TECHNICAL AND MAPPING SUPPORT FOR WASHINGTON MARINE SPATIAL PLANNING

FINAL REPORT

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About this report

This report identifies and evaluates seafloor, seabird, deep-sea coral and sponge datasets needed to support a range of marine spatial planning issues by the state of Washington. The physical and ecological targets of this report were chosen by the Washington Department of Ecology, with input from the State Ocean Caucus, to represent priority data sets needed for marine spatial planning along Washington's outer coast.

This technical report supports Washington's marine planning initiatives by identifying data needed to map and assess key physical and biological resources within their offshore marine ecosystem. The report is separated into two parts to present information on a spatial prioritization process for seafloor mapping, and an evaluation of seabird and deep sea coral and sponge surveys.

This report provides a blueprint to describe key participant groups, steps, their timelines, and expected outcomes necessary to conduct a spatial prioritization for seafloor mapping. The process includes planning a regional workshop, a spatial prioritization information query, and identification of steps to process and analyze data, implementation of technical/management oversight groups, an outreach strategy, and efforts to identify and improve leveraged assets/resources. This blueprint provides key strategic planning steps to expedite the next phase of the effort so that progress can quickly transition towards well planned, coordinated, and prioritized activities. Additionally, a geospatial data viewer of existing seafloor mapping information has been constructed to allow planners at Department of Natural Resources and their associates to visualize data organized into thematic categories and allow users to easily evaluate the extent, type, and quality of known data sources.

The evaluation of seabird and deep sea coral and sponge datasets includes inventories of existing data sets, lists of data sources, research on how similar datasets have been used by other marine spatial planners, and data gaps. This information is a summary of knowledge for seabirds and deep sea corals and sponge surveys, and is intended to be used by marine planners to assess available data, and resource managers and researchers to prioritize future research that will support marine planning. The evaluation does not identify or evaluate occupancy or abundance patterns, but the information contained herein will improve these analyses. Other data sets were identified by the Washington Department of Ecology and the State Ocean Caucus as priorities as well, but were not part of this evaluation due to time constraints of this project.

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Contents

About this report 2
1.0 Introduction 4
2.0 A Spatial Prioritization Process for Seafloor Mapping 5
2.1 Data Viewer for Washington Outer Coast 5
2.2 Mapping Technologies to Support Seafloor Mapping Products 9
2.3 Blueprint for Spatial Prioritization: An Exercise and Tool 13
2.3.1 Adaptations and Improvements to the Spatial Prioritization Exercise and Tool 17
2.3.2 Defining the Way Forward 19
3.0 Evaluation of Key Ecological Surveys 22
3.1 Seabirds 22
3.1.1 Available seabird surveys 23
3.1.2 Evaluation 24
3.1.3 Summary and Future Directions 29
3.2 Deep Sea Corals and Sponges 31
3.2.1 Available Deep Sea Coral and Sponge Surveys 33
3.2.2 Deep Sea Coral Predictive Model 34
3.2.3 Evaluation 34
3.2.4 Summary and Future Directions 35
4.0 Appendices 35

1.0 Introduction

Washington depends on a healthy coastal and marine ecosystem to maintain a thriving economy and vibrant communities. These ecosystems support critical habitats for wildlife and a growing number of often competing ocean activities, such as fishing, transportation, aquaculture, recreation, and energy production. Planners, policy makers and resource managers are being challenged to sustainably balance ocean uses, and environmental conservation in a finite space and with limited information. This balancing act can be supported by spatial planning.

Marine spatial planning (MSP) is a planning process that enables integrated, forward looking, and consistent decision making on the human uses of the oceans and coasts. It can improve marine resource management by planning for human uses in locations that reduce conflict, increase certainty, and support a balance among social, economic, and ecological benefits we receive from ocean resources.

In March 2010, the Washington state legislature enacted a marine spatial planning law (RCW §43.372) to address resource use conflicts in Washington waters. In 2011, a report to the legislature and a workshop on human use data provided guidance for the marine spatial planning process. The report outlines a set of recommendations for the State to effectively undertake marine spatial planning and this work plan will support some of these recommendations, such as: federal integration, regional coordination, developing mechanisms to integrate scientific and technical expertise, developing data standards, and accessing and sharing spatial data.

In 2012 the Governor amended the existing law to focus funding on mapping and ecosystem assessments for Washington’s Pacific coast and the legislature provided $2.1 million in funds to begin marine spatial planning off Washington’s coast. The funds are appropriated through the Washington Department of Natural Resources Marine Resources Stewardship Account with coordination among the State Ocean Caucus, the four Coastal Treaty Tribes, four coastal Marine Resource Committees and the newly formed stakeholder body, the Washington Coastal Marine Advisory Council.

2.0 A Spatial Prioritization Process for Seafloor Mapping

The following section provides a blueprint for conducting a spatial prioritization of future seafloor mapping activities along the outer coast of Washington. Many of the concepts presented here are based on NOAA's experience conducting similar exercises, either formally or informally, with other coastal States and Territories. Additionally, several non-NOAA groups have conducted spatial prioritization efforts for Coastal Marine Spatial Planning such as California, Massachusetts, and Rhode Island. The approach presented is an evolution of these previous efforts that incorporates technical and procedural enhancements to improve the process. The blueprint is a guidance document intended to provide a better understanding of the steps involved in planning seafloor mapping activities. However, the explicit details and approach requires additional customization to cater to the unique situation, constraints, or concerns of Washington State. A conceptual model of the process is shown in Figure 1.

