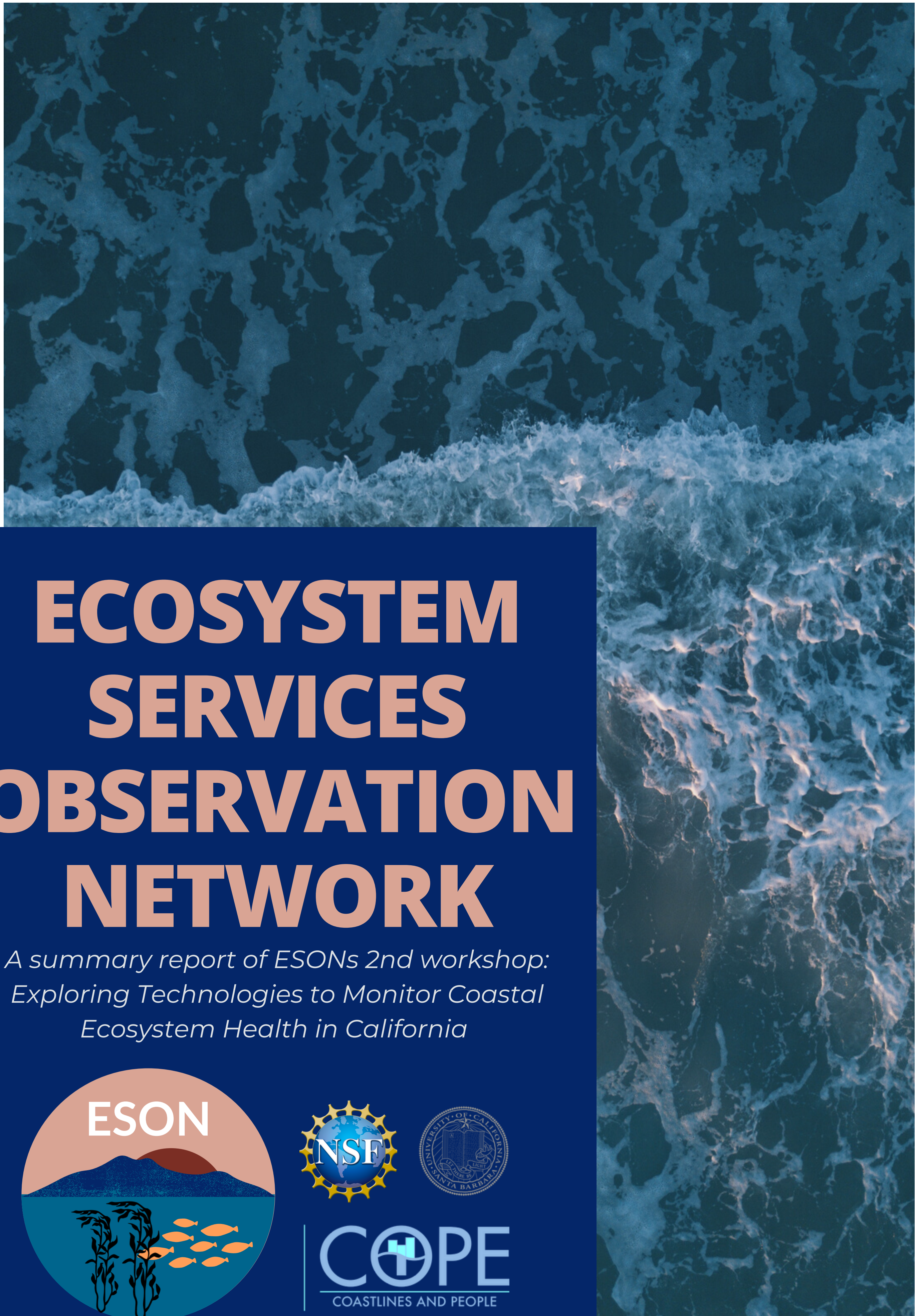

ECOSYSTEM SERVICES OBSERVATION NETWORK

A summary report of ESONs 2nd workshop: Exploring Technologies to Monitor Coastal Ecosystem Health in California

ESON

COPE
COASTLINES AND PEOPLE

EXECUTIVE SUMMARY

ESON hosted their second virtual workshop on Feb 10 and 11, 2022 in order to identify potential technology to monitor the biodiversity, migration, and ecosystem function of five key functional groups (primary producers, benthic primary consumers, pelagic primary consumers, nearshore predators, and pelagic predators). By improving the monitoring of these groups, we hope to gain a better understanding of ecosystem health in the California current. Day 1 focused on the specific technologies to measure these various groups, how to combine the data into useful integrated assessments, and if there are measurements of human activity that could be indicators for marine health. Day 2 focused on community science initiatives, the utility of data to communities, and best practices for deploying a monitoring network.

The main focus of the workshop was to identify the sensors that are most capable of measuring abundance, diversity, and vital signs in representative organisms in the five functional groups, which are indicators for biodiversity, migration, and ecosystem function. Cameras, aerial drones, acoustic recordings by underwater robots, moored buoys, and samples of environmental DNA (eDNA) were determined by participants to be the most critical in standing up a comprehensive monitoring effort.

An integrated assessment would be necessary to understand the status of these ecosystems. This assessment must identify critical thresholds and indicators, standardize data, use models to visualize dynamic ecosystems, pair biological and physical data, and identify indicator species. Measures of human activity can be integrated into this assessment. These measures include fishing logs, recreational fishing licenses, citizen science platforms, coastal recreation, tourism, renewable energy, human response to oil and sewage spills, and impacts of aquaculture. A key challenge is compiling existing data and integrating that with new data. Once all data are compiled, it will be key to make them widely available to the public and researchers alike. Participants expressed a pressing need for a single location of open sourced data, including reports on the status of various species.

A key effort of ESON is to involve the community in data collection to connect people with the ocean. A variety of existing technologies could be used to support community science initiatives. These include crowdsourced photos, collecting data using "fish finding" exercises, enabling recreational and commercial fishers to tag animals, enabling divers to deploy and collect sensors from low-movement species, scaling up current initiatives such as iNaturalist, and starting a community eDNA project.

Overall, ESON will need to continue to create strong partnerships with agencies to help create a sustainable monitoring network and work with various local groups to support a community science initiative. Data management and collating a repository of current data are the biggest challenges in terms of funding and having a full-time coordinator.

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OVERVIEW

Coastal ecosystems are changing because of climate change, pollution, and overfishing. California's fisheries, coastal tourism and recreation, and overall community health depend on vibrant marine ecosystems. While changes in our environment are readily measured through physical data, such as temperature, salinity, and oxygen, there is no comprehensive network to understand how marine life is responding to these changes, nor a pathway for understanding the existing and evolving role that the ocean plays in coastal lived experiences. Urgently needed are coordinated networks utilizing cheaper, faster, and higher quality techniques to collect time-series data with broad spatial coverage that capture changes in marine ecosystems from plankton to whales.

Obtaining adequate biological observations at appropriate spatial and temporal scales is necessary to reveal regional and global shifts in marine communities. By creating a comprehensive monitoring network with standardized ecological measurements, new biophysical links, dynamics, and emergent stressors could be detected. These new insights will help build and validate models to forecast future ecosystem change, which will improve our capacity for science-based decision-making for resource management and mitigation efforts. Additionally, early communication with stakeholders informing network design increases the relevance of the data collected for all users of the Californian coastal ecosystem.

The Ecosystem Services Observation Network (ESON) RCN (Research Coordination Network) is developing a plan for an integrated multiscale sensor and observation system to dramatically expand our ability to assess coastal change and facilitate a better understanding of ecosystem services and health. We will build a science, management, and education network across southern and central California that coordinates available expertise, prioritizes new techniques, and infrastructure and integrates these components into a cohesive implementation blueprint that will significantly advance our knowledge and understanding of the patterns and drivers of change in coastal systems.

ESON is working with a diverse network of people, including researchers, practitioners, community members, tribal members, recreational enthusiasts, and commercial fishers to help guide and inform the ESON framework and its outcomes. Through a workshop series, the RCN proposed to 1) identify and prioritize ecosystem indicator variables, 2) identify knowledge gaps, and ways to close those gaps with novel technological approaches, and 3) plan a multiscale sensor and measurement network to support ecosystem-based management.

OVERVIEW

WORKSHOP 1

ESON hosted its first workshop in June 2021 and prioritized working with various coastal groups to explore their needs within the environmental and biological monitoring realm (Burgos et al. 2021, Regional Ecosystem Services Observation Network Workshop Report: Ecosystem unknowns and societal monitoring needs in the California Current. University of California, Santa Barbara). During the workshop, attendees compiled key goals and species for which efforts should be targeted. A key takeaway from the first workshop was the call for increased real-time biological measurements to support risk. This first workshop was guided by a knowledge transfer framework (Figure 1). Stressors on the environment, such as marine heatwaves or nutrient runoff, affect the state of ocean ecosystems. Overall, ESON will look at how stressors will impact ecosystem function, animal migration, and biodiversity. The health of these systems, which is critical to communities and industry, influences the need for certain ocean data and knowledge about ocean ecosystems. Working with communities to understand their societal needs will shape ESON, which seeks to enhance the ability to observe the state of the ocean. By developing a deeper understanding of ecosystem health and processes, ocean use and management can be improved.

WORKSHOP 2

The results from Workshop 1 shaped the development of the second workshop, which explored various technologies to enhance the monitoring of key ecosystem functional groups to provide insight into ecosystem health. The focus included looking at technology that can fill in knowledge gaps under five key ecosystem functional groups: Primary producers, benthic primary consumers, pelagic primary consumers, nearshore predators, and pelagic predators. The workshop also had participants exploring and refining ways to tie together social and ecological indicators through targeted questions.

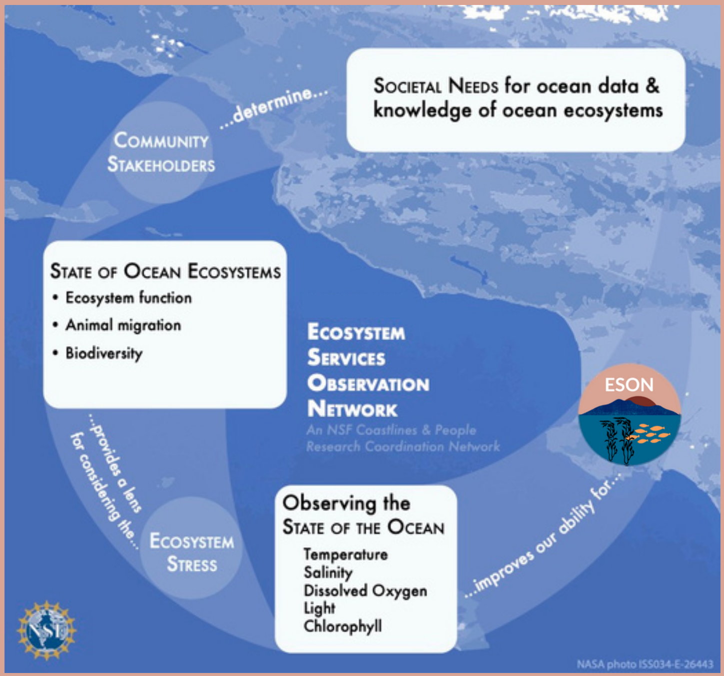


Figure 1: Knowledge Transfer Framework

PRE-WORKSHOP ACTIVITIES

CalCOFI ROUND TABLE

While planning the second workshop, ESON reached out to its partners to hear more about what specific species and functional groups were considered most important to understanding ecosystem health. ESON presented to the CalCOFI 2021 Conference: “Social-ecological indicators to support marine management in a changing climate” to review ESONs plan to advance technology to measure ecological indicators to understand the changing ecosystem due to climate change." Specifically, we reviewed our approach for the second workshop to understand how technology could inform biodiversity, animal migration, and ecosystem function. During the initial discussion, which had about 25 people at the roundtable, participants were asked “What type of technology do you think is critical for biological monitoring?” Four monitoring methods were consistently mentioned and stood out. This included 1. Passive + active acoustic monitoring 2. Remote sensing 3. eDNA and 4. Imaging.

