacidification.noaa.gov](http://oceanacidification.noaa.gov)

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## Introduction

This NOAA Ocean Acidification Education Implementation Plan has been developed from the engagement strategies identified in the NOAA Ocean and Great Lakes Acidification Research Plan. The Research Plan was designed to build progress towards addressing the core issues of ocean acidification and provide scientific guidance for the NOAA research community. Engagement strategies listed in the Research Plan aim to extend the reach of NOAA research findings to the broader community through education and outreach. This Ocean Acidification Education Implementation Plan establishes goals to fulfill this aim and outlines intended outcomes and associated objectives and actions to further progress. In order for the the goals and outcomes to continue to be timely and relevant, updates and revisions are planned every 3-5 years. By working to achieve the goals outlined in this Education Implementation Plan, NOAA will foster communication among scientists, educators, communicators, stakeholders and the public to improve environmental decisions in regions vulnerable to the effects of ocean acidification.

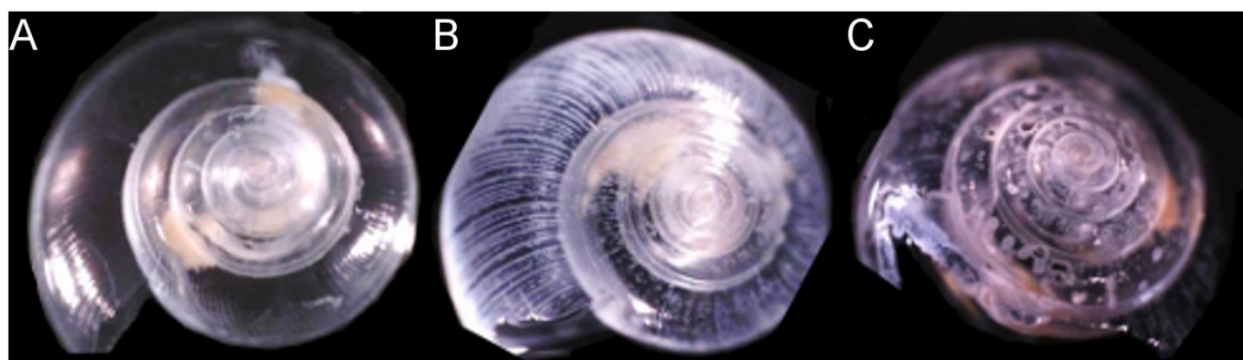


Figure 1. Shells from pteropods incubated in the conditions mimicking (a) *current* surface ocean conditions (b) *current* deep water and summer upwelling conditions (c) *future* deep water or surface conditions during upwelling. Image credit: Busch et al. 2014, PLOSOne

## Background

Human activities have resulted in the release of carbon dioxide (CO<sub>2</sub>) into Earth's atmosphere and these emissions have increased steadily since the Industrial Revolution.<sup>2</sup> Commonly, the rise of atmospheric CO<sub>2</sub> from 280 to 400 ppm is considered in the context of "greenhouse gases" whereby CO<sub>2</sub> is implicated in driving climate change (i.e. associated with increased sea temperature, sea ice melt, et cetera).<sup>3</sup> More recently, this increase has been directly linked to ocean acidification (OA) which is the change in ocean carbonate chemistry resulting from the absorption of CO<sub>2</sub>. Oceans absorb approximately 25% of anthropogenically released CO<sub>2</sub> annually and, through a series of chemical reactions, this CO<sub>2</sub> decreases

<sup>2</sup> Dr. Pieter Tans, NOAA/ESRL ([www.esrl.noaa.gov/gmd/ccgg/trends/](http://www.esrl.noaa.gov/gmd/ccgg/trends/)) and Dr. Ralph Keeling, Scripps Institution of Oceanography ([scrippsco2.ucsd.edu/](http://scrippsco2.ucsd.edu/))

<sup>3</sup> Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change Core Writing Team, Pachauri, R.K. and Reisinger, A. (Eds.) IPCC, Geneva, Switzerland.



the ocean's pH and carbonate ion concentration.<sup>4,5</sup> The chemistry changes associated with OA may affect a wide variety of marine organisms including, but not limited to, those that build shells and skeletons from calcium carbonate, such as shellfish and corals. The impacts of these changes are likely to be widespread and varied, affecting communities and stakeholders throughout the nation's coastal regions and beyond.