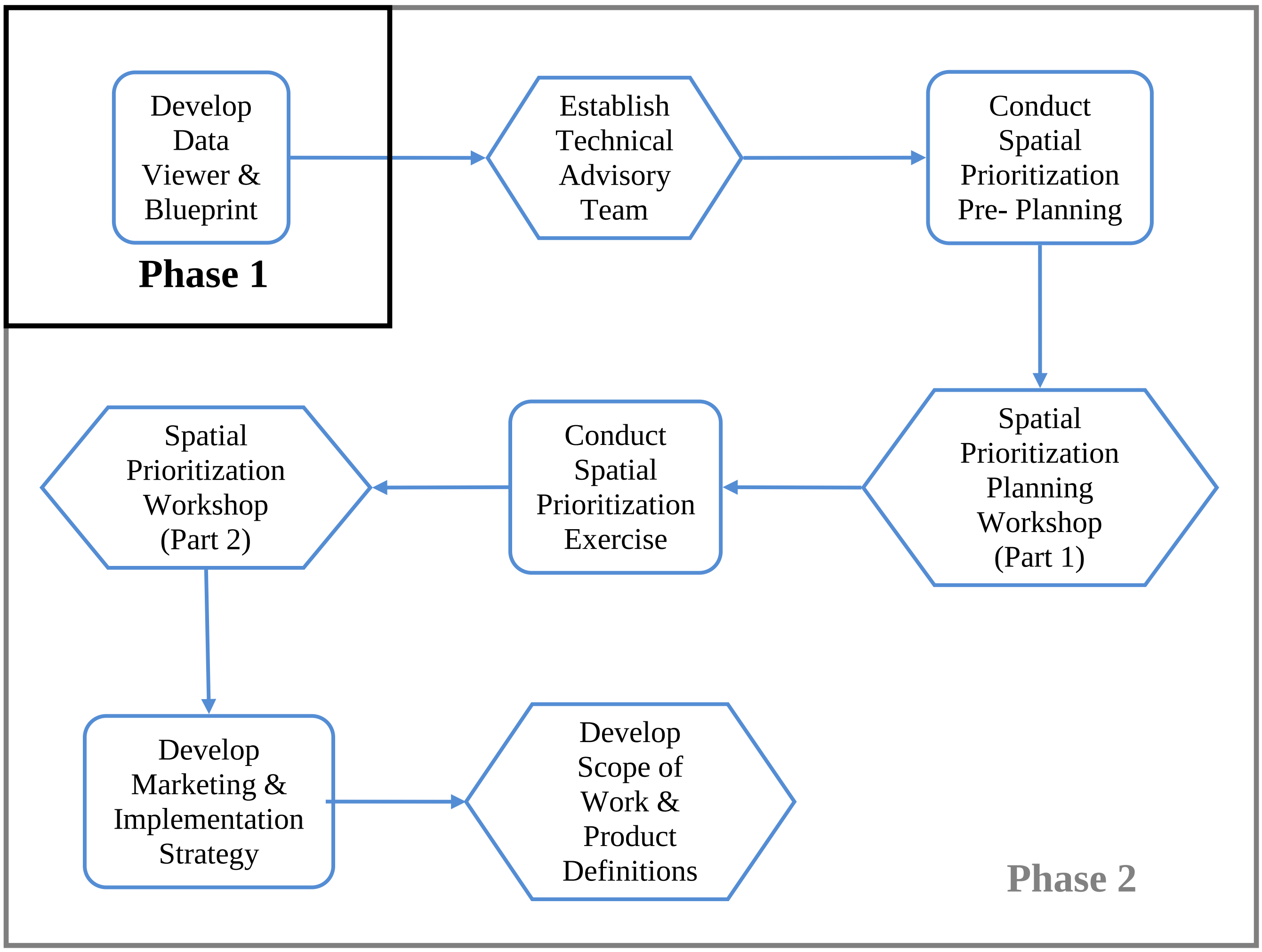

Figure 1: Conceptual steps to spatially prioritize seafloor mapping activities.

2.1 Data Viewer for Washington Outer Coast

During Phase 1, the Biogeography Branch was tasked with developing a data viewer of seafloor mapping information and posting results to an ArcGIS web-based server. The data viewer focused on compiling information within the Area of Interest (AOI) (Figure 2). With guidance from the Washington Departments of Natural Resources (WADNR) and Ecology (WADEC), the AOI was spatially defined and constructed. The AOI boundary is defined by the extents of: the coastal shoreline (NOAA Merged Shoreline 2007), the northern boundary of the Olympic Coast National Marine Sanctuary (NOAA OCNMS), 400 fathom isobath (NOAA Coastal Relief Model 2006), U.S. Maritime Limits Boundary (NOAA Office of Coast Survey), Federal Outer Continental Shelf Administrative Boundary (Marine Cadastre Viewer) and Washington/Oregon state boundary (WA DEC).