ACOUSTIC TOLLGATES

Currently, acoustic telemetry ”tollgates” are being used off the coast of Point Conception, CA to observe fish migrating along the coast past an observational line. There is at least one single frequency line being maintained, which provides a reasonable time series for researchers to work with. These existing moorings have enough power and telemetry bandwidth to be augmented with more monitoring technologies to expand observational networks in the pathway of migrating fish stocks. For rougher waters like the North coast of California, it was suggested that stronger equipment would be needed to withstand these high energy systems.

ENVIRONMENTAL DNA

Participants seemed to agree that eDNA has the most potential for the future of biological observation. Currently, eDNA has been shown to be a solid monitoring tool for detecting specific species in an area, but turning detection into quantitative estimates of biomass is challenging. Plus as a participant mentioned, “researchers can not tell the age, weight, or physical properties of an animal through eDNA.” However, eRNA might expand our observational capabilities, allowing for researchers to use these biological assays for ecological monitoring.

FURTHER DISCUSSION & QUESTIONS

There was also strong agreement for a pilot monitoring system using all major instrumentation to monitor the coastal ecosystem to determine which sensors performed the best before scaling the network out. Much of the discussion outside of technical specifics included questions such as how to fund a sensor network, how other existing networks would fit in, and who would run such a network? These questions will help guide the RCNs future discussions.

SURVEY

To better guide Workshop 2 and narrow down which species ESON should focus on, a survey was presented to the CalCOFI roundtable, Workshop 1 participants, plus other affiliates of ESON. Twenty-three different species or taxon groups were presented. These were initially chosen based on conversations from the first ESON workshop, plus various individual conversations with researchers, state and local agencies, and tribal members. It is important to note that not every species discussed with stakeholder partners was included in this initial survey. Based on a broader list, the ESON steering committee focused on species based on the importance to stakeholders, the importance of species as indicators of ecosystem health (keystone species), and the expertise of the steering committee. For example, while certain culturally important species such as *Olivella* and crabs were discussed, they were not included in the survey list because they are difficult to study, or their health is likely tied to the health of other keystone species as well.

The survey asked participants to help ESON select the species and functional groups to focus its monitoring efforts towards. We asked participants to think about which marine species are sensitive to change, which are culturally and economically important, which species have gone understudied, and overall, what species in the ecosystem they valued. We asked participants to choose up to five species. Forty-four people responded to the survey, with plankton garnering the most votes at 23. Next was kelp (20 votes), sea urchins (18 votes), anchovies (15 votes), and sardines (13 votes) (Figure 2). This provided us with three main functional groups to focus the ESON workshop on, primary producers, benthic primary consumers, and pelagic primary consumers. To take advantage of the expertise within the ESON steering committee, two more functional groups (nearshore predators and pelagic predators) were added to round out our final categories to present at the ESON workshop.

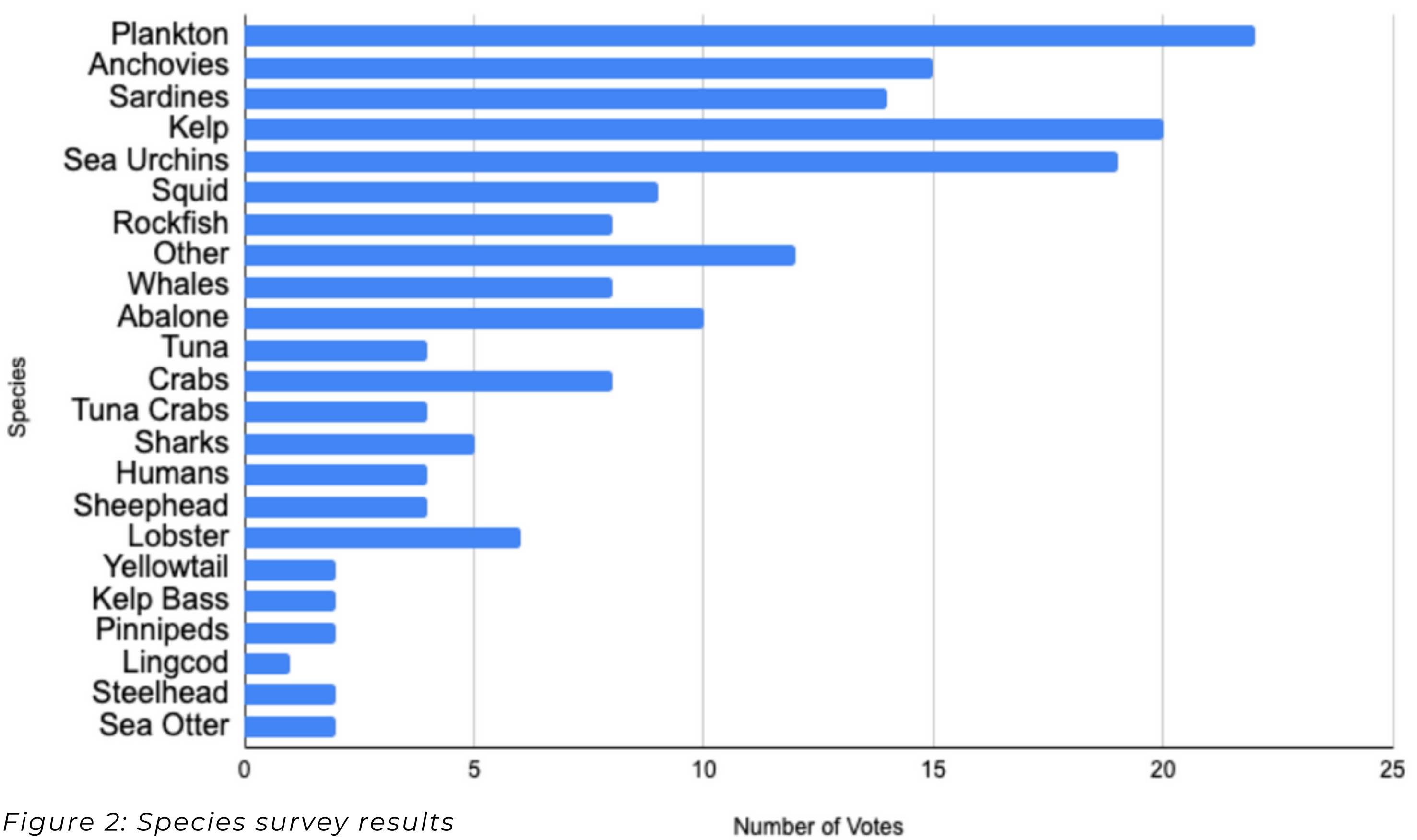


Figure 2: Species survey results

WORKSHOP 2 OVERVIEW

On February 10-11, 2022, ESON hosted its second virtual workshop, gathering a diverse network of people to provide insight into the best technologies to enhance the monitoring of key ecosystem functional groups to provide insight into ecosystem health. Day 1 of the workshop started off with an overview of ESON and then participants heard from 10 lightning talk speakers who presented on the technology they were currently using in biological monitoring and how it could be expanded for use in a network like ESON (Appendix pg. 22). The rest of the day prioritized discussing the best sensors and technology to provide insight into ecosystem health. Day 1 also looked at ecosystem synthesis, such as creating assessments and incorporating human use data into the sensor network. Day 2 then focused on community science initiatives, data utility to communities, and best practices for deploying a monitoring network. Fifty-seven people originally registered for the event, including the project's steering committee members. The full list of attendees with associated affiliations can be found in the Appendix (pg. 46). Fifty-seven people attended on day 1 and thirty-one people attended on day 2. The majority of participants were from academia with people from industry representing a significant portion as well (Figure 3). To foster more collaborative discussions, the group was broken into smaller breakout groups with a facilitator to discuss the predetermined topics and specific questions. Day 1 had six breakout groups, while day 2 had three groups.

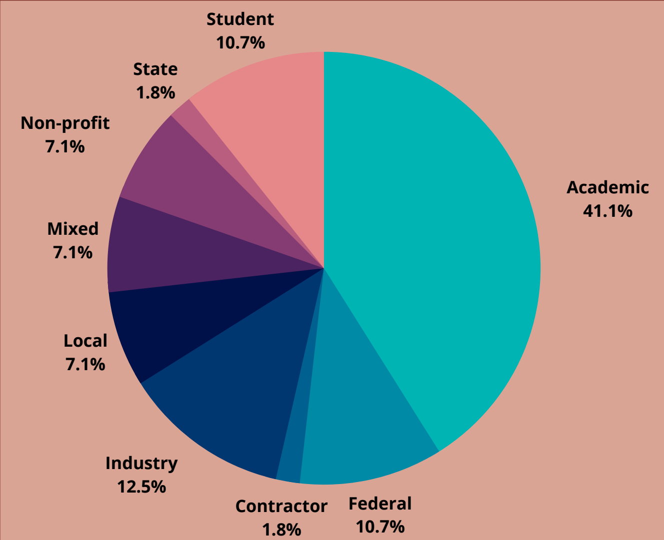
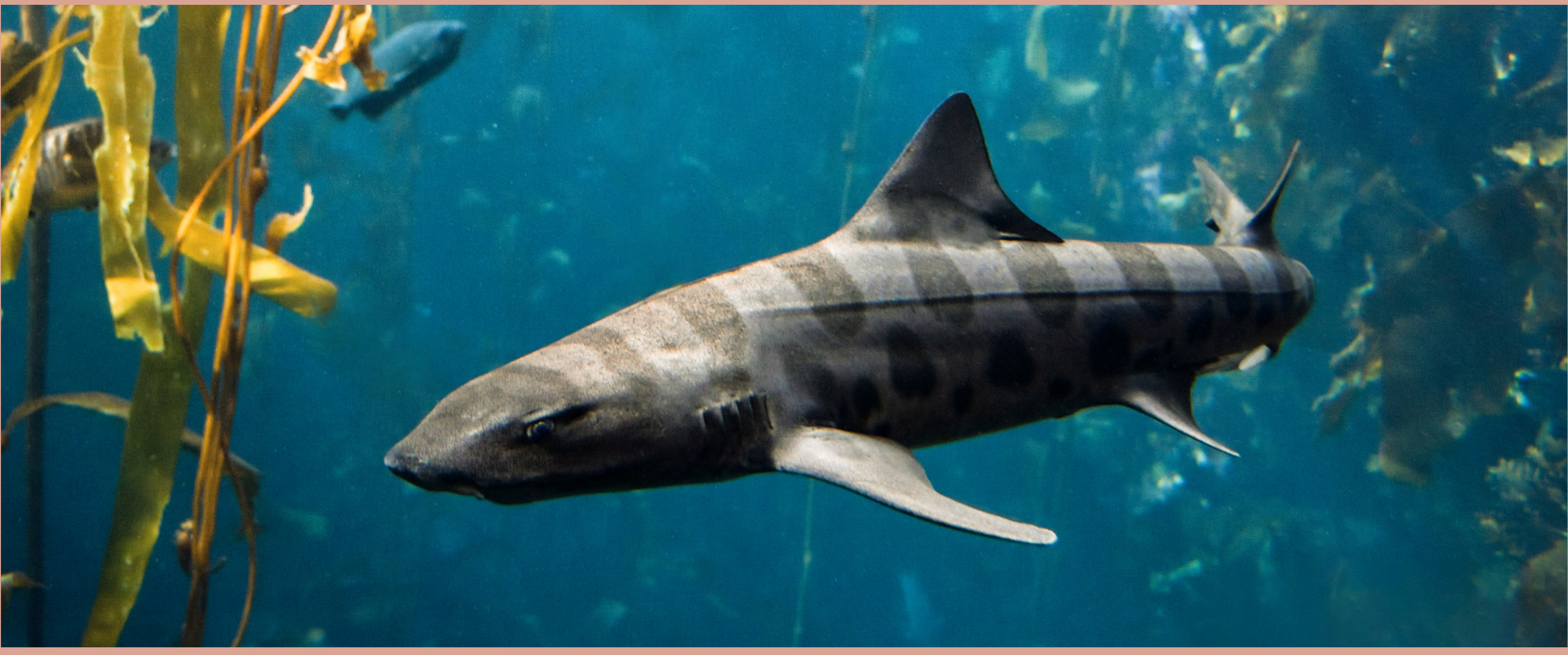


Figure 3: Workshop participant affiliation break down



TECHNOLOGY

OVERVIEW

On the first day, participants spent the majority of their time discussing the question “What sensors are the most capable of measuring abundance, diversity, and vital signs in representative organisms in these five functional groups: Primary Producers (phytoplankton, kelp); Benthic Primary Consumers (Sea urchins, Abalone); Pelagic Primary Consumers (Sardines, Anchovies, Squid); Nearshore Predators (Kelp forest fish, Sharks, Seals); Pelagic Predators (Tuna, Sharks, Fish)”. Each of the 5 functional groups had examples of species that fell under the groups based on previous discussions, specifically with participants from the first workshop, the CalCOFI conference roundtable, and the survey that went out to various stakeholders.

