U.S DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL OCEAN SERVICE
National Marine Sanctuary Program

West Coast Region
99 Pacific Street, Bldg. 200, Suite K
Monterey, CA 93940

August 5, 2011

Dear Colleague:

I am pleased to announce the completion of the *National Marine Sanctuaries of the West Coast Ocean Acidification Action Plan*. This plan was developed in response to the five west coast sanctuary advisory council resolutions calling for action on the topic of ocean acidification.

This action plan was develop by a task force consisting of members from each of the five west coast national marine sanctuaries, including Laura Francis (CINMS), Karen Grimmer (MBNMS), Kelley Higgason (GFNMS), Dan Howard (CBNMS), Ed Bowlby (OCNMS) and Dave Lott (WCRO). Other participants on the task force included Linda Krop (CINMS – Sanctuary Advisory Council), Dick Feely (NOAA OAR Pacific Marine Laboratory), and Libby Jewett (Director, NOAA Ocean Acidification Program). I would like to thank the task force members for their assistance in producing the report.

The West Coast Region has begun implementing several elements of the action plan, and we are pursuing options for new funding to support implementation. We will also periodically revisit and revise the action plan as information is updated and progress is made implementing the strategies.

Sincerely,

Carol Bernthal

Carol Bernthal
West Coast Regional Director (Acting)
Office of National Marine Sanctuaries

Olympic Coast
National Marine Sanctuary
115 E. Railroad Ave., Ste 301
Port Angeles, WA 98362

Cordell Bank
National Marine Sanctuary
P.O. Box 159
Olema, CA 94950

Gulf of the Farallones
National Marine Sanctuary
Building 991, Presidio of SF
San Francisco, CA 94129

Monterey Bay
National Marine Sanctuary
299 Foam Street
Monterey, CA 93940

Channel Islands
National Marine Sanctuary
113 Harbor Way
Santa Barbara, CA 93109

National Marine Sanctuaries of the West Coast

Ocean Acidification Action Plan

Dave Lott WCR, Ed Bowlby OCNMS, Dan Howard CBNMS, Kelley Higgason GFNMS, Karen Grimmer MBNMS, Laura Francis CINMS, Linda Krop CINMS SAC, Richard Feely PMEL, Libby Jewett OAR

August 5, 2011

I. Introduction

Anthropogenic release of carbon dioxide (CO_2) has resulted in a large increase of CO_2 in the atmosphere since the Industrial Revolution. Increases in atmospheric carbon dioxide levels have resulted in warmer air and water temperatures, with cascading effects on winds, precipitation, sea level, and ocean circulation, and additionally, have altered ocean chemistry. Although the world's oceans have served as a sink for up to 30% of all anthropogenic CO_2 produced since the Industrial Revolution, this overload of atmospheric carbon dioxide is slowly changing ocean chemistry by increasing the dissolved carbon dioxide concentration in seawater. This chemical reaction reduces seawater pH and the concentration of carbonate ions through a process called 'ocean acidification'.[1] The predicted direct adverse reactions as a result of lower pH in seawater include: increased difficulty for $CaCO_3$ forming organisms, such as corals, some invertebrates and some plankton, to produce and maintain their calcium carbonate shells; mobility, growth and reproductive problems associated with increased carbon dioxide levels in internal fluids in fish and other energetic species; negative changes to photosynthesis rates in certain organisms; acoustical disruptions from reduced sound absorption in seawater; and a disruption of critical olfactory cues in fish.[2]