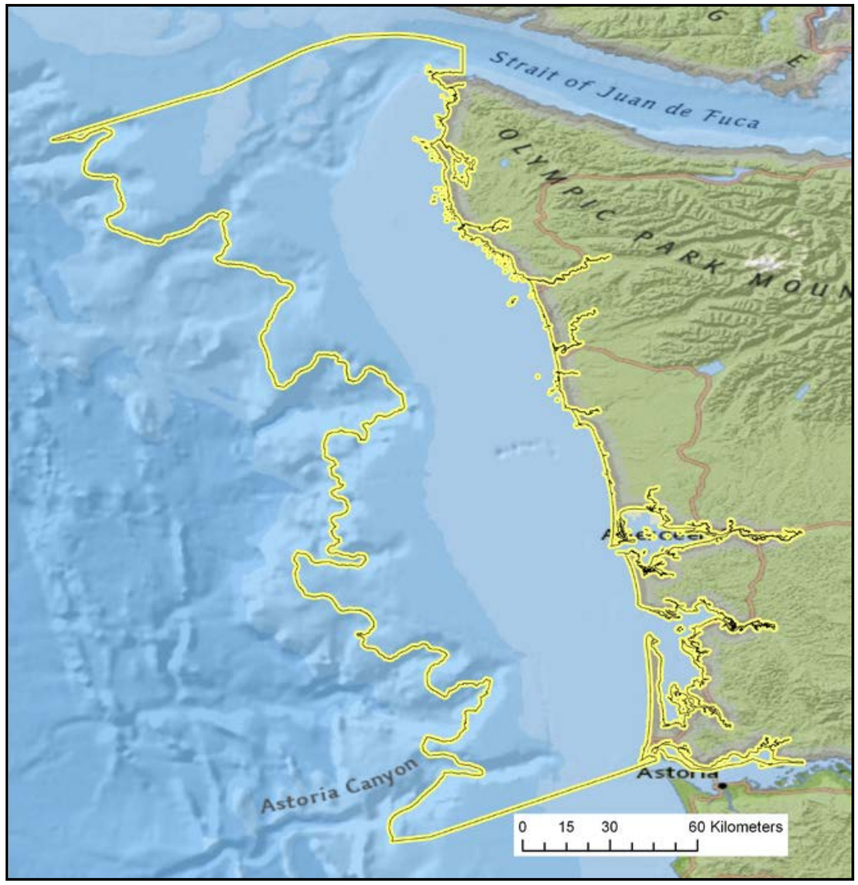

Figure 2: Area of Interest for Washington Seafloor Mapping Spatial Prioritization Exercise**.**

The data viewer was compiled by querying authoritative data center sites (e.g. National Geophysical Data Center (NGDC), Rolling Deck to Repository), directed requests to several key data holders, and assimilating all the compiled information into a standardized database. Information was gathered from the following key data holders: NOAA Office of Coast Survey, NOAA Coastal Services Center, NOAA OCNMS, NOAA NGDC, US Army Corps of Engineers, Oregon State University, WADNR and WADEC, and several smaller groups. The data records within the viewer were organized by the extent or boundary of individual surveys, and results clipped to the edge of the AOI. A host of seafloor mapping data was included in the data viewer primarily focused on gathering information on three different categories of data: source mapping data, groundtruthing data, and derived benthic habitat map products.

As outlined in the NOAA statement of work, we envision spatial prioritization for Washington in two phases. Phase 1 includes the compilation of existing seafloor information within the AOI into a web-based data viewer that allows users to assess the information, and compendium report that provides a framework for user assessments. This report and the associated data viewer represent the first phase of the process. The information compiled in Phase 1 will support Phase 2 activities in which future seafloor mapping priorities would be identified. The challenge of the Phase 1 exercise was identify and aggregate a range of data types acquired along the coast of Washington by disparate groups. To improve the consistency of display and querying, the feature information collected from various sources were translated into standardized attributes and categories. Additionally, the data was reviewed and a qualitative assessment conducted to provide an indication of data quality and data age

The Washington Spatial Prioritization Data Viewer (Figure 3) can be accessed here:
http://ccma.nos.noaa.gov/explorer/msp/wsp/wsp.html

