Supplementary

Workshop Report Appendices

National Marine Sanctuary Climate Change Science Priorities Virtual Workshop

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Appendix A: List Of Acronyms

AOML	Atlantic Oceanographic an Meteorological Laboratory
CFI	Climate Fisheries Initiative
CPO	Climate Program Office
eDNA	Environmental Deoxyribonucleic Acid
ENSO	El Niño Southern Oscillation
ERDDAP	Environmental Research Division’s Data Access Program
GFDL	Geophysical Fluid Dynamics Laboratory
GLERL	Great Lakes Environmental Research Laboratory
IEA	Integrated Ecosystem Assessment
IOOS	Integrated Ocean Observing System
IOOS RA	Integrated Ocean Observing System Regional Associations
MBON	Marine Biodiversity Observing Network
MERT	Marine Ecosystems Risk Team
NAO	North Atlantic Oscillation
NCEI	National Centers for Environmental Information
NCCOS	National Centers for Coastal Ocean Science
NCRMP	National Coral Reef Monitoring Program
NDBC	National Data Buoy Center
NESDIS	National Environmental Satellite, Data, and Information Service
NERRS	National Estuarine Research Reserve System
NMFS	National Marine Fisheries Service
NMS	National Marine Sanctuary
NMSA	National Marine Sanctuaries Act
NMSS	National Marine Sanctuary System
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NPGO	North Pacific Gyre Oscillation
OAP	Ocean Acidification Program
OAR	Office of Oceanic and Atmospheric Research
ONMS	Office of National Marine Sanctuaries
PDO	Pacific Decadal Oscillation
PMEL	Pacific Marine Environmental Laboratory
PSL	Physical Sciences Laboratory
WCOFS	West Coast Ocean Forecast System

Appendix B: NOAA Capacity To Meet Sanctuary Needs

Meeting the needs and achieving the actions identified in this report will require robust partnerships between sanctuaries and other NOAA programs and labs. Workshop participants identified many NOAA labs, programs, and offices that have the expertise and tools to meet the needs and actions identified in the workshop. These potential partners are listed by the need or action that they are most suited to address. The list is not exhaustive, as additional NOAA and other federal and local partners will be key to enhancing climate assessment and management in sanctuaries. Nevertheless, by pursuing or enhancing partnerships with the NOAA labs, programs, and offices listed herein, sanctuaries will make meaningful progress toward achieving the goal of a climate-ready system.

IDENTIFIED NEEDS

Incorporate multiple disciplines and perspectives into science, resource assessment and management, including traditional knowledge, maritime heritage, and socioeconomic questions

- Climate Program Office (CPO)
- Sea Grant

Provide useful and usable data and tools

- Integrated Ecosystem Assessment (IEA) Program
- Integrated Ocean Observing System (IOOS) Regional Associations
- NOAA CoastWatch/OceanWatch/PolarWatch
- Sea Grant

Standardize protocols and data management to support dataset development and data sharing among sanctuaries and NOAA partners

- Environmental Research Division's Data Access Program (ERDDAP)
- National Centers for Environmental Information (NCEI)
- Improve understanding of physical–biological linkages and related ecological changes, particularly the impacts of extreme events and multiple interacting factors, to inform ecological forecast development
- Integrated Ecosystem Assessment (IEA) Program
- Integrated Ocean Observing System (IOOS) Regional Associations
- National Centers for Coastal Ocean Science (NCCOS)
- National Coral Reef Monitoring Program (NCRMP)
- National Marine Fisheries Service (NMFS) Fisheries Science Centers
- Ocean Acidification Program (OAP)
- Expand and enhance sanctuaries as climate sentinel sites

- Integrated Ocean Observing System (IOOS) Regional Associations
- Marine Biodiversity Observing Network (MBON)
- National Marine Fisheries Service (NMFS) Fisheries Science Centers
- Ocean Acidification Program (OAP)
- Sea Grant

Enhance coverage of physical and biogeochemical monitoring infrastructure within and across sanctuaries, particularly for subsurface conditions

- Atlantic Oceanographic and Meteorological Laboratory (AOML)
- Integrated Ecosystem Assessment (IEA) Program
- Integrated Ocean Observing System (IOOS) Regional Associations
- Marine Biodiversity Observing Network (MBON)
- National Coral Reef Monitoring Program (NCRMP)
- National Data Buoy Center (NDBC)
- NOAA CoastWatch/OceanWatch/PolarWatch
- Ocean Acidification Program (OAP)
- Pacific Marine Environmental Laboratory (PMEL)
- Determine ecological connectivity
- Atlantic Oceanographic and Meteorological Laboratory (AOML)
- Integrated Ecosystem Assessment (IEA) Program
- Marine Biodiversity Observing Network (MBON)
- National Centers for Coastal Ocean Science (NCCOS)
- National Marine Fisheries Service (NMFS) Fisheries Science Centers
- Pacific Marine Environmental Laboratory (PMEL)

Expand existing modelling and prediction infrastructure to provide hindcasts, predictions, and forecasts on time and spatial scales meaningful to sanctuaries

- Climate Fisheries Initiative (CFI)
- Climate Program Office (CPO)
- Geophysical Fluid Dynamics Laboratory (GFDL)
- Integrated Ocean Observing System (IOOS)
- National Marine Fisheries Service (NMFS) Fisheries Science Centers
- NOAA CoastWatch/OceanWatch/PolarWatch
- Physical Sciences Laboratory (PSL)

Provide fora to integrate across the science–management interface

- Climate Program Office (CPO)
- Sea Grant

Train ONMS staff on climate science and data

- Climate Program Office (CPO)

- Integrated Ecosystem Assessment (IEA) Program
- NOAA CoastWatch/OceanWatch/PolarWatch

Increase human capacity within ONMS to assess and address climate impacts

- Climate Program Office (CPO)

RECOMMENDED ACTIONS

ONMS should inventory climate-relevant scientific and outreach activities, datasets, and tools that exist throughout the NMSS and create an accessible repository of these resources

- Environmental Research Division's Data Access Program (ERDDAP)
- National Centers for Environmental Information (NCEI)
- Office of National Marine Sanctuaries (ONMS)

Each site in the NMSS should work with NOAA partners to identify climate observational and research gaps

- National Centers for Coastal Ocean Science (NCCOS)

ONMS headquarters should standardize climate indicators, reporting, and data management procedures across the NMSS

- Atlantic Oceanographic and Meteorological Laboratory (AOML)
- Climate Program Office (CPO)
- Geophysical Fluid Dynamics Laboratory (GFDL)
- Integrated Ecosystem Assessment (IEA) Program
- Integrated Ocean Observing System (IOOS) Regional Associations
- Marine Biodiversity Observing Network (MBON)
- National Centers for Coastal Ocean Science (NCCOS)
- National Coral Reef Monitoring Program (NCRMP)
- National Marine Fisheries Service (NMFS) Fisheries Science Centers
- NOAA CoastWatch/OceanWatch/PolarWatch
- Ocean Acidification Program (OAP)
- Pacific Marine Environmental Laboratory (PMEL)
- Physical Sciences Laboratory (PSL)
- Sea Grant

Develop ecosystem service indicators and opportunities to advance socio-economic information relevant to sanctuaries and the communities they serve

- Climate Program Office (CPO)
- Integrated Ecosystem Assessment (IEA) Program
- National Centers for Coastal Ocean Science (NCCOS)
- Sea Grant

Integrate sanctuaries in the implementation of the NOAA Climate Fisheries Initiative

- Climate Program Office (CPO)

- National Marine Fisheries Service (NMFS)

Advance understanding of climate change effects on maritime heritage and cultural resources

- Climate Program Office (CPO)
- National Marine Fisheries Service (NMFS) Fisheries Science Centers
- Sea Grant
- Assess the feasibility for ONMS to increase staff capacity in sanctuaries with expertise to support climate assessment and adaptation
- Office of National Marine Sanctuaries (ONMS)

Establish sanctuaries as formal and informal climate sentinel sites

- Integrated Ecosystem Assessment (IEA) Program
- Integrated Ocean Observing System (IOOS) Regional Associations
- Marine Biodiversity Observing Network (MBON)
- National Marine Fisheries Service (NMFS) Fisheries Science Centers
- Ocean Acidification Program (OAP)
- Sea Grant

Develop and expand research initiatives that focus on advancing NOAA's ocean and climate monitoring and modelling capabilities

- Climate Program Office (CPO)
- National Centers for Coastal Ocean Science (NCCOS)
- Ocean Acidification Program (OAP)

Develop and expand research initiatives that improve the understanding of physical–biological linkages and the effects of multiple interacting stressors on living resources

- Climate Fisheries Initiative (CFI)
- Climate Program Office (CPO)
- National Centers for Coastal Ocean Science (NCCOS)
- National Marine Fisheries Service (NMFS)
- Ocean Acidification Program (OAP)

Develop and expand research initiatives that improve our understanding of ecological connectivity both between marine sanctuaries and to areas outside of them

- Climate Fisheries Initiative (CFI)
- Marine Biodiversity Observing Network (MBON)
- National Centers for Coastal Ocean Science (NCCOS)
- National Marine Fisheries Service (NMFS)
- NOAA CoastWatch/OceanWatch/PolarWatch

Use climate information to inform the designation and expansion of sanctuaries, with a focus on protecting areas contributing to climate resilience

- Atlantic Oceanographic and Meteorological Laboratory (AOML)
- Climate Program Office (CPO)

- Geophysical Fluid Dynamics Laboratory (GFDL)
- Integrated Ecosystem Assessment (IEA) Program
- Integrated Ocean Observing System (IOOS) Regional Associations
- Marine Biodiversity Observing Network (MBON)
- National Centers for Coastal Ocean Science (NCCOS)
- National Marine Fisheries Service (NMFS) Fisheries Science Centers
- Pacific Marine Environmental Laboratory (PMEL)
- Physical Sciences Laboratory (PSL)

Develop partnerships and tools to understand, anticipate, and manage the impacts of ecological tipping points with the potential to have high impacts on sanctuary ecosystems and local communities

- Atlantic Oceanographic and Meteorological Laboratory (AOML)
- Climate Program Office (CPO)
- Geophysical Fluid Dynamics Laboratory (GFDL)
- Integrated Ecosystem Assessment (IEA) Program
- Integrated Ocean Observing System (IOOS) Regional Associations
- Marine Biodiversity Observing Network (MBON)
- National Centers for Coastal Ocean Science (NCCOS)
- National Coral Reef Monitoring Program (NCRMP)
- National Marine Fisheries Service (NMFS) Fisheries Science Centers
- NOAA CoastWatch/OceanWatch/PolarWatch
- Pacific Marine Environmental Laboratory (PMEL)

Improve and expand observing infrastructure within and across sanctuaries

- Integrated Ecosystem Assessment (IEA) Program
- Integrated Ocean Observing System (IOOS) Regional Associations
- Marine Biodiversity Observing Network (MBON)
- National Coral Reef Monitoring Program (NCRMP)
- National Data Buoy Center (NDBC)
- NOAA CoastWatch/OceanWatch/PolarWatch
- Ocean Acidification Program (OAP)
- Build a collaborative network that allows for rapid responses to extreme events
- Atlantic Oceanographic and Meteorological Laboratory (AOML)
- Geophysical Fluid Dynamics Laboratory (GFDL)
- Integrated Ocean Observing System (IOOS) Regional Associations
- National Centers for Coastal Ocean Science (NCCOS)
- National Marine Fisheries Service (NMFS) Fisheries Science Centers
- Pacific Marine Environmental Laboratory (PMEL)
- Sea Grant

Appendix C: Breakout Group Summaries

This appendix contains the summaries of each breakout group submitted by the chairs. They are organized by region: system-wide, East Coast and Great Lakes, West Coast, and Pacific Islands.

SYSTEM-WIDE

Breakout Group: Variability and change in subsurface ocean conditions

Region: System-wide

Chair(s)/Author(s): Steven Bograd

ISSUES

Participants recognized that the most significant issue relating to 'subsurface ocean conditions' is the relative paucity of subsurface data when compared to surface observations. There is significantly more data – in terms of variables, length of time series, and frequency of measurement – obtained at the ocean surface, from a suite of observing platforms, than within the water column or in benthic habitats. There is a particular lack of subsurface biogeochemical observations in most regions, although the carbonate chemistry of coastal regions is expected to have strong climate-driven ecosystem impacts (acidification and deoxygenation). The capacity for models to forecast or project physical, biogeochemical and ecological changes is limited by the lack of subsurface ocean observations, which could be used both for data assimilation and model validation. Further, little is known about species-specific or ecosystem-wide responses, thresholds or tipping points associated with physical and biogeochemical changes in the subsurface coastal ocean.

Gaps in Knowledge and Capabilities:

- Much less data for the subsurface ocean, including the bottom, compared to the surface
- May not have sufficient observational records, particularly for subsurface biogeochemistry and benthic habitat—for providing a historical baseline, validating model output, etc
- We know there are likely a lot of gaps for subsurface data (subsurface data is generally absent for much of the ocean), BUT, where we do have subsurface data, maybe not right in, but nearby a sanctuary, do we have the methods to say we can use nearby observations as proxies for what is happening within the sanctuary?
- Variable information at ranges of depths is lacking for some locations (Carbonate dynamics and predicted changes in deep sea in tropical areas poorly understood)
- Understanding the changes in the mixed layer dynamics
- Changes in the biological pump and export from the surface to the benthos is not well constrained in existing biogeochemical models
- Impacts of subsurface variability (especially pH, O_2) on key species is not well known
- What are species-specific thresholds/tipping points for changes in biogeochemistry?

- What resiliency do organisms have to changes in physical parameters, is this something that can be mediated by human intervention?
- Forecast models may not be completely accurate
- Predictions may not be available at sanctuary level or regional level applicable to understanding these conditions

Obstacles to Using Existing Information:

- Data may not be collated together in an easily accessible format or may have data gaps
- How is subsurface ocean information best synthesized and disseminated for use by sanctuaries?
- Inconsistent use of data standards, lack of metadata

Obstacles to Applying Existing Products for Decision Support:

- What data, products, indicators are most useful to Sanctuaries?

CAPABILITIES

Participants identified a number of existing capabilities, including NOAA-led observing programs that provide subsurface ocean observations, such as the NOAA Ocean Acidification coastal surveys, and the long-term observations, modeling capacity and data management systems provided by the IOOS Regional Associations. Two programs were identified as providing important, management-relevant information to the Sanctuaries: (1) Each Sanctuary develops periodic condition reports, often with support from other NOAA and academic partners, that synthesize available information in that region. (2) There has also been a recent push to develop climate vulnerability assessments (CVAs), e.g. the fisheries CVAs led by NMFS and regional vulnerability assessments organized by the Ocean Acidification Program. ONMS has the capacity to develop sanctuary-specific CVAs. In addition, OAR provides a climate change web portal that provides easy access to climate projections from a suite of earth system models, which include subsurface ocean conditions.

Modeling, Observations, and Analyses:

- Stellwagen Bank may have long-term O2 data record from 50 m
- ECOMON Surveys
- NOAA OA Coastal Surveys (ECOA, WCOA, GOMECC)
- NOAA Ocean Acidification Observing Network (NOA-ON)
- IOOS Regional Associations typically support long term observations, oceanographic modeling capabilities, data management systems and have the ability to expand these systems with funding

Tools and Products:

- Climate Change web portal (**https://psl.noaa.gov/ipcc/**)
- Observational time series data can be applied to sanctuary management through sanctuary condition reports that assess conditions. Predictions can be used in sanctuary vulnerability assessments that will look at potential future conditions. Both the condition report and vulnerability assessments will inform the development of sanctuary management plans
- Advanced tech development targeting subsurface (e.g. “prowler”)

People, Human Capital:

- NOAA Fisheries CVAs
- OAP is funding Regional Vulnerability Analyses relative to OA around the country. These may be helpful for climate impacts as well. We should figure out how many sanctuaries fall within the areas already covered by OAPs RVA

SUGGESTED ACTIONS

Participants recommended a number of actions. In the near-term, participants recommended that each Sanctuary develop an inventory of the climate information most needed to meet local science and management needs. In many cases, this would include information on subsurface ocean conditions. It was also suggested that each Sanctuary carefully examines and catalogs existing data, to better identify both observational and research needs. In the mid-term, participants suggested making improvements to existing climate change web portals for more targeted use by Sanctuaries, and to produce taxa- or theme-specific CVAs focused on key ecosystem components, such as deep-sea corals and benthic habitats. In the long-term, the main recommendation was to improve the observing infrastructure across the Sanctuaries network. This would include gliders and moorings to enhance observations of subsurface ocean conditions.

Near Term:

- Carefully examine historical oxygen datasets for QA and investigate if that could be adopted to derive proxy estimates of historical dynamics in subsurface biogeochemistry
- Investigate where gliders are operating and the overlap with NMS. Can we detour these to cover sanctuaries?
- There is a need across the sanctuary network to conduct a vigorous statistical analysis of the existing time-series data sets to access if the frequency of observations are currently sufficient to discern secular change from natural variability. Existing methods (i.e. time of emergence) are readily available to apply to these data sets and it would offer valuable insight regarding the utility of the measures currently being made
- Sanctuary-specific (and species-specific) inventories of needed climate data and products
- Have resources available for data input/analysis within sanctuary system in event there are issues/delays with research partners for climate change assessments
- Better understanding of how existing data can be used to answer future climate questions to better identify what research needs exist

Mid Term:

- Enhance climate change web portal for easier use by sanctuaries for vulnerability assessments and other applications
- Examine high-resolution ocean reanalyses for use by sanctuaries
- Conduct OA vulnerability assessments for deep sea coral habitats
- Climate vulnerability assessments for benthic components of sanctuary systems, or important ecological components dependent on sanctuary resources

Long Term:

- Conduct OA and carbonate dynamics characterization and monitoring in deep sea coral habitats for areas with remaining gaps (tropical regions)
- Improved observing infrastructure across sanctuaries (gliders, moorings)

Breakout Group: Variability and change in subsurface ocean conditions

Region: System-wide

Chair(s)/Author(s): Hassan Moustahfid

SUMMARY

Several issues were highlighted during this breakout session. The participants noted the lack of subsurface observations (real/near-real time physical and biogeochemistry) at the space and time scale relevant to sanctuaries. Obstacles to using existing observations and information also come up during the discussion, for example, the uncertainty concerning whether the suite of observations collected by sanctuaries and others are digested by the global oceanographic databases that are used to evaluate climate change models (future projections) and model reanalysis. Participants also noted several gaps in knowledge:

1. Hurricane frequency and intensity will impacts benthos, sand plains and water column in the near future. More research is needed 1) to analyze hurricane-induced changes to benthic communities (reefs/seagrass beds), sand plains and water column, 2) to investigate cumulative impacts of these events on trust resources/habitats/ecosystems, and 3) to understand the extent and duration of hurricane impacts (e.g. sediment burial of habitats; water column water quality/transparency impacts—post-IRMA visibility and suspended sediments remained in Florida Keys water column for months, possibly over 1 year that may have impacted recruitment potential/losses.
2. El Niño impacts (i.e. shifts in currents, upwelling events frequency/intensity) on sanctuaries. There is a gap of understanding nearshore current patterns and focus research tasks on cumulative impacts from dredging, dumping, injection wells; how counter-currents and upwelling serve as drivers of pathogens, toxins or other pollutants.
3. Climate information most commonly provides for ocean surface conditions, however, changes at the seafloor or mid-water-column (e.g., oxygen minimum zone or micronekton/krill scattering layer) may be most consequential.

In terms of capabilities, participants noted several existing NOAA's observing systems and regional partners that provide access to integrated ocean observations from subsurface platforms (e.g. Sanctuaries data from moorings and buoys, IOOS Data portal, IOOS RAs portals, etc.). They also mentioned NOS Coastal Modeling capabilities, GFDL global models and IOOS COMT. However, most of these models they don't provide hindcasts, predictions and reanalysis products needed to address changes at the Sanctuaries scale.

To overcome some the issues noted above, the participants suggested several actions:

1. Strengthening partnering with NOS offices and other LOs on ocean observing relevant to Sanctuaries.
2. Sanctuaries are different (small, large etc.), there is a need to identify specific subsurface observations useful at the spatiotemporal scale of each sanctuary.
3. Research is needed to understand the impacts of hurricane-induced changes and El Nino events on water column and benthic habitats.
4. The subsurface and deep layers of the ocean/sea are difficult to collect obs. Therefore, there is a need to develop dynamical models and model-based data assimilation approaches, which simulate subsurface and deep layer parameters by employing in situ measurements and remote sensing data
5. For real-time and short-term applications, expand existing NOS coastal modeling and IOOS COMT efforts and prediction infrastructure and provide hindcasts, predictions and projections across sanctuaries time-scales
6. For long and distant term applications downscaling global ocean model (like GFDL and others) at the scale of sanctuaries.

Breakout Group: Variability and change in land–sea dynamics

Region: System-wide

Chair(s)/Author(s): Charles Stock

SUMMARY

This session addressed a diverse set of land–sea dynamics issues including the evolving coastline, changing water levels and waves, freshwater and sediment signals from rivers, and riverine inputs of nutrients, carbon, alkalinity, pathogens, and contaminants. It was recognized that all National Marine Sanctuaries were being impacted by numerous land–sea factors, and that climate change and other trends in the anthropocene were generating dynamic changes in them.

For shorelines, issues identified included a paucity of baseline coastline information in many remote areas and uncertainties associated with how shorelines would respond to sea level rise. These responses are also subject to ice sheet dynamics that dominate uncertainties in current global SLR projections.