For each functional group, workshop participants discussed the technologies and techniques most promising for assessing abundance, diversity, and vital signs. (Include a sample image of the Miro Board). They were also asked to consider if these technologies could provide real-time monitoring, if the technology could be easily and widely deployed, and what the potential cost would be. While the wording in the question was explicit in saying to choose the most capable, all groups listed a multitude of different technologies for all functional groups across all three attributes. Across all functional groups and attributes, the most commonly mentioned technologies were eDNA, cameras, and acoustics through the use of underwater robots, aerial drones, and moored buoys.

PRIMARY PRODUCERS

Multiple technologies were identified to be useful for monitoring primary producers that can be classified as remote sensing, including satellite imagery, unmanned aerial systems (UAS) or aerial drones, and autonomous underwater and surface vehicles (AUVs and ASVs). Participants acknowledged the utility in satellite imagery for not only capturing phytoplankton abundance, but also the potential for discerning diversity as new hyperspectral sensors come online. Participants suggested using high-resolution true-color imagery from satellites for mapping kelp forest abundance and density; however, UAS systems equipped with true-color and Lidar sensors also show potential for mapping the abundance of underwater vegetation in a more targeted sampling scheme. AUVs and ASVs are also capable of measuring phytoplankton abundance, as well as mapping kelp forest cover if appropriate sensors are integrated into the vehicles.

Many participants acknowledged the utility of having increased monitoring of phytoplankton abundance and diversity using advances in underwater imaging technology, such as the Imaging FlowCytobot (IFCB) and the Scripps Plankton Camera System. These in-water systems contain flow through

TECHNOLOGY

PRIMARY PRODUCERS CT.

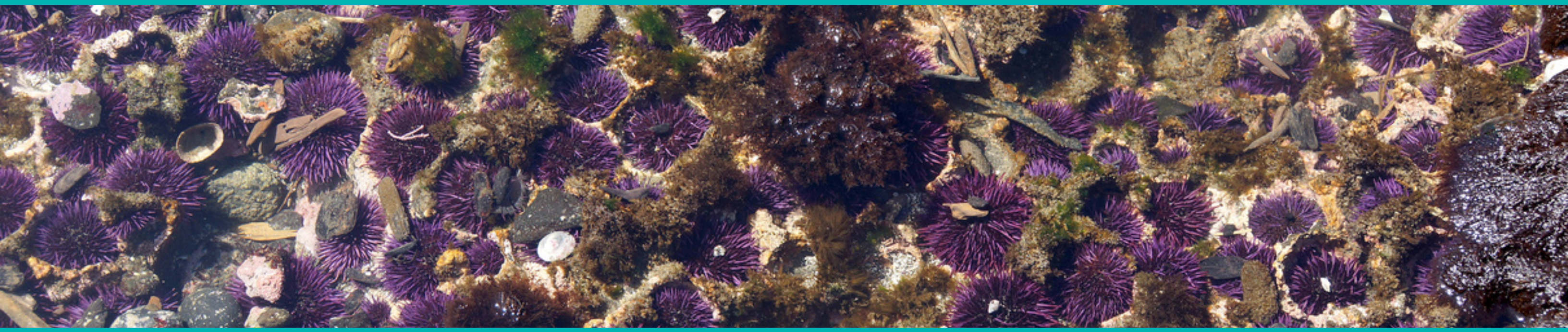
technology that can automatically identify and quantify primary producers in near real-time. To capture the abundance and diversity of kelp forests along the coast, participants commonly suggested using underwater cameras for monitoring. eDNA was also mentioned as a technology that may be useful for monitoring the occurrence of various species including primary producers, however, it was noted that this technology has a long way to go to be able to accurately describe the phytoplankton communities in the ocean due to how diverse phytoplankton communities in the ocean can be. However, this technology may be useful if we are concerned about particular species such as those that cause harmful algal blooms or are indicative of other ocean climate regime shifts.

Opportunities for involving community science monitoring programs were also discussed, including low-cost DIY monitoring tools, such as the Plankyoscope, which may be useful to engage with education and outreach partners. Additionally, some creative suggestions included using datastreams from the single beam echo sounders or “fish finders” that are common on many recreational vessels to map kelp forests. However, as is common for many community science initiatives, it was suggested that a central repository and data processing stream would need to be developed for this to be useful.

BENTHIC PRIMARY CONSUMERS

Many of the techniques suggested for monitoring benthic primary consumers relied upon direct human observations. Participants suggested supporting and growing underwater diver monitoring programs that included video or photograph transects and deploying settling plates to help quantify recruitment. However underwater imaging techniques like time-lapse cameras deployed in kelp forests of concern may also be useful for quantifying the measurements of benthic primary consumers. Additionally, remotely operated or autonomous underwater vehicles (ROV/AUVs) equipped with active acoustic and orthomosaic cameras may provide a more time and cost-effective solution for large-scale monitoring. For this technology to be successful and deployable in the long-term, however, advances in artificial intelligence and data processing streams would need to occur before monitoring could be scaled up.

eDNA may be useful for quantifying the presence and absence of benthic primary consumers and potentially reduces the amount of human effort required. However, we are currently limited in our ability to quantify abundance from eDNA data.



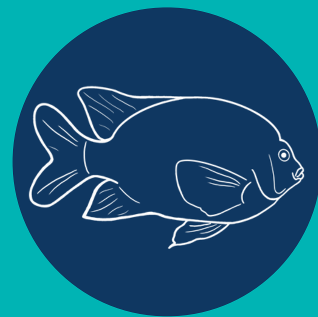
TECHNOLOGY

PELAGIC PRIMARY CONSUMERS

One of the most frequently mentioned technologies for monitoring the pelagic primary consumers was the technology currently used: active acoustics. While ship-based surveys are considered very valuable, potential for increasing survey coverage using AUVs and ASVs was acknowledged by participants. These transect style surveys could be enhanced with the addition of remotely sensed imagery from satellites or UAVs to potentially provide better spatial and temporal coverage of monitoring efforts, allowing us to monitor finer-scale dynamics. Similarly, capturing echosounder data collected by “fish finders” was discussed as a way to engage the community, however, a sensor calibration, data acquisition, and data processing pipeline would need to be developed for this technique to be deployable.

eDNA was again thought to be a useful technique for monitoring the occurrence of pelagic primary consumers, especially when considering monitoring shifts in the diversity of these species. Similarly, participants noted the utility of animal-borne cameras for video observations of species composition within prey schools. Both of these techniques may be able to provide important species composition information to active acoustics and/or aerial survey data.

NEARSHORE + PELAGIC PREDATORS



The technologies suggested for both nearshore and pelagic predators were similar. The most commonly suggested technologies included remote observation from satellites or UASs, which are most useful for monitoring air-breathing animals or those that frequently spend time at the surface. Underwater acoustic cameras or true-color time lapse cameras focus on areas of particular interest like coastal kelp forests, haul-out beaches, or in the pelagic system the use of baited underwater video camera traps. Additionally, animal-borne camera tags may be useful for increasing our observations of abundance and diversity in biologically concentrated coastal ecosystems. Other animal tagging efforts, including mark and recapture tagging, acoustic telemetry, and advanced bio-logging tags were also acknowledged for their ability to monitor the distribution and occurrence of important nearshore predators that don’t spend time at the surface. As mentioned, eDNA is a promising tool for detecting the presence and absence of nearshore and pelagic predator species. This may be especially useful for understanding the distribution and occurrence

TECHNOLOGY

NEARSHORE + PELAGIC PREDATORS CT.

of species that are difficult to observe or rarely encountered and therefore difficult to tag and visually monitor.

Complementary to these observations, leveraging community science observations from photographs posted to public naturalists databases (ex. iNaturalist), or records from ecotourism operations, (ex. whale watching charters) are datasets that have the potential to expand the spatial and temporal coverage of observation datasets. These datasets would be enhanced if infrastructure were developed to facilitate data collection, processing, and archival.

VITAL SIGNS

For all functional groups, physical, and chemical oceanographic properties were highlighted to be critical for assessing vital signs. These included environmental properties like temperature, dissolved oxygen, pH, and acoustic noise. Cabled moored sensor arrays or AUVs and ASVs outfitted with the appropriate sensors show promise for expanding the spatial and temporal coverage of our monitoring of these properties to pair with biological observations.

ECOSYSTEM SYNTHESIS

OVERVIEW

The first question in this section asked of participants was “How do we combine measurements of abundance, diversity, and vital signs into an integrated assessment of the state of the ecosystem?” Several different themes and ideas came out of this discussion, mainly revolving around identifying a standard set of ecosystem thresholds and indicators, linking the data together for an assessment, and making current and future data available.

THRESHOLDS AND INDICATORS

For effective integrated assessments, critical thresholds and indicators need to be identified. For example, what is the temperature threshold associated with the disappearance of a particular species? What are the critical spatial scales on which biology operates and how do these it vary across functional groups? What is the time scale of observation necessary to understand critical biological timeframes? These questions are vital for understanding integrated assessments like the California Current Report, National Marine Fisheries Service (NMFS) Ecosystem State Report, Southern California Coastal Water Research Project (SCCWRP) Bight report, and the NOAA NEFSC State of the Ecosystem Report, to be useful and impactful.

LINKING DATA

Standardization of metrics and data collection going forward would support more integrated assessments, and linking in-situ and lab data is going to be imperative for modeling efforts. Models will be key to improving our understanding of broader biological dynamics. Also suggested was pairing together biological and physical data, and downscaling these paired models will be needed to fill in data gaps and develop future forecasts of ecosystem health.

ECOSYSTEM SYNTHESIS

CREATING ASSESSMENTS

On the creation of useful integrated assessments, participants mainly discussed the need for standardization of thresholds and indicators for functional groups and that current and future data should be more readily available. There were several ideas, suggestions, and questions from participants regarding how we might structure these assessments. This included multiple assessments for ecosystem health, which can be further broken down by habitat or functional group, environmental and public impacts, and ecosystem services. Providing metrics for a “Winner or Loser'' for species or functional groups for a given year based on its health assessment could make these types of assessments easy to read for management and the general public. Additionally, assessments could include taking measurements across the food web in as many locations as possible with other measures of various aspects of the ecosystem in key locations. This could be accomplished with various technologies, such as real-time coastal moorings, or autonomous moving platforms equipped with cameras, passive acoustics, eDNA samplers, and physical ocean sensors.

Proper scaling of these assessments is also going to be key to providing the necessary information to researchers and managers. As a starting point, in addition to identifying critical species thresholds, identifying key indicator species and the ecosystem services they support and provide for, to describe a healthy ocean at 1 kilometer, 10 kilometers, and 100 kilometers resolution could provide the needed scaling. Overall, these health assessments need to be available and properly communicated to coastal managers and communities.

