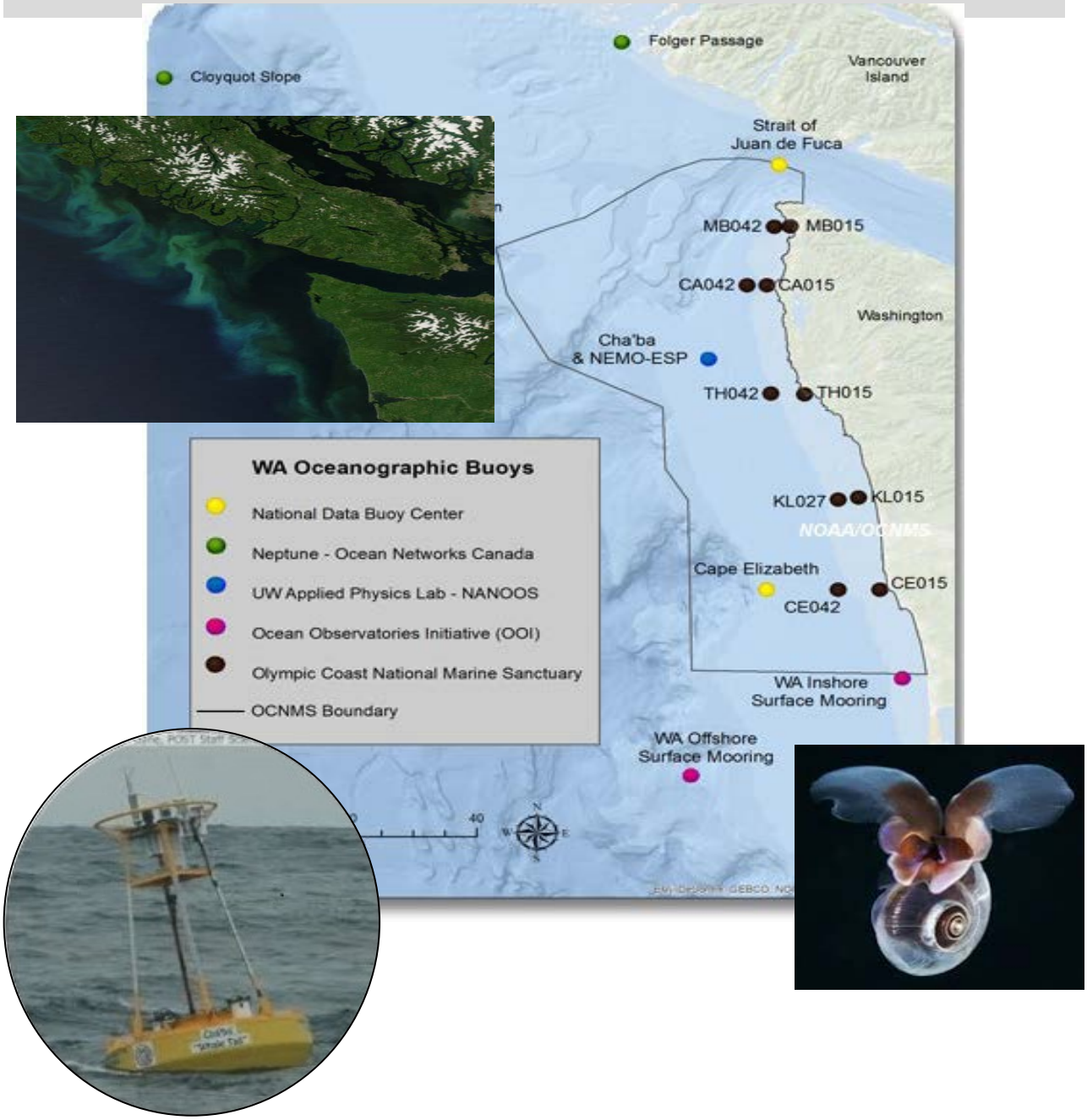
# Exploring Options for an Olympic Coast Ocean Acidification Sentinel Site (OASeS)

## Workshop Proceedings

September 2016



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## Background

### Olympic Coast

Washington's Olympic Coast is characterized by a narrow continental shelf, mountainous shoreline, steep rocky headlands, sandy pocket beaches with sea stack islands, and many small, and a few large, rivers. The area is also noted as exhibiting some of the greatest upwelling, by volume, in North America. This nutrient-rich upwelling zone drives high primary productivity and supports a multitude of marine habitats.

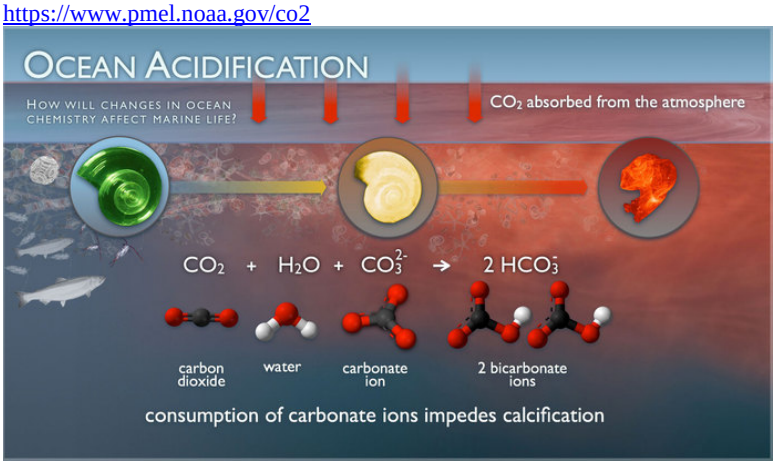
Designated in 1994, Olympic Coast National Marine Sanctuary (OCNMS or sanctuary) is a place of regional, national and global significance. The sanctuary, which is connected to both the Big Eddy Ecosystem and the California Current Large Marine Ecosystem, is the site of one of North America's most productive marine regions and spectacular, undeveloped shorelines. The intertidal areas of the sanctuary are also within the boundary of Olympic National Park, which includes 52 miles of wilderness shoreline. The Washington Maritime National Wildlife Refuge Complex, which includes more than 600 offshore islands and emergent rocks, is located within the waters of the sanctuary.

Located in a nutrient-rich upwelling zone, the region supports high primary productivity and is home to a diversity of organisms and habitats. Influenced by geology, ocean currents and other global processes, the Olympic Coast's temperate location and physical environment support critical habitats and unique communities of organisms, including commercially important fish species, marine mammals, large seabird colonies, deep sea corals, and one of the most diverse seaweed communities in the world.

Beyond its ecological significance, the sanctuary has extraordinary cultural significance. For time immemorial, American Indians have inhabited and cared for the coastal and marine ecosystems that are now part of the sanctuary. The Hoh, Makah and Quileute tribes, and the Quinault Indian Nation, continue to make their home on the Olympic Peninsula's outer coast maintaining the continuity of cultures that remain intimately connected with the ocean and its resources.

### Ocean Acidification

Figure 1 Carbon dioxide's role in the chemistry of ocean acidification is the reduction in seawater pH, carbonate ion concentration, and saturation states of biologically important calcium carbonate minerals NOAA PMEL Carbon Program https://www.pmel.noaa.gov/co2



Ocean acidification is the decrease in the pH of seawater for an extended period of time, a phenomenon driven by the oceans absorbing almost one-third of atmospheric $CO_2$ generated by human activities. Ocean acidification poses a serious threat to the health of the world's ocean and its ecosystems. Emerging research indicates that the West Coast of North America will face some of the most severe changes in ocean chemistry, the impacts of which could extend throughout food webs, threatening coastal ecosystems. The evidence for ocean acidification in the Pacific Northwest is compelling, consisting of published scientific literature, laboratory studies and field observations.

A combination of factors makes the Washington coast and coastal estuaries particularly vulnerable to acidified water. One of the most important regional factors contributing to ocean acidification is coastal upwelling, which brings offshore water that is rich in carbon dioxide and low in pH up from the deep ocean and onto the continental shelf. Corrosive waters are already negatively affecting Washington's $270 million shellfish aquaculture industry. Ocean acidification has the potential to seriously threaten the future health of the Pacific Northwest's marine waters and the significant economic benefits they provide.

## Ocean Acidification Sentinel Site (OASeS) Workshop Background

Ocean acidification has been recognized as an issue along the Olympic Coast for quite some time. In 2009, Olympic Coast National Marine Sanctuary's Sanctuary Advisory Council (SAC) passed a resolution that read "The Advisory council of the Olympic Coast National Marine Sanctuary recognizes ocean acidification and associated stressors as substantial threats to the long-term persistence of sanctuary resources and qualities..."

In 2011 OCNMS completed a revised management plan that included a strategy to propose to National Oceanic Atmospheric Administration (NOAA) leadership that the sanctuary be identified as a Sentinel Site for climate change research and monitoring. In addition, the Office of National Marine Sanctuaries' West Coast Regional Office coordinated an approach to addressing ocean acidification issues and developed the *National Marine Sanctuaries of the West Coast Ocean Acidification Action Plan*.

In November of 2012, the Washington State Blue Ribbon Panel on Ocean Acidification released *Ocean Acidification: From Knowledge to Power, Washington State's Strategic Response* – the first of its kind in the nation.

In 2013 the OCNMS SAC and the Intergovernmental Policy Council (IPC) formed a joint Ocean Acidification Working Group. The working group was tasked with reviewing the recommendations of the Washington State Blue Ribbon Panel on Ocean Acidification, identifying recommendations most relevant to the outer coast of the Olympic Peninsula, and providing advice on potential responses and actions for consideration by OCNMS, the SAC, IPC and other authorities on the outer Olympic Coast.

A 2015 SAC Climate Change Working Group identified seven priority recommendations for implementing climate-related activities, including "Work with partners to propose to NOAA leadership that OCNMS be designated as a NOAA Sentinel Site for Ocean Acidification and Sea Level Rise". The Working Group developed a Sentinel Site nomination letter and requested that it be sent to NOAA leadership and that sanctuary staff actively seek letters of support for this initiative from partner organizations and Tribes.

Building upon these efforts, in 2016 the OCNMS Advisory Council established the Ocean Acidification Sentinel Site (OASeS) Working Group, whose purpose was to help develop and plan a workshop to assist OCNMS in becoming a Sentinel Site for ocean acidification. Participants included Lee Whitford, George Hart, Jan Newton, Steve Fradkin, Casey Dennehy, Jennifer Hagen, Mitchell Tartt, Shallin Busch, Karlyn Langjahr, and Kevin Grant. In September 2016, OCNMS and NOAA's Ocean Acidification Program co-hosted a workshop in Forks, Washington involving 45 subject matter experts and resource managers representing Coastal Treaty Tribes, Federal and State agencies, academia, and non-government organizations. The workshop facilitated discussion, identified efficiencies and highlighted potential collaborations, and began to collectively articulate the desired core components and capabilities of an Ocean Acidification Sentinel Site for the Olympic Coast.

### Workshop Goals

1. Explore the scope and potential functions of an Olympic Coast Ocean Acidification Sentinel Site
2. Identify relevant collaborations and partnerships to support an Olympic Coast Ocean Acidification Sentinel Site
3. Determine priority information and products to meet science, management, communication and awareness needs regarding ocean acidification
4. Explore how an Olympic Coast Ocean Acidification (OA) Sentinel Site can leverage larger ocean acidification efforts within NOAA and other organizations

## Panel Discussion Summaries

To provide context for the workshop discussions and break out groups, the workshop began with four panel discussions covering the following topics:

### Science in National Marine Sanctuaries and OCNMS

This panel discussion informed workshop participants about Conservation Science in the Office of National Marine Sanctuaries, including prioritizing what to study, and how information is gathered and applied, across the sanctuary system and across ONMS program areas (e.g., research & monitoring, education, policy, resource protection, etc.). This session facilitated discussion of sanctuary science and how a Sentinel Site would fit into local, regional, and national programs.

Steve Gittings spoke about what drives conservation science for the Office of National Marine Sanctuaries. He informed participants that a 'simplified' mission of ONMS is to conserve and protect, but emphasized that ONMS also has a broad focus on ecosystem-level and cultural issues. The three types of applied science in sanctuaries (monitoring, characterization, and applied research) would feed directly into a Sentinel Site to allow for better ecosystem understanding and early warning, using a science-based approach.