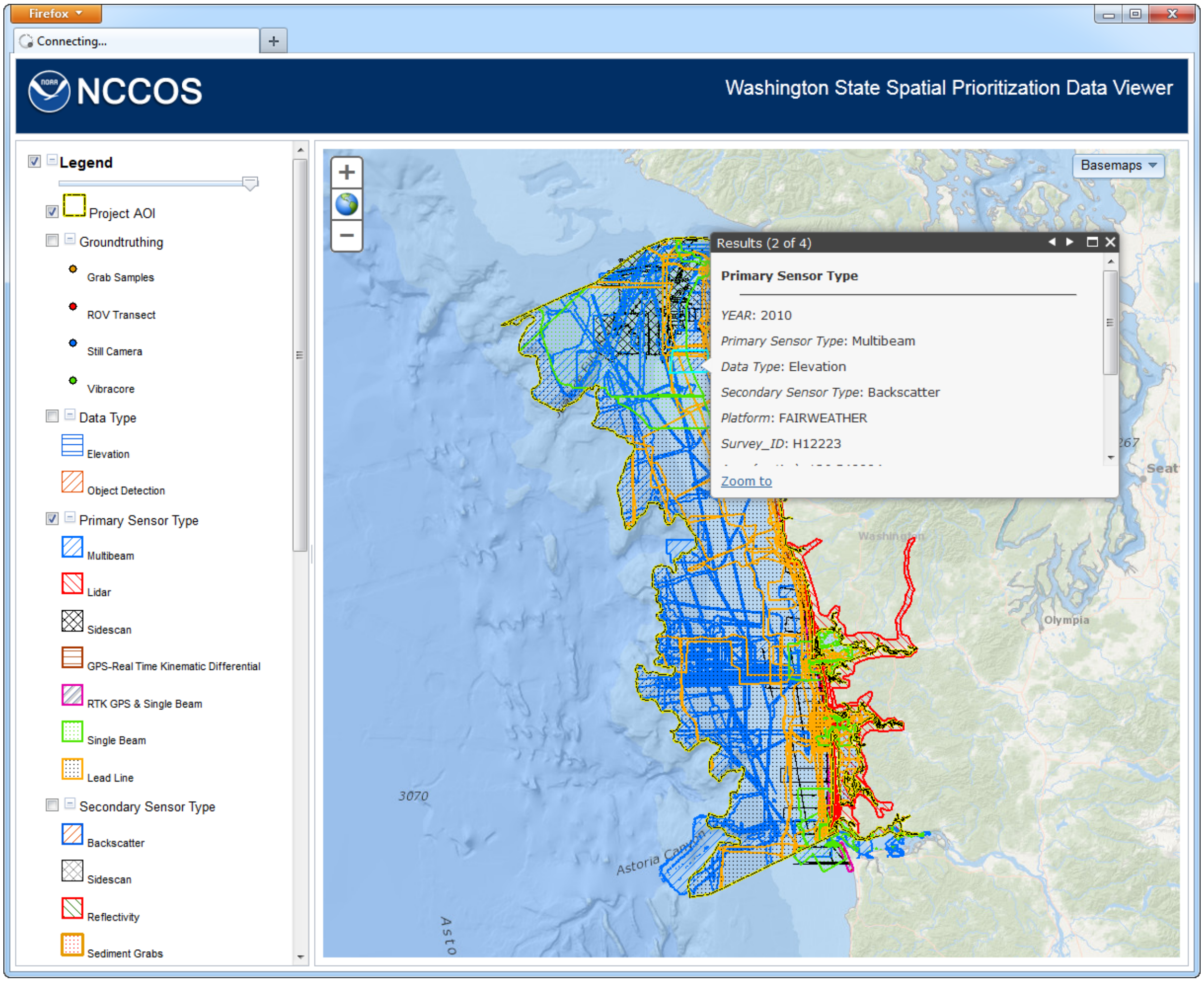

Figure 3: Washington State Spatial Prioritization Data Viewer

The data viewer displays a variety of categories which detail the types of seafloor mapping data that has been collected within the AOI. This includes:

1. *Data Type*: Displays the type of data collected including topographic or bathymetric elevation, and seafloor feature object detection (e.g. sidescan).

2. *Primary Sensor Type*: This indicates the type of technology used for collection which provides an indication of spatial coverage within a survey area (e.g. multibeam echosounder (MBES) versus single beam echosounder (VBES)).

3. *Secondary Sensor Type*: In the event that multiple sensors were deployed simultaneously during a survey, this provides an indication of coincident data available.

4. *Elevation Quality*: (High, Medium, Low, None, and Unknown) A qualitative assessment of elevation data quality based on sensor type, acquisition or processing artifacts, and density of spatial coverage. Surveys where elevation data was not collected are coded as “None”, and surveys where no elevation data was available to evaluate are coded as “Unknown”.

5. *Intensity Quality*: (High, Medium, Low, None, and Unknown) A qualitative assessment of intensity (i.e. multibeam backscatter, LiDAR (Light Detection and Ranging)), reflectivity, or sidescan intensity) data quality based on usability to discern seafloor habitat types, acquisition or processing artifacts, density of spatial coverage, and degree of processing. Surveys where intensity data was not collected are coded as "None", and surveys where no intensity data was available to evaluate are coded as "Unknown".

6. *Data Time Period*: Three time periods are displayed (2013-2003, 2002-1992, and earlier than1992). More recent data collections are generally of better data quality given improvements in spatial positioning, resolution, and sensor quality. In addition, older datasets may not reflect the current condition of seafloor habitats in locations altered by disturbances.

7. *Groundtruthing*: This indicates the locations and types of groundtruthing that has been conducted within the AOI.

8. Habitat Map Product: Displays locations where benthic habitat maps have or have not been produced using survey data.

2.2 Mapping Technologies to Support Seafloor Mapping Products

Sensors technologies used to "map" the seafloor have been exhaustively covered in other publications and an abbreviated description is provided here. For more detail about this topic, please see: Andrews 2003a; Andrews 2003b; OzCoasts; and ICES 2007.