ECOSYSTEM SYNTHESIS

DATA AVAILABILITY

Participants highlighted that there is a plethora of data being collected, but it is not broadly available. Either data sets are not in compatible formats to be integrated together, data are not accessible to outside users, or the existence of data just is not broadly known. This leads to a duplication of effort. For efforts on biological monitoring to be more streamlined, researchers need a wider knowledge of ongoing and existing datasets, models, process studies, and experiments. Identifying these projects would provide a way for data and projects to come together and build off of one another. Methods of data collection might not be comparable, but having an index of current projects, such as through a clearinghouse or a similar network, would help support data integration, inform future work and encourage method standardization in monitoring efforts. For a clearinghouse to be effective, however, data would need to be collated and organized in a fashion that is readily usable for end-users, as is currently prioritized by the U.S. IOOS Regional Association, including detailed metadata to inform users of how datasets were collected. To be of use, this clearinghouse would also need to be effectively communicated of its existence, and participants would need to upkeep and archive datastreams. By collecting data in a singular location, a better understanding of baselines could be created, which is necessary to understand currently changing systems.

HUMAN ACTIVITY INDICATORS

The second question from this section was 'Are there measures of human activity that are indicators for the state of marine ecosystem services?' Human activity plays an important role in the state of the marine ecosystem, and the ecosystem is vital for the U.S. economy. California coastal counties generated $662 billion in wages and $1.7 trillion in GDP in 2012.[1] Understanding how humans interact with the system will provide insight into how humans influence the ecosystem and also how the ecosystem influences human activity. Several different metrics of human activity can be measured to add to the data collection of ecosystem services.

ECOSYSTEM SYNTHESIS

HUMAN ACTIVITY INDICATORS CT.

The most common one mentioned was collecting data on fishing logs and recreational fishing licenses, which includes grounding data from recreational and commercial fishing. While commercial grounding data are collected, many times the bycatch that is discarded is not logged. Recreational fishing does not commonly measure species caught and released either. Collecting data on what people are catching would provide further information on which species humans are interacting with. It was also suggested to understand how the fish caught are used, such as being sold, bartered, shared, eaten, used in art/ceremony etc. Further, data on boating activity, such as noise, commercial shipping vessel traffic and port backups, and tracking the volume consumption of boat fuel per area as a proxy of activity in an area for inshore park waterways are all potential metrics for understanding how humans interact with marine waters.

Another large component of human activity influencing and being influenced by the marine ecosystem is coastal recreation and tourism. Workshop participants suggested collecting data on the number of people going whale watching, surfing, diving, taking out boats, and ocean sport rentals and purchases. Further, just understanding who and how many people are coming to the coast is not information that is currently studied en masse. These data could be collected by tallying daily parking permits, counting the number of beach-goers (including on the beach or in the water) through drone surveys, or amassing social media posts with geotagged locations. The latter two could also provide more spatial dynamics of where people are using coastal areas. Participants were also interested in the diversity of people who are accessing the coast such as understanding age, ethnicity, gender, and income, which could be collected via surveys.

A few other measures of human activity that participants were interested in included event response to oil/ sewage spills, renewable energy, and aquaculture infrastructure impacts, and the use and popularity of citizen science and nature ID platforms such as iNaturalist, iSeahorse, and Seek. Already, the Channel Islands National Marine Sanctuary conducted a human use assessment[2] where several of the listed data and analysis needs from the sanctuary were discussed within the breakout groups.

CONVERGENT RESEARCH

The second day of the workshop featured breakout rooms to discuss convergent research. Convergence research at the National Science Foundation (NSF) was identified in 2016 as a key future NSF investment.[3] While there are many definitions according to NSF, convergence research is a "means of solving vexing research problems, in particular, complex problems focusing on societal needs. It entails integrating knowledge, methods, and expertise from different disciplines and forming novel frameworks to catalyze scientific discovery and innovation." ESON aims to not only address societal issues but also get the broader community involved in the project. The next question asked was "What technologies from yesterday's conversations best support community science initiatives? What would this look like?"

One of the bigger questions that needed to be answered first though, is determining which indicator species are the most important in each functional group to get a better understanding of the health of the ecosystem. Once that is determined, there are various ways that community science projects could help gather data on these species.

One of the most popular topics was having the community use imagery through multiple platforms to collect data. Using crowdsourced photos is already widely used in community science and could prove to continue being useful. Platforms like iNaturalist could be adapted for marine organisms with a section for pictures of stranding's to be uploaded. Taking advantage of the tourism sector could also prove to be fruitful. Visitors could submit recreational photos of marine mammals, invertebrates, or birds for example via a database. Drone imagery that people already collect could also be uploaded via a website, or specific calls to action could be put out to the community.

The next most popular idea was to have "fish finding" exercises that encourage recreational and commercial boats to provide presence/absence information for species of interest. Actually tagging animals with identification tags, or various electronic tags, is another option possibly available to encourage participation from recreational and commercial fishers. The Channel Island National Marine Sanctuary is looking for more ways to involve the community and could act as a key partner to get a pilot project for a community science tagging program going. There are also diving communities such as ReefCheck that could deploy and recover sensors on sessile or low movement species, such as kelp and seagrasses, abalone, and sea urchins.

Because eDNA was the most popular technology among the participants, initiating a community science project focused on collecting samples for eDNA analysis would be extremely beneficial and relevant.

CONVERGENT RESEARCH

There are a few current projects that might be able to be scaled up. This includes UCLA, which has an eDNA community sampling project, along with NOAA's National Centers for Coastal Ocean Science (NCCOS), which has a Phytoplankton Monitoring Network, to better understand harmful algal blooms through volunteer monitoring. Their framework includes training community members and providing supplies for the volunteers to collect water samples in various locations. The Phytoplankton Monitoring Network uses a mobile app to identify HABs and the data are sent back to NCCOS researchers to verify the bloom. A similar process could be conducted for eDNA in ecosystems commonly frequented by citizen scientists, like nearshore environments. School groups could also collect water samples, conduct preliminary identification, and send the water sample plus data to an academic group, such as UCSB or UCLA, to verify the results. To get school groups involved, partnering with the LiMPETS (Long-term Monitoring Program and Experiential Training for Students) program would spearhead more of this work and add to their programming. This would also help reach more underserved students and increase their involvement in STEM fields.

Through all of this, having a well-organized and accessible database to collect and store community science data is going to be key. A well-thought-out and organized data management plan and system will not only make it easier and more enjoyable for community users to access and use, but it will also ease data collection and use by researchers. Participants pointed out that while smartphone applications are easy to use, especially for younger generations, web applications are generally more useful and more easily accessible because they do not need to be downloaded and there are no device-specific qualifications needed. Therefore, website-based applications would likely reach a larger audience, and be more appropriate for school groups. This website would need to be open access, and could also take advantage of synthesizing data to create publicly available dashboards and live data reports. Another suggestion for this site would be to have an ID tagging game for people to play and support Artificial Intelligence (AI)-based image tagging.

DATA STREAMS

The last question asked under the convergent research theme was "How can we co-create data streams that are beneficial to user communities and quantify the state of the ecosystem?" This question addresses combining the community science data with usable data for researchers and combining them in a way that can be directly beneficial to both communities and researchers. The most important aspect of the co-creation of data streams as seen by participants is to have various stakeholder groups engaged at the outset so the data and resulting products are usable and effective.

CONVERGENT RESEARCH

This can include academics, government agencies, school groups, beach users, commercial and recreational fishers, indigenous communities, and recreational ocean users (divers, surfers, etc). It will further be important to have agency cross-talk at various governance levels to ensure that we are leveraging, cost-sharing, and complementing investments that allow different communities to collaborate. Regular feedback sessions with these various groups will be key to hearing about needed changes to products or data streams. This can also help to further identify priorities given new data streams.

The collection of various high-volume datastreams will require a data management system that is properly designed and funded to handle all data types, including input and output of data. This would ideally also include a user-friendly landing page that can synthesize data into useful products for researchers and the public, potentially with separate pages for educational purposes including packaged lesson plans. The landing page would have raw data, plus dashboard style or infographic-style products for a larger audience. As mentioned multiple times by participants is the need for an ihome page that follows the KISS (Keep it simple, stupid) principle with a traffic light style dashboard that allows data to be interpreted quickly.

A few examples of popular landing pages are the Blue Water Task Force[4], Heal the Bay's beach report card[5], and the MARINe Intertidal database management system[6], which we could model a similar product from. Also, the CalOOS MPA tool is a good example of how we could merge MARINe and other nearshore databases with oceanographic and climate model indicators that benefit a wide user community. Similarly, the MARACOOS oceans map[7] displays clickable layers and time sliders that a user can toggle and adjust, which is a handy model that various stakeholder groups can use.

Other ideas included having an 'ocean weather' type app for animals to answer 'who are you likely to see today and where?'. This will help to further connect people to the ocean. It was also suggested to have recreationally important data alongside this such as wind, waves, and temperature. Overall, once data are collected, a well-organized and planned data management system will be key to the future use and accessibility of the data.

NEXT STEPS

ENGAGEMENT AND DATA CATALOGING

Finally, we asked groups to reflect back on these various questions to discuss the best ways forward to actually deploy a large-scale sensor network. The first part, as mentioned by multiple breakout groups, is to engage early with all of the various stakeholders interested in this realm of data. Partnering and surveying groups across various levels (such as state, local, federal, and academia) to determine what type of data is important to them is the first step that ESON has already taken with various one-on-one meetings, plus the first ESON workshop. Next, participants suggested determining what data streams already exist and cataloging their strengths and weaknesses. Determining what data will be useful for long-term use, how we gain access, cataloging the differences in scales, and integrating the data will be an important step to avoid redundant efforts and highlight the gaps. However, this type of data cataloging can be time-extensive and tedious. Various hackathons might be a way to jump-start data synthesis. These existing programs and data collection will also be key to validating any new data streams from emerging technologies. Partnerships will be key in this effort to garner ideas and support the overall development of ESON. Connecting with the community is extremely important and developing community science projects will hopefully connect people back to the ocean. Working with local outreach and conservation groups such as the Noyo Center for Marine Science and the Monterey Bay Aquarium can bring the importance of this network and opportunities to get involved to the public. Working with companies such as The Adventure Scientists and iNaturalist who have platforms built for crowdsourcing observations and samples, can be starting points for creating a marine monitoring community science initiative.

USEFUL TECHNOLOGIES

One of the most popular ideas that several groups suggested was investing in low-cost options that can easily be scalable to stretch across a wide area. Mentioned multiple times were small buoys, which have limits but are often more accessible for collecting time-series data. A simple instrument package would allow for more measurements of multiple ocean conditions to be taken frequently and automatically. Possibly partnering with offshore ocean energies groups would provide access to larger powered platforms, allowing for automatic data collection and transmission to shore over longer time scales. Overall, the monitoring network created should be easily scalable so it cannot only expand to other regions but also allow for other researchers to build onto it with other sensors.

NEXT STEPS

DATA MANAGEMENT

Regardless of the technology used, all groups were adamant that data management and collection is the most challenging and important piece to building a successful monitoring system. The most critical need would be to have set standards for data collection and format. A central open-source repository to store and use the data will be critical for others to access and use. The biggest challenge to this work is having adequate funding to keep a program running, in addition to supporting managing the backend data. However, if guidelines for data collection and storage can be agreed upon in the immediate California marine monitoring scientific community, this might alleviate some of the need for a full-time coordinator.

Overall, ESON will need to continue to create strong partnerships with agencies at all levels to help create a sustainable monitoring network and work with various local groups to support community science initiatives. The curation and distribution of data and synthetic products remains a major challenge and requires investment in people, power, and creativity.