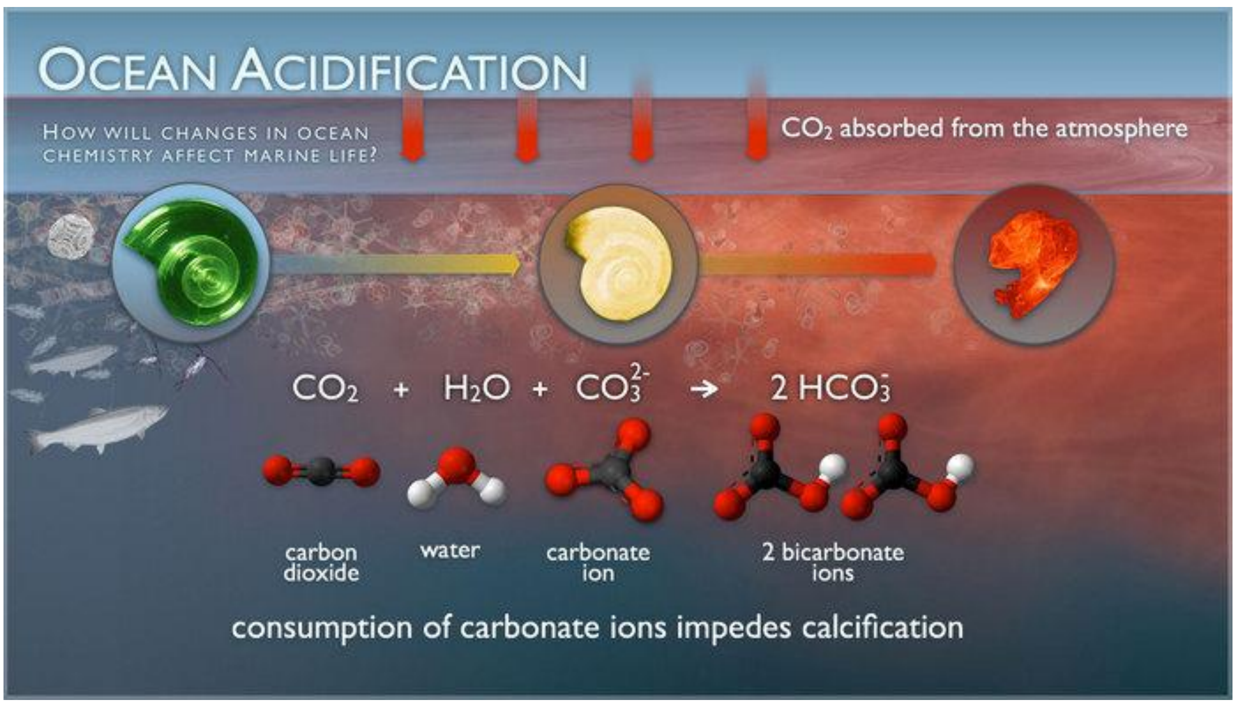

Figure 1. Schematic Diagram of the Ocean Acidification Process(image provided by the NOAA Pacific Marine Environmental Laboratory Carbon Group in collaboration with the University of Washington Center for Environmental Visualization).

Recognizing that ocean acidification could have significant ramifications for local ecosystems, the Channel Islands National Marine Sanctuary, Sanctuary Advisory Council Conservation

[1] NOAA Ocean Acidification Steering Committee (2010): NOAA Ocean and Great Lakes Acidification Research Plan, NOAA Special Report, 143pp.
[2] Orr, J.C. et al. 2005. "Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms." *Nature* 437:681-686

Working Group developed a report entitled *Ocean Acidification and the Channel Islands National Marine Sanctuary: Cause, effect, and response* in the fall of 2008.[3] The report gives an overview of ocean acidification, describes the potential impacts, and recommends action by staff and stakeholders. After the report was adopted by the Channel Islands National Marine Sanctuary Advisory Council, the other four sanctuary advisory councils on the west coast adopted resolutions recommending that the west coast sanctuaries recognize the importance of ocean acidification at each site, and, with the help of the West Coast Regional Office, take a coordinated approach to addressing ocean acidification issues. By January 2010, all 13 sanctuaries within the system had adopted resolutions concerning ocean acidification.[4]

As a result of the recommendations from the sanctuary advisory council resolutions, The West Coast Regional Office of NOAA's Office of National Marine Sanctuaries created a West Coast Ocean Acidification Task Force to take action on the resolutions. The task force includes one staff member from each of the five west coast national marine sanctuaries across all of the major program areas, an advisory council representative, and staff from NOAA's Oceanic and Atmospheric Research's (OAR) Pacific Marine Environmental Laboratory (PMEL) and National Ocean Service's (NOS) National Center for Coastal Ocean Science (NCCOS). The task force met in April 2010, and agreed to develop a regional action plan on ocean acidification.

The Task Force plan was completed in April 2011, and reviewed by the five west coast national marine sanctuary advisory councils. Input from the councils was incorporated into the final plan, which includes seven strategies: (1) Monitoring for Ocean Acidification; (2) Research on Ocean Acidification; (3) Education and Outreach; (4) Mitigating Damages to Sanctuary Resources; (5) Influencing Regional and National Policy; (6) Demonstrate Leadership by Reducing Carbon Emissions; and (7) Internal Coordination on Ocean Acidification Issues. Each strategy is implemented through recommended activities. For each strategy, the plan also includes a recommended five-year timeline and estimated cost. Within these timelines, priorities will be established based on available funding, resources, and importance or urgency of the strategy or activity.

II. Ocean Acidification and the California Current Ecosystem

Wind-driven upwelling, which pulls cool, nutrient-enriched water from the deep ocean to replace surface water that is lost near the coast, accounts for the high biological productivity of the west coast sanctuary sites. The upwelled coastal waters of the Northeastern Pacific Ocean are naturally rich in carbon dioxide (CO_2) and nutrients, lower in oxygen (O_2) and lower in pH than the waters they replace. This naturally occurring high-CO_2 condition is exacerbated by the uptake of anthropogenic CO_2 at the surface. Upwelled waters also characteristically have lower saturation states for the major $CaCO_3$ biominerals, aragonite (Ωarag) and calcite (Ωcal), than surface waters. Species with calcium carbonate shells, tests, or skeletons may have more difficulty maintaining their shells in the low pH surface water anticipated for the West Coast under future CO_2 emission scenarios.

[3] Conservation Working Group, Channel Islands National Marine Sanctuary. Ocean Acidification and the Channel Islands National Marine Sanctuary: Cause, effect and response. Adopted by the CINMS Advisory Council September 19, 2008. Prepared by S. Polefka and J. Forgie, Environmental Defense Center, Santa Barbara, CA.
[4] Ocean Acidification Resolutions: Sanctuary Advisory Council Recommendations to NOAA 2008-2010. http://sanctuaries.noaa.gov/management/pdfs/oareso_summary2.pdf

Within the California Current System (CCS) - which includes all five west coast national marine sanctuaries - there is strong regional variability in the intensity and duration of upwelling, as well as in the dominance of upwelling in controlling biogeochemical cycling and ecosystem susceptibility to ocean acidification. Of critical significance to ecosystems are the spatial and temporal scales of upwelling. The strong gradients in water conditions that are observed across the shelf or along the CCS are characterized by intense localized upwelling that may be as focused as a hundred meters or as diffuse as hundreds of kilometers, and are ephemeral with time occurring over days to months. Further, the intensity of upwelling and the spatial variability in the upwelling process is expected to change in response to climate change.[5] Indeed, the increased exposure of organisms to low-pH waters will be influenced by both changes in deep-water chemistry (increased CO2 concentrations) and changes in the depth from which water is upwelled (due to changes in winds). This variability in upwelling intensity emphasizes the need to do research in the sanctuaries to determine where the highest vulnerabilities exist and how they are changing.