Scott Noakes provided an example of a successful university-sanctuary partnership. The University of Georgia has been conducting OA research and monitoring in Grays Reef National Marine Sanctuary for over 10 years. They utilize a real-time data buoy and a seafloor platform, which requires diver deployment and servicing/data download. This example highlighted a

multi-partner approach to OA research, whereby the buoy-based monitoring includes funding by NOAA OAP, sensors from NOAA PMEL, and buoy maintenance provided by NOAA NDBC. Grays Reef NMS provides boat time and coordination, while the U.S. Coast Guard deploys & recovers buoys.

Liam Antrim informed participants about the science priorities for Olympic Coast National Marine Sanctuary. Liam highlighted specific sections of the OCNMS Management Plan, as well as the OCNMS coastal mooring program. This mooring program, initiated in 2000, includes both 15m and 42m oceanographic mooring arrays deployed by 38' OCNMS research vessel, the *R/V Tatoosh*. A large percentage of the OCNMS budget is applied towards this program. The program has fluctuated throughout the years, and has been sized down due to equipment & resource constraints. Despite this, OCNMS has received encouragement to continue this monitoring. OCNMS does not have oceanographers on staff. However, data collected is used by sanctuary partners for an OA algorithm and predictive models, among other uses.

Lee Whitford was the final speaker on this panel. She described the role of Sanctuary Advisory Councils, highlighted previous OCNMS advisory council efforts related to OA, and described how a Sentinel Site could empower the advisory council.

Notable questions/comments to the panelists include:

- The OCNMS moorings are the only near-shore water monitoring in the northern half of WA, & thus are extremely important.
- It is important to relate the physical measurements of OA to biological response to answer the "so what?" question.
- Discussion turned towards integrating chemistry, modeling and biology in monitoring plans.
    - The OCNMS the moorings are perfectly well situated but we'd need additional sensors (DO) & biological data, particularly if we can incorporate them into the modeling that Parker is doing. [To everyone present]: are we putting moorings into the context of the overall modeling methods, <u>&</u> collecting biological data, so we're collecting in an integrated way?
    - The Marine Biodiversity Observing Network (MBON), (a part of IOOS that connects with regional associations) focuses on integration of biology & biodiversity data. Smithsonian MarineGEO & Tennenbaum Marine Observatories Network (TMON) are also interested in understanding needs at OCNMS and how they can bring their tools to the west coast.
- Where are the vulnerable species, how do they react to events? We need to better define these via a risk assessment.
- The OA community has focused on shellfish, which is only a small percentage of fisheries biomass, so we need an analysis for species that we previously haven't considered, and at what life stages are they most vulnerable? For example, Whiting is a major species that spawns on the WA coast. Additionally, we need to include stock assessment people in these discussions.

**Partners and Activities**

Panelists provided brief context of their research and outreach priorities regarding ocean acidification, with the intent to develop a common understanding of current activities and partner capabilities with respect to an Olympic Coast OA Sentinel Site.

Richard Feely provided an overview of the current understanding of OA drivers and research goals. He stated that overall trends are difficult, and that the variability in our region is very large. The west coast has two main systems: 1) Upwelling regions with nutrient and $CO_2$-rich waters coming to the surface and organic matter descending to be broken down at depth; and 2) Estuaries with high atmospheric & anthropogenic input. The Olympic coast is the most sensitive region along the entire coast in that upwelling comes up over the shelf and onto beaches. There are strong seasonal and annual cycles in temperature, pCO2 & aragonite solubility, with much higher variability in summer than winter, and there are sharp spatial differences in vertical profiles as well. Data suggests that over 50% of the water column will be corrosive over next 20-30 years.

Libby Jewett described NOAA's Ocean Acidification Program (OAP) and touched on regional coordination ideas. OAP is working interagency to engage groups and leverage efficiencies. Work within OAP focusses on six themes: ocean acidification monitoring, biological response, socio-economic impacts, adaptation strategies (including modeling/forecasting and technology development), data collection & management, and education & outreach. OAP is investing nearly $1M in OA-related activities in national marine sanctuaries. In addition, OAP funds have been directed to projects such as NWFSC lab to test OA vulnerability, seasonal forecast modeling at UW, new technologies (i.e., carbon wave glider outfitted with $CO_2$ systems), subsurface sensors, and a number of outreach and education efforts.

Jan Newton spoke about the Washington Ocean Acidification Center (WOAC) and the Northwest Association of Networked Ocean Observing Systems (NANOOS). Washington State convened the Blue Ribbon Panel on OA, which recommended the creation of the WOAC to meet specific legislative goals. WOAC, which is funded by WA State, aims to assess OA processes and biology's responses to the chemistry shifts. WOAC provides funding/support for numerous OA projects throughout the state. NANOOS provides a data portal, providing the ability to see several things at once. This is a federal effort making coastal data available for public use. NANOOS, through its NANOOS Visualization System, provides easy access to observations, forecasts, data allowing users to visualize and download data. NANOOS supports both ocean forecast modeling as well as the comparison between model and observations; allowing users to extract data in different time scales.

Paul McElhany provided examples of a number of OA vulnerability & effect projects. He explained that vulnerability is based on sensitivity, exposure, and adaptive capacity. Rearing experiments in controlled C02 conditions at the NOAA Mukilteo station show that in in low pH conditions Pteropods show dissolution and crab larvae show lower survival. pH-Oxygen interaction studies are forthcoming for Dungeness crab and pteropods. A meta-analyses from literature (400 papers) has been published on relative responses of species in the California

current system, ranking their OA sensitivities (negative to positive). Paul's key message was that there are many vulnerable species (as shown in lab & hatchery-based experiments, & potential for exposure in system), but are they capable of adapting? Extrapolation to ecosystem scale is highly uncertain, and that $CO_2$ sensitivity experiments in the lab may not be sufficient to predict real-world OA effects.

Steve Fradkin described some of the OA work being done by Olympic National Park (ONP). ONP overlaps with OCNMS in the intertidal zone. The concept of an OA Sentinel Site fits within ONP's long-term monitoring context, with basic goal to understand key trends in natural resources & biological communities. The intertidal zone is not just important for commercial shellfish, it's an extremely diverse ecosystem with hundreds of species. A research goal of ONP is to characterize pH & aragonite dynamics seasonally and inter-annually, and correlate with trends observed via intertidal monitoring. ONP has a Chemistry Monitoring Program, characterized by a mix of continuous data from CTD system installed in highly dynamic tidepools, and grab samples (discreet water, processed in lab). The park has ongoing OA sites (since 2010) (mid coast, Brownspoints, San Juan), operating out of the Crescent Lake lab. ONP also monitors sandy beaches. The goal of these programs is to link carbonate chemistry with biological monitoring; sites throughout coast examine community structure over time. We look at dominant space occupiers, many of which are highly susceptible to corrosion.

Joe Schumacker provided an overview of some of the programs of the Quinault Indian Nation. He began by stating that Quinault is one of four treaty tribes, and that his presentation covers the Quinault Indian Nation's programs, but other tribes have their own programs. He highlighted that fact that there are many collaboration opportunities. The Olympic Coast is extremely remote, with vessel access only at West Port, La Push, and Neah Bay. The Quinault coast is a unique location for Intertidal monitoring, as it is a de facto reserve due to QIN access limitations. Members of the Quinault Indian Nation have lived off marine and intertidal organisms (e.g., barnacles, razor clams, blue mussels, California mussels, Dungeness crabs, salmon & steelhead), and want to maintain these resources now and forever, for subsistence and economic purposes. Many of these species are iconic parts of the QIN heritage. For example, the Blueback salmon are unique to the Quinault River (genetically different from other sockeye populations on West Coast). The Quinault are either involved in, or are particularly interested in, projects that study: the impact of hypoxia on razor clams; using modified crab pots to deploy sensors; seabird sampling; expanding marine protocols to include photo-monitoring for structure and abundance, and using the CMOP gliders to identify and track hypoxia events. Joe finished with the following statement: "We need this [Sentinel Site]; we need this badly. It's critical to all of us in this room, but I can't stress enough how critical it is to the tribes."

Notable questions/comments to the panelists include:

- Do any of you see a role for volunteers?
    - It can be challenging due to remote coastline; creates safety considerations. Hiking shoreline is required in many places, and taxonomic understanding could be a limitation. Sandy beaches are less diverse and possibly easier to study for citizen scientists.
    - COASST is a model for citizen science in this area, though there's room to grow into other programs (i.e., Sea Keepers). COASST has been approached about

expansion to other areas, including OA. They are interested, and have stressed that one would need to build a strong QA/QC component into any quality network.
    - We need ecologists' suggestions for possible citizen science observations. This is one thing that we could utilize in a Sentinel Site.
- Let's take a broader view of OA impact. Things we know right now relate to forams, pteropods & coral; let's use that info to show where our gaps are. We have observations in lab & field, but we need to make sure they're connected & understand how they're connected. For example, we observed migration of species as much as 2000 km in response to blob and OA. We had no understanding that these species are so sensitive to those impacts.
- Can Coho otoliths be used to determine carbon stress? Could we see a difference in C-isotopes from different years (i.e., good runs vs. crashes)? There are also concerns about OA effects on land lance (Hans Bowman at UCONN working to see if different OA treatments effect sand lance otoliths).
- There was a general discussion regarding a dearth of long-term data on the effects of OA on wildlife. PMEL is working to construct a proxy, possibly with existing resources (shells if we know collection site), to expand window of inference. Invest in these historical proxies since it will be a long time before we can see field observation evidence.

**Education and Communication**

Panelists explored communication channels and opportunities for formal and informal communications, as well as congressional engagement and outreach.

Laura Francis (Channel Island National Marine Sanctuary) provided an overview of the NOAA Ocean Acidification Education Needs Assessment. The assessment was informed by literature review and a snapshot survey from informal educators, research institutions and scientists, formal educators, and NGOs. The goals were to define who is talking about OA, determine their reach, and identify challenges / lessons learned. It turns out that there are a number of resources out there, including: curriculum aligned with Next Generation Science standards; two-week lab modules; models, data visualizations and simulations using real-time data; game-based and hands-on activities; and citizen science resources. Messaging insights indicate that messages should be simple and hopeful, and include a community-based solution focus. Messages must also include relevance to the intended audience. The literature review highlighted a number of existing OA-focused education and outreach efforts, including: National Network for Ocean & Climate Change Interpretation (NNOCCI); a deep-sea coral curriculum from the University of California; Virtual Urchin website and "Lost at Sea" connect science to outreach; Earth Echo International's Shell Shocked expedition in the pacific northwest; and the SOARCE webinar series.

Angie Thompson presented on the Washington Marine Resource Advisory Council (MRAC). The MRAC was created in 2013, in response to recommendations from the 2012 Washington State Blue Ribbon Panel on Ocean Acidification. The MRAC was created to facilitate good cross-table communication among policy makers, scientists, industry, etc. The MRAC tracks progress of the Blue Ribbon Panel's recommended actions. The MRAC is funded by the State,

and develops OA-related budget requests with agencies and the Washington OA Center. MRAC keys to success include being realistic and practical about priorities, capitalizing on broad support from policy makers, utilizing success stories to leverage past support, and including unconventional collaborators (e.g., industry).

Chris Krembs (Washington State Department of Ecology) spoke of a dilemma of many long-term monitoring programs. He began by highlighting a challenge – specifically that data collection, management, QC, and instrument maintenance often dominate monitoring activities to the detriment of data workup and presentation. The goal cannot stop with data collection. The goal of long term monitoring should include creating something that can be extended out into the world to aid in program visibility and harness the public's interest. Chris described how Eyes Over Puget Sound produces a condition report driven by images. The project averages 40,000 downloads per addition of images. By feeding the images to the public, the program can connect divers with visibility, or inspire the public to link scales (satellite vs plane vs what's happening on my favorite beach).

Meg Chadsey (Washington SeaGrant) provided some lessons learned while communicating about OA.

- Leave time in speeches for "solutions" and "what can people do?"
- Target youth! Young people can be assets; no child wants to listen to a boring adult. Children know how to communicate to their peers.
- Give people realistic solutions that they can do. Not everyone can go out on a boat & use sensors.
- Anything you can do to help the health of the ocean (i.e., minimize environmental stressors) helps mitigate OA.
- Power in numbers!
- Have consistent messaging! Need to create a consistent messaging guide for Sentinel Site; publish OA fact sheets, written by scientists for other scientists (not as beneficial for general public).