A variety of sensor types can be employed to conduct seafloor mapping of coastal and marine environment. The optimum sensor for a project largely depends upon the spatial scale of the feature of interest (e.g. sediment grain size, biological cover, geomorphology, seafloor topology, and cultural resources), water depth, and continuity of data coverage needed (Figure 4). Sensor types are generally grouped into three categories: 1) optical, 2) acoustic, and 3) physical sampling. Optical sensors can include airborne LiDAR or photography, as well as in situ devices such as Remotely Operated Vehicles (ROV) or Autonomously Operated Vehicles (AUV) with video or still camera imaging. The ability of airborne optical systems to map an area is generally limited by the depth to which light can penetrate the water column. This depth limit can be quite variable in coastal systems (and depending on the seasons) where clouds, rain, turbidity, wave action, ice, kelp beds or other environmental or biological factors may influence the signal. LiDAR systems can simultaneously measure elevation (seafloor bathymetry and land elevations) as well as "reflectivity". Reflectivity (also known as backscatter and intensity) is a measure of the secondary signal return from the sensor, providing a measure of surficial feature roughness and hardness. See references above for more detail.

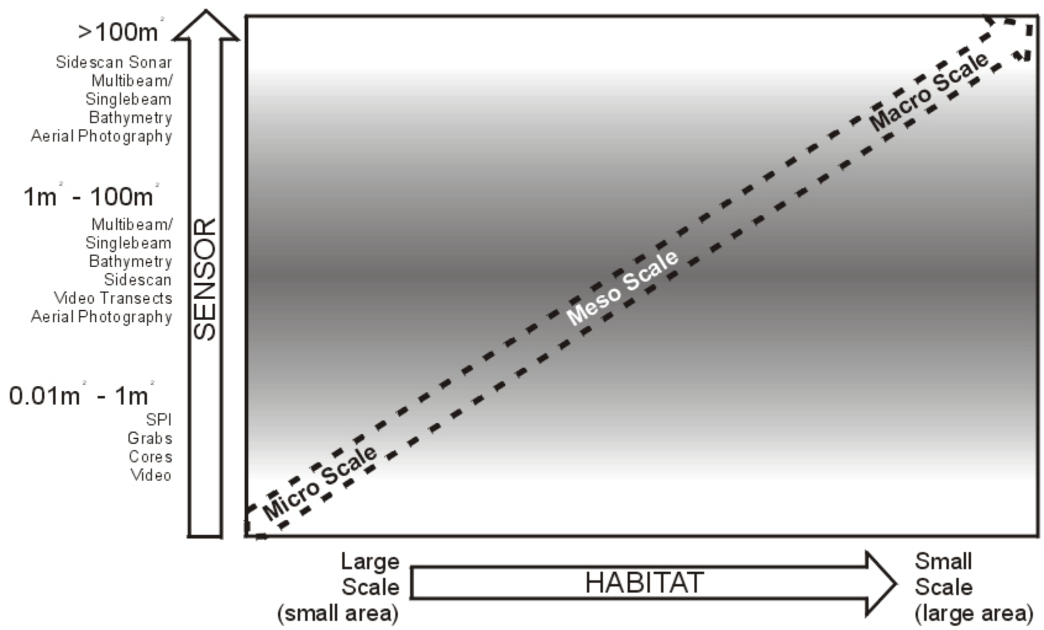

Figure 4: Relative scale of sensors and analysis for seafloor mapping (Andrews 2003a).

Acoustic systems can be useful for imaging the seafloor and underlying sediments. Acoustics systems can be employed in any navigable depth, but become increasingly less efficient at shallower depths as swath width decreases as a function of distance from the seafloor. Vertical beam echosounders provide discontinuous coverage of the seafloor with "single" soundings conducted frequently in transects. Swath systems such as multibeam echosounders and sidescan sonar can provide more continuous coverage of the seafloor. Multibeam systems can provide coincident bathymetry and backscatter. Most sidescan systems provide only backscatter, but some interferometric systems also provide both. Vertical beam echosounders typically only provide depth. Additionally low frequency acoustic systems (e.g. sub-bottom and streamers) are utilized to penetrate the surficial sediments to ensonify the composition of surface to subsurface sediment layers to bedrock. Physical sampling of the seafloor is usually conducted at discrete locations to provide fine scale "groundtruthing" characterizations at a given location. Common techniques employed, include a sediment profiling system, sediment grabs, sediment cores, or high resolution still photography.

While the capabilities of these technologies are well understood by the scientists that use them, resource managers are often uncertain about how these datasets can be used to inform decision-making. Improving the discourse and mutual understanding between survey scientist (data collector) and resource manager (end product user) is challenging given differences in expertise, absence of prior collaborations, and non-concordant objectives. Choosing the appropriate technology to fit a given management application is a relatively straightforward, but only **IF** the intent of the management or regulatory application is understood. There are several factors which may determine the success of a survey collection effort: depth of water, resolution of data needed, types of features needed to be mapped (e.g. number of habitat classes, spatial scale of habitat classes), environmental conditions of collection area (e.g. sea state, water clarity, cloud cover, hazards to navigation). The typical initial conversation between the survey scientist and the resource manager predictably occurs like this:

> Survey Scientist: “What do you need mapped?”
> Resource Manager: “Well what can you map?”