Research done by NOAA's Pacific Marine Environmental Laboratory suggest that the occurrence of more acidic deep water within the CCS onto the continental shelf could affect some of the most fundamental biological and geochemical processes of the sea in the coming decades and could seriously alter the fundamental structure of pelagic and benthic ecosystems.[6]

Recognizing that physical oceanographic features like upwelling are moving more acidic water into shallow areas on the continental shelf, and that this upwelling has been strengthening over the last few decades[5], it is possible that marine resources and habitats on the west coast could be affected by ocean acidification within time scales much shorter than the decades predicted under CO2 emission scenarios. Work conducted within national marine sanctuaries along the west coast would provide data to further understand acidification impacts on a site specific, regional and CCS scale.

III. Linkages to Other Ocean Acidification Plans and Activities

This action plan recognizes that there are number of existing planning activities occurring at both the sanctuary sites and national levels for climate change in general.

The four California sanctuaries recently completed and have begun implementing their new site management plans. While there are no stand alone action plans for climate change, the problem is recognized as an ‘emerging issue’ and is referenced in other areas of the management plans, particularly in conservation science. The Olympic Coast National Marine Sanctuary is currently undergoing a management plan revision process which will include a climate change action plan, and Gulf of the Farallones National Marine Sanctuary has begun work on their climate change action plan. This also illustrates how sanctuary sites could promote themselves as key components in the sentinel site concept along the west coast, thereby coordinating with other

[5] García-Reyes, M., and J. Largier (2010), “Observations of increased wind driven coastal upwelling off central California,” J. Geophys. Res., 115, C04011, doi:10.1029/2009JC005576.
[6] Feely, R.A., C.L. Sabine, J.M. Hernandez-Ayon, D. Ianson, and B. Hales. 2008. “Evidence for upwelling of corrosive ‘acidified’ water onto the Continental Shelf.” Science 320: 1490–1492, doi: 10.1126/science.1155676.

NOAA programs and leveraging other agencies and academia plans for research, monitoring and education/outreach efforts on ocean acidification within the sanctuary network.

The NOAA Ocean and Great Lakes Acidification Research Plan was created in direct response to the Federal Ocean Acidification and Monitoring (FOARAM) Act of 2009 which mandates that NOAA have an active monitoring and research program in regards to ocean acidification. Over 70 scientists across the agency - including sanctuary staff - contributed to this plan. In particular there is a direct reference in the NOAA research plan for proposing sanctuary sites as intensively studied marine managed areas for focused monitoring efforts on the west coast (Strategy 3.1.5, pg. 47). The National Marine Sanctuary System is also proposed as integral player in engaging the public through its robust education programs (Strategy 3.6.1, pg 56). In addition, opportunities exist for coordinating ocean acidification research and management efforts among NOAA's relevant departments and programs (such as National Marine Fisheries Service (NMFS) and the Pacific Marine Environmental Laboratory).

A new effort, California Current Acidification Network (http://c-can.msi.ucsb.edu/) is underway which grew out of concern for recent oyster hatchery failures in the Pacific Northwest. A meeting was organized in July 2010 convening various west coast fishery managers, ocean observing organizers, researchers and other coastal stakeholders to develop recommendations for responding to the shellfish grower concerns. A report was developed (http://www.sccwrp.org/Meetings/Workshops/OceanAcidificationWorkshop.aspx) and, more importantly, an advisory group was established which is now headed by Andrew Dickson at Scripps. The West Coast National Marine Sanctuary ocean acidification efforts should be coordinated in the context of the broader west coast effort.

The NOAA Ocean Acidification Program office has a director as of June 2011. This office which was mandated by the FOARAM legislation will be responsible for coordinating ocean acidification research, monitoring, outreach and education across NOAA and will assist the sanctuaries in leveraging their efforts with other NOAA activities.

Several national policy processes are underway which involve strategies for adaptation to climate change and ocean acidification. It will be important to keep the Office of National Marine Sanctuaries (ONMS) and the newly forming NOAA Ocean Acidification Program Office apprised of the west coast sanctuaries findings to contribute to these interagency processes. The mitigation and adaptation strategies developed for the west coast sanctuaries (and other ONMS regions) should also be shared with international partners through information exchanges involving the North Pacific Marine Science Organization (PICES), International Council for the Exploration of the Sea (ICES) and Intergovernmental Oceanographic Commission (IOC).

Other useful research partnerships exist with research institutions that are investigating Ocean Acidification. Examples include, but are not limited to:

- University of California Santa Barbara, Hoffman Labs
- California State University San Marcos, Fabry Labs
- Scripps Institution of Oceanography (Dickson and Send Labs)
- Marine Conservation Biology Institute
- University of Washington Applied Physics Laboratory (Newton Lab)

- Oregon State University (Hales Lab)
- University of California, Davis, Bodega Marine Laboratory (Hill and Largier Labs)
- San Francisco State University, Romberg Tiburon Center
- National Marine Fisheries Service, Southwest and Northwest Fisheries Science Centers

IV. Taking Action: Regional Strategies for Ocean Acidification

The following overarching strategies and activities attempt to address the question of regional coordination for ocean acidification in West Coast national marine sanctuaries.