Meg provided a great example of 'how to tell a story'. She explained how collaborations among three different organizations were highlighted in the West Coast Acidification blog, in a post titled "Synergy in the Near Shore". https://westcoastoa.wordpress.com/. Meg also encouraged the use of social media to connect to your audience.

Jacqueline Laverdure (Olympic Coast National Marine Sanctuary) presented on OA-related outreach and education programs led by, or partnered with, OCNMS. She mentioned a number of K-12 initiatives, including: the North Olympic Watershed Science Program (Now Science); Ecosystem pen pals; Earth Echo expeditions; Deep Sea Communities curriculum (partnership with all west coast sanctuaries); Nautilus Live ROV workshops; and Teacher / educator training and resources kits, which include everything one needs for hands-on OA activities. Jacqueline outlined how the Pacific Northwest Bay Watershed and Training (PNW BWET) has included OA as a focal priority. Jacqueline also highlighted the use of Olympic Coast Discovery Center docents, Festivals, POET Newsletters, social media, and the Shell Shocked video as positive examples of outreach. Finally, Jacqueline reiterated what other panel members stated, saying

that OA messages must be strategically framed to be solution-based, with a majority of the messaging being positive.

**Vision of an Ocean Acidification Sentinel Site**

This panel was designed to facilitate discussion of our collective 'vision' for an Olympic Coast OA Sentinel Site. This session was not intended to present a definitive characterization of an Olympic Coast OA Sentinel Site; rather it was designed to share the results from the pre-workshop collective vision survey. To ensure that this discussion reflected audience priorities and concerns, participants were surveyed prior to the workshop about their initial ideas on needs, general capabilities and the possible scope of activities relating to various aspects of an Ocean Acidification Sentinel Site. Specifically, participants were asked to share their initial ideas about:

1. FUNCTIONS OF THE OLYMPIC COAST OA SENTINEL SITE: Propose (in prioritized order) up to three key objectives for the Olympic Coast Sentinel Site for Ocean Acidification. For each, identify key partners to engage in supporting efforts to meet your proposed objectives.
2. PARTNERSHIPS AND COLLABORATIONS 1: List (in prioritized order) up to three capabilities of, or outputs from, the proposed Sentinel Site that would be most valued from your organization's perspective.
3. PARTNERSHIPS AND COLLABORATIONS 2: List up to three activities, resources, or program developments on the horizon (e.g. 2017 – 2020) at your program (or elsewhere) that may be leveraged with the proposed Sentinel Site.
4. EDUCATION AND OUTREACH: List (in prioritized order) up to three formal/informal education or outreach (public engagement) goals that you would want to see supported by an Olympic Coast Sentinel Site for Ocean Acidification.

The survey was sent to 39 participants; 20 responses were received. An anonymous summary of these responses was shared with the planning committee and panelists. Panelists highlighted the survey results below to offer initial ideas on the needs, core capabilities and functions, and possible scope of activities related to the general characteristics and qualities of an Olympic Coast Ocean Acidification Sentinel Site. It was intended that these results help focus participants in their breakout discussions and keep the discussions and ideas realistic and on target, in order to empower and enable OA work in this geography. Below are themes, in no particular order, that emerged from the responses to the pre-workshop survey.

**Question 1 – Functions of the Olympic Coast OA Sentinel Site:**

- Enhanced monitoring
    - oceanographic and biological (particularly at the ecosystem level); OASeS an opportunity for coordinated physical/chemical/biological observations
    - expand spatially (throughout OCNMS; benthic as well as water column)
    - expand temporally (OASeS seen as an opportunity for long-term coordinated observations)
    - focus on commercially-important shell- and finfish, particularly juvenile stages
- Validate models/improve forecasting
- Integration
    - Integrate OASeS with international/regional monitoring/data sharing networks

    - Science driven by information needs of managers, tribes, decision makers
    - coordinate among partners to leverage funding opportunities
    - engage treaty tribes as research partners
- Increased awareness
    - about OA and the role of the OCNMS in OASeS
    - to promote stewardship of coastal resources (esp. among local communities)

- Species impacts
    - In situ studies of mussel shells (strength and isotopic ratio analysis)
    - Lab studies of OA impacts on species within OCNMS (Dungeness crab, razor clams, mussels, copepods, smelt, Pacific whiting
    - Evidence for natural OA resilience?
    - HAB impacts
- Precedent
    - example of system-level OA research
    - model for subsequent Sentinel Sites
    - opportunity to test new technology and management strategies

**Question 2 – Partnerships and Collaborations (valued Sentinel Site capabilities/outputs)**

- Long-term data sets (physical and biological)
    - Centralize repository
    - Reliable (QA/QC)
    - Accessible (online)
    - User-friendly (to scientists and laypeople alike)
    - Real-time
- Short- & long-term projections (physical trends and biological impacts)
- Better coordination
    - between research/monitoring partners
    - between scientists and outreach/education specialists
- Routine reporting and interpretation for scientific community, public, educators, students, and decision makers
- Catalyze partnerships and leverage activities
- Opportunities for students and citizen scientists
- Test bed for new technologies

**Question 3 – Partnerships and Collaborations (potential activities/resources to be leveraged for OA efforts)**

- Forecast/Prediction
    - Oceanographic
        - LiveOcean daily OA forecast model (funded and ongoing)
        - Once 3 HF radar sites are installed (NANOOS), use data to help forecast onshore movement of anomalous conditions i.e., hypoxia, HABs, blobs, etc.
    - Biological
        - MERHAB-PNW HAB (harmful algal bloom) prediction system
- Data (management/analysis/sharing):

    - Northwest Association of Networked Ocean Observing Systems (NANOOS) portal can host info/data
    - Global Ocean Acidification Observing Network (GOA-ON)
    - West Coast Regional Ocean Data Portal: currently developing a story map (combines video, pictures, data, narrative) on changing ocean conditions along the west coast. Could highlight activities, data and resources of Sentinel Site.

- Assessments
    - Oceanographic
        - New hydrographic mapping leading to better understanding of OCNMS bottom habitat.
    - Biological
        - MBON - http://www.marinebon.org/
        - Annual razor clam stock assessment data collected at Kalaloch and Mocrocks beaches that can provide information on the success of larval recruitment and survival of adults.
        - Annual pre-season Dungeness crab test fisheries that are conducted off Destruction Island, Kalaloch and Raft River that can provide an index of adult crab condition.
        - Razor Clam stable isotope research and population assessment
        - Smelt Spawning distribution and timing research is conducted by the Hoh, Quileute Tribes and the Quinault Indian Nation
        - The Makah Tribe currently has funding through BIA to study climate change and ocean acidification impacts to bivalve shells and measure water chemistry on the Makah Reservation.
        - Potential resource/collaboration: Tim Wooten and Cathy Pfister (U Chicago) are continuing and expanding OA and ecological research on Tatoosh Island and surrounding areas.

- Monitoring
    - Oceanographic:
        - Nearshore seasonal monitoring of CT and dissolved oxygen (DO).
        - New accurate, affordable pH and $pC0_2$ devices coming online.
        - OCNMS oceanographic monitoring program (10 seasonal moorings) - these provide a long-term data set for certain oceanographic parameters. Hoping to supplement instrumentation for more direct OA measurements. Also including whole water sampling.
        - Partnerships with sensor developers to install/test instruments
        - Smartfin – surfboard mounted sensors
        - Monitoring changes in TIA in surface water will help assess the potential changes in the buffering capacity of Columbia River during southerly winds (rationale: predicted climate changes will affect the timing and chemical ionic composition of rivers. This will influence the buffering capacity of the freshwater-influences/productive-nearshore surface water against OA).
        - Enhanced water quality sampling at OCNMS oceanographic mooring locations

    - Biological
        - Year-around weekly monitoring of surf zone plankton assemblage along the entire coast of Washington and can document changes in the plankton community and frequency of HABs.
        - Funding from Long Term Ecological Research (LTER) Program (proposal submitted)
        - Expand monitoring off the Olympic Coast during PMEL's OA Survey, which is presumably planned on annual basis, to optimize data gathered during this survey (e.g., biological sampling).
- **Programmatic support**
    - Washington OA Center (WOAC)
    - Washington Sea Grant (WA Sea Grant)
    - OCNMS currently operates the only research vessel dedicated to the outer coast (currently the R/V Tatoosh, but working on vessel replacement strategy).
    - Coastal Treaty Tribes' Natural Resources Departments with staff able to respond as necessary
    - TNC's 'Floodplains by Design'-style multiple benefits/collective impacts program
    - Regional Ocean Partnerships—The Pacific Coast Collaborative (PCC) and West Coast Ocean Partnership have highlighted OA as a priority and continue to do work to advance OA policy and actions at the regional, national and international level. Currently working through the PCC/Interagency OA Working Group (IWG-OA) to identify monitoring assets along the West Coast and what it would take to develop a regional OA monitoring network.
    - Washington Dept. of Ecology - marine monitoring program in estuaries and modeling work in Puget Sound. Hosts monthly informal collaboration/coordination webinar that highlights connections of global/regional forces to local monitoring results (and impacts - e.g. salmon returns). *An example of something that could be developed for the coast?*
    - Programmatic support could also come from collaborations like a group analysis of future funding opportunities and coordination of partners to pursue funding to support OA research on the Olympic Coast.
    - WA Department of Ecology Water Quality Program (Submit pH exceedance criteria and 303d pH data submission).
    - WA Dept. of Ecology can offer expertise in OA education and outreach product development and OA scientific research approaches. It can also help get site accomplishments highlighted at national level
    - Strengthening partnership between ONMS (OCNMS) and NOAA's Ocean Acidification Program

**Question 4 – Education and Outreach**

- Citizen Science
- OA in the Classroom
    - Develop/disseminate curricula
    - Provide training to educators on use of OA resources
    - Utilize OASeS data and 'science stories' in educational material

    - Support a scientist/educator network
- Public Outreach
    - Reliable fisheries projections
    - Food web impacts
    - Connect causes, consequences and solutions/adaptations
    - Inspire action
    - Multiple formats (online, phone, print, and in-person) and interactive
    - Emphasis on images and stories
    - Regular condition updates
    - Collaborate with media
- Targeted Messaging to resource managers, decision makers, and more diverse audiences (not just 'the choir')
- Regular Conferences for scientists, managers, and stakeholders

After the panel presentations, participants asked questions and provided comment on the concept of an OA Sentinel Site for Washington's outer coast. Notable questions/comments to the panelists included:

- I found the WCOAH panel report/brochure incredibly well written & understandable. I would like to see us use a similar approach, though of course without dumbing down too much so that we can improve people's literacy while still getting the point across & not freaking people out.
- We'd like answers to public's '*what can I do*?' We hear things like the 'reduce other stressors', but what else can be used to tell people what they can do?
    - Sanctuaries West Coast Region is in the process of coming up with list of audiences & actions + messages & solutions, while making it a conversation like "How do you think you can help?"
    - Creating the dialogue versus spoon feeding really helps people think critically & keep the messages after the discussion
- Are there two messages needed given the difference in opinions on issues such as OA (sympathetic vs. non-sympathetic audiences)
    - Suggestions for resistant audiences: central point is the wallet. Good practice & policy make more money in business practice & policy design. Bad policy & practice tend to cost people more. (HABs might be a connection from OA to people's livelihoods, to correlate to economic to cross ideological boundaries)

## Breakout Discussion Summaries

After the panel discussions, participants were divided into four breakout groups to better facilitate active and engaged discussion on: 1) Vulnerability and Indicators; 2) Priority Questions to Ask of an Olympic Coast OA Sentinel Site; 3) Application of Information from an Olympic Coast OA Sentinel Site; and 4) The Awareness Campaign –Education and Communication. All four groups addressed each topic.

### Breakout Discussion A:

**Vulnerability and Indicators**

The first breakout discussion of the workshop was titled Vulnerability and Indicators. The objective was to have workshop participants identify habitats and species known or suspected to be vulnerable to OA, as well as potential baseline indicators and impacts, relevant to the Olympic coast. This was intended to be a step towards identifying and prioritizing what should be monitored as part of an Olympic Coast Ocean Acidification Sentinel Site.