In the absence of explicit product requirements (i.e. NOAA Hydrographic Standards), the two parties need to work together to better understand the best technology(s) suitable for a particular application, as well as the constraints and challenges. The survey scientist can facilitate the discussion by providing examples of prior mapping products, and explicit details of cost, time to produce, available sensors, and other impediments. Likewise, the resource manager should thoroughly evaluate the information needed to support management decisions and be able to describe what types of information are needed, accuracy of the map needed (spatially and contextually), and their capability to use spatial analytical products (e.g. GIS data, data at different levels of processing). It must be recognized that it is unlikely that one map product type (e.g. grain size, sediment texture, biological cover, and geomorphology) will be sufficient to capture the suite of informational needs of all users for the entire coastal environment. Thus, agreement will be necessary to capture the specific map product needs for different locales such as coastal embayments, MPA’s, riverine systems, canyons, deep shelf communities, and so on.

Generally, the end-user (e.g. resource manager) rarely uses the raw source data to support their decisions. Rather, they rely on derived maps which summarize information and are organized in such a way to be interpreted by end users. Understanding how the map products will be used and the detail of information needed (i.e., its thematic and spatial detail, its required accuracy, and how it will be utilized) is key when developing a data collection plan. This concept is demonstrated in Figure 5 which shows depth surfaces for the same geographic area at various spatial resolutions (1, 2, 5 and 25 sq. feet) (*Spatial resolution is defined as the size of any given pixel in the resulting image*). In this example, depth data collected at resolutions > 5ft^2 will be insufficient if a manager is interested in understanding the distribution of sand wave features. Furthermore, a derived benthic habitat map based on data at resolutions > 5ft^2 would likely misclassify sand waves, as they are undetectable in the source data. This constraint would also limit the utility of existing survey data to meet this explicit management need if the data resolution is insufficient to detect features of importance. New survey collects can be optimized to meet resolution requirements of end users if they are incorporated in advance of a data collection.

This issue of sampling scale can also of concern when conducting physical sampling. Careful attention must be paid to the spatial extent, density and number of replicates of data to ensure features of interest can be detected and verified during groundtruthing. For instance, seafloor feature types (e.g. boulder field) can vary considerably in size, patchiness, and distribution. A single replicate may not provide sufficient information to make an informed determination about the presence of the feature type or could misinform the results.

Concluding Points:

- Most managers require digital maps to support coastal planning.
- Providing useful maps requires explicit definition of what content maps should contain.
- Survey scientists and resource managers need to work cooperatively to define map product content and survey collection capabilities before surveys are conducted.
- Survey collection and maps can be customized to meet regional/place-based needs.
- Existing survey data may not be able to meet map product needs required by current or future coastal planning.
- Future survey collections should be planned to meet current coastal planning map product needs and consider future requirements.