Goal Statement:

> *"Understand and protect biological communities within west coast sanctuaries from the impacts associated with ocean acidification, develop adaptations to these impacts, and communicate these impacts and solutions to the public."*

Strategy 1: Monitoring for Ocean Acidification

The existing global oceanic carbon observatory network of repeat hydrographic surveys, time-series stations and ship-based underway surface observations in the Atlantic, Pacific, and Indian Oceans provide a strong foundation of carbonate chemistry observations to begin addressing the problem of ocean acidification (NOAA Ocean Acidification Steering Committee, 2010). Enhancing these activities and expanding the global moored time-series network with new carbon parameter and pH sensors will provide important information on the changing conditions in the open ocean. U.S. coastal and estuarine environments do not currently have coordinated carbon observing networks and are presently grossly under-sampled. Building on existing infrastructures, however, coastal and estuarine networks of shipboard and remote autonomous measurements similar to the open ocean network should be established. This will greatly facilitate the development of our capability to predict present and future responses of marine biota, ecosystem processes, biogeochemistry, and climate feedbacks. Some of the key questions regarding responses to ocean acidification are whether or not there are geochemical thresholds for ocean acidification (e.g., $CaCO_3$ mineral saturation state levels) that will lead to irreversible effects on species and ecosystems over the next few decades, and can we develop new biological methodologies to determine whether organisms and ecosystems can adapt sufficiently to changing seawater chemistry in ways that will reduce potential negative impacts of ocean acidification?

Parameters that can be measured routinely onboard ships include temperature, salinity, oxygen, nutrients, partial pressure of carbon dioxide (pCO_2), pH, total alkalinity (TA), dissolved inorganic carbon (DIC), dissolved organic carbon (DOC) and particulate organic- and inorganic carbon (POC, PIC). While some portion of these chemical species now can be measured on moorings and floats they are not yet broadly utilized on a global scale. Moreover, new method development is required for routine measurements of DIC and TA and proxies that may indicate stress on marine biota. The methods are well established and described in great detail in the "Guide to Best Practices for Ocean CO_2 Measurements".[7] In addition, appropriate standards are

[7] Dickson, A.G., Sabine, C.L. and Christian, J.R. (Eds.) 2007. *Guide to best practices for ocean CO2 measurements*. PICES Special Publication 3, 191 pp.

available for DIC, TA, and pCO_2. For ocean acidification research at least two, and preferably three, of the four carbon parameters should be measured at each of the sampling depths to allow determination of all DIC species and parameters and to ensure internal consistency of the data. The chemical measurements described above are critical for validation of sensors and assessment of accuracies. All measurements should follow procedures and protocols outlined in the Best Practices guides (Dickson et al., 2007; Riebesell et al., 2010).[8]

With respect to the biological parameters, measurements of net primary production, either directly or from nutrient or oxygen inventories along with hydrodynamic considerations in estuarine and coastal waters, are also necessary to allow physical and biological effects on ocean chemistry to be identified. These additional measurements are needed to predict ecosystem responses to ocean acidification. Since there are no agreed upon metrics for biological variables, it would be beneficial to monitor general indicators of marine ecosystem processes to create a time series data set that will be informative to future efforts to identify correlations and trends between the chemical and biological data. As critical biological indicators and metrics are developed, the program will need to incorporate those measurements into the research plan, and thus, adaptively respond to developments in the field.

Activity 1.1 Inventory existing west coast Office of National Marine Sanctuaries (ONMS) monitoring activities including oceanographic moorings and at-sea surveys. Determine what kinds of measurements are being taken (e.g., equipment and information) and how they can be accessed.

Activity 1.2 Identify the appropriate types of measurements and develop a long-term sampling plan to track changes in ocean chemistry and depth of upwelling. In addition, identify other types of measurement (such as dissolved oxygen, temperature and salinity) that should be collected to track additional stressors including changes in upwelling that may act simultaneously with changing pH in upwelling source waters. Recommend standardized methods for ocean acidification monitoring throughout the region. Compile existing information to determine locations where organisms are most exposed to lowest pH waters.

Activity 1.3 Consider modifying moorings and/or surveys to collect additional samples (e.g., CTD/Niskin bottles). Determine if additional training/expertise is necessary, and if so, whether this could be provided by PMEL or other groups. Determine if these samples could be sent to PMEL or other labs for processing and how costs would be covered.

Activity 1.4 Determine if we are maximizing benefits of current partnerships with organizations external to ONMS. Ensure we are sharing data with appropriate partners (e.g., regional Integrated Ocean Observing System (IOOS) associations and MPA Monitoring Enterprise program). Require partners using NOAA assets to submit/share their data. Consider archiving information using best practices as defined by the NOAA Ocean Acidification Program Office (workshop to be help in FY12).

[8] Riebesell U., Fabry V. J., Hansson L. & Gattuso J.-P. (Eds.), 2010. *Guide to best practices for ocean acidification research and data reporting.* Luxembourg: Publications Office of the European Union, 260 pp.

Timeline and Cost Estimates
Year 1: $20K to hire part time contractor or graduate students to assemble the needed information. Task could be potentially accomplished using existing staff. Complete activities 1.1, 1.2 and 1.4.