Therefore, many stakeholders have decided that continued research and monitoring of OA is important to understand the chemical trends and their potential biological and ecosystem impacts. The Federal Ocean Acidification Research and Monitoring (FOARAM) Act of 2009 calls upon NOAA to have an active monitoring and research program. Additionally, the FOARAM Act calls for education and outreach to improve the public's understanding of current scientific knowledge of OA and its impacts on marine resources. In 2010, the [NOAA Ocean and Great Lakes Acidification Research Plan](#) was developed to outline focal areas for NOAA's OA efforts in the various regions of the U.S.<sup>6</sup> One of the six focal areas for efforts in each region is "engagement", which involves "an education and outreach program to communicate the science and ecosystem consequences of ocean acidification to the public and stakeholder communities."<sup>7</sup> These communities include, but are not limited to, researchers, policy makers, marine resource users, teachers and students — groups that can use NOAA science to make informed decisions and support NOAA's mission of "science, service, and stewardship" through their actions. This Implementation Plan is designed to foster a coordinated and collaborative process across a wide range of programs and activities with the following aims which are outlined in the NOAA Ocean and Great Lakes Research Plan:



**Figure 2. A young audience engaged in a hands-on ocean acidification demonstration by NOAA National Marine Sanctuaries staff at an outreach event. Image credit: NOAA**

One of the six focal areas for efforts in each region is "engagement", which involves "an education and outreach program to communicate the science and ecosystem consequences of ocean acidification to the public and stakeholder communities."<sup>7</sup> These communities include, but are not limited to, researchers, policy makers, marine resource users, teachers and students — groups that can use NOAA science to make informed decisions and support NOAA's mission of "science, service, and stewardship" through their actions. This Implementation Plan is designed to foster a coordinated and collaborative process across a wide range of

programs and activities with the following aims which are outlined in the NOAA Ocean and Great Lakes Research Plan:

- Respond to OA issues raised by NOAA leadership, stakeholders, and the general public that require integrated education and outreach activities across NOAA;
- Coordinate education and outreach activities on OA and help disseminate information related to OA from the laboratories to NOAA leadership and outside communities; and
- Develop and incorporate OA assessment and adaptation policies with line offices and NOAA partners.<sup>8</sup>

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<sup>4</sup> Sabine, C.L., Feely, R.A., Gruber, N., Key, R.M., Lee, K., Bullister, J.L., Wanninkhof, R., Wong, C.S., Wallace, D.W.R., Tilbrook, B., Millero, F.J., Peng, T.H., Kozyr, A., Ono, T., Rios, A.F. The Oceanic Sink for Anthropogenic CO<sub>2</sub> 2004. *Science* 305: 367-371 doi:10.1126/science.1097403

<sup>5</sup> Global Carbon Project 2010

<sup>6</sup> NOAA Ocean Acidification Steering Committee, [NOAA Ocean and Great Lakes Acidification Research Plan](#)

<sup>7</sup> NOAA Ocean Acidification Steering Committee, [NOAA Ocean and Great Lakes Acidification Research Plan, ch 1.1.6 Engagement Strategy](#), pg. 25

<sup>8</sup> NOAA Ocean Acidification Steering Committee, [NOAA Ocean and Great Lakes Acidification Research Plan, ch 1.1.6 Engagement Strategy](#), pg. 25

One major requirement of the FOARAM Act is the development of an information delivery system whereby OA data and research activities within each region be made available to scientists, managers, educators and interested citizens (i.e., web portal and various Internet resources). Multiple NOAA websites display this information (i.e. [Pacific Marine Environmental Laboratory](#), [Integrated Ocean Observing System Regional Associations](#)). The [Ocean Acidification Program](#) now has a website that can be expanded based on the education and outreach needs, products and programs identified from the goals outlined in this implementation plan.