REFERENCES

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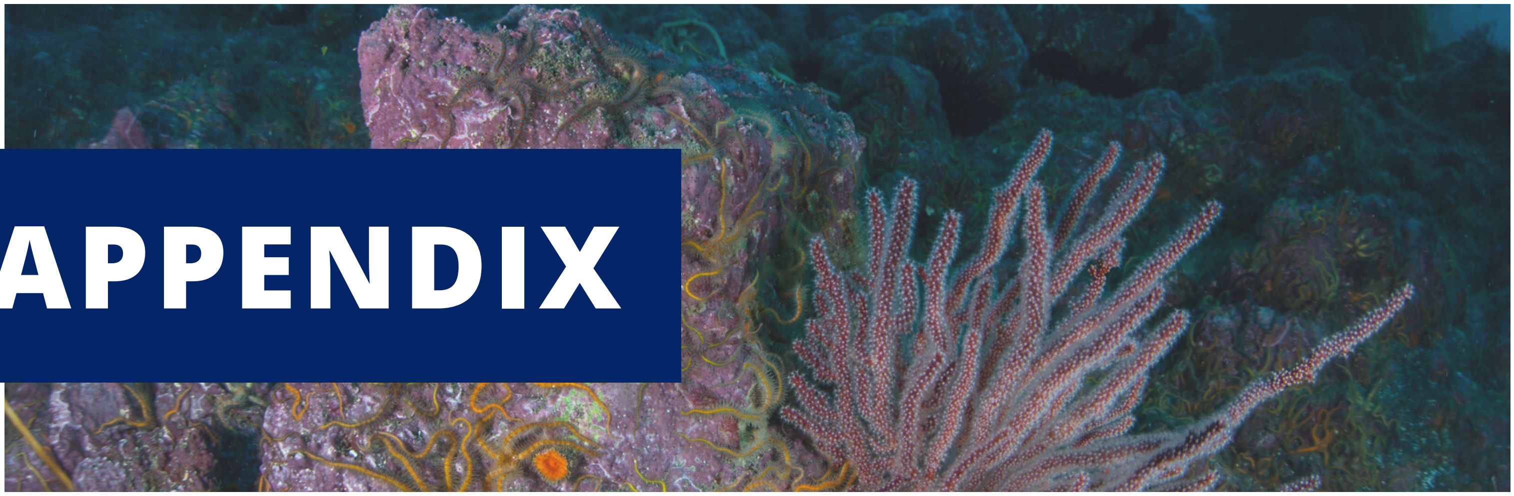
APPENDIX



AGENDA PROVIDED TO PARTICIPANTS

Workshop 2: Exploring Technologies to Monitor Coastal Ecosystem Health in California

Date: February 9th & 10th, 2022
Time: 9:00 am - 12:00 pm (PST)
Where: Virtual, Zoom (you can also call in if necessary (US) +1 346-248-7799)
https://ucsb.zoom.us/j/83864681068?pwd=Wk5OV0VJenRyTHVETnRmNnhLaWNuZz09

Workshop purpose: This workshop will explore various technologies to enhance the monitoring of key species within functional groups to provide insight into ecosystem health.

Agenda
February 9, 9am - 12pm:

8:50 Log onto Zoom
Please log on 10 minutes early to check your connection
The meeting will start promptly at 9:00 am PST

9:00 Welcome and Introductions *This introduction will be recorded*
Overview of RESON - Presentation by Bob Miller

9:15 Lightning Talks

10:00 10 minute break

10:10 Overview of breakout sessions

10:15 Breakout groups start (Technology)
*Question details can be found below

11:10 10 minute break

11:20 Breakout groups resume (Data)

11:50 Day 1 wrap up

12:00 Adjourn

APPENDIX

LIGHTNING TALK SPEAKERS

Fernando Lima - Cutting-edge in situ temperature monitoring across multiple scales
Brian Helmuth - Mapping physiology: biophysical mechanisms define scales of climate change impacts
Uwe Send- A low-cost real-time shallow-water mooring option
Andrew Thompson - New Technologies Will Help us Understand that Old Recruitment Problem
Clarissa Anderson - Leveraging the SCCOOS Network
Zack Johnson - In-situ monitoring using remote sensing and volunteer networks
Michael Sears - Innovasea Acoustic Telemetry
Chris Lowe- Shark monitoring along southern California beaches
Josh Kohut- Ocean robots: Tracking dynamic seascapes to inform offshore wind development
Kakani Katija - FathomNet: An underwater image database enabling artificial intelligence in the ocean

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Workshop purpose: This workshop will explore various technologies to enhance the monitoring of key species within functional groups to provide insight into ecosystem health.

Agenda
February 10, 9am - 12pm:

8:50 Log onto Zoom
Please log on 10 minutes early to check your connection
The meeting will start promptly at 9:00 am PST

9:00 Welcome and Day 1 Recap

9:10 Group discussion and thoughts from Day 1

9:30 Overview of breakout sessions

9:35 Breakout group (Convergent Research)

10:15 15 minute break

10:30 Breakout group (Next Steps)

11:10 10 minute break

11:20 Group reports
*Each group will have ~5 minutes to present 2-3 main points from their Next Steps

11:55 Wrap Up

12:00 Adjurn

AGENDA PROVIDED TO PARTICIPANTS

Break Out Group Details
You will be placed in a breakout group with 7-8 people. Each group will work through a set of questions across the two days. These questions will culminate into a few main points that your group agrees upon, and will be reported back out to the larger workshop group at the end of day 2. Workshop questions are below!

Technology

1. What sensors are the most capable of measuring abundance, diversity, and vitals signs in representative organisms in these functional groups:

    Ecosystem functional groups
    - Primary producers (phytoplankton, kelp)
    - Benthic primary consumers (sea urchins, abalone)
    - Pelagic primary consumers (sardines, anchovies, squid)
    - Nearshore predators (kelp forest fish, sharks, seals)
    - Pelagic predators (tuna, sharks, fish)

2. For these sensors…
    - Can you collect real-time monitoring? (yes, no)
    - Can it be easily and widely deployed? (yes, no)
    - What's the potential cost?

Ecosystem Synthesis

1. How do we combine measurements of abundance, diversity, and vital signs into an integrated assessment of the state of the ecosystem?
2. Are there measures of human activity that are indicators for the state of marine ecosystem services?

Convergent Research

1. What technologies from yesterday's conversations best support community science initiatives? What would this look like?
2. How can we co-create data streams that are beneficial to user communities and quantifying the state of the ecosystem?

Identifying Next Steps

1. What are the best ways forward to deploy this network?
    a. How can we build on and integrate with existing data and programs?
    b. What partnerships or collaborations would support this work?
    c. From your previous discussions, which technologies are the most cost effective, widely deployable, and spans various functional groups?

APPENDIX

WORKSHOP NOTES

Each breakout group utilized the online software Miro (a virtual whiteboard) to take notes. Each group was provided with a pre-made board to fill in their answers. Below is a summary of all notes across all groups. Bullets marked with an X indicates that it was mentioned in another group.

TECHNOLOGY

Primary Producers

Abundance

- Kelp overflights X
- Cameras
- Drones XXX
- SeaWifs satellite imagery
- Acoustic telemetry for kelp
- IFCB X
- Satellites (landsat for kelp canopy cover/density) XXXX
- Chlorophyll sensors
- Wire walkers
- Ship surveys
- ASV subsurface structure and species
- In-situ: sampling scheme (resolution in time and space, profiling vs. fixed-depth) as important as choice of sensor
- Chlorophyll flurometer – can resolve species
- Flow cytometry / continuous plankton recorder (real time / deployable)
- Satellite data can give a crude measure of overall chl-a / phytoplankton abundance (real time-ish/ deployable)
- Using fish finder on recreational boats to map subsurface kelp forest
  - Cost – fish finder, SD card, software to 'hack' fish finder, boat time (or put on AUV so it could be real time) human analysis (or develop ML tool to be automatic) – it works, upscaling might be a challenge (see github.com/cpagniel/KelpMapping)
- Automatic eDNA sampling/ sequencing for both phytoplankton and kelp
- qPCR for particular species of interst
- Phytoplankton is a diverse group cutting across taxonomic domains/ kingdoms
- Fluorometers
- Cameras on buoy systems
- AI to monitor rates of change/growth through time of sub surface species
- Photobot
- Submersible sampling & imaging
- AI post processing

WORKSHOP NOTES

TECHNOLOGY CONTINUED

Diversity

- IFCB XXX
- eDNA surveys XXXX
- Satellite hyperspectral imagery XX
- Other in situ cameras: SPC, IPAX, UVP, ZooCam, CytoBuoy
- Shore based imaging
- FlowCam
- PlankoScope
- Plankton tows
- Drones
- Community composition assessed by IFCBs can be connected to food quality which impacts vital signs
- Adjust optics on IPAX to monitor phytoplankton instead of zooplankton, current cost of platform is $500 – could be real time if deployed with surface buoy
- Arial drone surveys + AI to identify species
- Remote sensing of diversity of phytoplankton
- Daily u/w photos from vehicle transect or stationary camera
- Submersible sampling & imaging
- AI post processing
- Automated plankton traps (not real time)
- Biology dates transistors

Vital Signs

- Landsat
- Nutrient concentrations X
- Water temperature X
- Density structure X
- PAR X
- DO X
- pH
- NO3
- MAPCO2 OA
- Ancillary sensors with chlorophyll
- Drone photography of kelp growth X
- HAB toxins X
- From ESP – measure of physiological stress as well as directly impacts decision making
- Canopy physiological condition from hyper/multispectral RS
- Predation with IFCB
- Sensing/ logging light and light quality would help understand the performance of kelp

APPENDIX

WORKSHOP NOTES

TECHNOLOGY CONTINUED

Vital Signs ct.

- Cameras monitoring animals in kelp forests are also capturing pictures of kelp itself – used to asses kelp health, density, species etc. – could be real-time with a surface buoy
- Automatic camera traps targeting consumers – like squidcam but with kelp – could help understanding the system functioning
- Drone surveys pre-determined paths/ waypoints to look for signs of bleaching
- Underwater incubators measuring O2/ CO2 – requires new tech to yield real-time data at many locations for long periods of time
- Kelp coloration
- Fast repetition
- Rate flurorometer
- Pulse amplitude modulated flurometry (PAM)
- Cell size
- Growth rate
- Imagery
- Rate of cell division/ life cycle

Benthic Primary Consumers

Abundance

- Diver surveys XX
- eDNA XX
- Moored video / time lapse cameras XXX
- Imaging systems on AUV's, ROV's, moorings, underwater webcams X
- Sediment grabs
- Acoustic monitoring
- Buoy bound camera systems that can be retrieved and redeployed with relative ease
- Lidar
- Daily u/w photos from vehicle transect or stationary camera
- Transects or quadrats can compare to historical abundances where older surveys exist
- Hand count/ diver transect
- Drones
- Fathomnet

APPENDIX

WORKSHOP NOTES

TECHNOLOGY CONTINUED

Diversity

- Divers
- eDNA XXXX
- Imaging systems on AUV's, ROV's, Moorings XX
- ESP (envir. Sample processor)
- Settling plates
- Acoustic monitoring
- Onshore analysis – PPS – not real time but cheap
- Specimen sampling
- Hard to identify species in the field
  - Lots of cryptic N/S species along CA that look almost the same
- Not all specie groups respond the same to change – especially diverse inverts – so can't sample as subset of phyla and assume that it's representative of all diversity
- Fathomnet

Vital Signs

- MAPCO2 OA
- Temperature X
- DO
- Density
- O2 X
- pH
- Turbidity
- Salinity
- Heart rate sensors
- Sediment profiling cameras
- Sediment toxicity / contaminants
- Stable isotopes
- Tags (acoustics, accelerometer, heart rate, temperature)
- Viruses/ pathogens – eDNA, eRna
- IFCB (can theoretically monitor spores, larvae and other small particles that could give information on benthic invertebrate populations and physiological status
- SPATT for dissolved chemicals that could link back to vital signs like stress/ disease
- ESP – capture chemicals released by sick organisms as well as omics usages
- Cardiac frequency loggers for animals with hard, clean shells (abalone, not urchins)
- Urchin barrens
- Presence or absence of food source

APPENDIX

WORKSHOP NOTES

TECHNOLOGY CONTINUED

Vital Signs ct.