Year 2: $110-250K, the range of costs dependent on recommendations derived from activity 1.2. Need cost estimate for appropriate O_2 sensor technology (currently sensors for pH and CO_2 cost around $20K each). Costs for analyzing water chemistry samples will be based on sampling plan derived from activity 1.2. Complete Activity 1.3.

Year 3-5: $110-250K, continues the monitoring effort as outlined in activity 1.3. Range of monitoring costs will be determined by recommendations from activity 1.2. Contract $50K to summarize data collection and produce report to ensure that activity 1.4 is fulfilled.

Strategy 2: Research on Ocean Acidification
Prioritizing the collection of baseline physical and biological oceanographic data is important for understanding the local and regional effects of ocean acidification. There will be different observational needs for the open oceans, coastal areas, and areas with high risk, impact, and variability. Strong upwelling bringing low pH waters to the West Coast (Feely et al., 2008) makes it particularly important for data collection along the continental shelf and coastal areas of California, Oregon, and Washington. Thus, baseline studies are necessary to collect data and systematically identify data gaps and research needs.

Activity 2.1 Develop a plan that identifies indicator species for different sanctuary habitats in the five west coast sanctuaries that would be appropriate to monitor for short and long term ocean acidification impacts (e.g., aragonite calcifiers), and subsequent long-term monitoring strategies for these species (both local and general distributions of these species, as well as vertical distribution, should be evaluated over time). Plan should refer to species vulnerability Table 1.1 in the NOAA and Great Lakes Acidification Research Plan to select species from appropriate groups.

Activity 2.2 Encourage research within sanctuaries to better understand ocean acidification impacts to biological communities. Promote sanctuaries as representatives for the sentinel site concept which is currently being developed across the National Ocean Service. Research in areas with restricted access (e.g., EFH closed areas and marine reserves) and limited or no extractive uses could provide insights with respect to ecosystem resilience from ocean acidification and other simultaneous stressors such as changing temperature or reduced oxygen.

Activity 2.3 Identify and research ocean acidification impact mitigation measures as specific actions may be needed to bolster or replenish populations of species of particular ecological importance that become weakened or reduced by changing pH.

Timeline and Cost Estimates
Year 1: $20K for contract staff or graduate students to complete activity 2.1 for plan development and selection of indicator species.

Year 2-5: $20-100K. Cost range will depend on the level of sanctuary contribution to research activity lead by other resource partners. This may include providing vessel support and contributing some level of funding to leverage other agencies or academia scientific instrumentation and/or research activity.

Strategy 3: Education and Outreach

The five national marine sanctuaries within the West Coast Region (WCR) are natural place-based laboratories for engaging the public in learning about and understanding ocean acidification. They will play a critical and integral role in meeting 2009 FOARAM Act mandates by developing an increased awareness of the causes and potential effects of ocean acidification on our coast and ocean ecosystems. Sanctuaries serve in a coordinating role for educating communities and partners about ocean acidification. Existing WCR sanctuary education and outreach programs include visitor centers, exhibits, signage, adult education, volunteer programs, outreach events, professional development for teachers, citizen science, and field experiences for students and the public. This strategy begins with a needs assessment and inventory in year one and moves to formative evaluation and development of targeted messages, materials and programs in years 2-5.

Activity 3.1 Inventory, share and track existing ocean acidification education programs, resources and materials including the following:

- Existing ONMS educational activities
- Case studies of OA impacts to each sanctuary (work with research team)
- Hands on science activities and experimental kits demonstrating OA
- Potential partners including National Estuarine Research Reserves (NERRS), aquariums, Sea Grant, non-governmental organizations, Universities, and others such as shellfish growers, etc.
- Identify content standards and science process skills that link OA to Ocean and Climate Literacy programs

Activity 3.2 Assess needs of potential audiences, determine appropriate programs and products for each audience, and evaluate programs designed to increase awareness and understanding of ocean acidification, including the following:

- Review and evaluate programs designed to increase understanding of OA
- Assess needs of potential audiences and prioritize audiences that are important for National Marine Sanctuaries to reach.
- Assess potential effectiveness of messages, exhibits and displays in improving understanding of OA and subsequent action items
- Assess current learning research related to OA (Center for Research on Environmental Decisions, Oregon State University, California Center for Ocean Science Education Excellence (COSEE) and COSEE West, Monterey Bay Aquarium, Exploratorium)

Activity 3.3 Develop tools and resources that fill gaps in OA knowledge in prioritized audiences including the following:

- From prioritized audience lists, targeted for measurable change, determine where sanctuaries can be most effective.

- Work with research team to tie science stories to education programs to ensure that educators have the latest information.
- Develop effective messaging
- Develop OA Communication Training for Sanctuary Volunteers (this was piloted at CINMS in October 2010)
- Share resources and provide training on existing National Marine Sanctuary OA lessons and resources (such as the Multicultural Education for Resources Issues Threatening Oceans (MERITO) OA lesson plans) throughout the WCR region.
- Assess feasibility and pilot Citizen Science Program linked to Long-term Monitoring Program and Experiential Training for Students (LiMPETs) or other intertidal monitoring programs.
- Host an OA Communication and Education Conference focusing on Best Practices and develop a summary report describing model programs for teaching and interpreting OA
- Develop communications/media plans
- Pilot and implement teacher professional development workshops
- Develop and maintain ONMS OA Education web site, tool kits and resource lists, bibliography of current scientific research
- Develop collaborative working relationships with Climate Literacy working group, others identified in inventory in order to streamline messaging and materials.
- Develop a tiered list of personal actions audiences can take
- Develop resources that interpret research and monitoring conducted within the region related to OA
- Incorporate Messaging about OA into exhibits for visitor centers