National-scale coordination of NOAA and partner education and outreach efforts is important, but empowering communities and individuals to become ocean stewards is also important and can be achieved by developing connections to the people and places most directly impacted by OA. In 2011, members of the National Marine Sanctuaries of the West Coast created a regional [action plan](#) that outlined steps to approach education and outreach in this impacted region.<sup>9</sup>

Objectives outlined in the West Coast plan include:

- Inventory, share and track existing OA education programs, resources and materials;
- Assess needs of potential audiences;
- Determine appropriate programs and products for each audience;
- Evaluate programs designed to increase awareness and understanding of OA; and
- Develop tools and resources that fill gaps in OA knowledge in prioritized audiences



Figure 3. Channel Islands National Marine Sanctuary's Ocean Acidification web portal (<http://www.cisanctuary.org/ocean-acidification/>).

In an effort to expand upon this regional approach, communicators and educators from across NOAA and partner organizations attended a workshop convened by the West Coast National Marine Sanctuaries in September 2012: “Effective Practices for Communicating OA.”<sup>10</sup> The workshop provided an in-depth discussion on how the national education and outreach community can work together and use their collective momentum to develop new ways to explain and foster understanding of this complex environmental topic. The goals of this implementation plan align with those of both the regional action plan and the Sanctuaries’ workshop outcomes, including communicating OA science directly to those who must act and focusing more broadly on developing a deeper understanding of the causes of and most innovative ways to mitigate the chemistry changes happening to our ocean.

Since the Sanctuaries’ workshop, programs at zoos, aquariums, and science museums (ZAMs) across the nation have begun implementing new informal science education programs that include content on OA. Awardees of the 2012 NOAA Environmental Literacy Grants include three aquariums working collaboratively to increase the effectiveness of informal science educators in promoting public understanding of ocean issues and to encourage stewardship of coastal and ocean resources. Awardees in 2013 will be involved in a coordinated effort between scientists and informal educators to create

<sup>9</sup> Dave Lott, Ed Bowlby, Dan Howard, Kelley Higgason, Karen Grimmer, Laura Francis, Linda Krop, Richard Feely, Libby Jewett, [National Marine Sanctuaries West Coast Ocean Acidification Action Plan](#)

<sup>10</sup> Kearns & West, [Workshop Summary: Effective Practices for Communicating Ocean Acidification](#)

**Potential Education and Outreach Collaborators:**

*NOAA Office of Education*  
*National & State Sea Grant Programs*  
*NOAA Coral Reef Conservation Program*  
*NOAA Office of National Marine Sanctuaries*  
*NOAA National Estuarine Research Reserve System*  
*Regional Integrated Ocean Observing System*  
*Associations (IOOSs)*  
*NOAA Climate Program Office*  
*The Smithsonian Institution*  
*The Ocean Conservancy*  
*Institute for Systems Biology*  
*University of California Santa Cruz Center for*  
*Microbial Oceanography: Research and*  
*Education*  
*Oceana*  
*The Sven Loven Centre for Marine Sciences*

scientifically accurate and engaging OA educational activities.<sup>11</sup>

Additionally, San Francisco's Exploratorium, a long-time proponent of collaborations between educational and scientific institutions, uses its partnership with NOAA to provide the public access to environmental science data collected by agency technology. Its Wired Pier Project is an example of how scientific OA data can be made accessible and relevant to a local community.

Social media is becoming one of the most powerful tools for communicating with audiences outside of ZAMs and visitor centers. Social networking platforms (Twitter, Facebook, Instagram, et cetera) are being incorporated into outreach programs everywhere and have become essential means of communication for many NGOs. Through this technology, the NOAA OAP and education collaborators

can maintain close relationships with audiences who use these tools. Tailored messages can reach specific demographics based on interests and background knowledge, bringing current OA topics to people in a progressive manner.