- Reproductive status – recruitment rates age class structure
- Camera data
- Images of abalone for witherin syndrome
- AI to see changes in organisms
- RNA/ DNA ratios
- IR heart beat sensors

Pelagic Primary Consumers

Abundance

- Pelagic trawl surveys
- Active acoustics on moorings XXX
- eDNA X
- Imaging systems on AUVs, ROVs, moorings XXX
- Active acoustic surveys X
- CDFW - fisheries data
- Sonar
- Broad spectrum light
- Ship based egg / larval sampling
- Chlorophyll biomass – copepod food quality
- Temperature and other physical descriptions of water mass type as a proxy for forage populations
- Species distribution models
- Echosounders
- qPCR for zooplankton
- Logger that captures fishermens sonar data and send them through satellite?
- Then have citizen science network mapping pelagic fish abunace – would provide environmental data too (e.g. temp)
- Commercial fishery data X
- Cameras on animals
- Camera for ID
- CUFES
- Flow through imaging plankton system

APPENDIX

WORKSHOP NOTES

TECHNOLOGY CONTINUED

Diversity
- eDNA XXXXXX
- Active acoustics on moorings XX
- Pelagic trawl surveys
- Imaging systems on AUVs, ROVs, moorings X
- Cameras on animals
- CUFES
- Biology-gates transistors
- Flow through imaging system

Vital Signs
- Temperature X
- DO X
- Density
- pH
- Algal / zooplankton populations
- Tags (acoustics, accelerometer, heart rate, temperature)
- eDNA
- Habitat compression estimates from models parameterized in lab for specific taxa like anchovies and sardines
- Cardiac frequency loggers talking through acoustic modems
- Recruitment
- Zooplankton lipid content
- Acoustics
- Trawl data
- Fat content – maybe analyzed oil in the water
- CUFES

Nearshore Predators

Abundance
- Aerial drone surveys XXX
- Divers
- Passive acoustics on moorings XXX
- Vemco tagging
- Mark recapture
- Trawling surveys
- Satellite telemetry
- Image sonar
- Cameras XX
  - Time lapse
- Recreational or commercial fishing boats
- Drones for seals and other rookeries X
- Use images to assess abundance as well as animal health and also ca/val for satellite remote sensing surveys of animal patterns + abundance
- Cameras on animals
- Citizen science observations X
- Lidar mapping for primary habitat
- Long-term underwater cameras paired with passive acoustic monitoring (kelp forest fish make a lot of sound)
- Cabled acoustic cameras
- Fisheries independent sampling
- ROV surveys

WORKSHOP NOTES

TECHNOLOGY CONTINUED

Diversity

- eDNA XXXX
- Fish and invertebrates are better represented, plankton less so
- Historic and longterm datasets can be used to set a baseline
- Acoustic monitoring
- Camera systems time lapse
- Cabled acoustic cameras (blueview)
- Citizen science observations X
- Drone surveys w/ AI
- Stranding's/ shore-cast species
- BRUV/ FAD

Vital Signs

- Temperature X
- DO XX
- pH XX
    - pH and DO as proxies for metabolic health
- Acoustics XXX (presence/ absence)
- Passive acoustics
- If you know about the species, you can use environment data (temp, DO, etc) to model vitral rates (metabolism)
- Accelerometer
- Heart rate
- ATN established methods for measuring vital signs at individual organism levels – how to scale up to population level?
- Habitat associations as proxy for population health / food source abundance
- Cameras for assessing physiological health
- Changes in scat/ guano on rocks/ beaches
- Long-term underwater cameras paired with passive acoustic monitoring (kelp forest fish make a lot of noise)
- AUVs/ASVs with receivers, moorings with receivers
- Animal weight/ size from aerial drones (sharks/ seals)
- Movement patterns

APPENDIX

WORKSHOP NOTES

TECHNOLOGY CONTINUED

Vital Signs ct.

- Number and health of spawning aggregations
- Strandings/shore-cast species
- Biologging tech
- Remote sampling (biopsy used to measure stress hormones)

Pelagic Predators

Abundance

- eDNA X
- Drone surveys X
- Acoustic tags XX
- Vemco tagging
- Trawl surveys (fish)
- Fish landing reports X
- Aerial drone surveys
- Sightings X
- Biologging tags with CTD (or at least temp), know where animals are and conditions they are experiencing
- Animal – borne cameras
- Active acoustics on moorings and AUVs
- Fish telemetry
- Satellite imags X
- Fisheries data/ CDFW
- Photoid
- UAS survey

Diversity

- eDNA XXXX
- Fish landing reports
- Fisheries observer program reports
- Citzen-science observations X
- Biologging tags with CTD
- BRUV/ FAD
- Photos

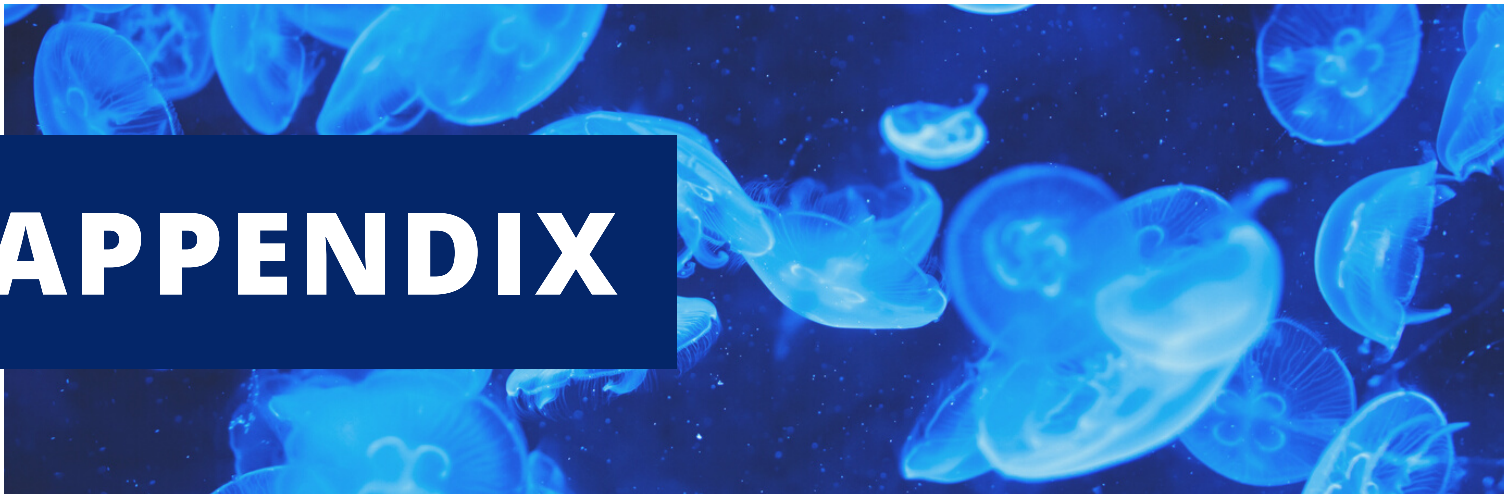
APPENDIX

WORKSHOP NOTES

TECHNOLOGY CONTINUED

Vital Signs

- Temperature
- DO
- pH
- Satellite tags X
- Observe prey (zooplankton acoustically)
- Biologging
- Ocean noise – hydrophones
- ESP
- Pop that that can provide detailed but delayed data
- Presence/ absence: acoustic telemetry
- AUVs/ASVs with receivers, moorings with receivers
- Presence/ absence: eDNA
- Archival tag data
- Strandings/shore-cast species
- Drones
- Biopsies
- Remote sampling (biopsy used to measure stress hormones etc.)



APPENDIX

WORKSHOP NOTES

ECOSYSTEM SYNTHESIS QUESTION 1

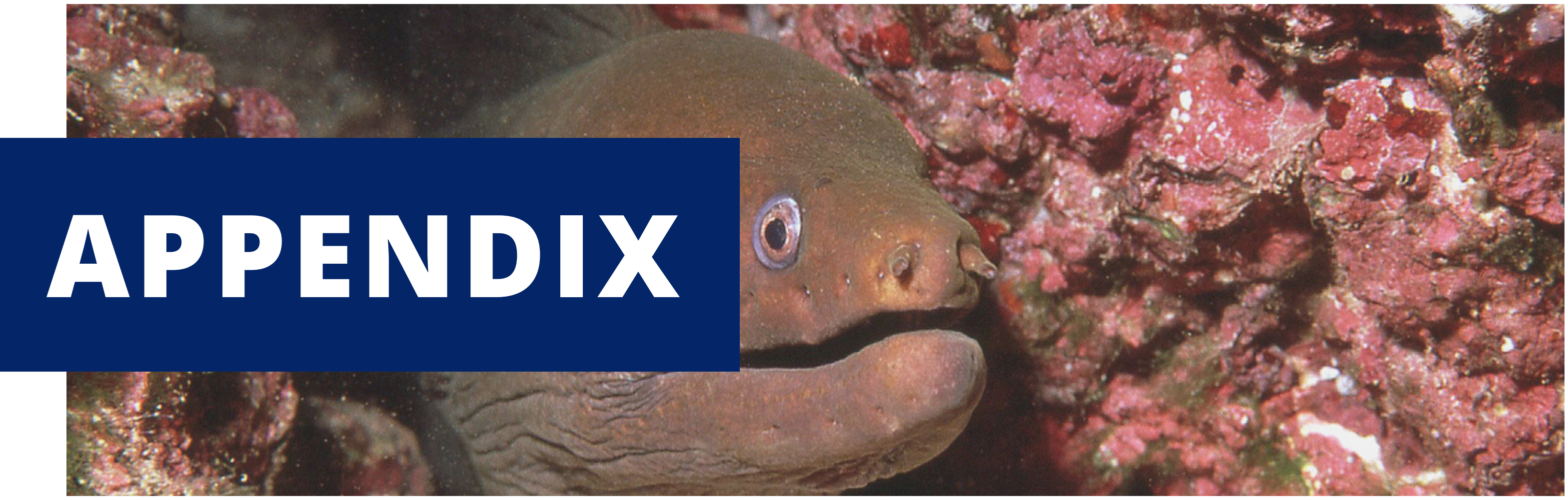
- Ecosystem models
- Coordinated data storage between modalities
- Functional diversity metrics computed from observations
- Benthic response index
- Fish response index
- Need intercalibration work to make monitoring with different tools operational
- Use related indicators from state of the CA current report, NMFS ecosystem state report, SCCWRP bight report
- Need to pair biological and physical data
- Downscaled physical-biological models to fill in the gaps/ forecast
- Lab meso/micro cosm studies to characterize exposure on biological response
- Standardization of metrics
- Duplication of efforts due to lack of access or knowledge of ongoing/ existing data/models/experiments
- Ocean hack week, data science efforts ongoing
- Do we need efforts to identify and bring data together and make it accessible?
  - Methods might not be comparable
- Lots of data currently collected is not broadly available (incompatible format, not accessible, existence is not broadly known)
  - Need for data to be openly available in a useable/ compatible format on a network so people know what is out there
- Needs to be effectively communicated to end users and made available
- What are critical thresholds (e.g. temp_ for when things disappear? Kelp fish lobster
- What critical timeframes are necessary for biological timescales? Seasonal fine-scale
- Need to determine what critical spatial scales are necessary for biological data (and physical) how does this vary across functional groups?
- Linking data, lab data, field data, modeling
- Monitor physical more often and fill in holes in biological data with modeling
- IEAs and sanctuary condition reports do a lot of this integration already but not have been merged in a broad sense
- Kelp forest assessment on a species or community level
- Are report cards even possible with complex systems and integrated assessments? Or do we break it down by habitat or functional groups?
- Need multiple report cards – ecosystem health, human effects
- Need set parameters and to address shifting baselines

APPENDIX

WORKSHOP NOTES

ECOSYSTEM SYNTHESIS QUESTION 1 CT.