Timeline and Cost Estimates
Year 1: $125K including $50Kfor a half time FTE to coordinate ONMS OA Education efforts, $50K best practices workshop, $20K web site, $5K develop logic models and evaluation plan. Year 1 includes: inventory existing programs, pilot volunteer training, develop and pilot OA tool kit and Sanctuary OA education web site, host conference on best practices, distribute MERITO OA lessons and provide training and supplies, align OA lessons to Climate and Ocean, work with research team to identify case studies relevant to each sanctuary. Limited progress can be made with existing staff resources. Some sub-activities are ideal for grant funding

Year 2: $125K including $50K half time FTE, $25K teacher training, $10K supplies and equipment, $5K implement volunteer OA communications training at 2 additional WCR sanctuaries, $30K develop and pilot citizen science, $5K implement evaluation plan. Year 2 includes Professional Development for teachers, assessing feasibility of citizen science LiMPETs OA monitoring and piloting this at one sanctuary site (includes training, coordinating citizen scientists, purchasing sampling equipment, kits, pilot, sample analysis), developing OA communications plan. Limited progress can be made with existing staff resources. Some sub-activities are ideal for grant funding.

Year 3: $250K including $70K for a 2/3 time FTE to implement OA education, $30K pilot coastal decision-maker workshops, $125K design OA exhibits for WCR NMS Visitor Centers, develop traveling exhibit to pilot, $5K implement volunteer OA communications training at 2 additional WCR sanctuaries, $10K citizen science, $10K evaluation. Limited progress can be made with existing staff resources. Some sub-activities are ideal for grant funding

Year 4: $125K including $70K for a 2/3 time FTE to implement OA Education, $10K evaluation, $45 K determine based on evaluation, determine what activities programs and work best and implement. Limited progress can be made with existing staff resources. Some sub-activities are ideal for grant funding

Year 5: $125K including $70K for 2/3 time FTE to implement OA Education, $15K evaluation, $40K determine based on evaluation, what activities programs and work best and implement, analyze data, produce evaluation report. Limited progress can be made with existing staff resources. Some sub-activities are ideal for grant funding

Figure 2. Screen Shot of Understanding Ocean Acidification Web Site, http://cisanctuary/acidocean

Strategy 4: Mitigating Damages to Sanctuary Resources

The goals and objectives set forth by the National Marine Sanctuaries Act direct sanctuaries to take an ecosystem-based approach to management, taking into account the multitude of issues these multiple use sites face, and their effect on the ecosystem as a whole. The mission of the National Marine Sanctuary System is to conserve, protect, and enhance each sites biodiversity, ecological integrity and cultural legacy, but with the many uncertainties faced as a result of ocean acidification, sites must develop adaptive and collaborative solutions now in order to prepare for, as well as mitigate, a changing future. Through identifying and protecting priority habitat for vulnerable species, promoting the restoration and protection of carbon sequestration habitats, evaluating projects for high carbon emissions, reducing other stressors acting on vulnerable species, and promoting collaborations to share resources and knowledge, west coast sanctuaries will work to increase ecosystem resilience and services and protect sanctuary resources to the best of our ability.

Activity 4.1 Review existing habitat characterization efforts to identify areas of priority habitat (physical habitat that supports either high species diversity, abundance or both, and/or species vulnerable to the effects of ocean acidification) within the west coast national marine sanctuaries. Work with staff and other scientists to identify information gaps, and further characterize priority habitats based on these gaps. Use this information to:

a. Prioritize research on the biological effects of ocean acidification in identified areas of priority habitat.
b. Evaluate the need for increased protection of priority habitat directly affected by ocean acidification (e.g., deep sea corals) or containing species affected by ocean acidification through regulatory actions (i.e., intertidal closures to reduce trampling), restoration efforts, and community outreach.

Activity 4.2 Work with staff and other scientists to identify sanctuary habitats that are most effective in sequestering carbon (such as tidal salt marshes, seagrass/eelgrass beds, and kelp forests).[9] Evaluate options for protection and/or restoration of these natural carbon reservoirs. Prohibit the loss and promote the expansion of habitat considered to function as a carbon reservoir.

Activity 4.3 Evaluate internal sanctuary projects for high levels of carbon emissions in EIS/EA Analysis; Management Plans; Marine Zoning Plans; and Action Plans. Consider methods for reducing emissions of these projects or pursuing alternative projects that result in fewer emissions.

Activity 4.4 Consider high levels of carbon emissions and/or actions that could cause loss or damage to habitat considered a carbon reservoir in permit applications. Include recommendations for alternatives or mitigation measures that can be adopted as part of the review process for such projects.

Activity 4.5 Reduce the impacts of additional stressors on habitats and species sensitive to the effects of OA in order to increase their resilience: Through outreach and/or regulatory actions, reduce the impacts of additional stressors, as outlined in each site's Management Plan. Examples of additional stressors include: disturbance to wildlife; invasive species; water pollution, and coastal development.