Each group was provided with three large vulnerability plots - one each for species, habitats, and processes. For each vulnerability plot, participants were provided five sticky-notes and asked to populate the plots in an attempt to identify which species, habitats, and processes are most vulnerable to the effects of ocean acidification along Washington's Olympic Coast. Examples of "at risk" species, habitats, or processes were provided on the applicable chart, however participants were not limited to the listed items.

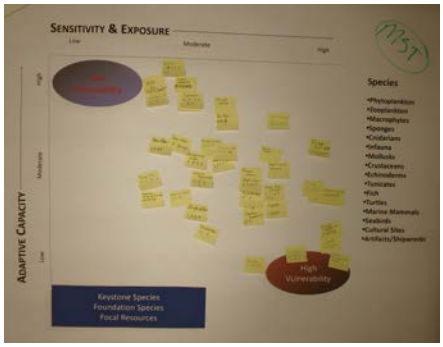
**Activities/Interactions:**

Facilitators led each group through the process of populating the vulnerability plots. Examples of species/habitats/processes were provided on the right side of each plot. These examples were provided as guidance, and participants were not limited to the examples listed. Using the following criteria, participants selected up to five species/habitats/processes that they believe to be susceptible to impacts from OA:

1. OCNMS management priority
2. Tribal priority
3. OA science community priority
4. Ecosystem importance
5. Commercial importance
6. Special management concern (TES)
7. Early warning or other indicator
8. Communication value

Participants recorded their selected species on sticky notes, also recording which criteria they used when making each selection. Participants then placed each sticky note on a vulnerability plot utilizing the qualitative ratings of sensitivity/exposure (x-axis) and adaptive capacity (y-axis) to differentiate among the selected resources, thus identifying those that the group considers more vulnerable to OA. Each group then repeated this process for both habitats and, time permitting, processes.

Figure 2. Exercise using Sensitivity and Adaptive Capacity Matrix




**Results:**

All four groups had completed vulnerability plots for both species and habitats. Three of the groups were able to provide completed vulnerability plots for physical processes, but one of those did not provide an image of the process chart for relative sticky locations.

The available information from all groups was compiled by species, habitat, and processes. The number of times each

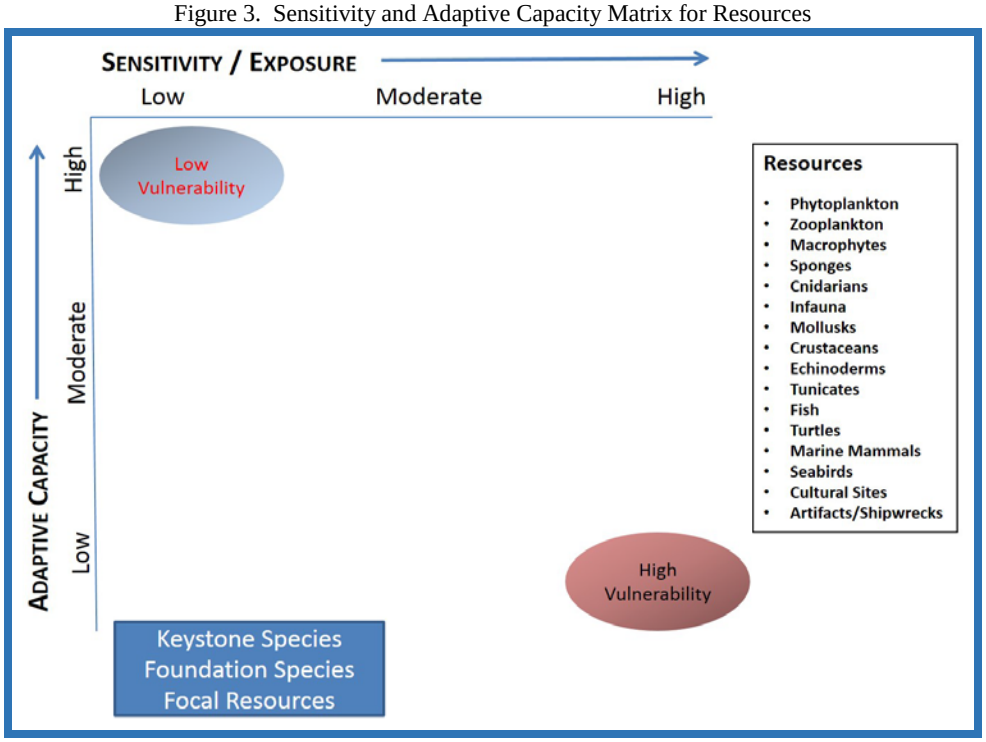
species/habitat/process was chosen by participants was recorded, as were the criteria participants used to support those choices. Based on the placement of sticky notes, the relative vulnerability of each species, habitat, and process was identified on a continuum ranging from low-to-moderate-to-high.

Overall, analysis of the results of this breakout proved to be difficult. Each participant within each group chose their species independently, often using differing terminology or taxonomic levels. Wide variation in rankings of sensitivity/exposure and adaptive capacity also proved difficult to compare. The same difficulties arise when trying to analyze the criteria chosen to support why a given resource (species, habitat) was important. It was therefore difficult to draw accurate comparisons across the groups.

Species

Taxonomic specificity, or lack thereof, made it difficult to compare data. For example, the Kelp group (breakout group 1), chose "Mollusk/bivalve, mainly Razor Clams" as a species of concern. However, the Mussel group (breakout group 2) chose "Razor Clam larvae", "Mussels", and "Oyster larvae", while the Pteropod group (breakout group 3) chose "Razor clams" and "Mollusks" and the Salmon group (breakout group 4) determined the vulnerability of "Razor clams", "Bivalves", "Mussels", and "Mollusks". The same conundrum applies to fish, where some groups simply listed "fish" while others listed whiting, salmon, forage fish, juvenile ichthyoplankton, or some combination thereof. Despite this, some trends were apparent at a macro- level:

Figure 3. Sensitivity and Adaptive Capacity Matrix for Resources




- All four groups selected **Pteropods**. All groups agreed that pteropods have High Sensitivity/Exposure, and Low Adaptive Capacity. This placed pteropods squarely in the

'Highly Vulnerable' category. Criteria 7 (Early warning or other indicator) and 4 (Ecosystem Importance) were cited the most.

- All four groups selected **Razor clams**. Sensitivity/Exposure ranged from Moderate to Moderately High, and Adaptive Capacity ranged from Moderate to Moderately low, resulting in razor clams being in the 'Vulnerable' category. Razor clams were identified by 15 individual participants. Criteria 2 (Tribal priority) and 5 (Commercial Importance) were cited the most.

- **Dungeness crab** was also selected by all four groups, but the Adaptive Capacity ranged from 'Moderately High' to 'Low' – same for Sensitivity. Given this range, it is hard to draw a conclusion other than simply stating that everyone identified Dungeness crab as an important species. In fact, Dungeness crab was listed by 21 participants – more than any other species. Criteria 8 (Communication value), 5 (Commercial Importance) and 2 (Tribal priority) were cited the most.

- **Fish** was listed, in some form (ichthyoplankton, whiting, salmon, forage fish), by at least 19 participants[1], the second highest listing by workshop participants. Sensitivity/Exposure ranged from 'Moderate' to 'Moderately High', while Adaptive Capacity ranged from 'Low' to 'High', resulting in wide variation in vulnerability indices. Criteria 5 (Commercial Importance), 2 (Tribal priority) and 4 (Ecosystem Importance) were cited the most.

- **Zooplankton** was listed, in some form, by 17 participants (zooplankton, copepods, krill, etc.). Sensitivity/Exposure ranged from 'Moderate' to 'High', while Adaptive Capacity ranged from 'Low' to 'High', resulting in wide variation in vulnerability indices. Criteria 8 (Communication value) and 4 (Ecosystem Importance) were cited the most.

- **Kelp** was listed by all four groups (11 individual participants). Sensitivity/Exposure ranged from 'Low' to 'High', while Adaptive Capacity was relatively consistent ranging from 'Moderately High' to 'High'. While there seemed to be some discrepancy in how groups rated the Sensitivity/Exposure for Kelp, everyone seemed to agree that Kelp has high Adaptive Capacity. Criteria 4 (Ecosystem Importance) and 5 (Commercial Importance) were cited the most.

- **Corals/Sponges** were only listed by six participants, but there was agreement that they have 'Moderate to High' Sensitivity/Exposure and 'Moderate to Low' Adaptive Capacity, making them very vulnerable to OA. Criteria 1 (OCNMS management priority), 4 (Ecosystem Importance), and 8 (Communication value) were cited most frequently.

- **Marine Mammals** (referred to by the various groups as marine mammals, orcas, sea otters, or a combination thereof) were identified by ten participants. There was general consensus that they have 'Moderate' Sensitivity/Exposure and 'Moderate' Adaptive Capacity. Criteria 8 (Communication value) and 4 (Ecosystem Importance) were cited the most.

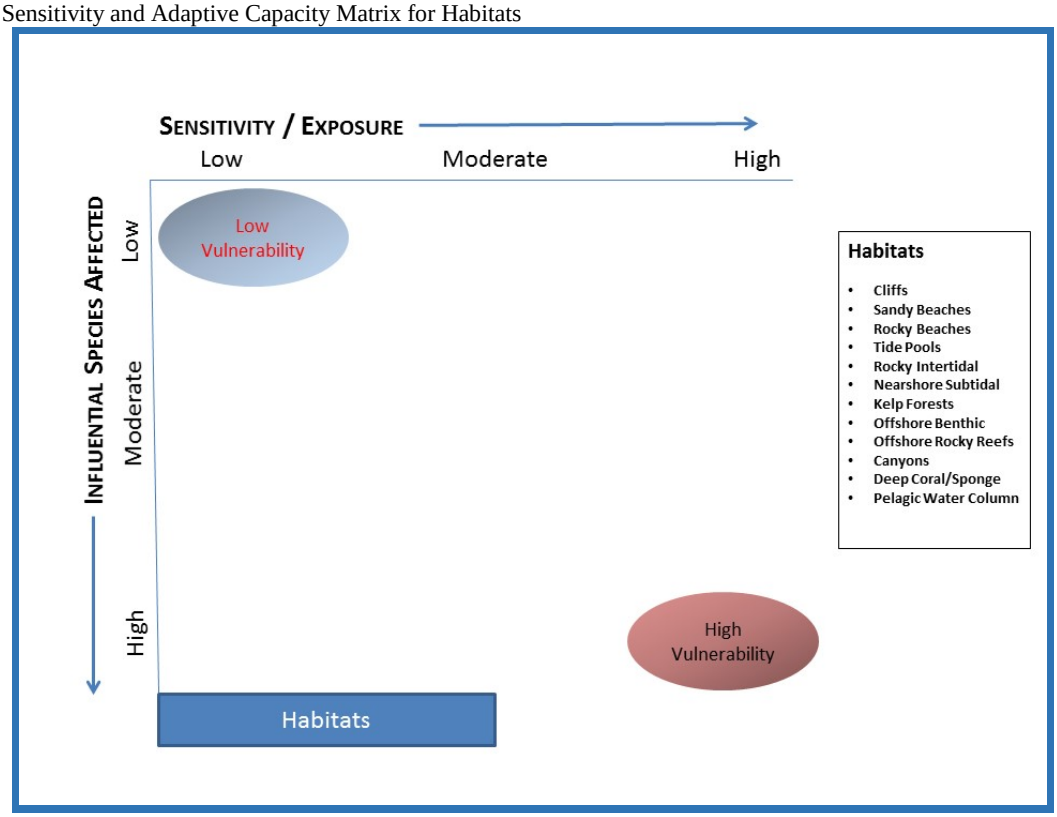
[1] The Salmon group vulnerability plots often had numerous sticky notes piled on top of one another. This made it difficult to ascertain, from a photograph, how many participants chose a particular species.

- Other species/groups listed included **Sea stars/Echinoderms/Urchins**, **Gelatinous zooplankton**, **Crustose coralline algae**, and **Barnacles**.

Habitats

The vulnerability plots for Habitats had a slightly altered axis. While Sensitivity/Exposure was still the x-axis, the y-axis was changed to 'Influential Species Affected'. This was done to help emphasize the importance of each habitat to any species of concern.