- Winner vs. loser – can have both along a given environmental/ parameter axis and how do we assess 'state' from contradictory outcomes in the ecosystem we capture change in terms of 'resilience' measurements from long-term datasets that help us capture the 'state' of the ecosystem?
- Have a standardization process - Address shifting baselines
- Need to break the 'state' up into categories of impacts, ecosystem services, ecosystem 'health'
- Measure one thing at the top and one thing at the bottom of the food web everywhere, then measure everything only some places
- Some platforms have all the sensor suites and others have a key few
- Not every platform needs to have all the top of line sensors, some are state of the art and some are at cost
- AUV monitoring of eDNA, collection for biodiversity/ chlorophyll concentration measurements, cameras for megafauna capture
- Need infrastructure to readily disseminate data and information to multiple stakeholders
- Top predators can be equipped with CTD & echosounders; integrate up the food web (e.g. temp. salinity, oxygen, chlorophyll, deep scattering layer etc.) go to regions of biological interest
- They are essentially a biological glider
- Real-time coastal moorings equipped with cameras, passive acoustics, eDNA samplers, physical ocean sensors (i.e. see, listen and measure – Sci comm people component)
- Autonomous moving platforms equipped with suite of sensors (phys ocean, echosoundsers, cameras, passive acoustics, etc.) to satisfy our grid-loving, repeatable track minds
- Need more specific indicators for 'smaller' groups (e.g. what species of phytop and zoo-plankton)
- Abundance vs. diversity vs. vital signals are of different importance for different groups
- NOAA NEFSC issues a regular 'state of the ecosystem' report
- Need to identify indicator species of ocean health at 1k, 10k, and 100k resolution and have researchers develop tools to make census & health assessments clearly on an annual basis
- It should be based on regionally specific criteria for healthy ecosystems
- What are the requirements a particular ecosystem assessment will be based on
- Ocean health index model
- A dashboard that combines report out from tech across functional groups
- Baseline health – what is considered healthy
- Early warning indication info
- Windy app for ecosystems
- Predictive capacity



WORKSHOP NOTES

ECOSYSTEM SYNTHESIS QUESTION 1 CT.

- Bayesian belief networks
- Indicator species for metric of 'health' across the integrate ecosystem
- HAB monitoring to large animal monitoring (buoys, tags)
- Conceptual framework and linkages within the system
- Indicator frameworks – especially SES frameworks
- Multiple scales of measurements and prediction (hindcast, near real-time, forecast, projection) for weather service level of information
- Ecosystem weather app
- Network analysis and qualitative network models
- Suites of species and how they interact (e.g. food web analysis
- Linkages and lags
- What do you look at to understand the state of the ocean on a given day
- M1 buoy & white shark buoy
- ERDDAP
- MHW tracker & stranding
- Historical LTER data + NWS NOAA
- Windy

ECOSYSTEM SYNTHESIS QUESTION 2

- Fishing boat logs (recreational and commercial)
- Noise from ship traffic
- Commercial shipping vessel traffic/ port back ups
- VMS
- Drone surveys
- AIS
- Marine debris (number of parking passes sold at the beach)
- Whale watching
- Drone surveys and AI processing could be utilized to detect large marine animals and vessels
- Social meta metadata around public beaches
- Aerial surveys
- Trash (trawl/beach)/ microplastics
- Daily parking reports for usage
- Ocean recreation usage
- Aerial imaging of shipping/boat activity
- Contaminants/ chemistry exposure/ CECs
- Event response: oil spills, sewage spills, DDT barrels

APPENDIX

WORKSHOP NOTES

ECOSYSTEM SYNTHESIS QUESTION 2 CT.

- Shipping and boat use
- Human pathogens (FIB, clopphage, HF183)
- Event response to oil spill or sewage spills
- Surfline website -cameras, many years of data
- Toxicity
- Fishing data
- Measurements of commercial, recreational, consumptive, non-consumptive activities
- Fish landings
- Volume consumption of boat fuel per area as a proxy of activity in an area? – for inshore park waterways
- Radar on islands that monitor activity
- Anthropogenic noise from recreational boats (can track boat movement with multiple sensors)
- Number of beach-goers/surfers/etc. from drone surveys
- Fishing permits issues
- Marine mammal tourism sales
- AIS/VMS data from boats
- Data on shipping
- What is the role of citizen science
- Availability of locally caught seafood (grocery stores, farmers markets, restaurants) local infrastructure for seafood processing
    - Availability of piers and boat ramps, harbors and other infrastructure
- How many people know how to swim, ownership or cost of renting boats, surfboards etc.
- Presence and relationship of people to the ocean in film, literature, performing arts, business names
- Typical uses of seafood that are caught (sold, bartered, shared, eaten, art/ceremony etc.)
- Diversity of who accesses the ocean (age, ethnicity, gender, income)
- Commercial and recreational fishing/open seasons (e.g. abalone)
- Number of licenses purchased for recreational fishing
- Social media tags of locations, geotagged location
    - Social media tags of different species
- Whale watching sales, dive boat sales, ocean sport recreation rentals/ sales
- Use and popularity of citizen science platforms and nature ID platforms (iNaturalize, iSeahorse, Seek)
- Whale alert app
- Spatial dynamics of how people use the ocean

APPENDIX

WORKSHOP NOTES

ECOSYSTEM SYNTHESIS QUESTION 2 CT.

- Human activity questions from CINMS science needs assessments:
  - Demographics, values, preferences, and motivations of those who do and do not use the sanctuary
  - Spatial and temporal patterns of sanctuary use by activity and community
  - Identification of indicators that can be used to predict human activities
  - Information about cultural heritage practices, the resources and conditions needed for the continuation of traditional land local knowledge and the culturally significant features and the landscape and ecosystem that support these practices
  - Estimation of the importance/satisfaction and knowledge, attitudes, values, and perception of sanctuary users
  - Identification of sources where various user groups obtain information about the sanctuary and connections among networks of sanctuary user communities
  - Quantification of human uses using existing and new technologies
  - VMS, AIs, radar, satellite images, drone images, passive acoustic monitoring, direct counts, stakeholder surveys
- From the CINMS Ecosystem service science needs assessments:
  - Identification of ecosystem services that are important to various groups of stakeholders/sanctuary users
  - Information on how sanctuary users perceive ecosystem services and risks to these services
  - Interactions and tradeoffs between services, activities, and benefits for different user groups
  - Where appropriate, quantification of economic value derived from specific ecosystem services
  - Where appropriate, documentation of intangible, spiritual, cultural, heritage, and other ecosystem services and the systems of practice and knowledge to which they are connected
  - Conditions, spaces, and resources needed for the continuation of traditional and local ecological knowledge, and barriers that exist to those processes
  - Perceptions of resource conditions in the past, present, and future
  - Assessment of how climate and the adaptive capacity of stakeholders influence that sanctuary's ability to provide current and future services, including identification of anticipated tipping points
  - Evaluation of opportunities for sanctuary-based research to examine the role of sanctuary resources (e.g. seagrass, plankton, kelp) in carbon sequestration and the value of the sanctuary for coastal protection (e.g. wave buffering by kelp, islands protecting the mainland from storms

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WORKSHOP NOTES

ECOSYSTEM SYNTHESIS QUESTION 2 CT.

- Fishing
- Whale watching
- Shipping
- Phone GPS tracking of ocean use
- Shellfish closures/ sickness
- Beach goers in the water
- Surfers
- Sailboats
- Divers
- Boaters
- Oil spills
- Ocean noise
- Catch limits on fisheries
- Market price of fishery species
- Tourism
- Citizen science
- Renewable energy and aquaculture infrastructure impacts
- Shipping/transportation: number of chips
- Outfalls – wastewater
- Recreation (e.g. days/ visitors at the beach)

CONVERGENT RESEARCH QUESTION 1

- Cameras = crowdsourcing photographs already used widely in community science – continues to be useful
- Water sampling for eDNA or other measurements
- iNaturalist, also CINMS / CINP naturalist corps has whale watchers record siting data
- Fishfinder / sonar mapping- lowrance network
- HABscope is now used widely in the Gulf for community science – has a machine learning classifer that is applied to images the community uploads to the cloud
- LiMPets, beachcombers, merito – underserved communities
- Community drone program, rec pilots flying sites via pre-developed mission plans
- Fishing vessels of opportunity for collaborative data collection
- Lobstermen and crabbers – marine debris clean ups
- Lobster + crab traps – temp loggers, DO, other BGC and physical info, cameras, SPATT, BRUC (RBR etc.)

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WORKSHOP NOTES

CONVERGENT RESEARCH QUESTION 1 CT.

- Tagging – recreational fishers CINMS looking for ways to involve this community more
- ReefCheck (and or PISCO, NPS, CINMS?) divers for deploying/ recovering sensors on reefs (MPA monitoring etc.)
- What are indicator species for each functional group? Can we track these
- Presence / absence
  - eNDA
  - Acoustic telemetry
  - Optical imaging
  - Passive acoustics
  - Active acoustics
  - Plankton recorder
  - Biologging
- Plankton sampling
- Environmental data and correlates to species abundances, health
- Species that interact with public (sharks, stingrays, HABs)
- What's the best sentinel species for presence/ absence?
  - Ties into the discussion of forage assemblages (sardines/anchovies/squid)
- Utilize the tourism industry in programs that have visitors submit photos of marine life
  - Database to upload your recreational data for science
  - Stranding photos from social media
  - Fish finders, temp., scuba diving photos/videos
  - What watching sightings, tracks of where they went, dive charters
- Water quality sampling in Hawaii
- UCLA eDNA community sampling project
- Kits given to people in locations where it is difficult to reach, kits for recreational boaters who are out on the water
  - Technologies that follow the KISS principle
- Using citizen scientists for images/videos
  - iNaturalist type observations
  - See Zooinerse – has a kelp labeling project from satellite images and a fish labeling project from NOAA
  - Public species sighting app
  - Drone survey database of coastline
- IDing inverts in intertidal via cell phone photos (diversity)
- Georeferences video surveys by police, fire, sheriffs, news

WORKSHOP NOTES

CONVERGENT RESEARCH QUESTION 1 CT.

- Hosting data (images/measurements etc.) for public access and further analysis
- Field sampling/means for easily reporting of field observations
- Open data access portals with user-accessible tools
- Technologies that people are using anyways (drones)
- Tech that community members may already use like drones
- Tech that is open to the public, photos, tag IDs of ocean critters people can hear – open data access
- Tach conducive to smartphone apps
- Camera data using AI to help citizen science ID/analyze data (iNaturalist has a “is this our organism” recommendation)
- For youth education – live videos
- Web applications are the best, easily accessible, no downloads/device-specific
- Open data sets, publicly available dashboards/live data reports
- Collection of human use and dimension data
- Imaging on cell phones to take pics that can be uploaded and shared (CalCOFI is working on a participatory science app like this)
- Analysis/annotation with AI (made into a game?)

CONVERGENT RESEARCH QUESTION 2

- Requires a data management system that is properly designed and funded to handle all data types, both input and output of data
- Webenized reporting – clickable, synthesized data products combined with infographics
- Involve stakeholders at the beginning of the process to ensure data synthesis is useful to them
- MARINe Intertidal database management system is perhaps an example of data management system that might work for this
- CalOOS MPA tool might be a good example of how we merge MARINe and other nearshore databases with oceanographic and climate model indicators that benefit a wide user community (mpa-dashboard.caloos.org/ecological-indicators/)
- Agency cross-talk at many governance levels to ensure leveraging, cost-share, and complementary investments that allow different communities to collaborate
- Information that follows the KISS principle
  - Traffic light style dashboards that are easy to interpret data quickly
  - Possible parallels: blue water task force, surfrider, heal the bay report card
- Public available AIS data for fisher/vessel tracking
- Daily/weekly attendance map of who’s (biology) here
- Disease-related stranding reporting

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WORKSHOP NOTES

CONVERGENT RESEARCH QUESTION 2 CT.