In rivers, sampling remains limited and reliant on older technology despite the relative accessibility of sampling sites. The rapid pace of riverine change in the anthropocene (e.g., deglaciation, urbanization) increases the urgency to address these sampling gaps to understand current patterns and address uncertainty in future projections. The importance of atmospheric inputs with terrestrial origins (e.g., dust and nutrient deposition) for some sanctuaries was also noted. These inputs suffer from similar challenges and uncertainties as rivers.

Many of the most marked sanctuary responses to land–sea dynamics were associated with extreme events, creating a need for rapid response sampling capability (e.g., pre- and post-hurricane). The potential utility of high-resolution synoptic salinity products was also noted for such applications. Ocean modeling efforts in most regions lacked linkages with dynamic terrestrial models capable of resolving changes in many important land–sea drivers. Exceptions could be found in those systems where river forcing was a predominant factor shaping local estuarine and marine ecosystems (Chesapeake Bay, northern Gulf of Mexico).

The fact that most land–sea problems crossed traditional jurisdictional boundaries was identified as a common challenge for land–sea science. Cross-agency and federal–state partnerships are likely needed to address monitoring and modeling challenges.

Capabilities to address the issues above exist across NOAA, in other agencies and at the state level. New observational/monitoring technologies (e.g., in-situ instrumentation, satellites, AUVs and gliders) provide new capabilities to cover the challenging space/time scales and cross-boundary nature of the land–sea problem. These are available through both government and commercial pathways. Earth system modeling advances have created modeling frameworks capable of tackling the holistic set of processes occurring across the land–sea boundary. Data portals have been developed to ease access to these tools and could be expanded. Academic partnerships provide a means of bringing in needed cross-disciplinary expertise and local knowledge.

The core recommendation was to enhance cross-boundary observational and modeling infrastructure to address challenges along the land–sea interface. This may require cross-agency and state/federal partnerships. NOAA's Climate-Fisheries Initiative may offer a path for expanding modeling frameworks to satisfy land–sea dynamics critical for living marine resources and other sanctuary interests. Sentinel sites in National Marine Sanctuaries should be holistically designed to monitor the land–sea stressors, and include capacity for rapid response monitoring (e.g., pre- and post-hurricane) There is also a need for tools that can communicate how the land–sea system is changing over time that could be included in dashboards for each sanctuary. The development of such tools could leverage expertise in numerous relevant NOAA efforts (e.g., IOOS, Sea Grant, OCM, RISAs, Digital Coast, OA-CANs).

Breakout Group: Variability and change in regional- to local-scale physical oceanographic processes

Region: System-wide

Chair(s)/Author(s): Cara Wilson and Kevin Grant

ISSUES

The current forecast models are inadequate on several levels:

- They are not accurate (for example most of them failed to predict the heatwave of 2014/2015)
- They are not available at the spatial resolution needed for sanctuary sites
- They lack uncertainty information
- They need better skill in biogeochemistry parameters, upwelling, and the near-surface circulation
- They don't simulate the dynamics of internal waves

There needs to be better coordination and guidance available for finding and interpreting what data currently exists (and will exist in the future). There are a lot of available observations and modeling data but there is no central clearing house for accessing this information. There needs to be a better flow of data, and understanding of the data, between the Sanctuaries and the climate scientists/modelers. This knowledge sharing needs to go both ways, for example Sanctuary Managers need help interpreting complex models and knowing which data might be relevant for them. But there is also observational data being collected by the Sanctuaries that is not currently being used in ocean reanalysis models. There needs to be some kind of inventory of who is doing what.

CAPABILITIES

There are currently a lot of capabilities:

- AUVs (gliders, etc.)
- Moored arrays
- Regional ocean models (historical and projections)
- Satellite Data provides long term observations at the surface (CoastWatch)
- Upwelling indices (west coast)
- Sanctuary vessels offer the opportunity for field surveys to add data or validate models
- IBMs that can be coupled with regional ocean models to predict connectivity patterns
- Some operational forecasts and observations within NMS exist already
- Integrated Ecosystem Assessments provide regional status & trends of conditions in Sanctuaries
- Data portals for climate output (e.g., **https://psl.noaa.gov/ipcc/**)
- CoastWatch offers hands on assistance and training for using satellite data
- Sanctuary and IOOS are already working together on web tools and products in some places

SUGGESTED ACTIONS

- Coordinate available data into unified and accessible databases (ERDDAP!)
- Maintain an inventory of who's doing what
- The CoastWatch model of providing dedicated people to help users use satellite data needs to be copied (or expanded) for use with climate and model data

- More platforms (workshops?) for cross-Line Office strategizing (OAR-NOS-NMFS-NESDIS)
- Offer NOFOs for the observations, models, and products that we need
- Set up process for better coordination for using Sanctuary ships
- Use climate projections to prioritize citing of new Sanctuaries
- Explore potential to assimilate near-real-time data collected by Sanctuaries in ocean models

Breakout Group: Extremes and large-scale climate phenomena

Region: System-wide

Chair(s)/Author(s): Ryan Rykaczewski

SUMMARY

This breakout group discussion focused on extremes and other large-scale phenomena in the climate system and their impact on the resources that marine sanctuaries seek to protect. Representatives from the Channel Islands, Florida Keys, Flower Garden Banks National Marine Sanctuaries, the Geophysical Fluid Dynamics Laboratory, the Southwest and Pacific Islands Fisheries Science Centers, and Coral Reef Watch (NESDIS) participated in the chat. The group's discussion was loosely directed, touching a bit on the issues, capabilities, and suggested actions or opportunities to improve the understanding and utility of climate information by the National Marine Sanctuaries.

ISSUES

There were several issues raised that addressed the current state of knowledge concerning climate extremes and their impacts on sanctuaries. Chief among these issues is a lack of consensus within the climate community regarding future changes in extreme events. For example, there is large uncertainty regarding whether El Niño Southern Oscillation (ENSO) events will increase or decrease in magnitude in the future. However, there is evidence that, despite uncertainty in the underlying climate phenomenon, the impacts of such events will increase due to mean changes in atmospheric water content and temperature. So, in some cases, some impacts to sanctuaries may be projected despite uncertainties in the intensity of climate anomalies.

While the consequences of ENSO are well studied, there are other types of extreme events for which the climate dynamics or underlying mechanisms remain vague. Examples include the factors that lead to sargassum inundation events that have occurred in the Caribbean, the characteristics that influence whether coral bleaching events end in mortality or in recovery, and the occurrence of harmful algal blooms in coastal waters. It is hypothesized that these events with extreme ecological consequences are, in part, related to climate anomalies. However, it is the confluence of several factors (some natural, like upwelling events, current shifts, and storms; and some anthropogenic, like wastewater, warming, acidification, and dredging) that make them more impactful. The science coupling climate stressors with other types of anomalies is still in its infancy.

A few more technical issues were also discussed by the participants. One of these issues is the insufficiency of monitoring and data collection within sanctuaries. While atmospheric and ocean models can offer predictions and projections of future events, the skills of these models are often compared to existing, large-scale datasets. If an objective is to make this sort of output useful to sanctuaries, sufficient in-situ data (for parameters and in habitats relevant to sanctuary resources) need to be collected. One expected result is that the spatial resolution of existing models is too coarse for much utility to sanctuaries, but that assessment has yet to be performed.

A final issue that was discussed also concerned the lack of in situ monitoring. Even if new observations were initiated, the absence of a long history of data inhibits assessment of the magnitude of extreme events. That is, it is difficult to say "how extreme" a particular event might be in an area for which there are sparse historical observations.

CAPABILITIES

Although sanctuaries' use of climate information concerning extreme events faces several challenges, we are not starting from square one. Global climate models can offer skillful outlooks at seasonal scales, and improvements are being made in assessing their skill at longer time scales. There are efforts underway to perform regional downscaling of global models for ecosystem-relevant concerns (e.g., the cross-line-office Climate and Fisheries Initiative), and coordinating the needs of sanctuaries scientists and stakeholders with those of the fisheries scientists working with that group would be prudent.

Although long time-series of in-situ data may be lacking, the community does have access to remotely sensed data from a number of different sources. NOAA's CoastWatch program is one example of a group that aims to facilitate the use of satellite data by those interested in understanding and managing our oceans and coasts. NOAA
Coral Reef Watch is another example of a program with the objective of providing data to users in coral reef environments worldwide. These two examples demonstrate the existing infrastructure for coordinating the distribution and use of climate data by ecologists and managers in the field. In addition to the distribution of satellite data products to users, NOAA's CoastWatch program has a history of organizing satellite data training courses that introduce potential users to the methods needed to access and utilize available data.

A final point raised in discussion of the current capabilities was the presence of citizen science programs that are associated with several of the sanctuaries. These programs allow the public to partner with scientists to answer real-world questions and could help to document impacts associated with extreme events.

SUGGESTED ACTIONS AND OPPORTUNITIES

To inform the downscaling of existing models and assess the relevance of current predictions, the participants saw an opportunity for a focused research project to compare existing in-situ data in sanctuaries with NOAA's climate forecasts of climate anomalies. The relevance of climate forecasts at the scales relevant to sanctuaries is uncertain, and there will be a range of accuracies across locations. Results will also be property- dependent, but such an exercise would help the community better understand where, at what scale, and for what properties improvements in models are needed. Such an exercise would also help to identify where the in-situ observations (necessary to assess model accuracy) are lacking.

A second opportunity identified is a strengthening of relationships between scientists working in the field at each sanctuary and the CoastWatch regional nodes where both large-scale climate data and the sanctuary scale in-situ data could be housed together. There is the opportunity to build upon the NOAA CoastWatch and Coral Reef Watch programs which have data-distribution infrastructure, and it is possible that some sanctuary-specific climate indicators could be jointly developed and then served broadly to the sanctuaries community.

On the same note, there is an opportunity to improve the awareness and participation of sanctuary staff in training courses organized by the CoastWatch network. There may be an opportunity to combine climate data (other than satellite data) in these courses, and sanctuary participants could collaborate on a "How To" that is tailored to sanctuary needs and shared throughout the program.

A final opportunity that was noted concerned the potential to partner outside of NOAA with others interested in climate extremes. In addition to state agencies, academic scientists and community members may offer insights into climate extremes at the local scale. For example, historical ecologists and paleoclimatologists (examining corals, sediments, tree rings, or other climate proxies) may offer perspectives not currently considered in NOAA's investigation of extreme events. Oral histories that exist at the community-scale could also be viewed as a resource, and working with community members or social scientists may bring those stories to light. Thus, looking outside the NOAA family to experts from local institutions, elders with site-specific knowledge (often based on very long-term data sets passed down through generations), local scientists working on specific species or ecosystems, local agencies, SeaGrant, etc. may be fruitful for this effort.

Breakout Group: Extremes and large-scale climate phenomena

Region: System-wide

Chair(s)/Author(s): Michael Alexander

ISSUES

The group noted that there are difficulties in matching climate/basin-wide scales to local place-based information, so it will be difficult to tailor forecasts and long-term projections to sanctuaries. Most data sets have records of limited lengths making it difficult to identify true extremes and most of the longer data records are at the surface. More data is needed in (near-) real time. In terms of new data, better in situ, low-cost sensors are needed to measure a full suite of BGC parameters to capture multi-stressor extremes such as heat waves/HABs/toxins. Current global models have substantial errors in representing near-shore regions, which will influence the representation of extremes. Complex coastal areas, such as estuaries, are often poorly represented or not included at all in climate models. It's unclear how some modes of climate variability, such as ENSO, will change in the future.

A fair bit of discussion focused on accessing and using data that already exists. Existing datasets may not be known about at other institutions, including sanctuaries. Sanctuary managers often don't have the time or background to obtain and synthesize relevant information and then act on it. Extreme events are episodic and require a rapid response; how do we respond quickly, including providing funding or putting staff in place to address needs?

How can climate information, including the uncertainty in future changes at sanctuaries, be best communicated to the public?

CAPABILITIES

NOAA (including Sea Grant and the IEA program) and partners have capacity to extend and interpret research to decision makers and stakeholders. Sanctuary staff can work with climate scientists to select indicators predicted/projected at longer timescales and then distill/synthesize into readily interpretable indicators for use by managers. This information can be incorporated into condition reports and management plans. The Natural Capital Project at Stanford is eager to address marine issues and assist in development of sanctuary-relevant products.

Many tools for displaying data and model results already exist. The Digital Coast website has many tools and technologies that are useful for decision makers. High resolution (~10 km) 20–30 year long ocean reanalyses (combination of observations and models), could be verified and used for analysis in coastal regions. NOAA/PSL has web-based tools such as the climate change web portal (**https://psl.noaa.gov/ipcc/**) and Web-based Reanalyses Intercomparison Tools (WRIT, **https://psl.noaa.gov/data/writ/**) for displaying output from observations, models and reanalyses. In the last few years the climate community has developed a Multi-Model Large Ensemble Archive (MMLEA), which has ensembles of model simulations with the same climate scenario (forcing) but different initial conditions. The MMLEA has many years of output to assess model uncertainty and detect extremes and how they may change in the future.

SUGGESTED ACTIONS

We suggest developing a catalog of sanctuary-specific desired variables using historical data, reanalyses, and climate model output. We also suggest building and strengthening effective relationships with NOAA and external partners who have capacity to develop technology, interpret data and model output, and extend research to decision makers. NOAA should work towards a co-production of knowledge (scientists/managers) to select appropriate indicators and syntheses that can be readily interpretable by sanctuary superintendents/resource protection staff. Development of a data hub to point users to data sets and applications held by NOAA and partners that could be useful to sanctuaries as well as those interested in climate, fisheries and marine habitats. Rapid development of high-resolution models by NOAA such as the regional version of MOM6 and WCOFS should continue including the ability to routinely run these models on high performance computers. Time and resources should be allocated to determine how regional models can best be used to examine ecological phenomena and used by sanctuary staff. To do the latter we will need a better understanding of the impact of extremes on marine organisms and ecosystems.

Breakout Group: Ecological tipping points and thresholds in a changing ocean

Region: System-wide

Chair(s)/Author(s): Sara Hutto

SUMMARY

This group discussed the issue of climate-related tipping points and thresholds for ecosystem functions, and when and where they will be reached. The group first discussed the need to better clarify how a tipping point is defined, and how to distinguish this rapid, lasting change from the periodic variability that also occurs in ocean ecosystems. A suggestion was made to define tipping points by the inability of a system to recover from the change. Many information gaps were identified for this issue, including identifying the key variables (indicators) that drive significant change, the thresholds of those variables (e.g. nutrient thresholds, multi-stressor thresholds), and the duration of exceedance that is significant for a given ecosystem function. Identifying specific thresholds requires knowing whether a system can recover from a stress, which requires historical data, as the velocity of change matters as well as the net amount of change. We need deep history on the dynamics of a given ecosystem, which is not always available. Specific data needs include: subsurface and satellite temperature data, observed and predicted changes to circulation and currents, and better understanding of how non-climate stressors may exacerbate climate drivers to reach ecosystem thresholds. Obstacles to using existing information include the potential inaccuracies of data being collected, as well as uncertainty in how to best apply those data (e.g. species-specific and spatial variance in thresholds of key variables). Also, how useful are "analogs" (e.g., CO2 seeps) for understanding acidification tipping points in other ecosystems? Obstacles to using existing products includes translating the relevant information for managers to more easily use. The only NOAA program identified as being able to fill some of the gaps identified (temp data, especially) is the Coral Reef Watch program.

Multiple capabilities were identified to address the gaps discussed. A recent UNEP report has predicted Annual Severe Bleaching thresholds for coral reefs globally, based on CMIP6 climate models, which may be of use for FKNMS. The Geophysical Fluid Dynamics Lab can provide modeling extremes (e.g., low pH/saturation state) and model output that is more accessible to stakeholder communities and sanctuaries in particular. NOAA's Coast Watch was mentioned multiple times as a potential resource for understanding tipping points (e.g. copepod to jelly transition), and access to ERDAPP datasets that are relevant to climate science questions. The ONMS Condition Report process was identified as one that may help in identifying indicators of ecosystem change and data on how these indicators are changing. Finally, collaborations with NOAA Fisheries Science Centers on their existing cruises to potentially increase sampling in sanctuaries was identified as a way to acquire / extend long term data sets.

A number of mid-term actions were identified to leverage NOAA capabilities in addressing identified data gaps and obstacles in data use. IOOS, Coast Watch, and site-specific partners can create easily useable/findable data products that synthesize data and make it easier for managers to act on, and NCEI and CPO can run summary reports of observed exceedance (dates of occurrence, frequency and duration, and change over time) as well as predict / project future exceedance for thresholds of interest to Sanctuary managers. Long-term actions were quite varied, and included AOML identifying hotspots and gradients within sanctuaries and partnering across NOAA labs to design and conduct experiments to answer specific questions from Sanctuaries (e.g. lab studies to test multi-stressor thresholds for organisms and field-based reciprocal transplant experiments to understand true in situ thresholds).

Breakout Group: Ecological tipping points and thresholds in a changing ocean

Region: System-wide

Chair(s)/Author(s): Val Brown and Charles Stock

SUMMARY

This breakout group focused on climate-related tipping points and thresholds for ecosystem functions. This included the combined impacts of multiple physical, biogeochemical, and ecological stressors and included discussions about marine heat waves, ocean acidification, and deoxygenation. The group had a wide range of expertise and points of view including education and outreach experts, climate modelers, sanctuary superintendents and research staff, and heat stress forecast developers.

The group identified a number of potential issues that make predicting and understanding ecological tipping points challenging. These included lack of knowledge, uncertainty in models and forecasts, capacity for analysis, awareness of and access to existing data sets. Specific knowledge gaps highlighted by the group include the physical limits and tolerances of key species for target ecosystems; the interaction of climate parameters (e.g. temperature and pH); synergistic impacts of both climate and non-climate stressors (e.g. land based pollution and overfishing); and lack of information about species' adaptive capacity and the variation of that capacity within a species. Uneven and generally limited monitoring across sanctuaries hinders advances in understanding. The group also noted that there is inherent uncertainty in any model, forecast, or projection and further, that potential thresholds may not be absolute or static over time. ONMS research staff noted that the sites often lack capacity to analyze and synthesize climate data to apply it to NMS sites

The group also noted that barriers to the development and application of tipping point information is outreach / in-reach on available climate data and tipping point indicators and how to use forecasts and projections; clear guidance on in-situ data NMS sites could collect to improve models and forecasts. Managers stated that they need better guidance on what to prepare for and forecasts of when tipping point may be reached. Further, managers need help to develop adaptive strategies that could delay or prevent ecosystem shifts (e.g. reduce local stressors, assisted adaptation, and restoration).

Discussions about capabilities were quite robust and the experts noted that a number of models, forecast, and monitoring tools are available including models included in the latest Coupled Model Intercomparison Projects (CMIP6), NOAA Coral Reef Watch, other marine heatwave monitoring and forecasts programs, Integrated Ocean Observing Systems, and NOAA CoastWatch. Group members clearly stated that in-situ data is highly valuable and data generated by Sentinel Sites, National Estuarine Research Reserve System sites, National Coral Reef Monitoring Program, Integrated Ecosystem Assessment efforts were highlighted. Species specific research on tolerance to climate parameters would also improve the development of tipping point threshold predictions and forecasts. This capacity exists in NOAA labs and with academic partners. The CMIP6 products generally have higher resolution than past models, but high resolution data is not available in all regions and smaller sites may still need downscaled models which may require time and funding. There are limited trainings on how to use models and resources on model uncertainty, but there is a need for a more formal program to promote and facilitate communications and training on models in the marine ecosystems (CPO Drought program was highlighted as an example, Climate Fisheries Initiative has discussed). Managers noted that some efforts are underway to delay ecosystem shifts or restore ecosystems (e.g. Mission Iconic Reefs).

The group recommended that some initial actions after this workshop should include an effort to articulate and adopt standard climate indicators that could be monitored at all sites and perhaps set threshold levels. Another short term step would be to improve communications about the resources available to managers to track and predict ecological tipping points. Managers noted that visuals and case studies about ecological

tipping points would be particularly helpful. Other recommendations may take longer to implement and include data collection, modeling, and communications.

Specific actions discussed included:

- Harnessing capacity within NOAA labs and academic partners to better understand the physiological and ecological responses of organisms to climate stressors leading to tipping points.
- Create down-scaled projections of physical and chemical parameters at all NMS and NERRS sites at seasonal to centennial-scales. Establish robust operational data portals for these outlooks.
- Establish Sentinel Sites monitoring key climate drivers and ecosystem responses at all NMS sites—NMS provide unique opportunities to bring partners together at particular sites with high conservation value and are highly visible.
- Develop adaptation strategies to manage or delay ecosystem shifts (e.g. address local stressors and restoration actions)
- Develop a Kelp version of Coral Reef Watch
- Improve the understanding of climate impacts and tipping points not just in shallow waters, but also in mesophotic and deep sea ecosystems and monitor key variables in these systems (i.e. deep sea temperature moorings)
- Use well known cases associated with temperature increases (sea star wasting disease and lobster disease in Maine) to improve forecasting and communications
- Develop technologies to improve data collection across large scales (e.g. mooring arrays, AUVs and wave gliders)
- Streamline regulatory requirements that hamper response and restoration activities in threatened ecosystems.
- Enhance training for use and analysis of climate/ocean predictions and projections in Sanctuaries and continue to provide fora to integrate across the science-management interface.