Figure 4. Sensitivity and Adaptive Capacity Matrix for Habitats




All four groups were able to provide completed vulnerability plots for habitats. All four groups identified Offshore Benthic, Rocky Intertidal, and Kelp Forest – but their 'Influential Species Affected' and 'Sensitivity/Exposure' ranged from Moderately High to Low – making it difficult to draw any conclusions other that these habitats were identified as important. General conclusions include:

- **Kelp Forest** was selected by all four groups, and was chosen by more individual participants (17)[2] than any other habitat. Kelp was chosen by all groups as both an important species and habitat. Criteria 4 (Ecosystem Importance), 8 (Communication value) and 1 (OCNMS management priority) were cited most frequently.
- **Rocky Intertidal** was also selected by all four groups. This habitat was listed the second most by workshop participants (11). Given the ranges of 'Influential Species Affected' and 'Sensitivity/Exposure' assigned by groups, it was hard to draw a conclusion other

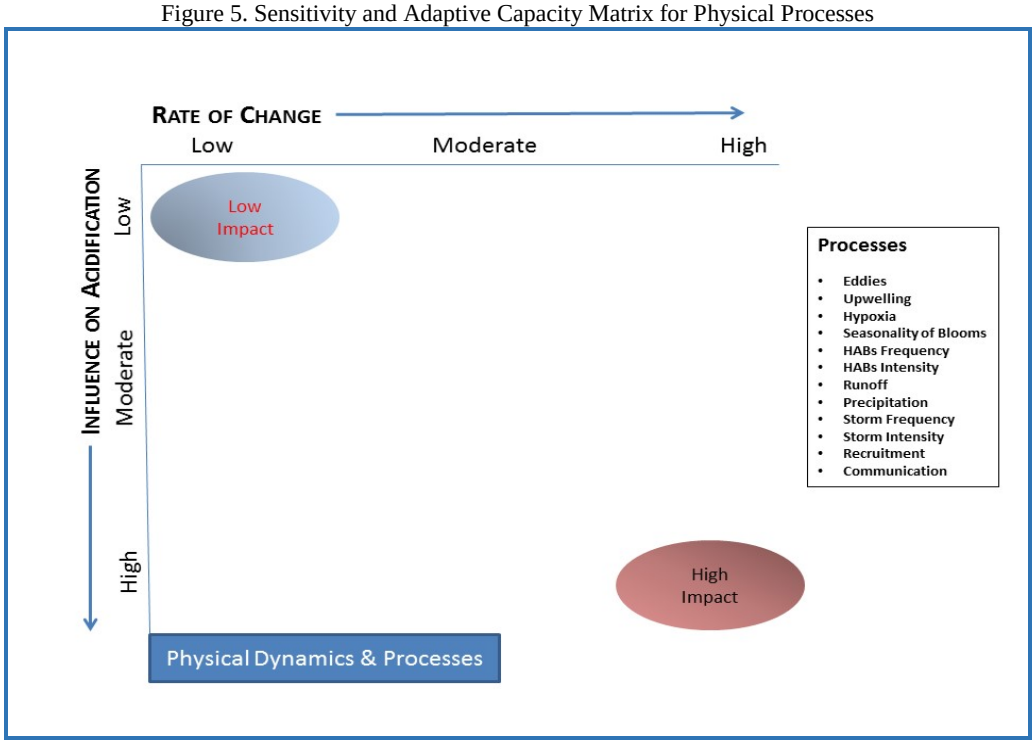
[2] The Salmon group vulnerability plots often had numerous sticky notes piled on top of one another. This made it difficult to ascertain, from a photograph, how many participants chose a particular habitat.

than simply stating that everyone identified the rocky intertidal as an important habitat. Criteria 4 (Ecosystem Importance), 7 (Early warning or other indicator) and 8 (Communication value) were cited most frequently. However, Criteria 1 (OCNMS management priority), 2 (Tribal priority), and 3(OA science community priority) were also cited numerous times.

- **Pelagic / Water Column** was chosen by ten individual participants (three of the four groups). Both 'Influential Species Affected' and 'Sensitivity/Exposure' were consistently ranked as Moderately High to High. Criteria 4 (Ecosystem Importance), 7 (Early warning or other indicator) were cited most frequently.
- **Offshore Benthic** habitat was selected by all four groups (eight individuals). Both 'Influential Species Affected' and 'Sensitivity/Exposure' were consistently ranked as Moderate to High. Criteria 4 (Ecosystem Importance) was referenced as an important criteria by all eight individuals.
- **Nearshore Subtidal** was selected by six individuals (three of the four groups). 'Sensitivity/Exposure' was rated as Moderately High by every group, but the 'Influential Species Affected' ranged from Moderately Low to High. The fourth group identified **Nearshore Intertidal** (not subtidal) and rated it as High for 'Sensitivity/Exposure' and Moderate to High for 'Influential Species Affected'. Criterion 4 (Ecosystem Importance) was cited most frequently.
- Other habitats identified include **Deep Sea Corals/Sponges**, **Tide Pools**, **Sandy Beaches**, **Canyons**, the **Shelf Break**.

<u>Physical Processes</u>

Figure 5. Sensitivity and Adaptive Capacity Matrix for Physical Processes



The vulnerability plot for physical processes used ‘Rate of Change’ for the x-axis and ‘Influence on Acidification’ as the y-axis. Only three of the four groups had enough time to address physical processes. All three groups identified the following five processes:

- **Upwelling** was, by far, the most commonly listed physical process identified. The ‘Rate of Change’ was identified as Moderate to Moderately High, but the ‘Influence on Acidification’ was universally recognized as High. Criteria 4 (Ecosystem Importance) and 3 (OA science community priority) were cited most frequently.
- **Harmful Algal Blooms** were the second most commonly identified physical process. The ‘Rate of Change’ was Moderate to High, but the ‘Influence on Acidification’ ranged from Low-to-Moderate to High. Criteria 4 (Ecosystem Importance) and 8 (Communication value) were cited most frequently.
- **Respiration/Metabolism** - Both ‘Rate of Change’ and ‘Influence on Acidification’ ranged from Moderately High to High. Criteria 3 (OA science community priority) and 4 (Ecosystem Importance) were cited most frequently.
- **Recruitment** - Both ‘Rate of change’ and ‘Influence on Acidification’ ranged from Moderately-high to High. Criterion 2 (Tribal priority) was cited the most.
- **Hypoxia** - ‘Rate of change’ was Moderately High, while ‘Influence on Acidification’ ranged from Moderate to Moderately-high. Criteria 4 (Ecosystem Importance) and 8 (Communication value) were cited most frequently, though Criteria 2 (Tribal priority) and 3 (OA science community priority) were also cited multiple times.
- Two of the three groups identified **Air Sea Exchange** and **Freshwater Input**.
- Other processes identified include **Blob**, **Primary Production**, **Seasonal Timing Changes**, **Stratification**, **Communication**, **Predator Avoidance**, **Methane**, **Runoff**, and **Carbon Input**.

## Breakout Discussion B:

### Explore Priority Questions to Ask of an Olympic Coast OA Sentinel Site

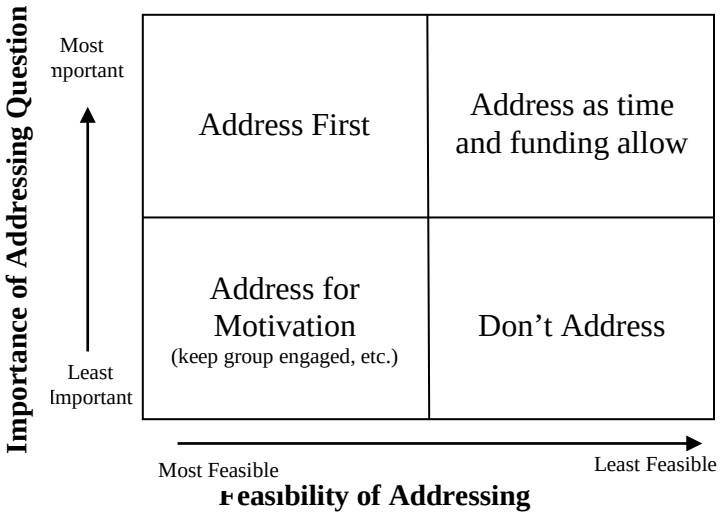
The second breakout discussion, and final of the first day of the workshop, was Breakout Discussion B: Explore Priority Questions to Ask of an Olympic Coast OA Sentinel Site. The objective of this session was to use the assembled expertise to determine the questions most relevant to the creation of a successful Olympic Coast Ocean Acidification Sentinel Site. In investigating the questions most relevant to a successful OA Sentinel Site, participants focused not only on OA science needs (i.e., research and monitoring) but also the needs of resource managers and the best approaches and tools to address the questions, including building upon those that exist and identifying new products or resources.

A list of 17 priority questions, related to the information needs of the outer coast regarding ocean acidification, were distilled from questions provided in a number of ocean acidification reports.[3] It was stressed to participants that this was a prioritization exercise, and that we were not trying to answer any of the questions during this session.

### Activities/Interactions:

Facilitators walked each of four small groups through discussion using a facilitation tool we called an Importance-Feasibility Grid. Each group first looked at all 17 priority questions before moving on to prioritization. Groups then rated the importance of each question on a continuum from *Least Important* (1) to *Most Important* (5), and rated the feasibility of addressing the question on a continuum from *Most Feasible* (1) to *Least Feasible* (5). Using these ratings, each group then placed each question on the Importance-Feasibility Grid.

Figure 5. Importance-Feasibility Grid




[3] State of Ocean Acidification in Washington Waters_MRAC_2015
The West Coast Ocean Acidification and Hypoxia Science Panel: Major Findings, Recommendations, and Actions. 2016.
Scientific Summary of OA in Washington State Marine Waters, NOAA OAR Special Report, 2012.
OCNMS Climate Change and Ocean Acidification 1-pager (2010) and OCNMS Sentinel Site website / OA

**Results**:
Table 1 below provides the average score for each question, in table format, based on the groups' rating and placement of that question on the grid. A scale for both x (importance) and y (feasibility) axes was used ranging from 1-5 based on the following:

- X AXIS – Feasibility of Addressing Question: 1 = Most Feasible; 5 = Least Feasible
- Y AXIS – Importance of Addressing Question; 1 = Least important; 5 = Most Important