Activity 4.6 Pursue partnerships with other agencies and organizations to:

a. Assess options for protection and/or restoration of priority and carbon reservoir habitats.
b. Conduct outreach efforts to ocean users and coastal industries on options for voluntarily minimizing carbon emissions (such as reduction in ship speeds when entering harbors to lower carbon emissions and reduce ocean noise).[10]

---

[9] Laffoley, D.d'A. and G. Grimsditch (eds). 2009. The management of natural coastal carbon sinks. IUCN, Gland, Switzerland. 53 pp
[10] Brewer, P.G. and K. Hester. 2009. Ocean acidification and the increasing transparency of the ocean to low-frequency sound. *Oceanography* 22:86–93.

Timeline and Cost Estimates
Years 1 – 5 $35K/year half time staff person or $15K/year half time graduate student to:

a. Identify areas of priority habitat, prioritize research needed on the biological effects of ocean acidification in identified areas, and evaluate the need for increased protection of priority habitat directly affected by ocean acidification;
b. Work with experts to identify sanctuary habitats that are most effective in sequestering carbon;
c. Assess options for protection and/or restoration of priority and carbon reservoir habitats at each site;
d. Work with sanctuary permit coordinators to create standard protocols for evaluating internal sanctuary projects for high levels of carbon emissions;
e. Work with sanctuary permit coordinators to create standard protocols for reviewing permit applications which ONMS has an oversight role for projects that would produce high levels of carbon emissions and/or cause loss or damage to habitat considered a carbon reservoir; and
f. Pursue partnerships to conduct outreach efforts to ocean users and coastal industries on options for voluntarily minimizing carbon emissions. Work with sanctuary educators to produce communication plans for various user groups.

Cost Estimate Notes: Some tasks could be done with existing resource protection staff if time was reallocated to focus on this work. The tasks could be broken up amongst multiple staff, or one person could focus on all. If time can't be reallocated, funds would need to be raised to support an additional half time staff person or graduate student. Tasks a., b., c., and f. could be funded through outside grants. Tasks d. and e. would need to include staff time from existing permit coordinators.

Strategy 5: Influencing Regional and National Policy
The Office of National Marine Sanctuaries and the West Coast Region will work with partners to employ risk assessment and risk management approaches as a means of determining ecosystem vulnerabilities resulting from ocean acidification and related stressors. The findings from the action plans strategies will be an important contribution to national decisions related to ecosystem conservation and mitigation policies, as well as regional activities, such as those outlined in the West Coast Governors Agreement on Ocean Health. The outcomes from strategies one through four if applied at the five west coast sanctuaries could provide information to: 1) to determine thresholds for benthic and planktonic community responses over long term; 2) to assess net effects of multiple stresses on marine ecosystems at the regional scale; and 3) to develop mitigation and adaptation strategies for specific national marine sanctuary ecosystems. Work done for these strategies should contribute data important for this risk analysis. Specific activities will involve:

- Determining the thresholds for key indicator species
- Determining the resiliency of ecosystems to multiple stressors (i.e., temperature, CO_2, pollution, hypoxia, etc)
- Identifying mitigation and adaptation strategies
- Findings from short and long term ocean acidification work in sanctuaries and the risk analysis will be shared with broader, national stakeholders and integrated into larger discussions.

Timeline and Cost Estimates
Years 4 – 5 $100K/year for full time staff to:
Synthesize data collected in strategies one through four to inform risk assessment and risk management analyses. The risk assessment and management work will be completed working with partners.

Strategy 6: Demonstrate Leadership by Reducing Carbon Emissions
ONMS has over 400 employees, with approximately 115 located in the west coast region. The agency has several major office buildings, satellite offices and visitor centers; and utilizes its own vessels, NOAA ships and aircraft. To carry out its green building mission, ONMS requires all newly initiated major building construction projects to be built to Leadership in Energy and Environmental Design (LEED®). This set of activities seeks to leverage a small amount of staff time and intern support at each site to perform a baseline emissions inventory, and then coordinate a sanctuary team to implement and eventually evaluate the "best practices" suggested below.

Activity 6.1 Inventory greenhouse gas emissions from sanctuary operations

a. Each site will conduct a baseline greenhouse gas emission inventory resulting from facility use, operations and transportation activities based on the model developed by the GFNMS Green Operations Working Group. Specific categories will include stationary combustion (gas), purchased electricity, mobile combustion (air, ground and sea travel), wastewater treatment, and solid waste.

Activity 6.2 Greening the Sanctuaries - Best Practices for Facilities and Operations

a. Meeting venues: ONMS gives preference to using meeting venues that have active and ongoing sustainability programs and policies. Specifically, preference is given to facilities that have a comprehensive environmental policy including:
    - Recycling (but encourage zero-plastic events)
    - Reducing waste and harmful chemicals in cleaning
    - Conserving energy and water
    - Offers mass transportation options and parking for carpools/vanpools
    - Clean-up crews trained to sort recycling, compost and trash
    - Provide tables, chairs and linens
    - Food and drink:
        1. Encourage participants to bring their own cup/reusable water bottle
        2. Abide with MB Aquarium seafood watch card when offering seafood during a meeting
        3. Use local vendors
b. Promote web and video conferencing over physical travel. Video conferencing will be made available by ONMS and encouraged.
c. Purchasing: NOAA's Green Buying Guide has listings of green purveyors that will assist NOAA employees to "go green" when purchasing goods and services. ONMS sites will utilize local green businesses whenever possible.