Efforts are underway by a variety of NOAA programs to develop and use effective communication tools and messages on OA. Many of these efforts were designed based on locale (i.e., cold, upwelling waters of the West Coast National Marine Sanctuaries) or program focus (i.e., calcification of coral reefs within the Coral Reef Conservation Program). Multiple programs within NOAA have been identified as valuable collaborators in OA communication. Many programs outside NOAA are actively developing OA education tools. In 2012, Washington State's governor commissioned a blue ribbon panel on OA, which included representatives from local, state, federal (including NOAA) and tribal governments, academia, industry, and NGOs, to summarize the state of OA science as it is relevant to Washington State and make recommendations for action. Panel recommendations included educating and engaging the public and decision makers on OA issues. Collaboratively developing and sharing effective tools and messages will be critical for both effectively communicating to a variety of audiences and the successful implementation of this plan. The OAP is positioned to take a role coordinating this effort to facilitate collaborations and strengthen OA education. This Implementation Plan aims to identify and use current and future resources within the OA education community to coordinate efforts to improve OA communication among all stakeholders as the community interested and involved in OA grows.

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<sup>11</sup> "Building Ocean Awareness Together (BOAT)"; [http://www.oesd.noaa.gov/grants/elg/elg12/Ocean\\_Ed\\_awards.html](http://www.oesd.noaa.gov/grants/elg/elg12/Ocean_Ed_awards.html)

## Goals and Objectives

The goals of this implementation plan are based on steps from the engagement strategies of the *NOAA Ocean and Great Lakes Acidification Research Plan*.<sup>12</sup>

### **Goal 1: *Develop and conduct a comprehensive needs assessment of education and outreach programming and potential audiences***

**Outcome:** Strengths and weaknesses within ocean acidification education and outreach programs determined and novel target audiences identified

### **Goal 2: *Prioritize and engage target audiences for ocean acidification education and outreach***

**Outcome:** Increased literacy in ocean acidification among students, stakeholders and the public

### **Goal 3: *Match ocean acidification communication needs with existing research, education and outreach activities***

**Outcome:** Trained, knowledgeable scientists, educators and communicators able to network to broaden the effective distribution of OA science, education activities and communication tools

### **Goal 4: *Develop innovative approaches for community involvement***

**Outcome:** NOAA and partner institutions identify and use innovative activities to encourage ocean stewardship through OA research, education and outreach

Each goal will be met as members of the NOAA OA education community (including collaborators) use actions outlined below to achieve the associated objectives. The actions necessary to reach the outcome for each goal will be evaluated as the NOAA OAP education and outreach programs develop and will be informed by the needs assessments completed in conjunction with this implementation plan.



Figure 4. An education specialist at Monterey Bay Aquarium discusses communicating about ocean acidification in aquariums at the "Effective Practices for Communicating Ocean Acidification" workshop, hosted by NOAA National Marine Sanctuaries. Image credit: NOAA

<sup>12</sup> Op. cit., NOAA Ocean Acidification Steering Committee, Theme 6, Task 1.6



## Goal 1: Develop and conduct a comprehensive needs assessment of education and outreach programming and potential audiences

*Outcome: Strengths and weaknesses within ocean acidification education and outreach programs determined and novel target audiences identified*

A needs assessment survey will provide an overview of existing educational and outreach programs; public information materials; collaborations among NOAA scientists, educators, communicators and partners; potential audiences and stakeholders; and detailed feedback on ways to improve OA education on international, national and regional levels. This initial evaluation of strengths and weaknesses will identify how the goals of the existing OA education programs align with the education and outreach goals outlined in the NOAA Ocean and Great Lakes Acidification Research Plan and will establish a baseline against which products resulting from this implementation plan can be assessed.<sup>13</sup>

*Objective 1.1:* Improve awareness and collaboration among OA education and outreach programs.

- Action 1.1.1: Collect needs assessment data and incorporate these data into a summary report, which includes a reviewed collection of current OA educational resources and outreach materials and identifies gaps in content and audience focus.

*Objective 1.2:* Evaluate education and outreach programs' effectiveness using NOAA's evaluation standards.

- Action 1.2.1: Establish an intra-agency working group to utilize NOAA's methods and tools to evaluate strengths, progress and potential areas of growth for OA education and outreach programs.
- Action 1.2.2: Implement these methods and tools to evaluate effectiveness and facilitate collaboration by sharing effective tools with the community.