**Table 1 – Average Feasibility and Importance Score for each Question**

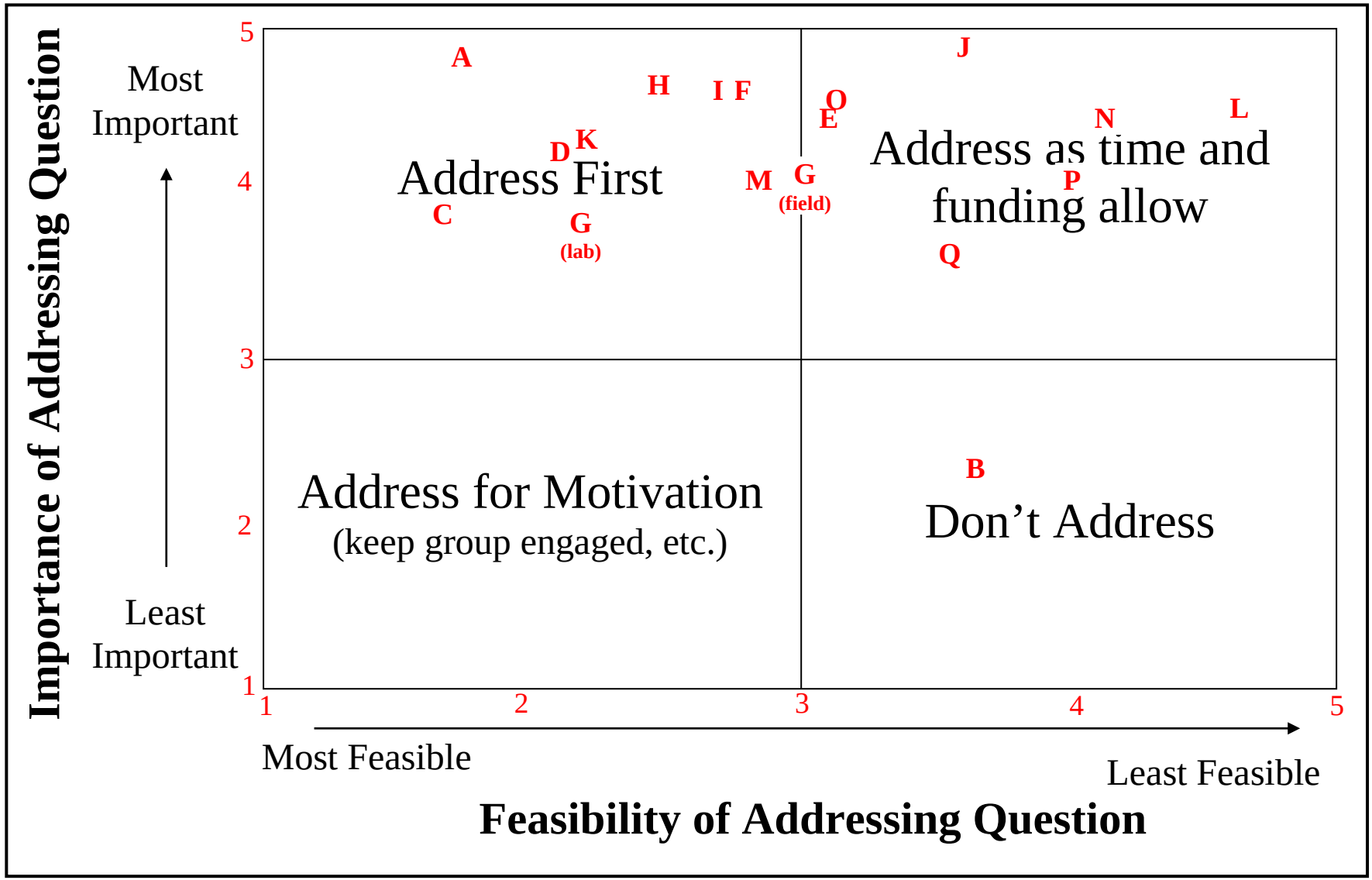
| Category | Question | Average Score | |
|---|---|---|---|
| | | Feasibility (x axis) | Importance (y axis) |
| Physical Dynamics | A. How rapidly is seawater chemistry changing, and at what locations will it change the most? | 1.75 | 4.75 |
| | B. Do local sources of nutrients exacerbate acidic conditions along the coast? | 3.63 | 2.25 |
| | C. To what extent does upwelling intensity affect ocean acidification? | 1.63 | 3.75 |
| | D. Can corrosive conditions in the nearshore or at hatcheries be anticipated by conditions offshore? | 2.13 | 4.13 |
| Wildlife Impacts | E. What habitats or systems are at greatest risk of change due to ocean acidification? | 3.13 | 4.38 |
| | F. What species, populations, or ecological properties are most sensitive to OAH? | 2.75 | 4.63 |
| | G. How do marine organisms at different life stages respond to changes in pH, DIC, and TA? | 2.38 (lab)<br>3.00 (field) | 3.75 (lab)<br>4.00 (field) |
| | H. Is OAH impacting biota now? | 2.50 | 4.67 |
| | I. How are the abundance, distribution and diversity of living resources affected by ocean acidification? | 2.75 | 4.63 |
| | J. How might marine food webs be altered? | 3.63 | 5.00 |
| | K. Are changes in oceanographic patterns (e.g., upwelling and its effects on OA) linked to hypoxia and harmful algae blooms? | 2.25 | 4.25 |
| | L. What levels of change will trigger substantial changes in biological communities? | 4.67 | 4.50 |
| | M. How does ocean acidification affect vital commercial and managed species such as salmon, rockfish, razor clams, geoduck, and fish? | 2.83 | 4.00 |
| | N. How might marine diseases respond? | 4.17 | 4.33 |
| | O. How can laboratory findings related to OA impacts on key species be supported through in-situ field validation efforts? | 3.17 | 4.67 |
| Response / Management Actions | P. Are there local habitat conservation and mitigation measures that can be taken to mitigate OA exposure on the outer coast? | 4.00* | 4.00* |
| | Q. What are the strategies to adapt to, and alleviate, the impacts of ocean acidification along the Olympic coast | 3.50* | 3.50* |

| | | | |
|---|---|---|---|
| | – i.e., Establishing and managing refuges for species vulnerable to ocean acidification? | | |

*Not all groups responded to these questions, so averages reflect 1-3 group responses.

During the evening of day one, the workshop team plotted each question on the Impact-Feasibility Grid below, using the average scores provided in Table 1 above. This was used during the session recap the following morning.

Figure 6 – Results of Importance-Feasibility Grid (based on average scores of all groups)



Only one question ranked below the grid's mid-line for importance (question B). In order to better differentiate among questions, both Feasibility and Importance were also ranked by their average scores.

**Feasibility of Addressing Questions (x-axis)**
After determining the average Feasibility score assigned to each question by workshop participants, the 17 questions were grouped into quartiles by their Feasibility ranking, with the top quartile labeled "Most Feasible" and the bottom quartile labeled "Least Feasible".

**Table 2 - Average Feasibility of Addressing Questions (x-axis) Broken Into Quartiles**

| | | | |
|---|---|---|---|
| **C** | To what extent does upwelling intensity affect ocean acidification? | 1.63 | Most Feasible |
| **A** | How rapidly is seawater chemistry changing, and at what locations will it change the most? | 1.75 | Most Feasible |
| **D** | Can corrosive conditions in the nearshore or at hatcheries be anticipated by conditions offshore? | 2.13 | Most Feasible |
| **K** | Are changes in oceanographic patterns (e.g., upwelling and its effects on OA) linked to hypoxia and harmful algae blooms? | 2.25 | Most Feasible |
| **H** | Is OAH impacting biota now? | 2.50 | Feasible |
| **F** | What species, populations, or ecological properties are most sensitive to OAH? | 2.75 | Feasible |
| **I** | How are the abundance, distribution and diversity of living resources affected by ocean acidification? | 2.75 | Feasible |
| **M** | How does ocean acidification affect vital commercial and managed species such as salmon, rockfish, razor clams, geoduck, and fish? | 2.83 | Feasible |
| **G** | How do marine organisms at different life stages respond to changes in pH, DIC, and TA? | 2.38 (lab)<br>3.00 (field) | Somewhat Feasible |
| **E** | What habitats or systems are at greatest risk of change due to ocean acidification? | 3.13 | Somewhat Feasible |
| **O** | How can laboratory findings related to OA impacts on key species be supported through in-situ field validation efforts? | 3.17 | Somewhat Feasible |
| **Q** | What are the strategies to adapt to, and alleviate, the impacts of OAn along the Olympic coast – i.e., Establishing and managing refuges for species vulnerable to OA? | 3.50 | Somewhat Feasible |
| **B** | Do local sources of nutrients exacerbate acidic conditions along the coast? | 3.63 | Least Feasible |
| **J** | How might marine food webs be altered? | 3.63 | Least Feasible |
| **P** | Are there local habitat conservation and mitigation measures that can be taken to mitigate OA exposure on the outer coast? | 4.00 | Least Feasible |
| **N** | How might marine diseases respond? | 4.17 | Least Feasible |
| **L** | What levels of change will trigger substantial changes in biological communities? | 4.67 | Least Feasible |

**Importance of Addressing Questions (y-axis)**
After determining the average Importance score assigned to each question by workshop participants, the 17 questions were grouped into quartiles by their Importance ranking, with the top quartile labeled "Most Important" and the bottom quartile labeled "Least Important".

**Table 3 - Average Importance of Addressing Questions (y-axis) Broken Into Quartiles**

| | | | |
|---|---|---|---|
| **J** | How might marine food webs be altered? | 5.00 | Most Important |
| **A** | How rapidly is seawater chemistry changing, and at what locations will it change the most? | 4.75 | Most Important |
| **H** | Is OAH impacting biota now? | 4.67 | Most Important |
| **O** | How can laboratory findings related to OA impacts on key species be supported through in-situ field validation efforts? | 4.67 | Most Important |
| **F** | What species, populations, or ecological properties are most sensitive to OAH? | 4.63 | Important |
| **I** | How are the abundance, distribution and diversity of living resources affected by ocean acidification? | 4.63 | Important |
| **L** | What levels of change will trigger substantial changes in biological communities? | 4.50 | Important |
| **E** | What habitats or systems are at greatest risk of change due to ocean acidification? | 4.38 | Important |
| **N** | How might marine diseases respond? | 4.33 | Somewhat Important |
| **K** | Are changes in oceanographic patterns (e.g., upwelling and its effects on OA) linked to hypoxia and harmful algae blooms? | 4.25 | Somewhat Important |
| **D** | Can corrosive conditions in the nearshore or at hatcheries be anticipated by conditions offshore? | 4.13 | Somewhat Important |
| **M** | How does ocean acidification affect vital commercial and managed species such as salmon, rockfish, razor clams, geoduck, and fish? | 4.00 | Somewhat Important |
| **P** | Are there local habitat conservation and mitigation measures that can be taken to mitigate OA exposure on the outer coast? | 4.00 | Somewhat Important |
| **G** | How do marine organisms at different life stages respond to changes in pH, DIC, and TA? | 4.00 (field)<br>3.75 (lab) | Least Important |
| **C** | To what extent does upwelling intensity affect ocean acidification? | 3.75 | Least Important |
| **Q** | What are the strategies to adapt to, and alleviate, the impacts of ocean acidification along the Olympic coast – i.e., Establishing and managing refuges for species vulnerable to ocean acidification? | 3.50 | Least Important |
| **B** | Do local sources of nutrients exacerbate acidic conditions along the coast? | 2.25 | Least Important |

"How might marine food webs be altered?" ranked as the most important question, but was also ranked as one of the least feasible to answer, while the question "To what extent does upwelling intensity affect ocean acidification?" ranked as the most feasible, but one of the least important to address.

The question "Do local sources of nutrients exacerbate acidic conditions along the coast?" was ranked as the least important (by far) and as one of the least feasible

**Based on both the Importance of the question and Feasibility of answering the question, the four highest priority questions to come out of this exercise were:**

1. How rapidly is seawater chemistry changing, and at what locations will it change the most? (Question A)
2. Are OA and hypoxia impacting biota now? (Question H)
3. How are the abundance, distribution and diversity of living resources affected by ocean acidification? (Question I)
4. What species, populations, or ecological properties are most sensitive to OA and hypoxia? (Question F)

It was noted during the session that the questions provided may not be specific enough for the geographic location. It was recommended that research/monitoring questions that are specific to the outer coast of Washington be developed utilizing the results of the importance/feasibility prioritization from this breakout exercise. Determining best approaches and tools to address these questions, including building on those that exist and identifying new products or resources, will be an integral part of a joint research/monitoring plan for the Sentinel Site.

## Breakout Discussion C

### Application of Information from an Olympic Coast Ocean Acidification Sentinel Site

The objective of Breakout Discussion C was to determine how information generated from an Olympic Coast Ocean Acidification Sentinel Site might be used. In order to better define how information might be used, participants were asked to consider the following while participating in the discussion:

- identify and explore what they would like to be able to do with the information;
- identify gaps between monitoring efforts and management needs; and
- determine how current partner efforts will feed into planned actions identified in the driving documents (West Coast Plan, OAP plan, Condition Reports, OAH, etc.).

**Activities/Interactions:**
Each group was led through a facilitated discussion exercise, focusing on the following four questions:

1. Is an early warning indicator a feasible or useful goal? What would be needed for episodic rapid response, for example to monitor an emerging oceanographic event related to ocean acidification?
2. What are the audiences for indicators, data or information?
3. What management responses are available to address management needs? Who can implement them?
4. What unmet information applications or needs can be addressed through a Sentinel Site, including observations, regular forums or meetings?

**Results:**

**1. Is an early warning indicator a feasible or useful goal? What would be needed for episodic rapid response, for example to monitor an emerging oceanographic event related to ocean acidification?**

When groups discussed needs for an episodic rapid response, they listed potential target indicators and locations, target players involved, the process to go about it, and potential target species.