Breakout Group: Ecological tipping points and thresholds in a changing ocean

Region: System-wide

Chair(s)/Author(s): Ben Haskell

ISSUES

Gaps in Knowledge and Capabilities; Obstacles to using existing information or applying existing products for decision support:

- We need biologically relevant thresholds for important species (especially for OA or multi-stressor impacts) to better know when approaching thresholds
- Also, thresholds need to be triggered by sublethal effects and this requires an understanding of what those sublethal effects are in a range of species of interest
- Need to understand multiple stressors and their synergistic effects, e.g. hurricanes and HABs
- We need calibrated, long-term in-situ datasets to calibrate satellite-based ecological forecasting products
- We need sustainable, predictable funding
- Need a constantly updated inventory of who's doing what
- Understanding tipping pts/thresholds at a local scale (sanctuary) is difficult but is it even possible at a national level?
- Need to use of models and forecast products to improve the response time of regulatory agencies which need to be more nimble
- ONMS needs to provide a list of the data, data products, and/or information that is needed at a national level so that it and its partners can start addressing the impacts/issues associated with tipping pts/thresholds.
- Focus efforts and early warning systems on vulnerable populations, e.g. species at their range limit or areas of the ocean, e.g. above or below the thermocline

CAPABILITIES

Modeling, Observations, and Analyses; Tool and Products; People & Human Capital

- Coral Reef Watch bleaching alert system provides an excellent model for a dashboard approach to threshold exceedances. **https://coralreefwatch.noaa.gov/subscriptions/vs.php**
- Dashboards were discussed repeatedly as effective ways to communicate a lot of information. IOOS is developing OA dashboards that pull from ERDDAP servers so important to leverage what IOOS is doing rather than reinvent the wheel.
- Related to this is funding a downscaled CMIP6 model to answer the question of when climate-related tipping points and thresholds for ecosystem functions will be reached, both regionally and globally
- Important for sanctuaries to understand habitat compression/reduction due to climate stressors and to have some consistent climate synthesis products common to all sanctuaries (SST,SSH, etc)
- Tribal authorities and tribal and indigenous knowledge can be useful in understanding thresholds and tipping points, especially in understanding historic baselines of conditions
- Various states offer strong capabilities that can be leveraged for understanding tipping points and many states utilize thresholds in their biological and water quality monitoring systems.

SUGGESTED ACTIONS: NEAR-TERM, MID-TERM, AND LONG-TERM

Near-term

- Use dashboards and curated data views with automated alert system built-in to warn of approaching tipping point or exceeding a threshold, see regional IOOS
- Better communication between agencies on use of tipping pts/thresholds for key species/habitats

Mid-term

- Menu of metrics for tipping pts/thresholds available to NMS' (linked to indicators discussion). Perhaps CPO can assist with this.

Long-term

- Model output data (e.g. a downscaled CMIP6) could be analyzed to provide information on when and where tipping points would be reached. Perhaps NESDIS and external academic community can assist.

Breakout Group: Ecological connectivity in a changing ocean

Region: System-wide

Chair(s)/Author(s): Ryan Freedman and Mandy Karnauskas

SUMMARY

The breakout session highlighted a number of issues around the management and assessment of ecological connectivity. All participants noted the importance of ecological connectivity to overall ecosystem health and expressed concern at how climate change may sever or alter connectivity nationwide. The breakout group agreed that the research community needs to have a better understanding of the mechanisms of connectivity to be able to forecast potential climate driven impacts. This information gap is compounded by the fact that connectivity needs to be understood at both local and regional scales and we know very little about how other aspects of ecosystem function (e.g. predator-prey dynamics, habitat quality, oceanographic conditions) and organismal life history dynamics (e.g. habitat selection, physiological limits and plasticity, migration, movements and range shifts) will change connectivity.

A reoccurring theme that was repeated heavily in this breakout group was that NOAA and its partners lacked the quantitative assessment tools to measure connectivity. However, the group pointed to a number of potential avenues to address this gap including direct measures of connectivity like genetic tools, telemetry and animal tracking, indirect connectivity measures like sound monitoring efforts and models that tie connectivity potential to environmental and seascape conditions. All three of these research themes will require increased collaboration to advance goals given the lack of staff noted by breakout participants. To overcome this, fostering increased collaboration and fund-sharing were critical aspects for success. For direct and indirect measure techniques like genetic tools and tracking, it was suggested to build formal support networks like the IOOS Acoustic Tracking Network (ATN) to share data, tools, best practices and leverage funding to understand large scale connectivity. No such network exists for other metrics like sound and genetics, but participants noted the need for new genetic toolkits that could be used by multiple management entities. ATN and similar groups like the MBONs could work to develop standard connectivity measures support resource management decision-making, baseline setting and comparison between different habitats. Model development will be key to tie connectivity to environmental parameters, which are more readily available, and for which a number of climate forecasts already exist. To date, environmental data have not been sufficiently tied to biological connectivity responses and more work in this field is needed in the eyes of the participants. Models should also be used to extend understandings of direct and indirect connectivity measures such as particle models being used in conjunction with genetics to understand connectivity.

Once these aspects have been further developed, participants spoke about a fundamental lack of information on the ability to manage connectivity aspects. More work will be needed to understand the role spatial protections (e.g. sanctuaries and other tools), ecosystem enhancement/restoration, and other management actions have in protecting connectivity. This included launching of directed research studies to understand connectivity better as well as the development of digital infrastructure to help managers track potential changes in connectivity over time. All participants advocated for increased funding on the topic and using RFPs and grant competitions to generate additional research; especially for large regional scale projects that might require the partnering of multiple groups to properly fund. Beyond directed studies, participants advocated using an IEA style approach to develop connectivity products that can be easily adopted and used by multiple resource managers. It was also stated that management agencies need staff dedicated to ingesting this information for agency use and that they should be heavily involved in tool development. This included the use of social scientists to gauge human adaptability to changes in chosen metrics of connectivity and responses to management action. IOOS and NMFS' NAUPLIS were called on for being ideal web presences to help serve 'webinized' connectivity data products and serve data products that are easily accessible and kept current with the most recent data.

Breakout Group: Shifting species and ecosystems

Region: System-wide

Chair(s)/Author(s): Lauren Wenzel

SUMMARY

The group began discussing issues/challenges in addressing this topic. Key issues include gaps in understanding in basic biodiversity and ecosystem structure in some ecosystems (e.g. coral reefs); gaps in understanding how ecological connectivity will change with respect to species movements, life history strategies, and predator/prey interactions; a current bias in studying commercial species and the need for additional information on others (e.g. forage fish); and the need to better link physical oceanography to biological parameters to understand what is driving species movement, such as species sensitivity to parameters such as temperature and dissolved oxygen. We also discussed the need for good species distribution models. The need for greater data sharing and integration, including common protocols, was also noted. Further integration with IOOS regional portals would be desirable.

Important capabilities discussed included programs that are integrating, visualizing and delivering data from multiple sources to support an ecosystem approach, such as MBON and IEAs; social science, including human use patterns and community vulnerabilities associated with resource use; real-time data with autonomous platforms and high-resolution satellite imagery; e-DNA analysis; ongoing research such as Stellwagen NMS research on forage fish distribution and predators; and projects like OceanAdapt that provide historical and current distribution maps of a wide range of species, as well as projections of future distributions.

Priorities for future actions included:

- Speed-dating workshops to share data and capabilities on biological observations
- Further integration of IOOS and MBON, with a focus on visualization tools for habitats, species and water quality integrated with IOOS regional data sets
- Hold workshop on e-DNA sampling protocols and workflows;
- Satellite applications for synoptic understanding of habitat change, and tagging of marine predators;
- Acoustic monitoring (PAM or gliders) to document shifts in habitat use
- Phenology, including potential disruptions to juveniles to learn how to forage

Breakout Group: Shifting Species and Ecosystems

Region: System-wide

Chair(s)/Author(s): Maria Brown

ISSUES

Warming waters are causing species to move further north. NOAA currently does not have the information to downscale models to the species level nor are able to forecast species movement. There is a need for models to forecast changes in the ocean subsurface and water column on the decadal scale and apply the information at the species level. Modelers will be challenged by species reacting differently to the same conditions. Scientists will need to understand shifts in behavior and occurrence of species in order for models to predict change. Sanctuaries are interested in predictions of species movements and how these movements will effect ecosystems so managers can proactively develop policies aimed at species and ecosystem resilience.

Questions that need answers include the following:

- What are the sanctuaries biological and ecological indicators? What are the key species that should be tracked in each sanctuary? How do we choose which species to observe and model (e.g. economic value, protected status, ecosystem engineers, ecosystem productivity)? How will the information be used to make management decisions?
- How are changes in species distribution effecting the ecosystem?
- How are these changes effecting human communities such as commercial and recreational fishing, bird and whale watching?
- Which biotic or abiotic indicators should be monitored? A species may shift do to prey availability rather than a response to abiotic factors.
- What are the linkages between native and non-native species?

CAPABILITIES

Models are available in each region, but they differ from region to region. Modeling is a powerful tool to understand species and ecosystem shifts. Ecological forecasting is still an emerging science and is often tailored to existing data. Regional Atlantis and Ecosim with Ecopath models may help with species linkages and social linkages.

SUGGESTED ACTIONS

An agreed upon list of indicators and formats in which the indicators will be used needs to be developed. This should include federal (e.g. NOAA, USGS) and non-federal (e.g. NSF awardees and NGOs) data producers who may be able to contribute information. Partnerships between the entities that collect the observations needs to be coordinated and data sharing increased with the ultimate goal of producing observations that can be applied to management actions.

The tools in each region need to be mapped to assess existing capabilities. Models that are effective at addressing species shifts should be identified and promoted to the other regions. Forecasts need to expand to higher level species and assimilate ecological data into constrained models. This can be facilitated through acoustic and image-based plankton observations in real time in the next 3–5-year timeframe. Ocean observations should be fostered in networks transitioning imaging, genetic, acoustic, and tagging into a more operational framework that can fill major data gaps to meet biological and ecosystem information needs in sanctuaries. MBON should be scaled up to make data comparable, aggregating data into meta analyses suitable for assimilation into models to tell the bigger ecosystem picture. OMIX genetic sensors can be used to track biological movement and provide early warning of system changes. Data streams can offer an incremental way to build system eDNA to track species movement.

NOS and NMFS should collaborate on the models. Combining fisheries models with temperature, marine mammals and habitat models to produce IEA ecosystem status reports and state of ecosystem reports. The models should be at the scale of sanctuaries.

Breakout Group: Effects of Changing Ecologies on Ecosystem Services

Region: System-wide

Chair(s)/Author(s): Chris Kelble and Chris Caldow

SUMMARY

The group discussed the topic of "How will climate-driven changes to ecological communities impact ecosystem services at the scale of individual sanctuaries and regions?" The discussion on the effects of changing ecologies on ecosystem services was multi-faceted and dispensed a lot of knowledge on the current state of the science on ecosystem services. To address this question, discussions focused on three key objectives: Identify gaps and obstacles; highlight capabilities; and identify short and long-terms actions. Notes and highlights for each of the three objectives are below. More detailed information that was generated during the discussion is listed in a Google Sheets worksheet file provided by the workshop organizers.

GAPS AND OBSTACLES

Ecosystem services are a new and emerging priority for sanctuaries and recently were included as a key component of their condition reports. In the process of incorporating ecosystem services it has become clear that sanctuaries system wide lack a basic knowledge of: 1) the value of services being delivered; 2) how these services are predicted to change with climate; 3) the appropriate scale with which to address this question against the backdrop of large variability in size of sanctuaries; and 4) tipping points at which a meaningful change in the provision of a service should be addressed via a management action vs considerations regarding the adaptability of the stakeholders.

CAPABILITIES

A number of tools exist to address the significant gaps in understanding sanctuary ecosystem services. In addition to climate modeling and visualization tools, a number of entities and efforts (e.g. MPA Watch, NMFS social vulnerability studies, coupled human activities modeling with MIMES and MIDAS) exist collecting and analyzing relevant data that could be incorporated into sanctuary assessments. Remotely sensed data on sanctuary use collected via satellites, AIS, VMS, radar, passive acoustic instrumentation and visitor surveys should also be evaluated. Various NOAA programs (e.g. National Coral Reef Monitoring Program (NCRMP), and Integrated Ecosystem Assessment (IEA) Program) collect and/or synthesize a variety of relevant indicators related to biophysical and socioeconomic parameters; while NOAA's restoration programs help communities adapt to changing ecosystem services and where appropriate and sensible help restore those services or mitigate their loss. Entities such as the National Center for Ecological Analysis and Synthesis (NCEAS) have resources to assess thresholds or tipping points at which management should intervene. Lastly, sanctuaries themselves have active education and outreach programs to disseminate information on ecosystem services including how they may change and how communities will need to adapt. While the working group recognized many potential points of intersection with these groups it was largely agreed that the data, models and syntheses developed are not targeted sufficiently to directly address sanctuary requirements.

RECOMMENDED ACTIONS

One recommended action is to further the work on tipping points related to ecosystem services. Specifically, we can extend the tipping point research to include human use assessments and determine if human behaviors might be useful early warning indicators of impending tipping points for ecosystem services.

It's fundamentally important to understand how sanctuaries are likely to change over the next 25, 50, 100 years and understand if the ecosystem services they are delivering are in decline and how to work with. The recommended actions are to buy rum and make classic daiquiris, rum and coconut waters, rum and cokes, and, of course, just rum with some ice cubes (and possibly a splash of key lime). After that, the most important next actions are to enhance our understanding of the delivery of ecosystem services in the sanctuaries and develop predictions for how ecosystem services are likely to change under climate change scenarios. This can start with developing ecosystem service indicators for the sanctuaries that do not yet have them. These indicators are largely based upon secondary data. Thus, the ongoing capabilities being developed to assess human use should be used to develop other ecosystem service indicators from primary data sources to make indicators specifically for each sanctuary and directly tied to human use. Then we need to determine how ecosystem services are predicted to change under the most likely climate change scenarios.

Breakout Group: Cultural Resources in a Changing Ocean

Region: System-wide

Chair(s)/Author(s): Stephanie Gandulla

SUMMARY

Presented with the issue at hand (and below) this group focused on the diverse and numerous culturally-significant resources within ONMS sites. These resources are significant to different cultures and are significant for different values. There is a range across sites as to which are known and included in sanctuary management (Papa and Olympic Coast are a good examples of successfully incorporating), but across the system needs much more work, to not only engage, discover, and understand these resources, but to actually include them in management decisions, on a regular basis and not in name only. The big gaps in knowledge to achieve this goal seem to stem from less than adequate engagement with diverse stakeholders, which is perceived to be driven more by a not knowing the appropriate means, rather than intent.

ISSUES

Climate drivers such as temperature and acidification impact cultural keystone species and other culturally significant species within national marine sanctuaries. These species are invaluable to the history, culture, identity, and subsistence of local sanctuary communities.

Gaps in knowledge:

- Understanding the full value of resources, ie, economical, ecological, cultural, etc.)
- Oral histories that are a source on observations and change
- How will climate affect these culturally important species, once identified?
- Once we know how these resources will be affected, how to protect??
- How to integrate needs and values of different stakeholders in managing vulnerability to climate changes

Obstacles:

- Information is too technical, not provided in first language/translated
- Understanding the appropriate medium on including and delivering messaging
- Culturally important species often don't receive as much attention and funding as species
- Being aware and understanding cultural sensitivities

CAPABILITIES

NOAA has state of the art scientific resources and a large, diverse research community to deploy and engage. Connecting the NOAA research community to sanctuary management is a next pivotal step!

Modeling, Observations, and Analyses:

- Buoys (ocean acidification buoy in Fagatele Bay
- NOAA OAP partnership with OCNMS

Tools and Products:

- ROVs
- Historic and current maps

- Great Lakes Observing System (and its parent, IOOS)

People, Human Capital:

- Existing knowledge
- Tribal communities
- OAP-funded Olympic Coast OA Vulnerability Assessment deliverable: workshop to facilitate transfer of project approach (participatory community-based social-ecological research) to other place-based contexts (basically what Libby said in the cell above!). Planning to deliver this virtual or hybrid workshop in late summer/early fall 2021.
- Explore how to interconnect NMS with RISA Teams if they don't already exist around intersection of climate and cultural resources

SUGGESTED ACTION

Near Term:

- Designate a site liaison
- Hiring diversity
- Indigenous seats on sanctuary advisory council
- Supporting training for diverse groups
- Collect information and materials from other similar programs—at all levels of governance, NGOs, academic studies, etc. Include international.
- Provide relevant examples of how this topic is addressed in other sites/places—especially in places where indigenous cultures are predominant.

Mid Term:

- Assess what works best for each site, create communications strategy that aims to add to existing platforms a means to gather info. or share info. and consult elders on what is culturally appropriate to do in sanctuary areas as a phased approach, work with them on gathering info. (however that is chosen—oral stories/histories via recording
- For the NMS climate vulnerability assessments, what information/forecasts do you need to do those that OAR/CPO might provide. Think about and identify those gaps in information that CPO might provide.

Long Term:

- Maritime Landscape Characterization (CBernthal's suggestion) to get at ALL current and historic cultural uses and values of a sanctuary area.
- Support training for next generation of community leaders who hold cultural knowledge (e.g., fellowships for tribal youth)
- Include cultural resources within an Ocean Guardian type program
- Dialed in system where traditional leaders trust us to share their experiences

Other suggested actions w/no stated timeline:

- Engage communities and work towards capturing oral histories (observations and change)
- Create permitting process for tribal partners?
- Both ONMS and CPO work to glean knowledge from elders/residents as they have knowledge and adaptation as they have evolved.

- Engage tribal and state historical preservation offices
- Create clear and open path of communication with all stakeholders and most importantly culturally diverse groups (previously left out)
- Apply NOAA Guidance for Incorporating TEK—see document (NOS and NMFS)
- Staffing needed to help bridge information for users (appropriate mediums and in language of place
- Bring interdisciplinary teams together: oceanographers and marine ecologists/biologist and anthropologists/social scientists
- As NMS's become more adept at climate-related vulnerability assessment its time now to start looking forward towards how to implement adaptation strategies and vulnerability reduction projects. NMS's could position themselves to become the test beds for natural and cultural resource adaptation to climate change for marine and coastal systems.

Other:

- Artist in residence to capture changes

Breakout Group: Maritime heritage resources in a changing ocean

Region: System-wide

Chair(s)/Author(s): Tane Casserley

ISSUES

Our group discussed how we at ONMS don't know how climate change is affecting historical resources. We acknowledged that we need to communicate our knowledge gap with our audiences and the need to pursue this research to preserve these sites. We don't know the risks and climate influenced threats, the majority of our information is anecdotal. We can see that sites are being moved by large weather events via storms, waves, erosion from climate change and that we need more and better public engagement.

Discussed that eroded hulls from OA or invasive species (ship worms) can cause habitat loss and invasive species can be devastating to these resources.

Need to acknowledge and include cultural aspects that are intangible. We can make connections through altered canoe landings and other cultural sites affected by climate change. Also have a renewed emphasis on cultural landscape documents as the foundation for resource and land use management.

CAPABILITIES

Need the desire to make the connection between climate change and cultural/historic resources. It's starting to be infused within ONMS, everyone is trying to contribute but we need to find a coherent way to integrate everything. Mentioned that data buoys are a start and help. We can learn a lot from other disciplines in regards to climate change.

SUGGESTED ACTIONS

Make sure we start talking to the right people. We need to communicate internally and externally. We need to conduct baseline studies to understand the situation. Another suggestion was to add climate change research to the existing suite of historical/archaeological research that we currently conduct. Partnerships are more critical than ever, we have to bring more people and disciplines into the conversation. We could also reach out to corporations to assist with tourism and economic seats on SAC's. Also consider environmental justice and all of its connections to climate change.

FROM THE WORKSHEET

Gaps in Knowledge and Capabilities:

- To my knowledge very few studies within sanctuaries have been done on how climate drivers affect cultural resources. I have researched and found a few from other organizations. Who or What NOAA program could consider execution?
  - Climate Program Office, Sanctuaries' Maritime Heritage Program, and sites that have cultural resources.
- Shannon Ricles In this web story, there are links to a few of the partners who worked on the issue in the Great Lakes.
- This is a new frontier for ONMS and there's not much currently done on the topic. Who or What NOAA program could consider execution?
  - Individual sites, MHP, research team
- How do physical climate changes affect different archaeological sites? Understanding the many ways: sea level rise inundating sites, Teredo (shipworm) migration, storm movement

Obstacles to using existing information:

- A disconnect for lawmakers and the public to the relationship between shipwrecks and climate change.

Obstacles to applying existing products for decision support:

- Need to connect the importance of monitoring climate change and shipwrecks because they act as habitat for a host of marine life. Especially off the NC coast. It is hard-bottom substrate and there is not much there to establish habitats other than shipwrecks. So if we can connect the dots people will see them as important to monitor. Not just that they are deteriorating faster.

Other:

- How to demonstrate relevance of archaeological sites at risk due to climate change?
- Intangible and non-physical resources are often missing. Examples include “routes” such as ancestral canoe journey and passages, also sacred places, etc.
- Landscapes, include past, present and planning for future; Paleo-shores.
- Managing cultural landscapes may require more interventions, specifically engaging Indigenous management for maintenance (clam garden walls under SLR, fish pond repair)

Breakout Group: Development of Climate Indicators

Region: System-wide

Chair(s)/Author(s): Dwight Gledhill and Steve Gittings

SUMMARY

Two sessions discussed the identification of indicators that could be applied system-wide in marine sanctuaries. The first was moderated by Dwight Gledhill/Steve Gittings, the second by Marissa Nuttall/Jenn Brown. The combined roster of participants is: Andrew DeVogelaere, Brent Lofgren, Emma Hickerson, Jackie Motyka, Jaime Jahncke, Julia Royster, and Katie Wrubel, Andrew Ross, Erica Ombres, Hannah Barkley, Melanie Abecassis, Nicole Besemer, Noura Randle, Richard Feely, Samantha Siedlecki, and Wayne Higgins.