d. Offices buildings: Many counties have "green business programs" that provide resources and assistance when conducting an office emissions inventory. ONMS sites will make every effort to green their office buildings. This can include simple measures such as using water filters for drinking water, composting waste, and recycling used computers and other equipment.
e. Vessel fuels: In 2007, NOAA launched the "Green Ship Initiative" which promotes use of B100 (100 % soy biodiesel). ONMS will continue to explore the use of biofuels for their small boat fleet. The challenges of access and cost will need to be addressed.
f. Vehicles: General Services Administration (GSA) offers alternative fuel vehicles (AFV) for federal agencies to lease or purchase. ONMS sites will make every effort to purchase hybrid or AFV vehicles,
g. Promote use of mass transit and biking to work for employees. Encourage staff to take advantage of the NOAA transit subsidy, take advantage of federal programs such as the bike subsidy to bicycle commuters (the Environmental Protection Agency has appropriated funds for the subsidies to help its employees under the Federal Employees Clean Air Incentives Act), have carpool spots in parking lots, etc. Provide car sharing for employees that take public transportation or ride their bikes to work.
h. Visitor centers: ONMS will incorporate principles of sustainable design and energy efficiency into all of its building projects, including visitor centers. All new projects will achieve the standards of a Silver certification through the Leadership in Energy and Environmental Design (LEED®). Visitor centers should include educational exhibits or signage informing the public about the steps that have been taken to increase energy efficiency and conservation, and reduce greenhouse gas emissions.

Activity 6.3 Encourage reductions in carbon emissions by sanctuary users
Working collaboratively the five west coast sanctuaries will take steps to lead by example and demonstrate how CO_2 emission reductions can be achieved. This will include working with its stakeholders to reduce CO_2 emissions activities and uses associated with the sanctuary. Opportunities for inventorying CO_2 emissions for the sanctuaries and its users may include:

Pursuing completion of individual sanctuary audits of CO_2 emissions associated with user operations.

a. Working towards a goal of operating carbon neutrality, identify measures that can reduce, offset, and ideally eliminate emissions.
b. Including CO_2 emissions inventorying and reduction measures in sanctuary management plan updates and appropriate action plans.
c. Soliciting sanctuary users for ideas on how to meaningfully and efficiently reduce carbon emissions.

Figure 3. Depiction of the MBNMS Santa Cruz Exploration Center currently under construction using LEED® building standards.

Timeline and Cost Estimates
Year 1: $10K for intern support and 10% of one existing staff person at each site to implement Activity 6.1. Conduct a baseline greenhouse gas emission inventory at each site.

Year 2: $10K for intern support and 5% of one existing staff person to implement Activity 6.2. Track use of best practices through implementing above recommendations.

Year 3: $14K for a part time graduate student to initiate Activity 6.3. Begin to inventory CO_2 emissions for sanctuary users through working closely with Sanctuary Advisory Council members at each site; produce a draft report. Continue to implement and track best practices at each site.

Year 4: $14K for a part time graduate student to complete Activity 6.3 Inventory CO_2 emissions for sanctuary users; produce a final report. Continue to implement and track best practices at each site.

Year 5: $10K for a paid intern plus 10% time of one existing staff to recalculate CO_2 emissions from sanctuary operations. Evaluate Activity 6.1 for any changes in emissions from sanctuary operations.

<u>Strategy #7: Internal Coordination on Ocean Acidification Issues</u>

Activity 7.1 Develop a mechanism to coordinate and share information amongst the west coast sanctuaries on ocean acidification (and climate change) issues across functional areas.

a. Create a standing ocean acidification action team across all five sites and major functional areas.
    - Conduct quarterly conference calls
    - Inform team members on ocean acidification related activities

- Disseminate information back to site management and staff including work completed and accomplishments
- Coordinate with ONMS Headquarters and other regions
- Coordinate with California Current Acidification Network
- Coordinate with the Integrated Ocean Observing System (IOOS) including the relevant regional associations (NANOOS, CeNCOOS, SCCOOS)
- Coordinate with the NOAA OA Program Office

Activity 7.2 Develop a five-year funding and prioritization plan for action plan strategies, and actively solicit funds to implement the plan.

Timeline and Cost Estimates
Year 1 – 5: This strategy is envisioned as a low-cost staff only activity. Staff time commitment is projected to be low (<5% of each staff member's time per year).

V. Implementation Costs and Priorities

A number of strategies and activities can be implemented at a low level with no additional funds assuming some portion of existing staff time is reallocated. Examples of strategies that could be implemented with existing staff include 1.1, 3.1-3.3, 4.3-4.4., 6.3 and 7.1. However, additional NOAA and outside grant funds will be required to fully implement all of the strategies and activities, see Table 1.

Table 1.Estimated Cost to Fully Implement All OA Strategies in $K

	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Strategy 1: Monitoring	20	250	250	250	250
Strategy 2: Research	50	100	100	100	100
Strategy 3: Education	125	125	250	125	125
Strategy 4: Mitigating Damages	35	35	35	35	35
Strategy 5: Influencing Policy	0	0	0	100	100
Strategy 6: Demonstrate Leadership	10	10	14	14	10
Strategy 7: Internal Coordination	0	0	0	0	0
Subtotal	**240**	**520**	**649**	**624**	**620**
				Total Five Year Cost	**2,653**

In the event there is no new funding available, especially considering the Federal budget outlook, the west coast regional office will work with the five sanctuaries to implement the no-cost and low-cost (i.e., staff time only) strategies where possible.