<u>Potential Indicators</u>
Data that could be used as proxy, early warning signals could come from water quality parameters and currents at surface and at depth, using bottom sensors (including temperature, dissolved oxygen, aragonite, pH, salinity). Changes in kelp or the presences of massive phytoplankton blooms could indicate high carbon dioxide. Monitoring for harmful algal blooms (HABs) might also help point to OA conditions, although the relationship is less understood.

Potential Locations
Workshop participants also shared monitoring locations that could help warn of an emerging OA-related event: canyon heads (San Juan de Fuca), Quinault canyon (~200 m), Quileute canyons, a mid-shelf location (~100 m depth).

Target Players
Players who could be involved in an episodic, rapid response include fishermen, who are out on the water daily and could share observations by contacting Sentinel Site partners/OCNMS as a springboard for action to increase monitoring efforts and eyes. Tribal members are critical, as they live on the coast and experience. A network or scientist "SWAT" team could be identified and assigned to react to an abnormal event (HAB, hypoxia, etc.), and respond quickly in collecting data on the water. This information would help provide researchers with both temporal and spatial data. Citizen scientists could be involved, depending on the frequency or their coastal monitoring. For example, COASST volunteers conduct monthly surveys at the same beach; streamlining data that they could collect or observe easily might be feasible for them. Another citizen science idea was to have volunteers put out settlement plates to establish a pattern of abundance in invertebrate organisms, or have volunteers change out sensors in the intertidal area. Another idea came forth with crab fishermen, using detector or instrument that could be put into their crab pots without interfering with catch, to capture data in the near-shore (seasonally).

Potential Species
Species listed for consideration as warning indicators included **pteropods** (indicator of corrosiveness), **Northern copepods** (nutritive impact), l**arval shellfish and/or Dungeness crab larvae** (survivorship), **larval fish** (e.g. larval black cod), possibly **Euphasids** (nutritive impact), **benthic calcifiers** (e.g. mussels, barnacles, etc. as corrosiveness indicators.), **razor clams** (adults in beaches/larvae), **fish otoliths** to determine whether a relationship with OA exists, and more. A group highlighted the consideration for finding species indicators that would give the "biggest bang for the buck," having rich existing or historic data sets, as well as temporal and spatial aspects of the data. **Seabirds** were mentioned for their integrative role in the ecosystem, which could signal water quality changes based on where they are feeding, wrecks resulting from food sources, and more. Information from certain plankton could be useful, as it is a key prey resource for commercially important species and an indication of potential recruitment rate.

It was pointed out that early warning systems could be helpful for human health in regards to disease concerns. Also highlighted was a requirement that overall, data needs to be easily discoverable and available to users.

**2. What are the audiences for indicators, data or information?**

Target audience members for this information span fishers to environmental agencies. Coastal communities are an obvious beneficiary to this data, as they and their subsistence and economies are directly impacted by ocean acidification and other related impacts on water chemistry and quality. Commercial and recreational fishers should be recipients of these indicators (and as

mentioned above, could potentially become partners in collecting data while they are out fishing), as well as recreational users (surfers, beach walkers, kayakers, etc.).

Government agencies and monitoring entities at the federal level include Fish and Wildlife Service, National Park Service, National Marine Fisheries Service; State agencies including WDOE, WDNR, WDFW, WDOH. Tribal and state fisheries and fish hatchery managers should be involved. Policy makers and planners include the West Coast Pacific Fisheries Management (PFMC), West Coast Marine Planning Body, Washington Coastal and Marine Advisory Council (WCMAC) and the Marine Resources Advisory Council (MRAC), legislators in Washington, D.C., state, Tribal and local representatives. Shellfish industry and growers could use the information, even if there are not many on the Olympic Coast; Willapa Bay, for example, would find the information valuable.

Academia and scientists are prime data users, as scientists often work with soft money. Therefore access to data strengthens their competitiveness when writing grant proposals and their ability to publish results, which in turn can lead to more research funding. The information would help boost regional ocean data portals, as well. Informal and formal educators could participate by incorporating data into lesson plans or case studies, especially with a shift in place-based education.

Given our geographical proximity and connectivity with ocean currents and eddies, a number of Canadian partners were listed, including Fisheries and Oceans Canada. Commercial fishery and shellfish growers (coastal and Salish sea), the Padilla bay (NERR) partnership, Pacific Coast Collaborative (including CA, OR, WA, BC and AK) and other West Coast policy leads, and the International Alliance to Combat Ocean Acidification were also mentioned as potential users of Sentinel Site data.

Finally, though the Olympic Coast is not very populated, the general public is an important stakeholder and could gain general ecosystem awareness. The example of the Eyes Over Puget Sound program was highlighted, as it greatly increased the public's knowledge of water conditions and trends. Media could be a strong audience member, particularly with visually appealing or meaningful products for their audience groups.

### 3. What management responses are available to address management needs? Who can implement them?

OCNMS regulations are in place, and staff could consider future impacts of resources and their response to long term permitting decisions (e.g. nutrient loading or restriction of discharge for some time). Sanctuaries do need more support (staffing, funding, etc.), including a functional research/monitoring vessel to continue supporting the oceanographic mooring program.

NPS and WDFW have the ability to close razor clam harvest for non-tribal response. Citizen science efforts are in place (COASST and NOAA Marine Debris), so volunteers could potentially respond to management needs, if suitable for their level of training and frequency of going on the beach. Volunteers could be engaged to mobilize additional monitoring or increase sampling efforts to better characterize events occurring along Olympic Coast.

There is a seasonal report of conditions and forecasted models. Results can, and do, help fisheries management and industry. Fisheries incorporate data into projection models for specific species (Hake, salmon, forage fish, krill, halibut) and to inform regulation decisions. This requires seasonal long-term reports, but could also be used in immediate response. Information is also communicated to PFMC, which is starting to consider climate change in its decision making.
Forecasts are available (e.g. NOAA's hurricane forecast) but there needs to be a self-explanatory product that people don't need to manipulate themselves. Data turnaround in general could be faster. NANOOS reports within a few days. NANOOS could add an advanced alert warning for corrosive conditions targeted at aquaculture.

There is a Grays Harbor Line LTER site (via UW proposal) and plenty of research in the Puget Sound, so if OCNMS/ Olympic Coast monitoring can show predictive power it will be more relevant to more inland, urban centers.

**4. What unmet information applications or needs can be addressed through a Sentinel Site, including observations, regular forums or meetings?**

Gaps and needs for ocean acidification applications highlight data, particularly the fact that a long-term data set is unavailable (20 years or more), as well as a highly OA vulnerable indicator species that has been studied over a long period. There has been inconsistent funding and resources for research and long-term studies in order to adequately understand life cycles of impacted organisms (e.g. larval studies). Sampling efforts have been sporadic using boats of opportunity (UW). Additional sites are needed, such as deployment of moorings throughout the water column in Juan De Fuca canyon. Gaps in habitats span the intertidal to deep sea. The intertidal zone is characterized by a gap in long-term community changes, and tends to showcase species versus communities. Deep sea coral reflect a less dynamic system and would act more as an indicator with gradual change. Information and historical records are needed about sediment and its changes in distribution, it relationship to food supply. Records of Foraminifera were mentioned as a need as well.

Currently, there is lack of a joint research plan for OA, which would aid in funding requests and proposals. An overall "wish list" for instrumentation, FTE's, data portal, etc. should be included in any joint research plan. The NANOOS portal provides OA-related information. It could be bolstered with a corrosive warning system for the Salish Sea or some of the information that MBON in the Gulf of Mexico includes. Efforts from having a Sentinel Site could perhaps participate in the Grays Harbor line of LTER site, if proposed. A reliable research and monitoring vessel is needed to support these efforts, ideally in the southern and northern areas of the Olympic Coast.

A response system to send resource managers a text message from an instrument/sensor could produce a warning (and also trigger more monitoring response)- could be similar to an Amber alert but for OA. There could be disease concerns, including human health (vectors and impacts to other organism resilience and quality of life). A HABs bulletin could be developed for OA template to keep user groups informed on a quarterly basis, along with an annual report card or

summary report (similar to Bering Sea report card)- it would have to translate raw data into digestible information. NANOOS could add an alert response system for corrosive waters targeted at shellfish growers. Advanced warning

Interest was expressed in having a one-day workshop on boundary conditions modeled on CALCOFI and Canadian publications to enhance boundary conditions section to engage and/or link the audience with status of conditions. The OA threshold for region is not known, but might be able to help with characterization of a major event (e.g. coral reef bleaching). Simone at PMEL is working on this for shellfish (event scale forecasts) using many sources and hopes to have operational in a few years.

An understanding of the social/ socio-economic aspects is important; particularly for the place-based communities (tribes), who will be dramatically affected. Communication needs for educators must be identified. The Newport line is a template for communication; uncertainty should be included (e.g. IPCC model).

**A joint research plan for OA would serve to focus efforts and aid in funding requests/proposals for a Sentinel Site. In addition, a reliable research and monitoring vessel, dedicated to the area, is needed to support all of these efforts.**

## Breakout Discussion D

### The Awareness Campaign –Education and Communication

The final Breakout Discussion of the workshop was titled *The Awareness Campaign – Education and Communication*. The objective of this sessions was to identify the key types of information needed, and best ways to deliver that information, for various audiences that could be targeted in an Olympic Coast Ocean Acidification Awareness Campaign. It was intended that participants would begin to develop the messages, and approaches to communicating and educating, about the information gained and activities taking place at the Sentinel Site.

**Activities/Interactions:**

For this session, four facilitated breakout discussions considered the information needed, and the best way to deliver that information to eight different audiences, including: 1) resource managers; 2) scientists and academics; 3) educators and interpreters; 4) Sanctuary visitors; 5) elected officials; 6) media; 7) local communities and 8) virtual visitors. Each breakout group was assigned two of these audiences.

Participants discussed potential goals of an awareness campaign, priority audiences, key messages and best approaches to communicating and educating about the information gained and activities taking place at the Sentinel Site. During each breakout group, the following questions were considered:

1. What does the Sentinel Site hope to accomplish from an awareness campaign directed at this target audience?
2. How will an awareness campaign directed at this audience benefit from an Ocean Acidification Sentinel Site?
3. What sort of information does the target audience need or want?
4. What resources or tools could be used to reach this target audience?
5. Which ones can be built into ongoing efforts? What new resources would need to be developed for a strong awareness campaign?

**Results:**

In regards to **scientists**, it was the general perception during the discussion that a Sentinel Site would provide opportunities to increase collaborations and partnerships in science and research – signifying that Olympic Coast is "open for business". It was also conveyed that a Sentinel Site would potentially attract more funding and scientists to Olympic Coast, and ultimately increase the availability of OA products derived from the data that collected by scientists.

Participants felt there was a strong link between scientists and **resource managers**, since decisions made by managers regarding ocean acidification often lead to long-term research decisions. It was suggested that as a result of an effective awareness campaign, attracting scientists and resource managers would boost science and credibility of the Sentinel Site and the issue of ocean acidification, and help facilitate communication up to policy makers.

It was discussed that a Sentinel Site would increase visibility of an ocean acidification awareness campaign by creating a geographic focal point, especially a pristine marine protected area like Olympic Coast National Marine Sanctuary. Participants felt that in addition to ocean

acidification, it would be important to also consider other parameters and stressors of water quality, including temperature, hypoxia, harmful algal blooms, etc.

The group expressed that scientists and resources managers need fundamental water quality data, especially real time data that is accessible and useable. For managers, there is a need for concise and objective synthesis products that tell the story and scale of ocean acidification – while also connecting the data to the place and to the communities.

Tools that can support this need include live webcams, images, infographics, diagrams and other powerful visuals. These outreach tools should include logos from multiple partners to increase credibility of the products. It was noted that it is important for resources managers to not focus on the good and the bad exclusively, but to present the facts of how things will be different - including "opportunities" and "challenges" – then allow audiences to develop their own conclusions. Another recommendation was that effective outreach should also provide managers with action options.

To increase effectiveness of the campaign with scientists and resources managers, it was determined that messaging should not be exclusive to ocean acidification. Participants felt that there is a need to characterize marine species assemblage, as this baseline data will help with developing messaging. It was also noted that providing accessibility to areas – including free site access, free boat time and dedicated science station(s) throughout Olympic Coast National Marine Sanctuary during summer months - would draw students and researchers. There were also comments for developing campaign strategies to attract international scientists to the area.