The identification of climate related indicators for the marine sanctuary system is part of an approach broadly applied by individual marine sanctuaries to track changes to sanctuary resources from a variety of human impacts. They track changes in the qualities of water, habitats, living resources, and maritime heritage resources, as well as the services to society provided by them. They rely on data for indicators associated with each one. Currently, these assessments are done at the sanctuary level and not at regional or system-wide scales. During this breakout session, we considered what indicators might be applied at a system-wide scale to do comparable assessments and inform related management actions. The focus area in this case, however, was climate change impacts, and not the many other human activities that might affect sanctuary resources. The guiding question was: What climate-related indicators should be the focus for monitoring at a system-wide scale to inform assessments and related management actions?

Discussions were prompted by a list developed prior to the workshop. It contained indicators that have already been used to determine status and trend ratings in condition reports in marine sanctuaries, or should be considered because they may reflect impacts of climate change. The list contained about 50 physical, chemical, and biological indicators linked to priority concerns facing the sanctuaries (e.g., biodiversity loss and change, range shifts, water chemistry, access to beaches and fisheries, and disturbance levels). Most are evaluated based on current levels relative to natural rates of variation, though these rates are not always known.

The initial discussion period identified priority indicators for system-wide assessments. A number of specific water chemistry variables were recommended, including temperature (surface and subsurface), several related to ocean acidification, dissolved oxygen, and salinity. Physical indicators included upwelling indices, mixed layer depth, sea level, storm intensity and frequency, and runoff. Some chemical and physical variables are related, of course (e.g., temperature structure and stratification). Furthermore, the frequency of significant anomalies that could involve concurrent changes in a number of these indicators (e.g., extended heat waves) was also identified as a priority indicator. All are associated with physical and chemical drivers of living resource quality in all marine sanctuaries through their influence on food chain characteristics, health, distributions, and habitat suitability and extent.

The second set of priority indicators were those related to living resources. Because living organisms vary so much from sanctuary to sanctuary, the indicators prioritized assessments of abundance, distribution, and condition of keystone or foundation species, particularly those known to be vulnerable to climate change. Selection of these indicators would have to be done either sanctuary by sanctuary or regionally, and tailored due to the variety of ecosystems in the sanctuary system and the fact that no single indicator species exists throughout the system.

One suggested metric that is often associated with climate change that could apply to many sanctuaries is the frequency and intensity of harmful algae blooms. Metrics directly related to the effects of ocean acidification were also recommended. These could vary by site, but would likely include shell thickness or calcification rates of vulnerable species and erosion rates. Lastly, one derived metric was suggested: habitat compression. This is a measure of habitat suitable for occupation and normal ecosystem function. It would also have to be measured differently across the system, but is a reflection of changing conditions caused by large scale ecosystem modification due to climate change.

Discussions by the groups confirmed that a mix of capabilities is required to meet the data collection needs for these measures. Some physical variables are best collected by autonomous, in situ instruments, and some of those may be best accomplished with partners that have proven data collection networks and management systems (e.g., Ocean Acidification Program, NDBC). Where instruments are not in place, some programs, including marine sanctuaries, conduct regular cruises, can collect the same types of data, and conduct localized assessments of indicators such as stratification, hypoxia extent, and abundance, distribution, and health of certain living resources. Satellite-derived data are suitable and available for certain information, such as sea level, storm frequency and intensity, upwelling indices, and HABs. Tailored or perhaps standardized manipulative methods could be required for process measures such as calcification and erosion.

Several key partners were identified by the groups because they have the capabilities to support data collection, data management, access, interpretation, and visualization. Several that were prominently mentioned included OAP, the IOOS regional associations, NESDIS, the IEA Program, NCEI, NOAA Fisheries, USGS, GFDL, CPO, the National Estuarine Research Reserves, and MBON. A number of existing academic partnerships are also critical for measurements in some sanctuaries.

Significant gaps in understanding and capabilities were also identified. Some involved uncertainties regarding connections between physical variables and suggested biological indicators (e.g., OA and plankton community dynamics). While some useful visualization tools exist (e.g., CoastWatch), as does some training, additional capacities (dashboards, time-series, interactive graphics) are needed to enable ready access to interpreted information. It will be important to work with partner programs to develop these for use in producing reports on sanctuary conditions, to contribute to other observing programs, and to populate models for forecasting.

Breakout Group: Development of Climate Indicators

Region: System-wide

Chair(s)/Author(s): Marissa Nuttall and Jennifer Brown

SUMMARY

The group discussed how the existing list of climate indicators were an aspirational goal and identified the need to prioritize variables in this list. Indicators need to be tailored to each site and the anticipated products identified to help guide this prioritization. However, the use of a common suite of physical measurements (i.e. water quality parameters such as temperature, OA, pH, DO, and salinity) and biological measures that exist across all sites were identified as priority indicators to focus on, system-wide. Additionally, the group identified that data that produced ‘rates’ (i.e. dissolution rates, growth rates… etc) are important for modeling, and, as much climate research relies on or produces models, there is a need to focus on collecting these data to build better models. In addition to the identified indicators, seascapes and eDNA were discussed as valuable with the potential to span system-wide assessments, but needed further in situ verifications. Additionally, the group identified the need for further work to characterize the relationship between physical parameters and changes in the biological community.

Several NOAA programs or partnerships were identified that produce relevant climate indicator datasets, including coral bleaching (NOAA Coral Reef Watch), ocean conditions (NOAA CoastWatch), and physical and biotic subsurface data (NOAA GFDL). NOAA CoastWatch also provides valuable training and online tutorials on accessing these data products. In addition to existing datasets, a need for additional in-situ data collection was identified to help improve models and fill data gaps, which could be achieved through partnership on existing surveys (i.e. NOAA Fisheries surveys). The spatial and temporal sampling frequency for indicators was discussed as being both data dependent and purpose driven, but that even irregular sampling was helpful for modeling. Further, the importance of standardizing sampling techniques was discussed and several colleagues and partners were identified as working to address this issue: Jiand et al (2021) introducing the Coastal Ocean Data Analysis Product for North America (CODAP-NA) and a NOAA OA/ MBON collaboration.

The need for enhanced local data processing capacity and improved data access/availability of existing datasets was identified by the group. Currently, there is limited capacity to process and interpret climate data at field sites which could be enhanced through providing sustained funding for data synthesis, potentially as a postdoc opportunity. Additionally, the limited knowledge of available datasets system-wide reduces their usefulness. This could be improved, perhaps, in the form of a summary of current climate data collected at each sanctuary site provided by research coordinators. This information would determine what climate indicators are being collected and where, highlight areas that can be compared, and could serve as the basis to develop a set of system-wide climate indicators. Further, currently held datasets need to be archived and available online to improve access. IOOS and NCEI were identified as potential programs that could execute this suggested action.

Breakout Group: Interdisciplinary and applied data and integrated information needs

Region: System-wide

Chair(s)/Author(s): Jennifer Brown

DATA GAPS AND OBSTACLES

The group discussed that it is challenging to identify key data gaps and obstacles because ONMS has not yet clearly communicated the program's priorities for climate related integrated data and products. It would be helpful to communicate these priorities and how they link to resources directly managed by sanctuaries (e.g., water quality, benthic habitats, maritime heritage) and priority management issues and potential actions. Connecting climate priorities to condition report questions could also help clarify specific data needs. However, a few species gaps in specific types of integrated formation were discussed, including:

- Species range shifts driven by climate change, especially related to fisheries and ecosystem services, in the context of Sanctuary boundaries;
- Long-term, calibrated in-situ/in-water datasets to calibrate/validate existing and planned satellite-based, ecological forecasting products for the different Sanctuaries; and
- Human dimension-related data (e.g., shoreline erosion, vulnerable coastal populations)

Many obstacles to using existing information and applying it to decision support were discussed including:

- Existing products are updated at different frequencies and some of the data is "out of date" or hasn't been collected over a long time period, all of which can make it difficult for a more integrated approach.
- Emerging technologies are improving the quality of data collection, but it is challenging to keep methods consistent in order to have comparative studies and long time-series.
- A lack of sustainable funding for continued development and expansion (to areas where a strong need has been identified) of existing and planned satellite-based and modeled ecological forecasting products.
- Quite a bit of physical oceanographic, biogeochemical, and biological data has been collected over the years within sanctuaries; however, it is difficult to access and integrate much of this historic data, especially when collected by academic researchers. Obstacles include finding and gaining access to this data, managing the data, applying appropriate QA/QC, and providing data in useful formats.
- Bringing data together and applying standards, QA/QC and adding value require some centralization, but networked distribution for downstream use is also needed. A 'one stop shop' is a useful concept, but we will need multiple shops for different user communities.

CAPABILITIES

The discussion group listed some of the existing tools and products that may be useful to filling some of the sanctuary program's information needs (available in the working group spreadsheet and appended below). However, this list highlights some of the challenges as well. The existing products are distributed across a wide variety of websites and data portals which can impede discovery and tracking. It is also difficult to determine which of the many tools and products that currently exist, are the top priorities for application to ONMS needs for climate information and integrated products. An inventory of the existing tools and products would be very helpful to both sanctuary staff and partners. Vetting of the available tools and products is needed once ONMS has a more refined and prioritized list of specific indicators and specific needs for integrated products.

PEOPLE/HUMAN CAPITAL

Efficient data integration requires people who are knowledgeable about formatting and metadata standard application. This is particularly true for biology and ecosystems data, but is regularly an issue for physical and biogeochemical data as well. Some training exists to build out these capacities, so it's a matter of continuing/expanding it. However, ONMS does not have much capacity to process and analyze data or to build integrated data products which necessitates a strong reliance on external partners. It can be challenging to identify those opportunities with partners and to align resources (such as funding and time priorities) to collaboratively create needed products. This would like to proceed more efficiently and effectively with some ONMS resources specifically dedicated to working with partners in this capacity. Two example targets for this focused collaboration are:

- CoastWatch has the data and expertise to do long-term time series of "seamless" parameters (e.g. SST, ocean color) if they have NOAA requirements. Assimilating satellite surface data into other models (especially for vertical resolution, water column model) can be facilitated with models and sanctuary partners. Model-based methods to fuse satellite, in-situ, and unstructured cruise data exist and could provide 3d estimates of coastal conditions back in time with uncertainty quantification. ONMS input is needed to identify "value added" products that can address needs of general sanctuary users (don't want or need to know how to work with satellite-based data) and which should be the focus of a CoastWatch course on ocean satellite data for ONMS staff and affiliates.
- IOOS has a mandate to integrate data from a wide range of data producers including individuals, non-government organizations, and academic institutions, and can work with providers to apply standards and get data into national level repositories, as well as available through regional servers/portals that feed into various onward uses including condition reports. This can bring non-Federal data into a NOAA accredited state. IOOS Regional Associations (RAs) provide centralized access to some of a region's coastal and ocean data, including both real-time and historical data, though data catalogs, data portals and web services to access data.

SUGGESTED ACTIONS

Near Term (<1 yr)

- ONMS (and its regional offices) needs to determine if they are already adequately addressing the most important issues/impacts identified in the Sanctuaries associated with climate change, ocean acidification, etc. For those that are not being adequately addressed, complete a data priority-setting exercise for each sanctuary, each region, and nationally so that ONMS can provide to partners a list of the specific data, data products, and/or information that is still needed, right now, at the National level.
- An inventory of existing climate tools and products.

Mid Term (1–2 yr)

- Develop a national strategy for how IOOS (w/MBON, ATN, COMT, OTT), ONMS, CPO, OAR, interact to deliver a portfolio of needed data and products, which accommodates some flexibility and new ideas.
- Use a two-part approach to 1) use previous and contemporary observations and studies to describe status and trends to date (condition reporting) and 2) use climate projection models to produce some climate change risk data/metrics (risk assessment and alternative management strategy evaluation).

Long term (3–5 yr)

- Coastal modelling and its application around various regions of national interest is rather variable in capability between reanalysis, operational/short-term forecasting, and coastal climate change projections. Having a roadmap for this, even if implementation cannot be supported initially, can help frame how these pillars of capability can come together for each region, including assimilation aspects where applicable.

- Provide contextual biological/physical/chemical/ecosystem descriptions of relevant boundaries for specific focal resource (e.g., feature, habitat, species of interest) and predict stresses and changes (both variability and long-term forced change) in the systems
- Assess at the site, regional and national scale, whether the sanctuary system is protecting the areas that actually need to be protected now and into the future
- NOAA Coral Reef Watch
    - daily global 5km-resolution satellite products
    - daily satellite 5 km Regional Virtual Stations (214 satellite-based stations)
    - Satellite Bleaching Alert Email System
    - NOAA Coral Reef Watch modeled Four-Month Coral Bleaching Outlook
    - NOAA Coral Reef Watch daily global 5km satellite Marine Heatwave Watch
- Allen Coral Atlas—Arizona State University
- NOAA National Centers for Environmental Information
- PMEL Carbon Program
- NOAA Data Discovery Portal

EAST COAST AND GREAT LAKES REGION

Breakout Group: Extremes and large-scale climate phenomena

Region: East Coast and Great Lakes Region

Chair(s)/Author(s): Michelle Johnston and Merrie Beth Neely

GAPS IN KNOWLEDGE AND CAPABILITIES

A major theme in the "gaps in knowledge and capabilities" topic was insufficient monitoring data, water column sampling, limited data buoys, etc., due to lack of funding. The lack of funding/instrumentation to document extreme events (i.e. are there signs before and after? what happens during events?) greatly hinders the ability of scientists to prepare, understand, and respond to events. IOOS may be the best group to discuss this further. There is also a lack of future projections and modeling for sanctuary sites and some regional areas. More research is needed on hurricane induced stress to benthic communities and interacting effects of different stressors (high water temps, runoff from storms, increased turbidity, changes in salinity etc.), and bathymetric remapping or photo mosaics needs to take place after extreme events, but we lack funds and resources for this. There is a lack of information on how ecosystems responds to events or combination of these events (e.g. FGBNMS coral mortality event). We do not have a firm understanding of how these extreme weather events are impacting the social and economic landscape of sanctuaries. How many fewer fishing or dive trips took place because of the number of hurricanes last year? How are the extreme weather events impacting research capabilities? We also need more information on socioeconomic impacts of extreme events and evaluation of ecosystem services lost. The expertise from economists is needed for this. NMFS regional offices have economists on staff, so we may be able to ask for their time and assistance, especially through the NMS Management chain. It can be fodder for NMFS- NMS bilateral management cooperation meetings, which tend to happen annually.

OBSTACLES TO USING EXISTING INFORMATION

Most global climate models poorly resolve the Gulf Stream and its response to climate change (Saba et al 2016), resulting in poor projections of future mean SST and marine heatwaves along the East Coast. It was suggested that downscaled models are necessary. There are insufficient funds for response to extreme events (e.g. hurricanes, mortality events, etc.). For example, FGBNMS had the partners and expertise to respond to hurricanes and the 2016 mortality event, but response funds were limited, as well as funding for academic partners for research. Another problem is that multiple institutions are in charge of collecting the data and at times, the data is privately owned. It is hard for scientists to know everything that is out there and available, and how to easily get what is needed. Therefore, for the problem of not being aware of available online tools/products that are useful, IOOS and SeaGrant are partners that may be able to assist with this obstacle.

OBSTACLES TO APPLYING EXISTING PRODUCTS FOR DECISION SUPPORT

There are limited outreach products connecting the impact that coastal ecosystem system services have with offshore sanctuaries. For example, we discussed the question "what would our offshore sanctuary be like without the low lying coastal plane and marsh habitat and services of filtering run off water, nursery habitat, etc." Therefore, useful outreach products may be useful.

We also discussed response to events, and how response depends on what type of extreme your site has, so action and monitoring plans are important. All sites need to have these plans and the support and ability to carry them out. Most sites are currently understaffed and scraping by. Also, most response efforts are currently reactive in nature, in that monitoring and data collection occur after an extreme event. With long-term monitoring datasets with environmental proxies, sites would have a better ability to predict/forecast what we could expect of extremes in the future. This info can be used to drive management decisions/cruise preparation in the future. We lack the forecasting/predicting ability at the site level.

CAPABILITIES

Modelling, Observations and Analysis—downscaled sub- to seasonal and interannual projections are available from GFDL and partners. Also Mandy Karnaskaus reports there is a comprehensive red tide and hypoxia monitoring effort on the West Florida Shelf, involving state (FWRI), federal, GCOOS, and fishermen.

For People and Human Capital: There are opportunities to work with USGS- sharing of data and products and the capacity exists for putting in place multidisciplinary subject matter expert response teams for Events—conference call for things to plan for in event response actions or sampling. This would be similar to what was put in place after the DWH Oil Spill.

Several Tools Products and Services were mentioned that are valuable for NMS and Extreme Climate phenomena, including: Coral bleaching monitoring and forecasting and Marine heatwave monitoring and forecasting available through Coral Reef Watch and various NMFS laboratories. Also access to climate data, products and services through the Maps & Data tab on NOAA's **Climate.gov** website. Finally, the following information sites were recommended as data-mining opportunities on the NOAA Tides and Currents website: PORTS, Coastal Inundation Dashboard, Tide Predictions, High Tide Bulletin, Harmful Algal Bloom Forecasts, Coastal Condition Forecasts.

Socio-economic valuation of ecosystem losses or threats from extreme climate events was mentioned as an issue and the NMFS Regional Offices have Economists who might be able to assist with such estimates. The states and regional associations/Gulf of Mexico Alliance, SERA, etc. freely share data and event response—they are valuable partners. Also the federal Ocean Observatories Initiative have sites in the Atlantic and Pacific near NMS. NOAA GLERL has a Western Lake Erie HAB model to help city water managers help prepare (ex. Toledo "do not drink" order a few years back). There are quite a number of buoys and observing stations now in the Western Lake Erie because this happened.

SUGGESTED ACTIONS NEAR-TERM TO LONG-TERM

Near-term: Right now, three suggested actions could be taken to prepare for extreme or large-scale climate phenomena.

1. Support scientists working on extreme events (bleaching, mortality, etc.) with training, such as accessing ERDAPP datasets, in NOAA Coast Watch Courses; also reach out to CoastWatch to find your Node Manager for training and finding out more about your customized products to help your NMS management. It is suggested this be done through your NMS leadership and directly to NOAA CoastWatch Nodes. NMS Leadership needs to be involved to cement the Line Office to Line Office management-level interactions for communication of importance of support role and funding of support functions of CoastWatch.
2. Prioritize creating positions/hiring an oceanographic modeller for each sanctuary site. Many sanctuaries have the data available and the expertise to analyze the data, but lack the modelling capabilities or knowledge of partners to reach out to for that modelling. It was suggested that ONMS staff and partners and NOAA Sea Grant would best be suited to initiate or accomplish this.
3. Support funding to help predict weather events (ex. AUV Gliders) – it was suggested that Dr. Catherine Edwards (Skidaway Institute of Oceanography) is a good person to discuss this with.

Midterm: The breakout group felt it was important to plan for and execute two main things in the 1–2 yr planning timeframe.

Create "how to" & "what is available" type of resource for helping sanctuary research teams access useful resources. More efficient if it happened for all sanctuaries in the region than if each sanctuary needed to set this up individually since sanctuaries tend to be resource strapped.

1. Using as much real time data as possible- create a "warning system" for sanctuary staff to monitor.

Long-term: Four items were identified for long range planning goals.

1. Develop partnerships between sanctuaries and CoastWatch regional nodes for monitoring extreme events. Again, it is suggested this be done through your NMS leadership and directly to NOAA CoastWatch Nodes. This mutually beneficial relationship would position NMS at the forefront of new product development and provide CoastWatch an engaged user base to develop new products of use to the NOAA users. In some cases, enabling the fulfillment of legal mandates (ship tracking and IUU fishing in Papahanaumokuakea Marine National Monument).
2. Laboratory studies to test response of organisms to different extreme events or to test resilience/thresholds for those extremes to try to understand what to expect in the ecosystem. Academic institutions, and NCCOS, were suggested as points of contact to enable this.
3. Support funding to evaluate the soundscape before, during and after extreme events. Sanctuary Sound and NOAA Fisheries/Navy/ 7NMS were suggested as partners to execute this.
4. Model development and improvement—data assimilation products – modelers want fisheries data too! Speak to Breakout Group member Andrew about executing this goal– also NOS and NWS.

OTHER

What would be needed to go into NMS needs to have infrastructure, personal, etc., to facilitate the move to online clickable Condition Reports for every site?

Breakout Group: Ecological tipping points and thresholds in a changing ocean

Region: East Coast and Great Lakes Region

Chair(s)/Author(s): Charles Stock and Ben Haskell

SUMMARY

This focus group contained participants spanning a broad range of expertise (climate science, ecosystems, marine resources) and regional expertise spanning the broad geographic scope of the group's charge (U.S. East Coast and Great Lakes).

A number of ecosystems in this region are likely already undergoing tipping points, or showing signs of potential tipping points. Coral ecosystems, including those in the Florida Keys National Marine Sanctuary, are experiencing more frequent bleaching and disease outbreaks. Unprecedented influxes of sargassum to the Carribean and Gulf of Mexico have plagued beaches and further perturbed changing ecosystems. In the Gulf of Maine, recent shifts in zooplankton communities away from lipid-rich Calanus finmarchicus to warm water species have broadly impacted the ecosystem of the Stellwagen Bank National Marine Sanctuary, including the prevalence of iconic whale species. Other issues raised include changing prevalence and severity of harmful algal blooms (HABs) and marine pathogens in the Great Lakes and other regions, ecosystem shifts associated with invasive species, shifts in patterns and severity of hypoxia, and changes in the frequency and strength of "doldrums" events and subsequent ecosystem effects.