### **Potential Needs Assessments Participants:**

*IOOS Regional Associations-  
Education/Outreach Staff  
National Sea Grant- Safe and Sustainable  
Seafood Supply Focus Area  
State Sea Grant Extension- Climate  
Team & Extension outreach staff  
National Marine Sanctuaries- Climate/OA  
focused education/outreach staff  
The Ocean Conservancy- OA Program  
staff  
Consortium for Ocean Leadership  
Sustainable Fisheries Partnership  
ZAMs- MBARI/Monterey Bay Aquarium,  
Pacific Science Center, Aquarium of  
the Pacific, The Exploratorium,  
National Museum of Natural History  
New England, Seattle, Georgia, North  
Carolina and Baltimore Aquariums  
NOAA Cooperative Institutes  
C-CAN, NECAN  
COMPASS  
Ocean Carbon and Biogeochemistry Woods  
Hole Oceanographic Institute*

<sup>13</sup> Ibid.

## Goal 2: Prioritize and engage target audiences for ocean acidification education and outreach

*Outcome: Increased ocean acidification literacy among stakeholders and the public*

OA is a burgeoning field of research and a new topic for much of the general public. Data from a 2012 public opinion poll showed that about half of those polled considered OA a serious threat, although only 7% could say they knew much about the issue.<sup>14</sup> This Implementation Plan focuses on improving these numbers by reaching target audiences who can contribute to an informed society that uses a comprehensive understanding of the role of the oceans, coasts, and atmosphere in the global ecosystem to make the best social and economic decisions. Identifying target audiences for NOAA's OA education and outreach programs will help communicators develop better methods for communicating the changes caused by OA and how we can change our behaviors to promote ocean stewardship.

*Objective 2.1:* Identify successful methods of communication for target audiences.

- Action 2.1.1: Develop a matrix of data from the OA needs assessment (Goal 1) of target audiences, effective messages and tools, gaps and recommended actions to guide further education efforts.

### **Potential Audiences:**

- **industry**
  - hatcheries
  - shellfish harvesters
  - fisher people
  - aquaculture
- **recreationers**
  - divers
  - anglers
- **university students**
  - Research Experience for Undergraduate students
  - Hollings Scholars
  - interns
  - fellows

- Action 2.1.2: Establish educational content and programs digitally and in other forms that are most directly available to target audiences.
- Action 2.1.3 Create a social media campaign to connect with the public through creative, informative and interactive messaging.
- Action 2.1.4: Align media campaigns with regional issues surrounding coastal and OA.

*Objective 2.2:* Engage audiences in OA programming and public events.

- Action 2.2.1: Use and increase number of exhibits, kiosks, signage and other platforms at NOAA and collaborative institutions to further OA literacy messaging.

- Action 2.2.2: Work with media to increase public prominence of national and/or regional OA issues.
- Action 2.2.3: Facilitate new partnerships in the arts to emphasize the connections among art, the ocean and science.

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<sup>14</sup> Edge Research, "US Public Opinion Ocean Acidification Research," Six Americas Study.

### Goal 3: Match ocean acidification communication needs with existing research, education and outreach activities within NOAA

*Outcome: Trained, knowledgeable scientists, educators and communicators able to network to broaden the effective distribution of OA science, education activities and communication tools*

#### **Potential Programs/Products:**

Upwell  
Inquiry to Insight  
The Sven Lowe Center for Marine Science  
Climate Interpreter  
New England Aquarium  
MBARI  
C-MORE Center for Microbial Oceanography:  
    Research and Education  
Digital Explorer Oceans (UK)  
OCEANA  
Pacific Science Center  
Institute for Systems Biology  
NOAA National Marine Sanctuaries  
Smithsonian (Ocean Hall)  
Liberty Science Center  
Baltimore Aquarium  
Georgia Aquarium  
North Carolina Aquarium  
Disney's Epcot Center  
The Exploratorium  
Centers for Ocean Science Education  
    Excellence

Collectively, NOAA's education initiatives have greatly advanced the public's awareness of NOAA science and are continuing to do so by expanding to include OA as a topic.<sup>15</sup> The NOAA Ocean Acidification Program and OA educational communities at NOAA's National Marine Sanctuaries, Office of Education, Coral Reef Conservation Program, Climate Program Office and the National Sea Grant Program are committed to improving understanding of OA issues by supporting efficient development of education and outreach programs to stay on the cutting edge of scientific communication.