For **Educators** and **Sanctuary Visitors,** participants talked about opportunities a Sentinel Site would provide in raising awareness of Olympic Coast National Marine Sanctuary and ocean acidification, as well as raising awareness about other marine issues. It would also be an opportunity to raise awareness of the national value of the area's commercial resources and create public support and benefit events similar to that seen in the past, such as Live Aid, Farm Relief and Tsunami relief.

Discussion included ideas that a Sentinel Site may increase grant funding and help generate support for educational programs like NOAA's B-WET (Bay Watershed Education and Training) Program. New resources, including data collected as a result of increased research from an ocean acidification awareness campaign, would be well received by educators and interpreters as they are craving new and fresh data and information.

A Sentinel Site also presents opportunities for citizen science. Participants suggested that an App to collect data on razor clams may be particularly popular and useful. It was also recommended that social technology be integrated in citizen science programs to engage more people.

Additionally, it was commented that access to scientists and educators working directly with Sentinel Sites – a Network of Sentinel Site Ambassadors - would help connect local communities and virtual audiences to the Sentinel Site and issue of ocean acidification. To maximize outreach, it would be dependent on partners to help disseminate information.

In regards to **Elected Officials**, it was discussed that an awareness campaign could provide needed visibility, support and money on all legislative levels: local, state, Tribal and federal. Garnering solid federal support could lead to high level policy changes (ex: Implementing Clean Water Act section 303d), while increasing the amount of legislation moving from local levels to global levels. Support, including financial, for ecosystem-based decision making at local levels will only be increased through a higher-level (federal and state) understanding of the place-based challenges of an acidifying ocean.

Participants also felt that an awareness campaign would be able to expand the local understanding of human/community health and its direct connection to the health of their local environment or "place". Raising this awareness with the Elected Officials' audience can help raise the salience around OA, providing support to decision makers building a strong case for relevance when making difficult decisions. There is a tangible pride among residents in Olympic Coast as their chosen home. Raising awareness of the issue to support positive leadership would be complemented by the regional pride for leadership actions, with an Olympic Coast Sentinel Site leading the way for national progress on OA.

Existing and new tools would be needed for our elected officials. It was clear that there is already the projected cost of inaction, and the potential economic impact to our coastal communities. Tools still to be developed would include a concise one-page update that includes an OA report card, as well as well briefed staff of elected officials prior to contacting the elected official member. Also providing a trusted source to be the network to carry messages forward would increase success with elected official outreach and community representation.

It was discussed that **Media** as an audience has obvious benefits to an Olympic Coast Sentinel Site through proper engagement. Media can provide message amplification and refinement raising public awareness while increasing local ownership of the issue. Media can also push a wide spread 'call to action', knowing who to contact and where to build relationships to see the action to its fullest potential. Participants also saw the media as a way to connect the larger general audiences to education on the issue, keeping communities up to date on episodic events and increasing integration of marine conditions in weather forecasts as big picture events to increase fluency of communications.

In order to fully bring the media audience on board, there does need to be flashy or "splashy" news or "scoop" as well as effective graphics and data visuals of indicators that can be easily interpreted by the general audience of the media. It is also important that media has consistent messaging around OA to keep from confusing the issue, knowing the difference between fact versus hypotheses and good geographical context. It was discussed that youth reporters using social media platforms like Instagram and Snapchat, can more easily reach the next generation of ocean scientists, educators and managers through a peer to peer connection.

The group believed that in order to be a productive partner in disseminating OA information, the media audience would need clear and concise writing and a consistent source or contact for follow up, access to experts and likely some science communication training. It was seen among participants that there is value in developing personal relationships with media personnel and

importance in including compelling stories about local people or businesses. The media has potential to play a significant role in the solutions side of the story, providing a local context while speaking to a global scale for hope. Media would also need general messaging around OA regionally. The National Network of Ocean and Climate Change interpretation offers key messaging that resonates with the larger audience regardless of social or political leanings, leading to more productive discussions and solutions. The media, with the proper training and support could use these tools to successfully interface with a variety of audiences.

When looking at the audience of **local communities**, a good awareness campaign could lead to individual and community based behavior changes through community buy-in, as well as awareness of their marine protected area working to protect their resources. A general awareness of scientific issues and a greater understanding of what we stand to lose if action is not taken, could lead to more personal investment in their community and the local advocacy for a clean and healthy Olympic Coast. A greater local interest in their "place" increases diversity of supporters and can bring everyone to the table.

Highlighting the importance of food security and economic sustainability as well as cultural preservation and increased human health (ex: Harmful Algal Blooms and marine resources) could engage local communities to really take action with this increased sense of place. Ultimately, a well-defined and executed awareness campaign has the potential to cultivate OA ambassadors within a community, rallying their neighbors and community members in higher political engagement for government action.

Tools to reach local communities include fact sheets or infographics, public presentation and social media campaigns. It was largely agreed that good "hooks" like videos, or charismatic stories and case studies could go a long way in community buy-in. These "hooks" would also be particularly persuasive with virtual visitors as an audience.

**Virtual visitors** make up a unique audience that could be hundreds or thousands of miles away from an Olympic Coast Sentinel Site. Still, the group saw the potential of similar goals in an awareness campaign including a general change in behavior and awareness of Olympic Coast National Marine Sanctuary, and marine protected areas as Sentinel Sites. With a growing interest in Olympic Coast as a destination to world travelers, increased knowledge of the OA issue and what is at risk of loss to Olympic Coast and its communities could lead to increased diversity and reach of engaged supporters while also inspiring political awareness and the impact of personal and community actions.

In order to fully engage this virtual audience, participants saw concise information, charismatic beautiful pictures and stories and the "whoa" factor image as key tools for this platform. Utilizing popular social media platforms like Facebook, Twitter, Instagram etc., there was also interest in using web cams, public television and radio stations and utilizing partners like EarthEcho International to increase the reach of a dynamic awareness campaign. However, it was noted that better internet connectivity along our coastal communities and increased funding and human resources would be required to fully realize the potential of this audience.

## Partner Perspectives

As a wrap up to the OASeS workshop, a number of participants were asked to offer their perspectives on workshop highlights, concerns, what remains to be explored, any take away ideas and/or actions, and any general opinions on the future of an Olympic Coast Sentinel Site for ocean acidification.

Christopher Krembs, from the Washington Department of Ecology, spoke of the potential of a Sentinel Site as it relates to outreach regarding OA. He stated that "the main concern is the lens: how does ocean acidification affect our state? How does OA affect the state economy?" Chris also highlighted the need to "make the connection between the sanctuary and inland waters – Why does the sanctuary matter to the majority of the state's population (i.e., the Salish Sea)?" Chris emphasized that the sanctuary and NOAA have the opportunity to weave these broader, large-scale changes into the narrative of what is happening at local, regional, national and even global scales.

Jan Newton represented the Washington OA Center and NANOOS. Jan began by stating that collectively, we're still struggling with "what is a Sentinel Site?" She quickly followed up by assuring everyone that this is not a problem, and that it might take a while to define. She stated that it doesn't matter if this is an OA Sentinel Site or and OA/HAB/Hypoxia site, because if we're studying OA, we're capturing all of those other concerns. Jan highlighted the need to determine the top 3-5 questions in the various OA action plans that can be addressed on the outer coast, noting that there must be integrated chemistry and biology in OA research and monitoring. Jan summarized her opinion on the potential for an OA Sentinel Site by self-declaring the Sentinel Site!

Richard Feely, from NOAA's Pacific Marine Environmental Labs, began by stating that we "must define explicitly what we consider a Sentinel Site…we need to establish it, agree upon it, and support it!" He stated a need for us to collectively figure out a way to express the concerns regarding OA sensitivity and impacts on this region. He asked that we create an inventory of OA work that is being conducted, and actively maintain that inventory. He asked that while we all have our own resources, how to we work together? He noted that this will take time and efforts, but there is a great sense of opportunity. He ended by emphasizing his belief that if we [here in the pacific NW] establish a Sentinel Site, define it, and execute research and mitigation – our nation will follow.

Libby Jewett, Director of NOAA's Ocean Acidification Program, began her wrap up by outlining a concern: "How will we distinguish this [Sentinel Site] effort from all the other OA efforts in this region?" She reminded participants of many of the OA efforts already underway. Libby again reiterated the importance of combining chemistry and biology, noting that she was looking to the Pacific NW to figure out best practices, and to display methods of effective and coordinated bio-chemical monitoring and research. She added that an inter-agency working group is creating a National OA Information Exchange that might have some special use for Sentinel Sites. Overall, she expressed support for the concept expressing her hope that this Sentinel Site effort would result in a transferrable model for other regions to utilize collaborative methods of responding and adapting to the threat of OA.

Joe Schumacker, representing the Quinault Indian Nation, notes that these types of efforts have come and gone in the past, but that "this one is important" and we need to "keep the momentum going." Joe also requested that we collectively define what it is to be a Sentinel Site, and consider the value added that being a Sentinel Site brings to the region. Joe highlighted the need to share important OA information (i.e., Revelle factors) with our communities. Joe stated that the Federal government has a trust responsibility to maintain resources for the Tribes, and that an OA Sentinel Site may directly assist in those efforts. He also stated that tribal leaders have unique access to funding, and can use the information/products/messages that the Sentinel Site puts forth to fight for funding to support mitigation efforts.

## Next Steps

Notable questions/comments during the workshop wrap-up include:

- What you are learning and proposing here is relevant to the Gulf of Maine. You're setting a model for the entire nation. Especially impressed by the attention to societal impacts and outreach/education.
    - This was echoed by another participant who stated that this Sentinel Site has the potential to be a world leader in OA education/outreach.
- Please make sure that seabirds are included on the 'indicator' list.
    - Because many people visit the outer coast to bird watch, it's powerful to incorporate birds into outreach
- It will take some time to develop sentinel species, we don't want to launch outreach only to not see any response in the species.
    - Agreed! If we are going to connect the biological to chemical, we need thoughtful data analysis before determining sentinel species
    - Do an analysis to determine what's the most bang-for-the-buck in terms of sampling efforts if the question is "How do we detect OA in specific species?"
- The Sentinel Site should also be able to address the question "Why should I do my research in the Sentinel Site?"
- How do we incorporate long-term changes in OA into planning?
    - We can design our observing systems around modeled projections, then have expectations & validate the models. We thus plan not just for the next funding cycle, but also for the next decade.
    - Let's make sure to document what we are seeing now, so we can keep a record of conditions now for future researchers/modelers.
    - It's important to provide the understanding of how the ecosystem will adapt.

# Exploring Options for an Olympic Coast Ocean Acidification Sentinel Site (OASeS)

| NAME | AFFILIATION | NAME | AFFILIATION |
|---|---|---|---|
| Libby Jewett | NOAA-OAP | Kara Cardinal | The Nature Conservancy |
| Jennifer (Jenn) Mintz | NOAA-OAP Education | Lee Whitford | SAC Chair, Education seat |
| Jan Newton | UW-APL/ OA Center | Rich Osborne | UW-ONRC |
| Dick Feely | UW-PMEL | Christopher Krembs | WDOE |
| Simone Alin | NOAA/PMEL | Evelyn Lessard | UW |
| Carol Bernthal | OCNMS | Parker MacCready | UW |
| Kevin Grant | OCNMS | Micah Horwith | WDNR |
| Liam Antrim | OCNMS | Jennifer Hennessey | WDOE |
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| Meg Chadsey | Washington Sea Grant | Dan Ayres | WDFW |
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| Joe Schumacker | Quinault Indian Nation | | |
| Jennifer Hagen | Quileute Tribe | | |
| Adrianne Akmajian | Makah Tribe | | |
| Joe Gilbertson | Hoh Tribe | | |
| Angie Thomson | MRAC/Puget Sound Partnership | | |

**NOTE TAKERS:**

| | |
|---|---|
| Laura Spencer | UW SAFS PhD student (starting fall 2016) |
| Mariko Kobayashi | UW College of the Environment grad (B.S.) |
| Alex Mitchell-Morton | UW Oceanography graduate (B.S.) |
| Rebecca Lewis | OCNMS Americorps service member |
| Chris Butler Minor | OCNMS Volunteer, M.S. Portland State University |