The group raised a number of key uncertainties, the most fundamental of which was the confusion surrounding what defines a tipping point. We need to be aware of the public's interpretation of a tipping point that ambiguity does not lead to mistrust.

There was general recognition that the thresholds and triggers for most potential tipping points were still poorly understood. While physiological thresholds for some species were characterized for some ecosystem stressors, tipping points reflect an ecosystem response requiring an understanding of biodiversity, adaptive capacity, and ecosystem interactions stretching beyond physiological thresholds of individual species. Improved baseline understanding of biodiversity and how it shapes ecosystem functions and resilience is needed.

The tipping points experienced in the region, and those that may be on the horizon, likely arise from a combination of climate and other factors. Non-climate tipping point drivers raised included nutrient runoff, sunscreens, pharmaceuticals, endocrine disruptors, human viruses, and fishing. Tipping points with climate linkages must be understood within this multi-stressor context.

It was recognized that addressing tipping points along the east coast will require monitoring programs, process studies, data synthesis/sharing, and modeling activities. The NOAA NMS, NMFS, and other NOAA LOs support monitoring programs that could be expanded with established and new technologies to provide holistic measurements of stressors and ecosystem responses. NOAA and its partners have the laboratories required to probe multi-stressor thresholds. IOOS, NCEI and MBON all offer data management capabilities. NOAA and its partners have diverse expertise and computational infrastructure to produce the physical and biological models needed to understand and anticipate tipping points.

Suggested actions included:

- Develop consistent definitions and communications strategy for tipping points and tipping point-like behavior.
- Assess upcoming RFP's for alignment with needs.
- Support effort to inventory, integrate and standardize existing NMS-relevant ecosystem datasets to maximize utility/interoperability.

- Support targeted cross-disciplinary/multi-program efforts to understand, anticipate and manage high impact potential tipping points in marine sanctuaries (e.g., shifting zooplankton for Stellwagen Bank, coral bleaching and disease in the Florida keys, etc.),
- Advance and implement a national eDNA sampling and data management strategy.
- Training programs for sanctuary staff, citizens/volunteers, and partners to collect critical biological measurements and format/archive for broad use.
- Expand and enhance NMS sentinel sites to better monitor stressors (e.g., temperature OA, oxygen) and ecosystem responses (e.g., biodiversity).

Breakout Group: Ecological connectivity in a changing ocean

Region: East Coast and Great Lakes Region

Chair(s)/Author(s): Mandy Karnauskas

SUMMARY

Group discussion focused largely on challenges that Sanctuaries managers in the East Coast Region face related to ecological connectivity. The first part of the group discussion was focused on understanding exactly what "ecological connectivity" means in the context of a Sanctuary, and identifying key information gaps. Participants noted key information needs with respect to connectivity of different species groups as well as different life stages. For example, managers need to understand how Sanctuaries may serve as corridors for adult fishes or mammals. Other questions were related to oceanic or physical connectivity; for example, understanding physical connectivity of habitats, spawning connectivity of corals, the spread of pathogens such as coral tissue loss disease, or the replenishment of shallow coral reefs from mesophotic sources. It was also noted that Sanctuaries managers protect habitat but do not have jurisdiction over fisheries, and that Sanctuary boundary designations rely on understanding the importance that specific habitat areas have in supporting the larger ecosystem and its components. Managers noted that by strengthening the scientific understanding of habitat connectivity and communicating its importance, there would be improved decision-making regarding Sanctuary boundary designations.

With regard to existing capabilities, the group noted a number of resources available, such as acoustic technology for understanding animal movements, habitat mapping, and eDNA methods for understanding connectivity. It was also noted that there were some existing connectivity modeling efforts (e.g., for Queen Conch), that could potentially be transferable to ask questions about localized coral loss or disease. The group also noted satellite observations as a key resource, and noted that resources such as CoastWatch are available to help researchers match data with their needs. Additionally, maximizing the sampling that is carried out by NMFS (e.g., SEAMAP) was seen as important for addressing connectivity questions.

Suggested actions included increasing coordination and collaboration among NOAA investigators via workshops and metadata collection on connectivity based studies. Additionally, having data access and CoastWatch trainings tailored to sanctuary sites would be valuable.

Breakout Group: Shifting species and ecosystems

Region: East Coast and Great Lakes Region

Chair(s)/Author(s): Mark Monaco

SUMMARY

This report was developed from the breakout group's Shifting Species and Ecosystems worksheet and the discussions the group had on the issue: How, where, and when will species and species assemblages move and change in relation to changing climate parameters (temperature, ocean acidification, oxygen, other physical parameters, etc.) and how will this affect ecosystem function? Are there indicator species that can be used to reliably track these changes?

The breakout group first defined gaps in knowledge and capabilities to address the shifting species issue as identified by previous meetings. At both the national and regional scale the lack of consistent and comparable environmental and habitat data and associated map products hinders biological and socio-economic model development. In addition, from the living marine resource perspective, we had several conversations about the bias of primarily sampling and monitoring commercially important species that contributes to gaps in knowledge of the distribution of other species, such as, marine mammals, forage fishes, and invertebrates. This hinders our ability to develop robust trophic networks and ultimately models to support ecosystem based management under various climate scenarios. Challenges exist to develop predictive models if we do not have a good understanding of the flora and fauna in a region (e.g. southeast) and this also impedes our ability to develop quantitative models to define species habitat affinities by life-history stage and our ability to define the strength of coupling between species and associated pelagic and benthic habitats.

Discussions addressed the gaps in National Marine Sanctuary sites along the entire east coast and only having cultural based sites in the Great Lakes, as it limits our ability to predict the impact of species' shifts from a biogeographic perspective versus changes only within the boundaries of existing marine sanctuaries. This limits our understanding the role that species with changing distributions are likely to play within and outside of existing marine sanctuary boundaries and difficult to place in context the impact of transient, temporal, and invasive species in response to changes in environmental and habitat conditions. Key NOAA entities and partners are listed in the worksheet with respect to programs that can contribute to reducing the information gaps discussed above.

The workgroup then moved our discussions to focus on capabilities and tools to address understanding and predicting species distribution influenced by changing environmental, habitat, and species predator/prey interactions. Please refer to the worksheet as many capabilities and tools were identified. Some of the often mention or discussed capabilities included the use of animal acoustic (especially fish) telemetry to define changes in species home ranges and location of life stage functions (e.g., spawning and nursery grounds), sanctuary biological sound monitoring, and standardized and consistent monitoring of representative species across the food-web. We need to continue to advance capabilities to deliver and visualize data and information and fill physical, biological, and social science data gaps through activities, such as IEAs, MBON, Biogeographic Assessments, and defining the strength of coupling between the natural and social ecological systems within and around National Marine Sanctuaries. In part, the needs can be addressed with real-time data collection with autonomous technologies and platforms and high-resolution remote sensing imagery from platforms such as satellites, drones, and un-crewed systems, e-DNA analysis, and socio-ecological models to predict changes in sanctuary ecosystems under various climate scenarios.

A suite of suggested actions are listed in the worksheet and range from development of meta-data inventories to facilitate cooperative work, directed efforts to synthesize long-term observations, better use of citizen science programs, increase animal tracking telemetry arrays, and satellite tagging, and more investments in the use of machine learning techniques and artificial intelligence.

Additional suggestions included:

- “Speed-dating workshops” to share data and capabilities on biological, physical, and social science data collection and analysis efforts;
- Workshops to standardized e-DNA sampling protocols and workflows;
- Continued advancement of Integrated Ecosystem Assessment products and development of IEAs in areas currently not fully addressed (e.g., US Southeast and US Caribbean).

Breakout Group: Effects of changing ecologies on ecosystem services

Region: East Coast and Great Lakes Region

Chair(s)/Author(s): Katie Lohr

SUMMARY

Breakout group participants noted that gaps exist in four major areas: (1) baseline data on ecosystem services, (2) understanding the link between ecosystem services and ecological change, (3) site expertise and capacity for socioeconomic study, and (4) understanding public perception of and developing effective strategies to communicate with the public about ecosystem services. In terms of baseline data, participants noted that comprehensive habitat maps could improve understanding of intermediate ecosystem services like carbon sequestration and nutrient cycling. In addition to direct data on services themselves, participants also indicated a need to collect baseline data on public perception of these services. Baseline data can aid in studies of how ecosystem services may change with ecological shifts. Data on projected changes to ecosystem services are also lacking; for example, it is not clear what services may be lost or gained due to climate change. However, multiple participants highlighted the lack of socioeconomic expertise at sanctuary sites as a major limitation to collecting these data. Support from social scientists is important, particularly for assessing intangible ecosystem services. A great deal of discussion also focused on the need to develop effective communication strategies regarding ecosystem services and how climate change may affect these. Specific needs raised included support for communicating about ecological changes in ways people understand and in terms of things people care about, finding ways to communicate the importance of non-charismatic, foundational species (e.g., copepods), communicating what the public can do to about these changes, and understanding how well public perception matches reality.

A number of existing capabilities that could aid in filling these key gaps were identified. These included the sanctuary condition report process, which assesses the status and trends of a number of ecosystem services. Additionally, building partnerships with economists at NMFS, OR&R, and Sea Grant was recommended, as these teams frequently conduct studies in regions that encompass sanctuaries. Furthermore, OR&R and ONMS have some established methods for ecosystem valuation in the context of damage assessments; some of these techniques could be applied more broadly to studies of ecosystem services. In addition to potential partnerships, some datasets and products exist that could be used or modified to better encompass ecosystem services. Biological datasets such as coral bleaching predictions could be overlaid with ecosystem service information to better predict change. Additionally, the Ocean Health Index provides data (e.g., for the Gulf of Maine) that could be relevant to sanctuary ecosystem service assessments. MBON uses infographics to communicate information about sanctuary regions (e.g., CINMS); these could be modified to illustrate more ecosystem service information. Finally, SACs may be good resources for developing public-facing studies. As SACs represent key user groups, they could aid in understanding the questions most important or relevant to local communities.

A number of actions NOAA could take to help understand the effects of changing ecologies on ecosystem services were also proposed. Increasing the number of staff focused on ecosystem services (e.g., placing an economist within each sanctuary region) would aid in gathering key data. However, external capacity could also benefit sanctuaries; for example, adding social scientists or economists to SACs may be beneficial. Increasing partnerships with academic institutions and building on existing fellowship programs (e.g., Nancy Foster, Knauss) could help increase the number of projects focused on socioeconomic questions in sanctuaries. Use of grants as a mechanism to facilitate more social science work in sanctuaries was also recommended.

Training opportunities were also highlighted as an important action area. DOC, NOAA, or cross-organizational trainings focused on social science and best practices for communicating ecosystem service information to the public would benefit ONMS teams. Furthermore, trainings on working with Indigenous communities on ecosystem services questions (including building partnerships, asking the right questions, and including services that some peoples prefer not to assign monetary value) would be beneficial.

Collection of new data was also proposed as a key action item. In the short-term, studies of how sanctuary use may have changed as a result of the COVID-19 pandemic (e.g., increase in fishing permits issued) and whether these changes persist post-pandemic was suggested. In terms of climate impacts on ecosystem services, increased study of how climate change may impact maritime heritage resources was recommended. Increasing the ability to forecast and model how ecosystem services may change with climate (and other factors, such as population change) was emphasized. The ability to plan for a variety of scenarios for how ecosystem services will change with climate would be useful.

Finally, workshop participants placed a great deal of emphasis on the importance of NOAA taking steps to communicate more effectively about ecosystem services (and their dependence on healthy natural resources). Participants recommended increasing the amount of public-facing products focused on ecosystem services, particularly visual formats such as infographics, and disseminating these widely to groups such as FMCs, SACs, and Sea Grant offices, as well as to the public through web stories and social media. If climate-related, these products could also be disseminated through **climate.gov** to reach a broader audience. Additionally, products should be geared toward the administration and congress to highlight the value of sanctuaries in terms of ecosystem services, making the connection between people and sanctuaries clear. Ecosystem services could also be increasingly incorporated into sanctuaries' education programs, including materials focused at translating the "language" of ecosystem services. In general, all public-facing materials should be clear that ecosystem services, including economic benefits, are dependent on healthy ecosystems and may change with ecosystem declines. Lastly, when speaking to the public about ecosystem services, it is important for NOAA to learn how to connect these services to things that people value most (e.g., homes, livelihoods). This is a particular challenge that must be addressed for offshore sites, where it may be difficult to translate the value of these sites to people who may not interact with them directly.

Breakout Group: Cultural resources in a changing ocean

Region: East Coast and Great Lakes Region

Chair(s)/Author(s): Tane Casserley

SUMMARY

- The breakout group acknowledged that it's a challenge when sometimes the native or indigenous group is no longer in residence in the area and that we need to recognize when newer cultural groups have moved in and are now using the resources (i.e. African-Americans) for hundreds of years.
- Sometimes the species has moved out of the area such as the sturgeon moving out of Maryland where they were traditionally caught. We need to create a list of these compelling species to gain a better understanding of their use over time.
- It's essential to create effective messaging on this topic, in the majority of ONMS it's lacking.
- Cultural historic landscape documents are pivotal to gain an understanding of the use of these species. Sometimes we learn that a culturally important species was actually artificially introduced into the environment like Brown Trout in Lake Huron/TBNMS and now play a critical role in the local economy.
- Also need to realize that sometimes cultural groups have to shift species and adapt to new ones due to the species movement out of their traditional areas.
- Social economic studies within ONMS can help ID key species. We should begin thinking about applying economic studies to commercially AND culturally important species equally.
- Parallels in NPS and ONMS.
- Local connections and expertise are critical for accuracy and community buy-in.
- Tribal councils are experts and a huge resource we need to partner with.

ISSUES

Gaps in Knowledge and Capabilities:

- Gaps in understanding and connecting with tribal/native partners
- Understanding what ARE the culturally important species? And to who? Understanding how they use the resource.
- Importance to commercial industry is also important to consider.
- Shifts in the distribution ranges for important species- timing of stock assessments, long term data.
- Shifts in culturally important species- introduced species.
- Cultural importance to overseas communities (ex. sea cucumbers, jellyfish).
- Looking at the OBX (and other areas) as having indigenous people. People who have been there for hundreds of years and have been dependent upon certain species for their livelihood. Looking at pictures from the 1930s the fish were big and through the years, the fish keep getting smaller or extinct. Florida had an article done on this in the late 1990s and the pictures were amazing to look at over 50 years!
- We need to figure out what the cultural key species are for each sanctuary and perhaps even for foreign countries.
- Substitute fisheries- shrimp to jellyfish.

- When thinking about cultural resources changing due to climate change- I'd like to make sure maritime archaeological resources degrading (or even appearing!) due to OA and changing temperatures, SLR, storms, etc.
- Changing baselines of what species are important- oral histories.
- **Climate gentrification**

CAPABILITIES

Modeling, Observations, and Analyses:

- Discussions with the socio economic groups within NOAA and our partners to help identify and analyze culturally important key species. Who or What NOAA program could consider execution?
  - ONMS and partners?
  - Sea Grant--better universal messaging on these topics. TBNMS has relied on Sea Grant heavily on connections to tribal groups and they do a better job than they do. Very helpful to have Sea Grant (local) to do surveys as they know the community and the area.
- Find partners to get local by-in like the Chesapeake Bay Foundation, Chesapeake Federation, and others that are local to Mallows.
- To know more about the science of climate change and to spark the flow of conversation (vulnerability studies). Who or What NOAA program could consider execution?
  - CPO
  - Tribal councils especially for CINMS, OCNMS, HIHWNMS.
- Understanding the status (abundance, distribution) of these culturally important species (stock assessments, tagging studies). Who or What NOAA program could consider execution?
  - NMS, DNR, NMF
- Socioeconomic valuation. Who or What NOAA program could consider execution?
  - NCCOS, Climate and Societal Interactions division under COCCA

People, Human Capital:

- Sea Grant partnerships. Who or What NOAA program could consider execution?
  - NOS/OAR

Other:

- Rapid Vulnerability Assessments. Who or What NOAA program could consider execution?
  - NOS/NMS
- More detailed assessments for culturally important species. Who or What NOAA program could consider execution?
  - NOS/NMFS/OAR, protected species?
- Pulling historical information on present and culturally important species from oral histories, poems, traditional songs, prayers, etc.

SUGGESTED ACTION

Near Term (0–1 y, Rapid Progress):

- Begin discussions on identifying the culturally important species for each site and talking with CPO office and socio economic groups on starting the process for surveys. Who or What NOAA program could consider execution?
  - ONMS sites, MHP
  - RFPs
- Assess existing CPO RFPs branding natural and social science for near-term opportunities to develop compelling end-to-end climate change narratives around culturally significant resources.

Mid Term (1–2 y Enhancing or developing new products):

- Pull together “tiger team” of bio, phys, social scientists, historians, cultural practitioners who can identify how these respond to each other- can then model relationships if there’s data.
- Maritime landscape reports
- Design future RFPs to support development of these narratives.

Breakout Group: Maritime heritage resources in a changing ocean

Region: East Coast and Great Lakes Region

Chair(s)/Author(s): Stephanie Gandulla

SUMMARY

Connecting maritime heritage resources and climate change effects offers an opportunity to inspire action in more diverse audiences and interest groups; some that may not be inspired through climate change threats to natural resources.

NOTE: some of the same participants were in the Day 2, Maritime Heritage group, and throughout the Day 3 session, referred back to the same issues, capabilities, etc.

ISSUE

All sanctuary sites protect historical and maritime heritage resources. How do climate drivers such as warming ocean and Great Lakes, storms, sea level rise, fluctuations in water levels in the Great Lakes, changes to sedimentation, and ocean and lake acidification impact these significant historical resources?

GAPS IN KNOWLEDGE

- Very few states have maritime programs

OBSTACLES

- Funding
- Political climate
- Communicating the value of maritime heritage when compared to natural resources, when it comes to threats of climate change

CAPABILITIES

Modeling, Observations, and Analyses:

From CPO: 20th Century Reanalysis uses ship records to drive a weather model that can reconstruct weather all the way back to 1850. The intersection of the data sources with many of the maritime heritage resources as well as the fact that many of the wrecked ships were likely collecting data could offer an interesting context/communications/education opportunity. **https://www.psl.noaa.gov/data/20thC_Rean/**

People, Human Capital:

- OAR labs
- Citizen science groups (scouts, etc.)

SUGGESTED ACTION:

- Connect with CPO and other agencies
- More frequent monitoring and documentation of maritime heritage resources
- More monitoring and documentation products
- Investigate funding to do above
- Partner w/universities to connect natural and cultural resource programs
- Create specific proposals for students to study climate change effects on maritime heritage resources; promote maritime sites (sanctuaries!) as climate science study/monitoring sites

Breakout Group: Development of climate indicators

Region: East Coast and Great Lakes Region

Chair(s)/Author(s): Steve Gittings

Worksheet: **Link**

SUMMARY

Following the Day 2 discussions about climate and climate impacts indicators that could inform our understanding of system-wide changes in the marine sanctuaries, a regional break out group discussed indicators that could be used in the East Coast and Great Lakes region. It was chaired by Steve Gittings and included Andrew Ross, Brent Lofgren, Dwight Gledhill, Frank Muller-Karger, Ian Enochs, Lauri MacLaughlin, Marissa Nuttall, Nicole Besemer, and Noura Randle.

For climate impacts, as well as other issues of concern to marine sanctuaries, the use of indicators to track the status of the quality of water, habitats, living resources, and maritime heritage resources is currently done at the individual sanctuary level and not regional or system-wide scales. During this breakout session, we considered what indicators might be applied at a regional scale to do comparable assessments and inform related management actions. The focus area was climate change impacts to sanctuary resources and the group considered the east coast of the U.S. and the Great Lakes. Most of the discussion focused on the ocean, but it was recognized that there may be substantial similarity and synergy in the indicators selected to track climate impacts in the two systems, and that similar indicators may be used in other areas. But the guiding question was the same for both: What climate-related indicators should be the focus for monitoring at a regional scale to inform assessments and related management actions?

Like the system-wide breakout, discussions were prompted by a list of indicators developed prior to the workshop. That list was modified after the prior day's discussion about system-wide indicators. It contained 50+ climate-related physical, chemical, and biological indicators that have already been used to determine resource status and trends in marine sanctuary condition reports. Within the list of indicators, those identified by the system-wide breakout were highlighted to facilitate the discussion.

There seemed to be general agreement that most indicators prioritized by the system-wide breakout group were also suitable for regional use. The water chemistry variables included nutrient concentrations (typically dissolved nitrogen, phosphorus, silicate), ocean acidification (pH, dissolved carbon dioxide, and/or alkalinity), dissolved oxygen, and salinity. Physical indicators included temperature (surface and subsurface), light attenuation (turbidity), mixed layer depth, sea level, wave height/frequency, wind speed and direction, storm intensity and frequency, sound diversity and intensity, and runoff (upwelling, which had been identified by the system-wide breakout group, is not as significant a driver on the east coast as it is on the west coast). Furthermore, the frequency of significant anomalies, which could involve concurrent changes in a number of these indicators, was also identified as a priority indicator. Human presence and activity indicators were also considered to be critical and are needed to differentiate climate change impacts from those that may be due to long-term or repeated acute localized human activity.