*Objective 3.1:* Establish a communication and coordination network among NOAA OA research groups and NOAA and collaborator education and outreach programs.

- Action 3.1.1: Leverage existing OA community resources to link scientists at NOAA labs and partner research institutions with educators and communicators at NOAA and NOAA-partner education and outreach programs that are actively teaching about OA topics

through webinars, peer mentorship programs, resource posting on web portals (i.e. OAP website) and/or network listserves.

- Action 3.1.2: Disseminate timely and effective OA outreach and education messages at appropriate venues to develop a framework for OA education literacy principles.

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<sup>15</sup> NOAA Ocean Acidification Strategic Research Plan, *Linking to Existing Programs and Organizations*, 2012 draft.

- Action 3.1.3: Encourage and participate in workshops to engage formal and informal educators and those involved in OA outreach to share activities that demonstrate or teach OA concepts.<sup>16</sup>
- Action 3.1.4: Foster communication among the NOAA OAP, other national programs and state-based or local programs to ensure OA communication strategies are relevant and timely for locally impacted communities.

*Objective 3.2:* Incorporate education and outreach requirements into NOAA OA research activities.

- Action 3.2.1: Where appropriate, funding opportunities for NOAA OAP scientific research grants should include guidance to facilitate collaboration and time accountability with NOAA OAP education programs or outreach efforts that enhance community involvement and awareness of local OA research and issues. This is also encouraged in other NOAA programs supporting OA research.
- Action 3.2.2: Funding opportunities for NOAA OAP education programs should, where guidance is not under Congressional purview, encourage collaboration with a NOAA lab, scientist or partner research institution to highlight OA research through education and outreach programming. This is also encouraged in other NOAA programs supporting OA education and outreach projects.

## Goal 4: Develop innovative approaches for community involvement

*Outcome: NOAA and partner institutions identify innovative ways to encourage ocean stewardship through OA research and education*

OA issues stand to impact coastal communities in ways yet to be realized and will require that NOAA continue to find new methods of empowering people to be ocean stewards. Collaboration between NOAA and its affiliates through local, state, regional, national, and international partnerships will encourage an open dialogue and present the opportunity for communities to change how complex science topics are communicated among scientists, educators, and local citizens. By encouraging innovative solutions, NOAA remains flexible in its outreach message, educational approach and partnerships to serve the immediate and future needs of OA education and outreach.

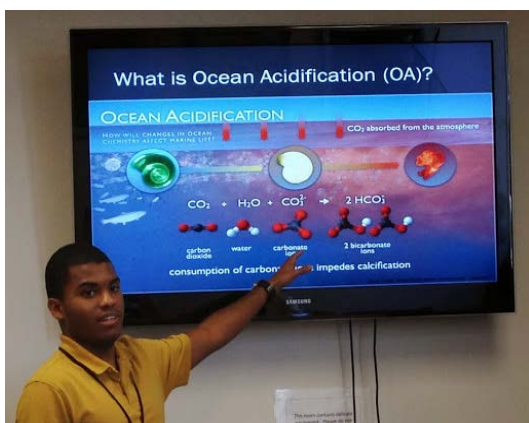


**Figure 5.** Hollings Scholar working in the Northwest Fisheries Science Center Ocean Acidification (OA) lab on an experiment to study the response of larval oysters to OA. Image credit: NOAA

<sup>16</sup> op. cit., Kearns & West.

*Objective 4.1:* Encourage collaboration among scientists, educators and stakeholders.