- Easily accessible species location, time and environmental covariates databases. Useful for: classes, researchers etc.
  - Environmental and biological datasets for K-12 teachers
  - Educators usually need packaged lessons – science education intermediate to get data to lesson plans
- Go pro video website/collection; HOBO monitoring website collection site; soundscape collection site; somewhere where everyone can put their data, upload common types of cool information
- Involving stakeholders (fishers, indigenous communities, etc.) in the co-creation of study designs and data products
- CA equivalent of https://oceansmap.maracoos.org/ ?
  - Can make one with the biological information along with the environmental observations
    - Clickable layers and time sliders users can toggle/adjust
  - Need to co-create, and collaborate with these user communities at the outset to effectively ensure the data is actually usable
- User communities:
  - Think broad here
  - Academics
  - Government agencies
  - School groups
  - Beach users, surfers
  - Commercial fishers, rec fishers
  - Indigenous communities
  - Divers, whale watching ecotourism
- Regular check-ins to solicit feedback, identify priorities given the current/new data >> requires effective science communication
- Tracking device in fishing vessels that are able to measure different parameters (e.g. partnering with global fishing watch)
- Participation in user collected data can help with engagement
- Recreational ocean users will want a subset of data (temp., wind, waves, species-specific stuff for fishing)
- Co-create the data plan with the communities represented at the planning table
- Important to focus on the variables that affect decisions or experiences that people are having- or to make that link clear
- Important to have regular feedback to communities if they are participating

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WORKSHOP NOTES

CONVERGENT RESEARCH QUESTION 2 CT.

- Ocean weather app for animals – who are you likely to see today and where? Connect people to the ocean
- Easily accessible and interpretable results – nice web pages, apps, etc.
- Measurement metrics must align with key attributes for each user community
- The data users are collecting are useful to as many users as possible (recreation, science, etc.)
- One way to get at this might be to think internally on how we use data streams for our creational/personal use (e.g. do we have divers, fishers, etc. in the group)

NEXT STEPS

- Better integrate cross- shore activities: IOOS RAs, state agencies, regional monitoring programs, POTWs (SCCOOS works closely with OC sanitation district and LA SAN, same with Massachusetts authorities and GoM folks; SCCWRP's mandate is to work with POTWs)
- Existing programs should be used to validate any new tech
- Active sonar spans multiple groups
- Need biological monitoring network lobby group
- Overwatch Aero – for drone collaboration
- What is out there already?
    - Inventory of what is currently available
    - What long-term monitoring programs already exist vs. what can we help ensure continues long-term
    - How can we get information about what exists already? How do we get access to existing data? How do we integrate existing data? Differences in scales, methods, formats etc.
        - Hackathons
    - Data inventory is good for highlighting data gaps and avoiding redundant efforts
- Funders should require data accessibility
- Central repository for hobo data for example (collected widely and consistent)
    - Who will collect and manage these?
- Data coordination: format, accessibility
- How usable are these data?
    - Archiving data for future use: camera data, eDNA, soundscape – can be used eventually once reference libraries become available, once AI is better
- Lagging in biological measurements (compared to oceanographic)
- Need for a full-time data wrangler
- Collecting new data

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WORKSHOP NOTES

NEXT STEPS CT.

- Quantity > quality (but still good)
  - Small buoys to get more out there, limited but more accessible
  - Simplify instruments to be able to take more measurements
- Real time eDNA, plankton tows
- Physiological correlates are possible but not at the scale of physical data that are being collected
- Can we decide what needs to be measured to draw conclusions about everything in between? E.g. plankton and top consumers
- Partner with offshore ocean energies groups – platforms will have power!
- Make the platform scalable- so others can build onto it
- Accessibility and usability of output data: how much training or additional data are needed to use it?
- TECH – low cost data buoy platforms
- TECH – off the shelf drones, the MPA collab has a cool u/w drone program in CA
- PARTNERSHIP: local outreach/ conservation groups (Noyo center, OI, Dana point, MB aquarium)
- PARTNERSHIP: the adventure scientists, iNaturalist, have platforms built for crowdsourcing observations and samples
- PARTNERSHIP: Available data sets or applications already in place for some of this data to be integrated with ESON, planetlabs for ESRI for satellite flyovers, surfline/Sofar for wave/wind data etc.
- Remote sensing will probably need iridium/SWARM/ Starlink coverage, these tech all have networks for government/ non-profit
- New network to aim for complement existing data streams, including those that are collected by citizen scientists
  - Start figuring out what is collected and maybe not communicated well and then to identify where to fill in gaps with new sensors and synthesize individual pieces of data
- Survey or other way gather info on what types of data user communities would use most
- Public data and open source code
- Partner with groups that have identified that type of data as important to them and who could rally people to be citizen scientists (e.g. surfrider and water quality)
- Cohesive and open source data backend will be critical
- Partner with computer science people for developing needed AI
- Adding new tech to existing platforms
- Filling gaps in existing programs with community science
- Partner with groups with a volunteer base (surfrider, waterkeepers)

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WORKSHOP NOTES

NEXT STEPS CT.

- The big question regarding tech usage – how do we get a high density of persistent data in as low cost and as close to real time as we can
- What is important to everyday users of the ocean & citizens?
- Identify what the community cares about the oceans do a survey of the information they want
- Identify metric that can easily communicate ocean health and function to the public
- Imaging + AI (smartphones + Community science)
- In situ video cameras, possible AI sampling of data
- Ships of opportunity
- Need to decide what is the science side and what is the community side and how do you merge these?
- Engagement/partner across multiple levels (state/ local gov., academia, local business, citizens etc.
- In-situ eDNA + may partner w/ caleDNA
- Use of data and metadata standards (e.g. EML, DarwinCore, ISO)
- Imaging (in situ and otherwise) is cost effective collection- wise, if not in terms of storage and analysis
- Engage interest early – grade school/ high school citizens
- Agreement upon standardized measurements
- Analyze existing data streams down to important metrics for identified user groups – go beyond what is important to scientists –rather what interests every day user groups

MAIN TAKEAWAYS

- Know what already exists – coordinate effectively with what is already out there
- Design an 'optimal' observing system, beginning with current inventory and gap analysis
- Identify and engage potential 'stakeholders' early to prioritize and co-design observing needs
- To engage communities, need to make our outputs user friendly
- Need to make it possible for communities to input data too
- Standardization & coordination that address multiple interests
  - What we're measuring
  - Allowing cross-platform engagement
  - Good interfaces and effective communication /data translation
- Methods (imaging, eDNA, data processing) are conducive to community engagement
  - But requires effort and active research to develop out
  - Bring teams together to bring ocean data into an aggregated portal/ database
- Navigating wanting low quality data everywhere vs. wanting high quality data in few key places
  - Low quality data everywhere is less expensive, if a sensor is lost…

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WORKSHOP PARTICIPANTS

Name	Organization/ Affiliation
Amelia Ritger	student note taker, UCSB
Amy Brookman	Innovasea
Annie Lovell	student note taker, UCSB
Barbara Block	Stanford University
Bob Miller	UCSB
Brian Helmuth	Northeastern University
Caitlin Manley	student note taker, UCSB
Camille Pagniello	Stanford University
Chris Caldow	NOAA Channel Islands National Marine Sanctuary
Christopher Lowe	California State University Long Beach
Clarissa Anderson	Scripps Institution of Oceanography

APPENDIX

WORKSHOP PARTICIPANTS CT.

Name	Organization/ Affiliation
Corey Garza	CSU Monterey Bay
Dana Allen	Innovasea
Danielle Haulsee	Potential RESON postdoc, Stanford Univ
Danny Tang	Orange County Sanitation District
David Demer	NOAA / SWFSC and UCSD / SIO / MPL
Deanna Mireles	student note taker
Elliott Hazen	NOAA SWFSC
Emily Montgomery	CSU Monterey Bay
Eric Orenstein	Monterey Bay Aquarium Research Institute
Erika Eliason	UCSB
Erin Satterthwaite	CalCOFI

APPENDIX

WORKSHOP PARTICIPANTS CT.

Name	Organization/ Affiliation
Fernando Lima	CIBIO/BIOPOLIS, Univ. Porto, Portugal
Francisco Chavez	MBARI
George Robertson	Orange County Sanitation District
Igor Pessoa	UCSC
Jacquelyn Veatch	Rutgers University
James Anderson	Postdoc to Chris Lowe
Jennifer Selgrath	NOAA CINMS
Jessica Couture	student note taker, UCSB
Josh Kohut	Rutgers University
Juan Silva	student note taker
Kakani, Katija	MBARI

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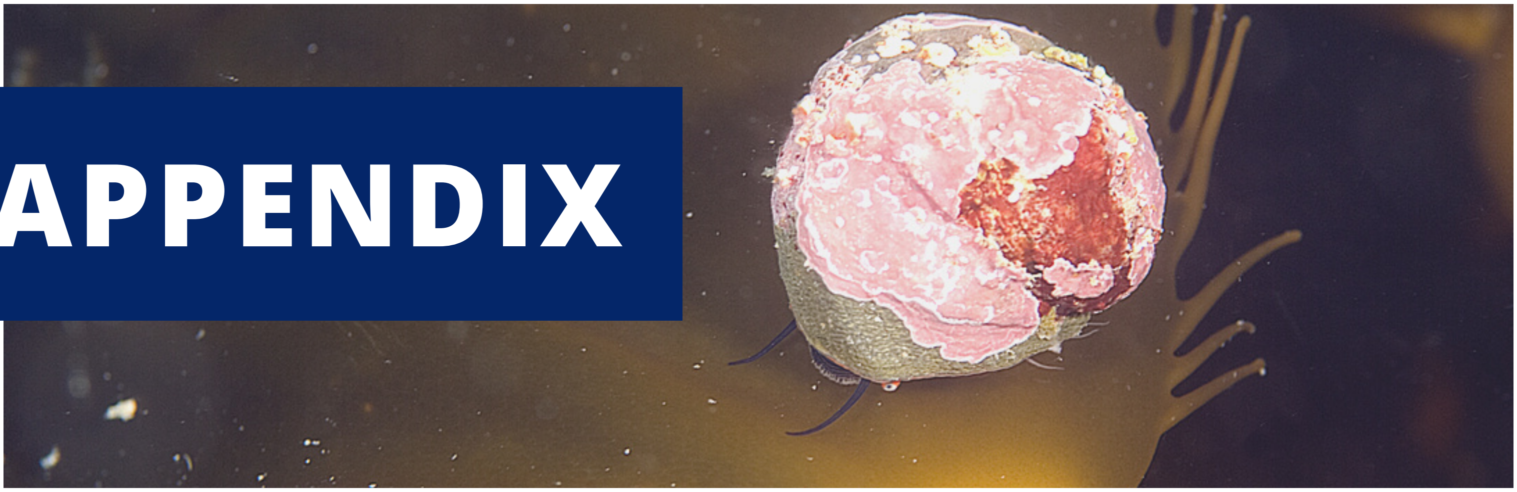

WORKSHOP PARTICIPANTS CT.

Name	Organization/ Affiliation
Karen McLaughlin	SCCWRP
Kerri Dobson	NOAA OAP
Laura Nazzaro	Rutgers University
Leta Dawson	CSU Monterey Bay
Logan, Ossentjuk	UC Santa Barbara Bren School
Marisa Nixon	West Coast Ocean Data Portal
Matthias Lankhorst	Scripps Institution of Oceanography
Megan Cimini	UCSC/NOAA
Michael Sears	Innovasea
Molly Troup	SB Channel keeper
Nick Nidzieko	UCSB

WORKSHOP PARTICIPANTS CT.

Name	Organization/ Affiliation
Samantha Alaiml	Rutgers University
Steven Bograd	NOAA Southwest Fisheries Science Center
Tenaya Norris	Independent Contractor
Thomas Fougere	McLane Research Labs
Tom Bell	Woods Hole Oceanographic Institution
Uwe Send	Scripps Institution of Oceanography
Violet Renick	Orange County Sanitation District
Yuki Honjo	McLane Research Laboratories
Zack Johnson	Sofar Ocean Technologies

THANK YOU

Thank you to all of the workshop participants for engaging with ESON to share your knowledge and time. We are grateful for the insight each of you provided to help shape and provide direction for ESON.

We are excited about the opportunities that ESON can play in expanding and connecting biological monitoring. Creating a network of researchers, practitioners, community members, and Tribal members will provide a robust connection between our coastal ecosystem and human use of the ocean.

We want to continue to hear from you, so please reach out to us with any questions or comments.

Contact: Bob Miller, ESON PI
rjmiller@ucsb.edu

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