All the above indicators influence living resource quality by altering wildlife populations, food chain characteristics, health, distributions, and habitat suitability and extent. Priority indicators related to these conditions are generally those linked to abundance, distribution, and condition of selected keystone or foundation species (this included specific mention of "ecosystem engineers" and invasive species), particularly those known to be vulnerable to climate change. Selection of these indicators could be tailored to sanctuaries in the region, as resources and ecosystems differ from sanctuary to sanctuary.

Other living resource metrics were frequency and intensity of harmful algae blooms, shell thickness or calcification rates of vulnerable species, and erosion rates. The derived metric habitat compression could

also apply as a measure of the extent of habitat suitable for occupation and normal ecosystem function. Though it would have to be tailored to individual sanctuaries, it reflects changing conditions caused by large scale ecosystem modification due to climate change.

Physical and chemical indicators suggested during this breakout group discussion that were added to the list included changes in nutrients and related measures (e.g., light penetration and production cycles), and regional changes in precipitation, wind fields, sound diversity and intensity, and runoff. Additional biological indicators were plankton diversity, migration patterns, the timing of relevant events and processes (phenology) for native and non-native species, and recruitment rates for non-indigenous species (particularly invasive species).

While most of the time was spent discussing marine systems, many of these indicators are also relevant to the Great Lakes. Specifically mentioned were changes in mixed layer dynamics, which integrates changing water temperatures, circulation, wind fields, fresh water discharge and their nutrient concentrations, and storm intensity, and controls the timing and magnitude of seasonal lake productivity.

In addition to the discussions about priority indicators, participants made important points about programs that could complement, support, and share costs for the collection of regional observations and associated data inventory, management, analysis, archiving, and dissemination needs. One recommendation was to consider adapting approaches of the National Coral Reef Monitoring Program (NCRMP) for use in regional assessments, particularly those related to water quality changes and bioerosion. Others suggested partnerships and co-funding with MBON and the IOOS regional associations in the northeast, mid-Atlantic, southeast, and the Great Lakes.

A number of reporting suggestions were also made. Participants encouraged strong connections with IEA regional reports and the new National Marine Ecosystem Status website, and to the extent possible jointly developing and deploying indicators and other metrics with other programs such as MBON, rather than duplicating efforts. They also recommended creating the ability to provide up-to-date reporting through interactive data portals like those being developed by MBON, CoastWatch, IOOS Regional Data Portals, and others. These tools provide information to multiple programs with management responsibilities, including ONMS (primarily for sanctuary condition reports) and NOAA Fisheries. It was also suggested that opportunities for partnerships with Sea Grant should be explored in all areas, including collection, managing, interpreting, and disseminating observing information.

WEST COAST REGION

Breakout Group: Variability and change in subsurface ocean conditions

Region: West Coast

Chair(s)/Author(s): Steven Bograd

ISSUES

Some of the participants in this breakout group also attended the National 'subsurface ocean conditions breakout' on Day 2, and many of the same issues, capabilities and suggested actions identified for the National network are the same as those identified for the West Coast region. Participants recognized that the most significant issue relating to 'subsurface ocean conditions' is the relative paucity of subsurface data when compared to surface observations. There is significantly more data—in terms of variables, length of time series, and frequency of measurement—obtained at the ocean surface, from a suite of observing platforms, than within the water column or in benthic habitats. There is a particular lack of subsurface biogeochemical observations in the West Coast regions, with the possible exception of the Olympic Coast NMS, which has implemented a mooring array that obtains high-frequency subsurface information at select locations. However, given the upwelling-driven dynamics on the West Coast, it is recognized that climate driven ocean acidification and deoxygenation are critically important here. The capacity for models to forecast or project physical, biogeochemical and ecological changes is limited by the lack of subsurface ocean observations, which could be used both for data assimilation and model validation. Further, little is known about species-specific or ecosystem-wide responses, thresholds or tipping points associated with physical and biogeochemical changes in the subsurface coastal ocean.

Gaps in Knowledge and Capabilities:

- Much less data for the subsurface ocean, including the bottom, compared to the surface
- May not have sufficient observational records, particularly for subsurface biogeochemistry and benthic habitat—for providing a historical baseline, validating model output, etc.
- We know there are likely a lot of gaps for subsurface data (subsurface data is generally absent for much of the ocean), BUT, where we do have subsurface data, maybe not right in, but nearby a sanctuary, do we have the methods to say we can use nearby observations as proxies for what is happening within the sanctuary?
- We are still working out what impacts events like the large marine heatwaves had on subsurface temperatures; subsurface long time series are still very patchy with regards to many oceanographic properties
- Upwelling-driven system on west coast—OA and hypoxia critical issues
- Narrowness of shelf can compress species in small areas
- River/freshwater inputs particularly important in northern CC—representation improving in models
- Variable information at ranges of depths is lacking for some locations (Carbonate dynamics and predicted changes in deep sea in tropical areas poorly understood)
- Understanding the changes in the mixed layer dynamics
- Changes in the biological pump and export from the surface to the benthos is not well constrained in existing biogeochemical models

- Impacts of subsurface variability (especially pH, O2) on key species is not well known
- What are species-specific thresholds/tipping points for changes in biogeochemistry?
- What resiliency do organisms have to changes in physical parameters, is this something that can be mediated by human intervention?
- Forecast models may not be completely accurate
- Predictions may not be available at sanctuary level or regional level applicable to understanding these conditions
- Earth system models used in climate change studies do not have a benthic ecosystem included

Obstacles to Using Existing Information:

- Data may not be collated together in an easily accessible format or may have data gaps
- Other than buoys, offshore data is limited to argo floats and possibly certain glider data sets; this limits the inferences to monthly time scale in most cases
- How is subsurface ocean information best synthesized and disseminated for use by Sanctuaries?
- Are the climate related data that Sanctuaries are collecting being served in central locations—like IOOS RAs? This will help with model/forecasts
- Inconsistent use of data standards, lack of metadata

Obstacles to Applying Existing Products for Decision Support:

- What data, products, indicators are most useful to Sanctuaries?
- Inconsistent use of data standards, lack of metadata

CAPABILITIES

Participants identified a number of existing capabilities, including NOAA-led observing programs that provide subsurface ocean observations, such as the NOAA Ocean Acidification coastal surveys, and the long-term observations, modeling capacity and data management systems provided by the IOOS Regional Associations. Participants also noted that observing infrastructure (gliders, moorings, ship surveys) does exist in many regions of the West Coast, and these data should be better integrated into Sanctuary Condition Reports and other assessments. In addition to the programs identified as being important in the National 'subsurface ocean conditions' breakout (Sanctuary Condition Reports, Climate Vulnerability Assessments), participants made particular note of existing data portals (e.g. OAR-PSL) that provide CMPI6 model output and searchable information on climate model projections. It was also noted that there are downscaled climate models for the West Coast, which provide projections at a much finer scale (~10 km) than broader earth system models (~1°)
and therefore are more useful to understanding climate change at the Sanctuary scale.

Modeling, Observations, and Analyses:

- CMIP6 output such as that provided by OAR-GFDL
- Some observing infrastructure in place on West Coast—gliders, moorings, ship surveys
- IOOS Regional Associations typically support long term observations, oceanographic modeling capabilities, data management systems and have the ability to expand these systems with funding

Tools and Products:

- Climate Change web portal (**https://psl.noaa.gov/ipcc/**)
- CMIP diagnostics such as ESRL, including the climate change web portal and means to analyze and display data sets

- Downscaled climate models for the West Coast at Sanctuary-relevant scale (SWFSC)

People, Human Capital:

- Existing partnerships between NOS, OAR, NMFS scientists on the West Coast
- NOAA Fisheries CVAs
- OAP is funding Regional Vulnerability Analyses relative to OA around the country. These may be helpful for climate impacts as well. We should figure out how many sanctuaries fall within the areas already covered by OAPs RVA

SUGGESTED ACTIONS

Participants recommended a number of actions, many of which parallel the recommendations made by the National 'subsurface ocean conditions' Day 2 breakout. In the near-term, the primary recommendation was the development of West Coast sanctuary-specific inventories of the climate information most needed to meet local science and management needs. In many cases, this would include information on subsurface ocean conditions. In the mid-term, participants noted the importance of improving physics in regional ocean models, particularly within coastal areas (e.g. freshwater runoff). It was also noted that there is a strong push being made within NOAA to fund and implement the Climate Fishery Initiative (CFI), which would improve the modeling infrastructure to provide relevant climate information, forecasts and projections across NOAA. NOS should be a key proponent and active participant in the CFI. Within this context, participants also recommended greater cross-line-office communication and coordination. In the long-term, participants noted the need for improved benthic ecosystem models to better assess how Sanctuary activities affect species of management concern (corals, crabs, kelp, etc.).

Near Term:

- Catalog of Sanctuary-specific desired variables, products needed by Sanctuaries (historical data, reanalyses, climate model output). Useful to have access to visual outputs and also to data so that it can be incorporated into ecosystem assessments.

Mid Term:

- Improved physics in regional ocean models (freshwater input, etc.), particularly as it pertains to coastal areas since that is where all sanctuaries are located
- Enhanced cross-line-office communication to exchange needs, data, ideas
- Climate Fishery Initiative (CFI) would provide significant advances in modeling/forecast capacity in the sanctuaries

Long Term:

- Need for benthic ecosystem models to help sanctuaries assess how proposed sanctuary uses might affect species of management concern (Dungeness crab, sea urchins, lobsters, deep sea corals, sponges, kelp) and how they might affect other ecosystem dynamics (e.g. invasive species)

Breakout Group: Variability and change in regional to local-scale physical oceanographic processes

Region: West Coast Region

Chair(s)/Author(s): Mike Jacox

SUMMARY

This breakout group was focused on variability and change in regional to local scale physical oceanographic processes along the U.S. west coast. Participants represented west coast sanctuaries (GFNMS, CBNMS, OCNMS), NOAA's National MPA Center, IOOS regional associations (CeNCOOS, NANOOS), NMFS/SWFSC, OAR/PSL, and CoastWatch. Outcomes from this breakout group discussion are organized under three headings below: Issues, Capabilities, and Suggested Actions.

ISSUES

A number of issues were raised related to insufficient collection/production of climate information in west coast sanctuaries. On the observational front, a need was expressed for enhanced monitoring throughout sanctuaries, especially for open ocean environments and throughout the water column, with specific physical and biogeochemical measurements tailored to different portions of ecosystems (e.g., waves and currents in the nearshore environment, dissolved oxygen in the subsurface). On the modeling front, accurate predictions of ocean conditions, particularly marine heatwaves, are needed with lead times of months to a year. Prioritization of observational needs should also ensure that they inform models.

For existing climate/ocean observations and models, issues related to data access were raised. Specific examples include Bodega Marine Laboratory mooring data, which have QA/QC challenges, OCNMS mooring data, which are difficult to access and not available in real time, and ACCESS cruise data, which are embargoed for publication. Some effort has been made to port ACCESS data to the CeNCOOS data portal, but additional funding is needed for this task. Finally, ONMS needs help connecting with existing climate and ocean model outputs. Personnel familiar with the models are needed to translate model outputs to a form that is usable for ONMS staff.

CAPABILITIES

Similar to the issues identified above, discussion of capabilities was focused on observational and modeling assets. Observational assets in sanctuaries that were highlighted include ACCESS program data, existing moorings, other data sets hosted on IOOS regional association portals, and a new class III vessel coming online in OCNMS, which can be leveraged as a research asset for partners. Relevant modeling outputs include global climate forecasts and projections (timescales of weeks to decades) and regional ocean models that provide 3D ocean conditions for a variety of timescales (historical, 1–12 month forecasts, long-term projections), with availability and resolution of model output being region dependent. For the Pacific Northwest, the combination of regional ocean models and in situ observations has proven valuable for highlighting spatial variability in ecosystem stressors. Added-value products that have been developed from west coast model and datasets include climatology apps (NANOOS, CeNCOOS, SCCOOS), west coast upwelling indices (NMFS/SWFSC), and NOAA West Watch webinars held every two months to summarize current conditions.

SUGGESTED ACTIONS

The primary near-term action that was suggested was a matchmaking exercise in which climate needs and capabilities are inventoried and providers are connected with users. Many of Sanctuaries' needs for climate and ocean information can already be satisfied in full or in part by existing capabilities, particularly if support is directed toward personnel to distill models and data into digestible formats. The NOAA West

Watch webinar series was highlighted as a useful resource for ONMS staff, and we should ensure that they are aware of it (anyone can be added to the list by emailing Dan McEvoy; **daniel.mcevoy@dri.edu**).

On longer timescales, NOFOs should be offered for establishing observations, modeling, and products to support Sanctuaries' needs, emphasizing a requirement for collaboration across NOAA. The group discussed the potential utility of a distribution list for period summary reports of relevant west coast conditions, which could also be accompanied by a briefing (the CPC ENSO advisories and ocean briefings are examples). Similarly, ONMS staff could benefit from curated sanctuary-specific dashboards hosted on regional IOOS portals. Lastly, the group highlighted two practical applications of climate/ocean science in ONMS on a continuing basis and with long timescales in mind: helping to site observational assets within sanctuaries, and helping to site sanctuaries themselves.

Breakout Group: Extremes and large-scale climate phenomena

Region: West Coast Region

Chair(s)/Author(s): Sara Hutto

SUMMARY

This group focused on how extreme events (heatwaves, storms, harmful algal blooms) and large-scale climate phenomena (El Niño-Southern Oscillation, Pacific Decadal Oscillation, Atlantic Meridional Oscillation, etc.) will change in the future, relative to the variability in the long term record. Much of the discussion focused on marine heatwaves (MHW), as this is one of the more severe and recent extreme events to occur on the US West Coast. Discussion began with the uncertainty around how extremes are changing. For example, it is still unclear as to whether MHW are actually increasing in frequency and severity, or if it's merely a definition/threshold issue related to the underlying long-term trend (how you define a MHW). What are the differential impacts of a temperature increase due to a heatwave vs an El Nino (or other scales of variability)? We need more comparisons about the relative impacts (may be species/location dependent). When you de-trend the data to remove background heating, MHW may not be increasing after all. That being said, this doesn't really matter to the species—if it's too hot, it's too hot. But how we de-trend matters, as it's important to distinguish between the two components—the gradual trend vs the singular events.

Data gaps identified during discussion included thresholds and duration of stress that matters to organisms, the timescale and time of year to apply to data collection and analysis (what are the critical times of year to focus on? What is the response time of organisms?), the "hot spots" of most likely extreme event impacts (are they in Sanctuaries?), impact of multiple stressors (e.g. OA, HAB, SST), and ability to use responses to extreme events as an 'analog' for projected climate change. Obstacles to applying existing products include the uncertainty in the predictability of extreme events and how we can use the data and products we have to inform management and the need to interpret products on a large spatial scale for relevance to sanctuary management. Finally, there was some discussion around the use of satellite data; however, many sanctuaries are near land/islands. Are there issues with satellite measurements near land we should be aware of? The connection of satellite data to buoy or land-based (pier) data? Can one be used as a proxy for the other, or vice versa? Resolution is typically the issue with using satellite data.

Numerous capabilities to address identified data gaps were discussed. A low-tech option is simple observation of extreme events—plenty of people live next to sanctuaries, and could be leveraged to support this. What can we learn from the 2014–2016 MHW that could be applied to planning for future extremes? Coastal gliders and buoys can collect subsurface data to be used as an indicator of the "flavor" of the heatwaves as they move towards the sanctuaries; this is potentially a data gap for some regions, though likely there is some data available that can be applied. The field of historical ecology can offer great insight into past extremes and ecological impacts (what were historical ecological responses to extreme events?); experts in this field should be identified and consulted by Sanctuaries to link reanalysis of environmental conditions and historical ecological data. Sanctuary research vessels and existing ocean-going sanctuary surveys, and existing moorings or opportunities to deploy new instrumentation in sanctuaries, can be used to collect and share data, validate models, etc. UCSC (Edwards) have ocean models and reanalysis products for the West Coast, and finally, consistent indicators for the West coast can be leveraged to provide consistent data (the West Coast Ocean Alliance is developing OA indicators).

There was robust discussion around near-term actions to leverage capabilities to address identified data and information gaps. An initial fairly easy lift would be to document lessons learned from 2014–2016 MHW "blob" event across US West coast Sanctuaries and provide an inventory of needs following that event—what variables or indices? What spatial and temporal scales are relevant to marine life in the sanctuaries? Accessing existing glider data (can start with Scripps spray gliders) is another fairly easy task, and to understand where that glider data is lacking could inform further investment. An additional near-term action could simply be increased communication between ecologists/sanctuary managers and data

providers regarding time of year that stress is most critical, duration of stress that is relevant, and particular taxonomic groups of interest or that sanctuaries have observed changes in, recognizing that developing the information in response to this increased communication would be a longer-term action. Integrating needs for indicators (e.g. physical limits of marine life) into science needs assessments may be another way to leverage Sanctuary processes to address knowledge gaps. Finally, a longer-term action recommended is to co-mentor post-docs and Nancy Foster Scholars to achieve some of these—particularly linking large-scale processes with sanctuary-scale conditions and trends.

Breakout Group: Ecological tipping points and thresholds in a changing ocean

Region: West Coast Region

Chair(s)/Author(s): Liz Drenkard and Maria Brown

SUMMARY

We discussed important ecosystems (e.g., kelp forests) within west coast sanctuaries and the broader California Current Large Marine Ecosystem, and identified ocean acidification (OA), harmful algal blooms (HABs), Marine Heat Waves (MHWs), and Deoxygenation as major stressors and stress events that threaten these systems. Part of our initial discussion entailed defining 'tipping points', thresholds and indicators. In order to recognize signs of systems approaching tipping points, we need clearly defined, quantitative thresholds with rationales linked to organism physiological, and ecosystem structural responses. We also identified the need for intermediate indicators of systems approaching tipping points to enable early management action. Some thresholds are better understood than others, such as the impact of anomalously warm seawater temperature on kelp growth. However, the effect of other environmental stressors are less clear. For example, do we understand the impact of reduced dissolved oxygen on a variety of key species? Choice of indicator also raises some questions: are certain species more representative of ecosystem-wellbeing than others? Do we consider loss of an individual species a tipping point if another species fills its functional role and the overall system remains intact? Ideally, we would aim for a full ecosystem approach, assessing both physical and chemical habitat aspects as well as all trophic levels. However, this can be challenging outside of controlled laboratory settings because there are multiple stressors acting simultaneously and accurate attribution requires working with a large number of observations.

Some sanctuaries have observation programs in place that collect regular data regarding local ecosystem conditions which can be leveraged to address these needs. Can/should these programs be further developed, expanded or (re) focused to provide the most relevant information? For example, should observation efforts target "hot spots" and/ or potential environmental/ biological refugia? Should we preferentially monitor species that are expected "losers" under acidification or should we consider "winners" as well?

Data integration presents additional challenges: often, different groups and organizations are focusing on different ecosystem components (e.g., physical, biological, etc.) and they use different analytical tools (e.g., Python, Matlab, R) and generate data products in different formats, which impedes inter-organizational data sharing. We highlighted the need for centralized information archiving. The ERDDAP data server has seen increasing use by sanctuaries for condition reports and is particularly useful for making data available in multiple formats and graphics. Other portals like NANOOS NVS and other IOOS RA platforms facilitate data exploration, model products, and analysis. Data curation on a larger scale would be helpful along with recommendations for "best practices" for archiving model and observation data. Workshops/tutorials run by data-generating institutions would provide additional resources/ opportunities for sanctuary managers to learn about ways of using different data products.

Regarding projections of future marine sanctuary conditions, numerical models can provide managers with insights into possible future sanctuary trajectories. However, there are inherent limitations to these products and managers would benefit from knowing which model products are available, which are appropriate to use in relation to their sites, and what data streams are most useful to follow and utilize? Modeling efforts are somewhat dispersed; existing high resolution, near-term ocean forecasting programs include JSCOPE, as well as pending projects such as CA ROMS-NEMURO for ocean acidification and hypoxia forecasts, WCOFS-NEMURO, and regional ocean modeling efforts at GFDL. Hindcast reanalysis (i.e., assimilated physics) products exist and provide useful, historical insights, but assimilating biogeochemical information is a challenge and ongoing effort. Some modeling groups and organizations are utilizing environmental model output to inform and forecast changes in marine species distributions. We also discussed the potential for applying burgeoning machine learning techniques to forecasting efforts. The overarching question was: how

can we best use these tools and information to anticipate future conditions and do better scenario planning to prepare for a multi-stressor future?

Lastly, we discussed the need for effectively integrating information and data streams to communicate a coherent story to partners and stakeholders. Exemplary efforts include weekly HAB monitoring undertaken by SCCOOS and CeNCOOS: their data and analyses are integrated into operational products such as state databases (CA HAB Bulletin), Empirical HAB model (C-HARM) output, and CA marine mammal rescue group planning. These products are co-designed and co-created with stakeholders, state agencies, and academia to maximize community utility. In order to convey scientific needs, sanctuaries are working to produce documents that ID data and analysis gaps. We also discussed utilizing sanctuaries as sentinel locations for place-based observation and interpretation of high priority national issues. Specifically, sanctuaries could test adaptation and mitigation strategies that can then be shared with communities outside of sanctuaries. Similarly named efforts have been pursued by NOS; sanctuaries may be able to leverage information and knowledge from these projects to maximize effective ONMS implementation.

RECOMMENDED ACTION MOVING FORWARD

Support for Sanctuary Observations and Research

- Continue/ sustain investment in comprehensive observation programs (biological and environmental) within sanctuaries and support expert analysis and interpretation.
- Take advantage of emerging technologies (e.g., eDNA) and automation of observations to increase payloads on moorings, gliders, other AUVs; support R&D on new, low-cost BGC sensors for a full suite of parameters.
- Identify multi-stressor research that is more targeted, including work that can be conducted in situ.