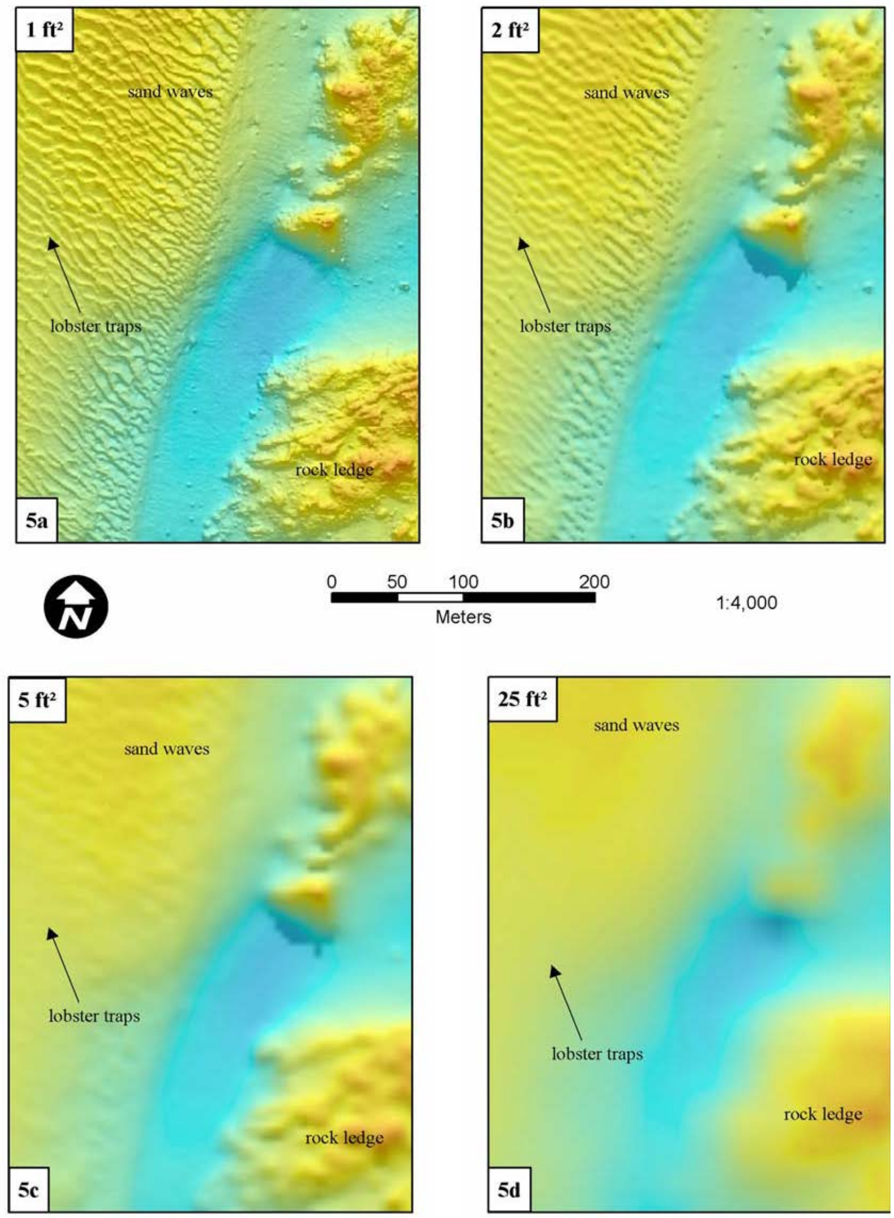

Figure 5: Multibeam data showing effect of data resolution on visualizing seafloor habitat at different spatial scales (Andrews 2003a).

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2.3 Blueprint for Spatial Prioritization: An Exercise and Tool

The blueprint provides a roadmap that describes decision points, steps, their timelines, and expected outcomes necessary to conduct a spatially prioritize seafloor mapping for the outer coast of Washington. The approach presented provides an approach to capture the spatial and thematic management needs of Washington so that future investments are made where they are most needed, map products are produced to meet the identified needs, and priorities can be used for budget planning exercises and leveraging additional resources.

In order to be successful, the steps in the spatial prioritizations exercise need to be sequentially nested such that subsequent steps are focused by results of the preceding steps (Figure 1). Many aspects of the spatial prioritization have to be determined a team of regional experts. The experts include two different steering and participatory bodies: Technical Advisory Team and stakeholder Participants. The Technical Advisory Team would be comprised of 3-5 individuals who have an important role in customizing the spatial prioritization process design, components, and participants to overcome spatial, jurisdictional, and informational challenges unique to the region. The Participants group is a larger stakeholder body that includes individuals involved in conducting seafloor mapping and managers who be the beneficiaries of seafloor mapping products.

Several critical aspects of the seafloor mapping spatial prioritization exercise that will require collective consensus include:

- Defining Interim and Final outcomes of the spatial prioritization.
- Defining phases and timelines for the spatial prioritization.
- The content to be input by participants, technical approach, and perceived biases.
- What groups will participate in phases of the exercise and identify explicit points of contact for each group.

<u>*LIS Spatial Prioritization Case Model*</u>
A seafloor mapping spatial prioritization exercise was recently conducted in Long Island Sound (LIS) with success and is proposed as viable approach in Washington. Modifications and improvements can be incorporated into the Washington approach as necessary. These steps are graphically depicted in Figure 1.

1. Establish Technical Advisory Team and Spatial Prioritization Pre-Planning: (2 months)
   Technical Advisory Team Tasks:
   - Descriptions of Interim and Final outcomes developed.
   - Descriptions of exercise Phases and draft timelines developed.
   - Planning workshop Agencies and Participants identified.
   - Approach for collecting participant input discussed.
   - Tasks assignments made for next steps.
   - Agenda, presentations, read-ahead materials, and logistics for workshop developed.
   - Prepare data viewer of existing seafloor mapping information
   - Invitations for Planning Workshop sent out.

2. Spatial Prioritization Planning Workshop Part 1: (3 months)
   Technical Advisory Team and Participant Tasks:
   - Presentations from selected managers on seafloor mapping product needs.
   - Presentations from Technical Experts on seafloor mapping technical approaches, product types, challenges, and considerations.

- Discussion on the proposed approach (i.e. Spatial Prioritization outcomes and objectives; timelines and phases; and next steps).
- Presentation on the proposed Spatial Prioritization Exercise approach and Data Viewer.
- Breakout exercises with managers to refine Exercise questionnaire and capture details on products needed to support marine planning.
- Agency representatives selected to conduct the spatial prioritization exercise.
- Compile Workshop findings and action items in report.

3. Conduct Spatial Prioritization Exercise (2 months)
   Technical Advisory Team Tasks:
   - Spatial Prioritization memo sent to participants that were selected to represent and consolidate input for their respective agency.
   - Key Components of Exercise include:
     A. Web-based data viewer which compiles existing seafloor mapping information and spatial grid for organizing input (Figure 6). http://ccma.nos.noaa.gov/explorer/msp/lis/msp_lis.html