- Action 4.1.1: Encourage NOAA labs and scientists performing OA research to become mentors for NOAA scholarship students and fellows (such as the Ernest F. Hollings Undergraduate Scholarship Program, Education Partnership Program, Presidential Management Fellowship and John A. Knauss Marine Policy Fellowship) and strengthen collaboration with universities.
- Action 4.1.2: Promote consistent messaging on OA throughout NOAA OA educational programs by working with the current [Ocean Literacy Framework](#) upon which formal and informal OA education should be founded (in cooperation with NOAA OAP, NOAA Education Council and partners).<sup>17</sup>
- Action 4.1.3: Offer training opportunities for educators to strengthen their comfort with and fluency in OA scientific concepts and ability to use resources and tools to effectively educate about OA science.
- Action 4.1.4: Build relationships with and continue to share research, communication and education strategies with citizen networks (such as the California Current Acidification Network (C-CAN), Northeast Coastal Acidification Network (NECAN) and the Integrated Ocean Observing Systems (IOOS) program).



**Figure 6.** NOAA Hollings Scholar presenting his research project which focused on effective ocean acidification outreach in the Northeast US. Image credit: NOAA

- Action 4.1.5: Administer small grants through various NOAA programs to support school and community partnerships that focus on OA curriculum development and provide avenues for sharing experiences and best practices for OA education and outreach.
- Action 4.1.6: Develop data streams, videos, visualizations, and images based on NOAA data that can be accessed online and interpreted by educators in place-based locations such as National Marine Sanctuaries and National Estuarine Research Reserves; in informal education centers such as aquariums and science museums; and in classrooms, outreach talks and research lectures.

- Action 4.1.7: Establish a working group to develop methods and tools to evaluate strengths, progress and potential areas of growth and integration of programs within the OA education community.

*Objective 4.2:* Provide incentives for NOAA scientists to participate in education and outreach activities and for NOAA educators to become more fluent in understanding and communicating NOAA science.

- Action 4.2.1: Encourage and facilitate active participation in education and outreach activities by OAP staff and NOAA OAP-funded scientists. This is also encouraged in other programs supporting OA scientific research.

<sup>17</sup> [Ocean Literacy: The Essential Principles and Fundamental Concepts of Ocean Sciences for Learners of All Ages](#), Version 2: March 2013



Action 4.2.2: Offer training opportunities for scientists to communicate their work to diverse audiences that include educators, science communicators and education/outreach staff from programs such as the National Marine Sanctuaries, National Estuarine Research Reserve System or Sea Grant.

*Objective 4.3:* Demonstrate a commitment to mitigating OA by encouraging reductions of carbon emissions.

- Action 4.3.1 Raise awareness about the link between OA and CO<sub>2</sub> emissions. Tools such as the carbon footprint calculator can be used by those conducting education and outreach to evaluate personal carbon footprint values and identify ways to reduce it.
- Action 4.3.2: Promote best practices for reducing facility, operations and staff carbon footprints, such as encouraging staff to take advantage of mass transit subsidies, carpooling and bicycle commuting options and actions highlighted in the annual [DOC Energy and Environmental Stewardship Awards](#).<sup>18</sup>
- Action 4.3.3: Incentivize NOAA science, education and outreach program participants to not only reduce their individual carbon footprints, but to find and initiate innovative carbon reduction and mitigation projects at the community level.



Figure 7. University of Washington (UW) technician and research student from UW Louis Stokes Alliance for Minority Participation Program fabricate rearing chambers for experiments on the response of crabs and krill to ocean acidification. Image credit: NOAA

## Conclusion

The NOAA Ocean Acidification Program and other programs involved in OA research, education and communication understand that progress in OA mitigation and adaptation requires support of key stakeholders, from policy makers to educators to the general public. The importance of effective education and public outreach should not be overshadowed by the challenges of disseminating scientific information to a broad audience. While many within the education community have created engaging education and outreach programs and products related to OA, the goals outlined in this Ocean Acidification Education Implementation Plan should serve to channel the efforts of the scientific and education communities in productive directions while continuing to encourage innovation and creativity. The ultimate result will be an integrated, effective, coordinated effort to understand and communicate OA and its impacts.

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<sup>18</sup> Website for Department of Commerce Energy and Environmental Stewardship Awards, [http://www.osec.doc.gov/oas/OSEEP/energy\\_environmental\\_awards\\_main.html](http://www.osec.doc.gov/oas/OSEEP/energy_environmental_awards_main.html)