Data Management:

- Increase data curation efforts to provide centralized information and standardized products for managers to access in different formats.
- Host user access workshops/ tutorials for different lab data and analytical products.

Numerical Modeling:

- Extract relevant information (i.e., variables-of-interest) from global climate models at sanctuary sites to facilitate sanctuary use of global climate model output and projections.
- Generate sufficiently long regional hindcast reanalysis simulations that utilize high resolution wind products and include biogeochemical conditions. This facilitates identification and study of past tipping points and management opportunities, which can inform climate projection analyses.

Communication:

- ONMS conveys the importance of hypoxia, HAB, and OA research to funding programs. This research improves our understanding of thresholds and tipping points for organisms and the impacts of hypoxia on key organisms in NMS.
- Continue manager communication of sanctuary science needs (e.g. HABs, OA, hypoxia) across NOAA line offices and through the annual science board meeting to ensure continued emphasis in funding efforts.
- Pursue/continue support for integrated platforms, programs (similar to CA IOOS efforts) and partnerships.
- Leverage prior Sentinel Site efforts and knowledge pursued through NOS.

Breakout Group: Ecological connectivity and shifting species and ecosystems in a changing ocean

Region: West Coast Region

Chair(s)/Author(s): Lauren Wenzel

SUMMARY

This group included several participants who had participated in the Shifting Species breakout group from the system-wide discussions. So they built on some of the concepts that were discussed earlier. The group started by identifying key issues or gaps, such as:

- How will climate impacts to key physical parameters affect species in sanctuaries? This is better understood for some physical parameters than others.
- How will habitat change in sanctuaries? This includes questions like how climate effects like sea level rise will affect critical habitat for species, such as coastal wetlands or seagrass beds.
- How will biological communities change? Will they migrate north or offshore? Concerns about conflicts with other ocean uses, such as whales may follow krill into shipping lanes.
- Where will biodiversity persist? And what management tools do we have to manage biodiversity in new areas? (e.g. dynamic management, establishing new MPAs, managing corridors with partners).
- How can we make shifting species relevant to ocean and coastal stakeholders?
- Need for modeling to verify models of species movement

We then moved to a discussion of capabilities within ONMS, NOAA and partners. Several participants noted the capacity within NOAA Fisheries, including current work on climate scenarios for the West Coast over the coming 50 years, including vulnerability assessments for forage species and marine mammals and the need for connectivity. NMFS is also conducting modeling to project historical and future species locations. Several partners are active in monitoring of species distribution (ACCESS, Beach Watch), and the IOOS regions have monitoring data for sanctuaries. Sanctuaries has developed capabilities in acoustic monitoring through SancSound that could be expanded. Sanctuaries is moving toward serving more timely data and synthesized information for Condition Reports, as is NOAA for the National Climate Assessment. The group also discussed the advantage of West Coast sanctuaries being linked by the California Current, and being adjacent for Central California, allowing for better understanding and information sharing on species movements. On a larger geographic scale, Sanctuaries have international partnerships that can promote species protection across borders.

Suggested actions included:

- Developing a federal funding opportunity on connectivity in the California current, with a focus on sanctuaries;
- Seek funding for creation of a data synthesis and visualization system and techniques across the West Coast to allow detection of species shifts, including changes in presence/absence, abundance/density, spatial extent/range (boundaries).
- Build on current efforts to keep sanctuary Condition Reports updated with timely information, and streamline sanctuary management plans so they can be updated more frequently.
- Hold a matchmaking workshop to identify opportunities for collaboration on West Coast connectivity and species shifts

- Work with policy staff to identify ways to make management actions/regulations more adaptive and responsive to emerging science and issues
- Clarify the role of restoration in sanctuaries to create refugia and maintain ecological function, and conduct the science to identify priority restoration areas for climate resilience
- Take a regional/landscape approach to encourage collaboration (e.g. through Landscape Conservation Cooperatives)
- Conduct a science based gap analysis to identify areas of current and future high biodiversity importance as potential locations for new MPAs

Breakout Group: Effects of changing ecologies on ecosystem services

Region: West Coast Region

Chair(s)/Author(s): Jay Peterson

SUMMARY

The group discussed the topic of "How will climate-driven changes to ecological communities impact ecosystem services at the scale of individual sanctuaries and regions?"

To address this question, discussions focused on three key objectives: Identify gaps and obstacles; highlight capabilities; and identify short and long-terms actions. Notes and highlights for each of the three objectives are below. More detailed information that was generated during the discussion is listed in a Google Sheets worksheet file provided by the workshop organizers.

GAPS AND OBSTACLES

The group identified a variety of data and information needs to better assess the climate-driven impacts on Sanctuaries, what ecosystem services each Sanctuary provides, and how critical those services are to users of the Sanctuary. These needs (gaps) include:

- Identify appropriate indicators and track trends in ecosystem services
- Collect data on use/appreciation of 'beyond the basic' ecosystem services (i.e., we need better data on cultural and recreational services, sense of place, and non-tangible heritage, etc.)
- Develop measures for non-monetary benefits and existence values
- Document spatial and temporal patterns of sanctuary use by activity and user group
- Improve understanding of the ecosystem services interactions (2-way) that are most relevant to communities tied to the social-ecological system (i.e., human activities that benefit ecological functions, and other relationship-based aspects of ecosystem services)
- Assess climate impacts on local and traditional foods
- Generate early warning information for harvesters and other users on anticipated impacts to ecosystem services
- Account for types of uses/services that are missing owing to challenges in quantifying them (e.g., related to coastal community well-being and cultural dimensions), or lack of social science capacity
- Develop indicators that can be used to understand when and why users are present and ultimately predict future use and changes due to climate.

In addition, there were also several obstacles identified that hampers the use of existing information.

- Some measures that are tracked are often not repeated, making it impossible to assess change over time.
- Communication products for public audiences need to be developed and/or improved.

CAPABILITIES

A number of resources were identified that are helpful for addressing questions regarding climate impacts on Sanctuary ecosystem services. These capabilities are divided up into several categories.

Modeling, Observations, and Analyses:

- Local and traditional knowledge holders from Tribal and local communities adjacent to sanctuaries are important in identifying ecosystem services and status and trends, including historic observations. For example Quinault elders observed fewer major fish kills from hypoxia in the past that we are seeing more frequently today.
- Long-term observations through buoys, regular surveys, etc.
- Qualitative network modeling that links predicted biological changes to likely effects on ecosystem services

People, Human Capital

- There is an important, but currently very limited, capacity in social sciences to characterize and assess a full range of ecosystem services

Tools and Products

- Visitation Surveys being led by University of West Virginia
- Human use—indicator development work lead by Channel Islands NMS
- ONMS-OMB social science question bank (should be approved this FY)
- IOOS Regional Associations—NaNOOS, CenCOOS, SCCOOS
- Satellite imagery. Combined with artificial intelligence and machine learning (AI/ML) techniques to extract information on Sanctuary use.
- Ocean Health Index
- Washington Marine Spatial Plan
- Sanctuaries have the potential to provide a HUGE ecosystem service in the realm of carbon capture and sequestration. It will be important to find ways to appropriately track and credit this service.

RECOMMENDED ACTIONS

The final portion of the group discussion focused on identifying steps that NOAA can take to address the data and information needs and better identify how climate-driven changes to ecological communities will impact the ecosystem services that West Coast sanctuaries provide.

The actions are divided into near-term, medium-term, and long-term time frames.

Near Term (0–1 yr):

- Pull together a community of practitioners to help bridge information gaps, especially regarding non-consumptive and non-tangible services
- Maintain and enhance ongoing tracking of important ecosystem service indicators to better assess status and trends for future condition reports and partner with relevant NOAA staff (Northwest Fisheries Science Center, IEA team, Southwest Fisheries Science Center, etc.)
- Reach out to Tribal and local communities adjacent to Sanctuaries to assess needs, establish partnerships, and share knowledge
- Dig deeper into cultural ecosystem services as a program through ONMS and partners
- Host public/sanctuary user-focused ‘mixers’ to hear about information needs and learn about capacities that aren’t usually discussed in more formal expert-oriented workshops. i.e. NOAA open house meets speed-dating.
- Use social media to track “use” of sanctuary assets

Medium-term (1–2 yr):

- Develop innovative and ethical ways to track human use using a variety of technologies (unscrewed systems, AIS, VMS, satellite, etc.) in partnership with ONMS, NCCOS, NMFS Science Centers, others.
- Hold a workshop to identify and select a combination of physical, biological and social indicators
- Increase participation by diverse users/beneficiaries of services
- Increase (non-economic) social science capacity within NOAA

Long-term (3–5 yr):

- ‘Blue carbon’ assessment, testing, to determine the current capability and future potential of sanctuaries for carbon capture and climate change mitigation.

Breakout Group: Development of climate indicators

Region: West Coast Region

Chair(s)/Author(s): Jennifer Brown

PRIORITY INDICATORS FOR THE WEST COAST REGION

The group discussed that certain physical and biological measures are key indicators for tracking changing ocean conditions and drivers of change in the associated ecological and human systems. These physical measures include temperature (SST, subsurface), ocean acidification, pH, dissolved oxygen/hypoxia, upwelling, harmful algal bloom frequency and intensity, and marine heat waves. It was noted that putting these west coast observations in the context of larger basin-scale drivers of conditions (e.g., PDO, NPGO, ENSO) can be helpful. Relative abundance and condition of zooplankton, in particular pteropods, copepods and krill, are useful biological indicators of ocean conditions and the base of pelagic food webs. Key data providers include CCIEA, ACCESS, SCCWRP, CalCOFI). Counts of beachcast seabirds are another indicator of changing conditions in the pelagic food web and provide community science opportunities (i.e., BeachWatch, COASST program, BeachCOMBERS, BC Ocean Guardians).

Indicators of impacts to habitats, specifically sea level rise and kelp canopy cover, were discussed. CO-OPS National Water Level Observation Network (NWLON) and NESDIS for satellite altimetry were noted as key data sources for sea level and flooding data. Kelp canopy cover, which can be tracked through satellite and unmanned aerial system (UAS) surveys in addition to diver surveys (e.g., PISCO), is shifting rapidly along the west coast and an important indicator for tracking the relative abundance and condition of this important nearshore habitat and associated community. Additionally, improved data and modeling of connectivity and habitat changes are needed to predict potential invasive species and shifts in species distribution along the west coast.

Indicators of climate impacts on coastal communities, human dimensions, and ecosystem services are significant gaps in the ONMS indicator list. ONMS HQ and sites (i.e., CINMS, OCNMS) should work with partners to develop priority indicators and leverage existing information from social science surveys and human use data (e.g., AIS; VMS; satellite data; ocean noise, etc). An RFP specific to developing regional ecosystem services indicators and promoting novel approaches to integrating varying data sets on human use and human dimensions may be needed to fill this gap in a timely fashion. Partnerships to explore include CPO, NCCOS, WA Sea Grant, and CCIEA. Additionally, engage with traditional knowledge holders (e.g., Ocean guardians program) and incorporate traditional knowledge into indicators when appropriate, and engage with indigenous-led regional stewardship efforts (e.g., B.C. First Nations Coastal Guardian Watchmen program).

There was significant interest around expanding engagement of coastal communities through community science (i.e., citizen science) programs and initiatives which can add capacity for collecting indicator data, increase public awareness of climate impacts, and build community support for management actions. Examples included the COASST program near Olympic Coast sanctuary (run by UW), the coastal almanac initiative (NSF grant), Beach Watch (run by GFNMS) and Beach COMBERS (now run by USFWS). Mobile apps are being developed to facilitate standardized data collection by community members and linking these to regional (and national) data services and pipelines could facilitate use of this data for indicator tracking and management application. For example, the National Stranding Network could use a DAC (data assembly center) and pipeline to support these regional community science programs and for data integration across sites and regions.

Suggested next steps emphasized the need for programmatic coordination, indicator prioritization and strategic allocation of resources. Clarifying which indicators are the top priorities for observing is very important since there are very different resources needed if you have 100 indicators vs 10. Ensure that any indicators developed for ONMS, are consistent, provide added value, and do not duplicate others in NOAA and federal, state and local partners. The current ONMS indicator language does not always clearly convey what to measure and how to measure it. Harmonizing use of indicator vocabulary/ontology across parts of NOAA, but also between state and local interests, would also make it easier to identify areas of overlap and opportunities for efficiency. It was recommended that we leverage efforts of the West Coast Ocean Alliance and their members, who are prototyping ocean health indicators starting with ocean acidification indicator recommendations (led by NANOOS) and considering heatwave and HAB indicators (scorecards) at the west coast level. Additionally, network with other science teams who are working on related and parallel indicator suites on climate change in the CCLME (e.g., Pacific Fisheries Management Council: Climate and Communities Initiative).

ONMS should initially focus on indicators for which we can readily obtain or collect and analyze the data. Additionally, we should first try to use or adapt existing products before developing anything new for sanctuaries. For example, MBNMS is working with the CCIEA team to downscale the existing CCIEA marine heatwave tracker to a regional scale relevant to each west coast sanctuary. We need to allocate resources (staff/contract funding) to support the integration/interface/discussions that link observation data to sanctuary products. This takes time, and ongoing support of discussions among scientists, managers, research interpreters, condition report developers. Need to consider appropriate risk assessments, with forecasting and ecosystem services.

Breakout Group: Interdisciplinary and applied data and integrated information needs

Region: West Coast Region

Chair(s)/Author(s): Clarissa Anderson

SUMMARY

Gaps in Knowledge: Evaluation of data to better understand the ecosystem may be advanced by emerging methods in Machine Learning (ML) applied to sound and imagery data, bioinformatics & biomolecular tools for 'omics surveys, etc. The group anticipates better, more efficient predictive capacity using ML methods and coordinating cloud capabilities across NOAA. Sustained observations (both physical and biological) are critical to creating ecological forecasts that feed into meaningful, useful products for decision makers. In addition, the human dimension component has not been well articulated, included, represented, nor understood, such that data integration has not yet resolved a certain class of impacts. For this reason, semantics and cultural barriers—even within a given field—bleed into the indicator definitions, making it hard to separate semantic from ontological differences.

Obstacles to using existing information: The Data capacity and technology exist, but resources devoted explicitly to synthesizing information into usable products for evaluation and assessment is limited and highly distributed. Some data sets that have been mentioned as valuable for use at a system, regional, and site level (e.g., satellite-based SST) are provided by multiple programs (e.g., CoastWatch and IOOS regional associations), but it can be unclear which groups sanctuaries should be partnering with to create the sanctuary focused synthetic data products and do this in a way that is an efficient use of both sanctuary and partner time and resources. ONMS needs to determine who on the ONMS team engages on product development for needs that are shared across regions or the system and focus on being strategic in allocation of ONMS and partner staff time and resources while maximizing sanctuary-centric product development.

Obstacles to applying existing products: The highly distributed nature of data and products across agencies and line offices means that managers are often at a loss for what to use for decision support; better coordination and replication can both help here. The group discussed how we can better share with our partners and the public what we know and don't know about multistressor impacts and their relationships through creative visualizations? Some physical relationships are well established such as between temperature and dissolved oxygen, but other relationships are far less straightforward and areas of active research. Is there a good way to communicate this through NANOOS/CeNCOOS/SCCOOS and other fora? Having an informed and ocean-literate public helps during management planning for sanctuaries and for promoting ocean stewardship. Indicator pipeline planning should involve targeted stakeholder groups to guide investments that can be scaled up.

CAPABILITIES

Modeling, Observations and Analyses: Ecological forecasting is still in its infancy for most of the food web. There is a need to advance R&D here, meaning more BGC/biology obs, more validation of models, better calibration based on observations, and closing that loop as models improve.

Tools and Products: FAIR data practices and dissemination of best practices encourage integration of data, product development. Interoperability is key for facilitating data use, synthesis, and cross-talk/harmonization of data portals/databases; ERDDAP is key to the interoperability solution. ERDDAP is a great resource that makes data accessible for both visualization and data download. Many IOOS RAs have ERDDAP servers where Sanctuary data could be served, thereby meeting federal requirements and better informing sanctuary management (such as through condition reports). Both gridded data (like satellite and model data) and tabular data (such as in situ data) can be served. The California Current Integrated Ecosystem Assessment program provides a suite of indicators through their indicator table, also served by and run from ERDDAP. Some of these indicators have been identified in other discussion groups as important for climate change assessments for sanctuaries. Currently, some of the CCIEA indicators are provided at a scale that is relevant to sanctuaries, while many others need to be downscaled to be more directly applicable to individual sanctuary status and trend assessments.

People and Human Capital: Products are only usable if stakeholders, end users, decision makers are able to express their needs early, are trained to understand theoretical and technological limitations, and are treated as respected partners w/ frequent communication and feedback opportunities. The sanctuary network could be leveraged here, but requires networking a data portal that could be applied across all of the sanctuaries, with an identical architecture. Using OA impacts on tribal communities as an example, there is a chance to create a framework that can hopefully be replicated in other systems. NOAA CoastWatch and the IOOS programs are both Value-Added Providers, in the sense that they have people available to help people access data as well as work with them to develop products. This is a crucial service that has been repeatedly expressed during this workshop and that is still missing for a lot of data. Moreover, there is currently very little capacity to do the translational science work—that is, working with the data providers and the users, especially sanctuaries, to translate the science into usable products that are readily available and understandable to a broad audience and fill identified needs for either condition assessment, management, education, etc.

SUGGESTED ACTION

Near-term: It seems that there are two separate goals associated with data value—one is associated with analysis and visualization, and one is associated with archiving and accessibility. Both of those objectives don't need to be solved with the same platform. It may be that the analysis and visualization goal can be accomplished with a smaller number of datasets in a focused portal or format that can be replicated across sanctuaries, perhaps with IOOS support, or perhaps with a sanctuary-specific portal, or perhaps using something else. The group suggested leveraging existing portals on the West Coast to create pan-regional products (IOOS RAs, WCOA, etc). There is a need to define in more detail how to deliver data for indicators, including more of the maturing methods, and to document specific indicator products, which can be prototyped and evolved with feedback. The West Coast Biology Observing Network could help facilitate this, taking advantage of the IOOS networks that already reach out to academic, individual, and other types of data producers, also linking others, such as OAR, NFS, USGS, and NSF investments. Individual investigators need to be shown how they can be part of IOOS and benefit from having their data integrated alongside a large catalog of data to address the needs of Sanctuaries and more.

Mid-term: Global climate model and regional ocean model output (historical and projections) generated by GFDL could/should be made available to sanctuaries in a more digested/ accessible format along with tools for doing additional analyses. We need to link ecological forecasting planning with the increasing availability of BGC and BioEco data to help make the leap to assimilating these data types, e.g. pH, nitrate, and zooplankton...here through the lens of Sanctuary indicators. This includes evolving tools like that used for data assimilative model output.

Long-term: Resources are needed for sustaining delivery of data synthesis and interpretation to targeted stakeholder groups and the public.

PACIFIC ISLANDS REGION

Breakout Group: Extremes and large-scale climate phenomena

Region: Pacific Islands Region

Chair(s)/Author(s): Atuatasi Lelei Peau and Ryan Rykaczewski

SUMMARY

Pacific Island communities are especially vulnerable to changing and more energetic climate systems. Given the close relationships between human society and the environment and the physical isolation associated with island communities, climate change impacts are amplified in the Pacific and profoundly affect the natural environment and island communities – placing lives, traditional cultures, and property at risk. Coordinating information and action on climate extremes and large-scale phenomena is timely and critical in the region.

In this focus group of the workshop, we discussed some of the regional challenges faced in the region's sanctuaries regarding extreme events in the climate system. The primary topics raised included the need for increased human capacity, improved communication, climate predictions and projections that are on spatial scales relevant for sanctuaries, and recognition that experts in the local communities retain information in oral histories of value to the understanding of extreme events.

Regarding the human capacity within the sanctuaries, it was recognized that there are comparatively few staff members contributing to sanctuary tasks in the region. Current staff are unlikely to have the capacity to assess and interpret the available information concerning climate extremes, and so are reactive to crises associated with climate extremes rather than proactive. While some capacity may be present outside of the region, a full-time presence in the community is necessary to develop the relationships required for effective communication of climate information. Translation of the physical climate science to the factors relevant to sanctuaries, and subsequently, communication of that information to stakeholders in the communities dependent on the affected resources requires a sustained investment in human and scientific capacity.

The need for improved communication is also evident among the various federal, regional, and local agencies and groups working in the region. While recent events have demonstrated that cooperation occurs in times of crisis, such coordination and sharing of data should occur as part of the standard operations. For example, workshop focus-group participants noted the need for an inventory of scientific activities and outreach in the region to develop a better understanding of what actions are possible when the region faces a future crisis.

In addition to the need for increased human capacity and communication, workshop participants noted the demand for scientific information that is on the spatial scales relevant for conditions within the region's sanctuaries. For instance, the physical climate-science community have the capacity to predict large-scale extreme events such as El Niño with some skill, but the relevance of such information to the conditions within the sanctuaries (e.g., precipitation and drought, bleaching events, sea level) has yet to be assessed. Improved spatial resolution and investigation of forecasts at the island scale are necessary.

Additionally, while there are few "success stories" in which scientific products have been targeted towards improving information for resources of the Pacific Islands (e.g., Coral Reef Watch, the Allen Coral Atlas), many opportunities remain for improving the scientific information relevant to the region's sanctuaries (e.g., information on the future intensity and frequency of tropical storms, changes in prey resources for pelagic species, changes in future precipitation, application if in-situ data for calibration of satellite and ecosystem models). Any extreme weather and shifts due to climate change have the potential to impact the Pacific

Islands region. The shift from normal patterns may also influence the distribution of rainfall impacting agriculture, exposure of reefs, fish migration, tropical cyclones, etc. from what the region is accustomed to. Many island communities have a laissez-faire attitude (e.g., “let’s not worry so much about it until it happens”), but that approach is not sensible with an issue as large as climate change.

Finally, workshop participants noted that the history of conventional scientific and socioeconomic surveys in the region is not long. This lack of traditional historical data poses challenges to framing the magnitude of extreme events in a historical context. However, the oral histories that exist within the island communities are rich and could be viewed as a resource with value exceeding that of typical scientific data. Building upon existing partnerships and mutual respect may help reveal information about climate extremes and resilience that have yet to be recognized. Thus, looking outside the NOAA family to experts from local institutions, elders with site-specific knowledge (often based on very long-term data sets passed down through generations), local scientists working on specific species or ecosystems, local agencies, SeaGrant, etc. maybe fruitful for this effort.

A common sentiment shared among workshop participants was that this whole issue is very complex and requires a much lengthier discussion. A key recommendation of the participants was to conduct an assessment of local capacity to address the climate science question and recommended actions.

Breakout Group: Ecological tipping points and thresholds in a changing ocean

Region: Pacific Islands Region

Chair(s)/Author(s): Val Brown

SUMMARY

This breakout group focused on climate-related tipping points and thresholds for ecosystem functions in the Pacific Region. Due to significant overlap in participants from Day 2 session 2- Ecological Tipping Points, the group built on the previous conversations to focus on the Pacific Region. The group had a wide range of expertise and points of view and included representatives from sanctuary sites, Pacific Marine Environmental Laboratory, CoastWatch / OceanWatch, Coral Reef Watch (CRW), NOAA Fisheries (NMFS), and Pacific Integrated Ocean Observing System (PacIOOS).

The group reviewed issues associated with ecological tipping points and thresholds generated in Day 2: 2-Ecological Tipping Points. These included lack of knowledge, uncertainty in models and forecasts, and lack of capacity to use existing data sets (please see Day 2 report for more details). The group noted that ONMS should better define "Ecological Tipping Point" and articulate needs clearly to help target future efforts. There are broad scale climate models and tools, but these may not address specific islands or units within sanctuaries. There is also a need to understand how specific organisms and ecosystems react to these stressors and to develop models that don't just predict thresholds, but also potential ecological impacts (e.g. refine CRW to predict mortality) and ecological tipping points.

There is a need to better understand fine scale and species specific responses to climate stressors. Biological sensitivity to temperature and pH should be incorporated into models to identify regions that may be stressed and those that may be refugia. This includes how tolerance to climate impacts (temperature and pH) varies spatially and within and amongst species (e.g. is tolerance of corals to bleaching in MHI different from the same species in NWHI). Information is also needed on thresholds by location (e.g. corals in the Ofu Pools in AS have a higher bleaching threshold, CRW products for equator need improvement). The group asked how resilience and recovery factor in and pondered if timing between stress events could be an important component in determining tipping points (e.g. coral bleaching events shift from decadal to annual). They also noted that invasive species and disease, including stony coral tissue loss disease, pose potential threats as climate conditions put pressure on native species and modify habitat conditions.

Information on mesophotic and deep-sea ecosystems is very limited and sanctuary sites are just starting to obtain data on species presence and range and oceanographic conditions. There is a need to collect baseline data on carbonate chemistry and calcification in these deeper ecosystems and to develop monitoring protocols that can track changes in both biological and oceanographic parameters over time. Further, models are needed to inform managers about how conditions in these deep areas may change over time. It is unknown if these species may be able to shift in depth or latitude with changes to habitat conditions (e.g. species found deep in MHI are found shallower in NWHI).

Experts noted that a number of models, forecast, and monitoring tools are available including models included in the latest Coupled Model Intercomparison Projects (CMIP6), CRW, PacIOOS, and CoastWatch. PacIOOS, CoastWatch and others provide training on how to use these resources. There is some work being done to create downscaled forecasts / projections of ocean physics and biogeochemistry including carbonate chemistry at AOML and the group noted that NMFS PIFSC and CoastWatch are working together on ocean acidification data from satellites. Group members clearly stated that in-situ data is highly valuable (e.g. NCRMP climate stations, NMS monitoring data) and could be added to existing models to improve predictive abilities.

The group noted that in-situ data collection has been constrained recently due to ship time and the global pandemic. This highlighted the importance of new technologies for data collection including autonomous

underwater vehicles, unmanned aerial systems, sea gliders and wave gliders. Ocean acidification buoys are collecting data on a suite of oceanographic parameters and data is available online, but biological data still mostly needs to be collected in situ by divers. However, NOAA, University of Hawaii, and University of Guam have started using ‘omics including epigenetics, and metabolomics to better understand species response to stressors and eDNA to understand changes in distribution including spatial and temporal changes in community structure.

The group recommended some initial actions that ONMS should take. The first is to define “Ecological Tipping Point”. The next is to build stronger connections with CoastWatch to access data for key indicators and build a stronger connection with NWS for prediction work. The group noted that it would be helpful to match models. Other recommendations may take longer to implement and include expanded data collection, improved modeling, and communications.

Specific actions discussed included:

- Improve access to NOAA ships or shore based charters to improve in situ data collection
- Downscale models for NMS sites
- Incorporate in-situ data, tolerance, and threshold information into existing models to improve outputs
- Improve bleaching products in the equatorial regions
- Further explore the potential use of AUV and UAS to collect more in situ data
- Find more opportunities to deploy sensors in remote places (e.g. AUV, wave glider, and moorings)
- Further develop algorithms for mooring data sets and LIDAR datasets—can be combined with other data and to validate models. There are good examples from NW Pacific and these are updated regularly (5 years)
- Improve remote sensing observations and models
- Support physiological studies to understand how thresholds change among species, among locations, and across depths
- Implement Citizen Science programs to increase in-situ data
- Contract smaller vessels more frequently around populated islands as an alternative to ship time
- Obtain better information about mesophotic and deep sea species and species ranges and how might these shift across depth and space. It is important to note that some may already be at their limits (ex. mesophotic algae at limits of PAR)
- Improve understanding of carbonate chemistry in deep sea (may change sooner and be a warning)
- Connect with other modeling efforts at appropriate scales

Breakout Group: Effects of changing ecologies on ecosystem services

Region: Pacific Islands Region

Chair(s)/Author(s): Julia Royster

SUMMARY

Climate change combined with ecosystem services is complicated, especially in an oral society where members hold a lot of information and are not quick to trust others with their knowledge. The top three issues raised were: 1) the need to communicate what an ecosystem service is, roles ecosystem services provide to local communities, and why the services should be preserved, 2) the need to understand how existing data or tools can be used to evaluate ecosystem services, and 3) attributing climate change versus a myriad of other factors as the cause for changes to ecosystem services is difficult.

To move forward, it is critical that Sanctuary and NOAA staff develop communication products and engagement opportunities to increase understanding around climate change impacts on the local community and the benefits ecosystem services provide. Existing modeling, observations, and analysis, such as Stolazzi et. al 2019 or NOAA's work on social vulnerability and climate change, should be inventoried and used as a backdrop when developing site-specific products and messages related to valuing ecosystems for coastal protection and other ecosystem services.

While the group discussed suggested actions at the sanctuary, system, and NOAA levels (see below), the actions that rose to the top were the need to: 1) determine region-specific climate change and ecosystem service indicators and make sure resource managers have access to the data required to track the indicators, 2) identify clear, specific actions for the public to take to preserve ecosystem services, and 3) serve climate data, analyses, and reports in one central NOAA dashboard location. The most useful data is consistent time series allowing for a greater understanding of the changes and potential interactions of climate and ecosystem services that could be felt and/or understood by the local community over time.

RECOMMENDATIONS

At Sanctuary Level:

1. Hire an economist and/or add a socio-economic focused seat to Sanctuary Advisory Council (SAC).
2. Assess what socioeconomic data is being collected, where results are stored, if they are served to the public, and how the Sanctuary or ONMS has used the information.
3. Develop relationships with state entities and NOAA offices with resources to conduct socio-economic evaluations and products.
4. Create trainings focused on learning more about the ecosystem services of a particular sanctuary and include how students, and/or the public can help preserve the services.

Office of National Marine Sanctuaries

1. Integrate and promote NOAA-wide integration of social sciences with biological and physical sciences to increase our understanding of public perception related to climate and ecosystem services.
2. Financially support and implement Socioeconomic Assessments for the system and/or at the site level with products that result in clear dollar values, as well as non-dollar values—ONMS audiences need both (e.g. Congressional staff, resource managers, local organizations).
3. Use results of public perception at the sanctuary and system level to develop, prioritize, and fundraise for the research that needs to be done to understand climate and ecosystem service connections.

4. Partner with SeaGrant (and identify internal NOAA and external offices) to assess socioeconomic assessment/valuation needs and increase pathways to share information, public exposure to the concepts, and provide clear, consistent messaging about climate and ecosystem services.
5. Conduct focus groups with SAC members to facilitate sanctuary-wide questionnaire to better understand how and what to social science to integrate into research priorities at the system and/or sanctuary level.

NOAA-wide

1. Create consistent messaging for climate and ecosystem services in the local language(s) of all U.S. territories to increase relevance and digestibility by local communities.
2. Document oral histories when possible to help increase the time-scale of consistent data for a specific geography and supplement more standard data.
3. Identify the most relevant climate and/or socioeconomic data to NOAA & ONMS, then identify and partner with national and local partners that have relevant scientific information that NOAA does not currently have in its databases.
4. Conduct focus groups across NOAA line offices to do deep dives on specific climate topics. They could be one and done groups, or the start of a continued forum for sharing information, setting priorities to address data, analysis, training, or product needs.
5. Develop a NOAA-wide climate dashboard that includes maps, data portals, curricula, reports, discussion boards for sharing information, and a place to network based on expertise. *This could be an internal NOAA site, or for external consumption.

Breakout Group: Interdisciplinary and applied data and integrated information needs

Region: Pacific Islands Region

Chair(s)/Author(s): Hannah Barkley & Jon Martinez

ISSUES

Several gaps were identified as part of this group:

- Lack of data at appropriate spatial and temporal scales: in situ, climate physical, ecological & socioeconomic data
- Lack of integration of existing data, including the use of conceptual models such as Integrated Ecosystem Assessment (IEA) approaches
- From the data user/resource manager side, improvements could be made in data requests (defining, articulating and planning for data needs, including identifying key indicators early on)
- In many cases, data users are unable to access, analyze, interpret and utilize data and may have general unawareness of existing data sources
- Funding

CAPABILITIES

There are many recognized existing resources which include data streams and technical experts who can provide data, visualization and interpretation capabilities. Existing capabilities are not being broadly integrated and could be leveraged much more. Resulting discussion points on different data types are below.

Remote sensing products:

- Many products exist for remote sensed data (Coral Reef Watch & CoastWatch); however, resource managers and data users are not completely aware of all of the resources, nor how to access and utilize them

Data access, visualization & training:

- Resources for data visualization and access, such as PacIOOS and the Allen Coral Atlas, currently exist and could be expanded upon or leveraged in the future
- NOAA CoastWatch provides training in data access and utilization (pending training for March 2021 for ONMS)

In situ data:

- Several programs collect in situ climate and ecological data with the intention of data integration, but integration is currently limited
- Most long-term in situ data come from the National Coral Reef Monitoring Program (NCRMP) and Monument Research, which include largely static datasets which are discretely archived and not broadly accessible as a data stream

IEA Framework Conceptual Model:

- Available as a model which could be applied to achieve data integration to spatially explicit areas but aren't integrated into Pacific Island Region sanctuaries/monuments as of yet

SUGGESTED ACTIONS

Numerous suggested actions were proposed and mainly relate to the following themes:

- ONMS & data users can improve communication on needs by clearly defining, articulating and planning for data needs including identifying key indicators early on
- Integration of data streams require: Partnerships, collaborations, communications, and coordination between data providers and users/managers
- Data providers can improve accessibility of data and support building capacity (analysis, access the data, interpret data) with data users through training and or customized data portals or products.
  - Example: customized portal for ONMS to access data from various sources such as (NCRMP, CoastWatch, NCEI, everything on ERDDAP & Thredds etc)
  - Example: NOAA CoastWatch trainings provided to ONMS March 2021
- Improve data collection:
  - For in situ data, increase spatial and temporal frequency of sampling for existing variables (OA & temp) at scales appropriate for ONMS needs
  - Collect new data variables, particularly physical drivers (wave activity—magnitude, direction, duration plus forecast)
- Improve data integration by leveraging existing data (Coastwatch, Coral Reef Watch)
- Consider conceptual modelling approaches such as used by IEA as approach for ONMS research and management

CONCLUSIONS

The major takeaways from this breakout session are a consensus that there are many necessary components to effective integration of data which, in many cases, have necessary linear steps, but can also be iterative. In addition, funding and staff capacity were recognized as limitations and necessary for each area that was discussed. This appears to be true generally and for the Pacific Islands Region specifically.

Key takeaways:

1. Data needs should be well defined and articulated
2. Building integrated data streams requires collaboration, communication and coordination across multiple groups
3. Data users must be able to easily access and analyze data

As a result of the workshop discussions, it is recommended that true efforts to integrate data streams include several following components:

1. Ensuring that data users & managers clearly define, articulate and plan for data needs including identifying key indicators early on
2. Effectively communicating needs with data providers early on to assess capabilities and set expectations (include discussions on scale and variability etc.)
3. Data providers and researchers clearly understand the needs and strive to produce data in formats that can be used by data users
4. Data users are able to access, analyze, interpret and utilize data (may need training or support from data providers)

Appendix D: Participant List

This appendix presents a list of workshop participants and their affiliations. Affiliations were provided by participants upon registration. While this list is representative of the breadth of expertise and representation at the workshop, some participants opted out and thus this list does not present a complete accounting of workshop participants. Participants that acted as breakout chairs or are members of MERT or the workshop planning committee are **bolded**. Participants that are members of MERT or the workshop planning committee are also written in **blue**.

NAME	AFFILIATION
Alex Harper	CeNCOOS/MBARI
Alexi Archer	Gray's Reef National Marine Sanctuary
Alison Soss	Gray's Reef National Marine Sanctuary
Andrew DeVogelaere	Monterey Bay National Marine Sanctuary, NOAA
Andrew Leising	NOAA-SWFSC
Andrew Ross	Princeton/GFDL CIMES
Antonietta Capotondi	NOAA PSL
Atuatasi Lelei Peau	**NOAA/ONMS National Marine Sanctuary of American Samoa**
Ben DeAngelo	CPO
Ben Haskell	**Stellwagen Bank National Marine Sanctuary**
Brady Phillips	NOAA Sanctuaries
Brent Lofgren	NOAA/OAR/Great Lakes Env Res Lab
Cara Wilson	**NMFS/SWFSC**
Carol Bernthal	Olympic Coast National Marine Sanctuary
Charles Stock	**NOAA/GFDL**
Chip Young	PacIOOS—UH Manoa, Honolulu, HI
Chris Caldow	**Channel Islands National Marine Sanctuary**
Chris Kelble	**OAR/AOML**
Clarissa Anderson	**SCCOOS/Scripps Institution of Oceanography**
Dan Barrie	**CPO**

Danielle Lipski	NOAA Cordell Bank National Marine Sanctuary
Danielle Schwarzmann	ONMS
David Herring	**CPO**
David Wiley	Stellwagen Bank nationl Marine Sanctuary
Derek Manzello	NOAA/AOML
Digna Rueda-Roa	University of South florida
Dwight Gledhill	**NOAA OAR OAP**
Ed Lyman	Hawaiian Islands Humpback Whale National Marine Sanctuary
Ellen Spooner	NOAA
Enrique Curchitser	Rutgers University
Enrique Montes	College of Marine Science, Univ. South Florida
Erica Ombres	NOAA Ocean Acidification Program
Frank Muller Karger	University of South Florida / Marine Biodiversity Observation Network
Gene Brighouse	National Marine Sanctuary of Anerican Samoa—CPC
Giselle Samonte	ONMS
Hannah Barkley	**PIFSC**
Hassan Moustahfid	**NOAA/NOS/IOOS**
Henry Ruhl	**CeNCOOS**
Ian Enochs	NOAA AOML
Ian Miller	Washington Sea Grant
Jackie Motyka	NERACOOS
Jacqueline De La Cour	NOAA Coral Reef Watch and University of Maryland/ESSIC
Jaime Jahncke	Point Blue Conservation Science
Jan Newton	University of Washington & NANOOS
Jan Roletto	Greater Farallones National Marine Sanctuary
Jay Peterson	**NOAA Fisheries**
Jeannine Rossa	Hawaii DLNR/HIHWNMS (Comanager)
Jennifer Brown	**Monterey Bay and Channel Islands national marine sanctuaries**
Jennifer Dorton	SECOORA
Jennifer Selgrath	Channel Islands National Marine Sanctuary

Jenny Wadell	NOAA Olympic Coast National Marine Sanctuary
Jin Huang	NOAA/CPO
John Armor	ONMS
John Dunne	NOAA/OAR/GFDL
Jonathan Martinez	**ONMS Papahānaumokuākea Marine National Monument**
Julia Royster	**NMFS/OHC/RC**
Kalani Quiocho	NOAA ONMS Papahānaumokuākea Marine National Monument
Karen Grimmer	Monterey Bay National Marine Sanctuary
Katie Lohr	**ONMS HQ**
Katie Rousseau	Great Lakes Observing System (GLOS)
Katie Wrubel	Olympic Coast National Marine Sanctuary
Kelly Collins Choi	Maryland Department of Natural Resources—Mallows Bay NMS
Kelly Montenero	NOAA AOML/CIMAS
Kevin Grant	**Olympic Coast National Marine Sanctuary**
Kimberly Puglise	**NCCOS**
Kimberly Roberson	ONMS/ Gray's Reef National Marine Sanctuary
Kris Sarri	National Marine Sanctuary Foundation
Laura Stone	National Marine Sanctuary Foundation
Lauren Wenzel	**NOAA ONMS**
Lauri MacLaughlin	Florida Keys National Marine Sanctuary Science Team/Resource Manager
Libby Jewett	**NOAA OA Program**
Lilli Ferguson	NOAA, Cordell Bank National Marine Sanctuary
Liz Drenkard	**NOAA GFDL**
Mandy Karnauskas	**NOAA SEFSC**
Margo Schulze-Haugen	NCCOS
Maria Brown	**Greater Farallones National Marine Sanctuary**
Marissa Nuttall	**Flower Garden Banks National Marine Sanctuary**
Mark Eakin	NOAA Coral Reef Watch (GST contractor)
Mark Monaco	**NOS NCCOS**
Meg Chadsey	Washington Sea Grant

Melanie Abecassis	UMD for NOAA/NESDIS/STAR
Melissa Poe	Washington Sea Grant
Merrie Neely	**GST—embedded at NOAA/NESDIS/STAR**
Michael Alexander	**NOAA/Physical Sciences Laboratory**
Michelle Johnston	**Flower Garden Banks National Marine Sanctuary**
Michelle McClure	OAR-PMEL
Mike Jacox	**NMFS/SWFSC and OAR/PSL**
Mitchell Tartt	NOAA/ONMS/SHD
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Nicole Besemer	NOAA AOML/ UMiami CIMAS
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Oriana Villar	NOAA NOS IOOS
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Paul Hirschberg	CPO
Randall Kosaki	NOAA ONMS Papahanaumokuakea Marine National Monument
Rebecca Briggs	NOAA Sea Grant
Richard Feely	Pacific Marine Environmental Laboratory/NOAA
Roger Griffis	NOAA Fisheries Service
Roger Pulwarty	NOAA Physical Science Laboratory
Roxanne J Carini	NANOOS
Ruben van Hooidonk	University of Miami / NOAA AOML
Ryan Freedman	**Channel Islands National Marine Sanctuary**
Ryan Ono	Ocean Conservancy
Ryan Rykaczewski	**NOAA Pacific Islands Fisheries Science Center**
Samantha Siedlecki	UConn
Sara Hutto	**Greater Farallones National Marine Sanctuary**
Sarah Close	Lenfest Ocean Program
Sarah Stein	NOAA Office of National Marine Sanctuaries
Shannon Ricles	NOAA/NOS/ONMS/Monitor National Marine Sanctuary
Simone Alin	NOAA Pacific Marine Environmental Laboratory

Stan Rogers	Gray's Reef National Marine Sanctuary
Stephanie Gandulla	**Thunder Bay National Marine Sanctuary**
Stephanie Oakes	NMFS
Steve Gittings	**NOAA/NOS/ONMS**
Steven Bograd	**NOAA NMFS Southwest Fisheries Science Center**
Susan Langley	Maryland SHPO
Tammy Silva	Stellwagen Bank National Marine Sanctuary
Tane Casserley	**NOAA/ONMS/Monitor National Marine Sanctuary**
Tom Shyka	NERACOOS
Valerie Brown	**NOAA National Marine Sanctuary of American Samoa**
Veronica Lance	**NOAA CoastWatch / OceanWatch /PolarWatch program (NESDIS)**
Virgina Selz	**CPO**
Wayne Higgins	CPO
Will Sassorossi	Monitor National Marine Sanctuary
Zachary Cannizzo	**ONMS/CPO**
Zephyr Sylvester	University of Colorado Boulder / NCAR