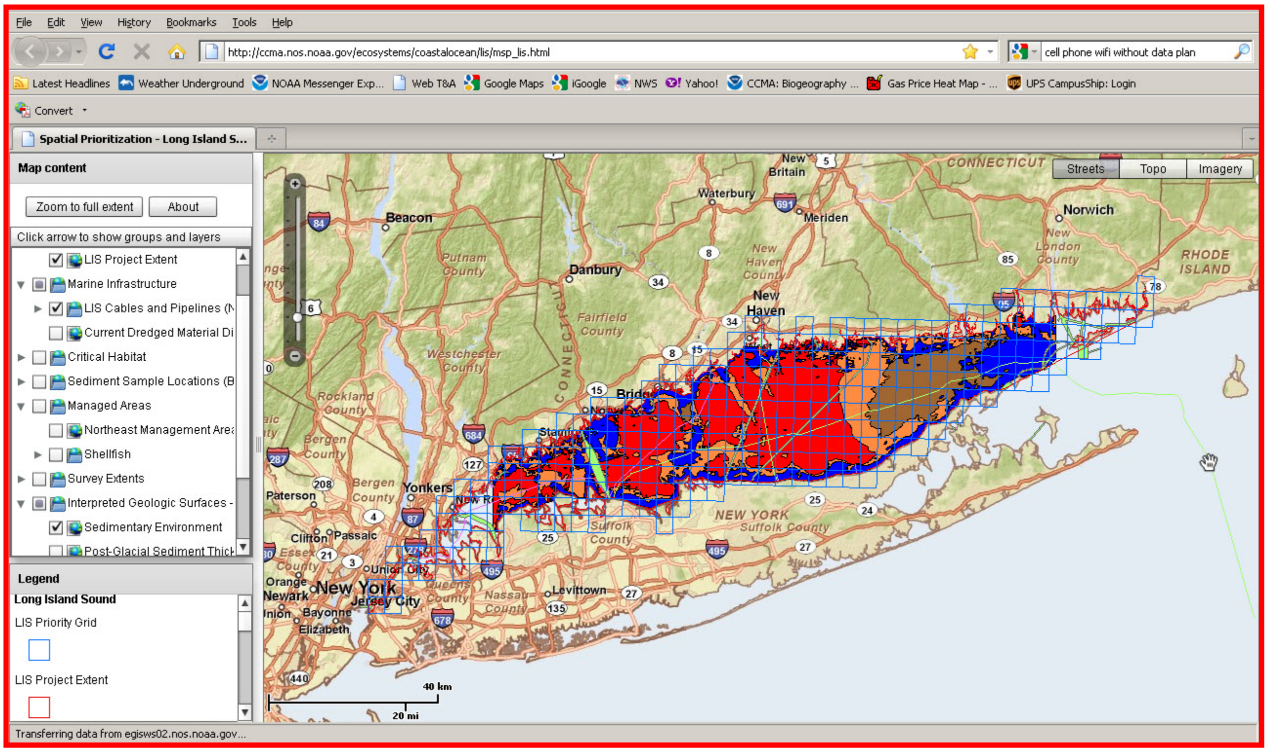


Figure 6: LIS web-based spatial prioritization data viewer.

B. Input Form (Figure 7)

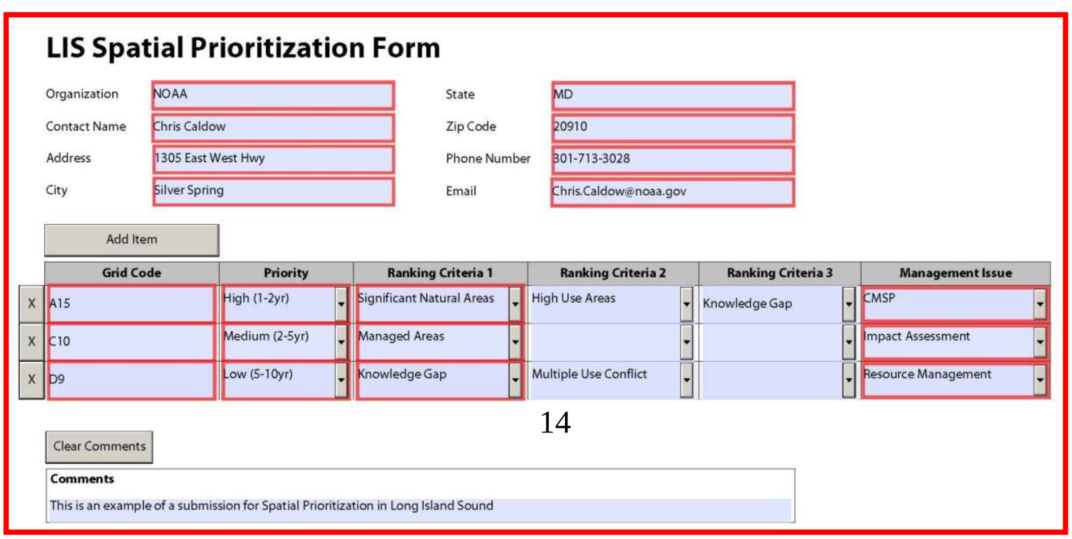


Figure 7: LIS spatial prioritization exercise input form.

- Each participant completes prioritization form (Figure 8). Grid cell information is completed to capture: 1) priority (high – within 1-2 years, medium – 2-5 years, and low – 5-10 years); the general management issue driving the need for seafloor mapping information; and the ranking criteria(s) identifying the explicit need for seafloor mapping information.
- Input is submitted to the Technical Advisory Team for further spatial and thematic analysis.

4. Spatial Prioritization Workshop Part 2 (2 months)
Technical Advisory Team and Participant Tasks:
- Workshop participants are sent results of spatial prioritization exercise prior to the workshop.
- Exercise results are presented to the group (Figure 8 and 9).

<u>Categorical Findings:</u>

Figure 8: Spatial prioritization categorical results by management issue and ranking criteria.

Spatial Hot Spot Analysis

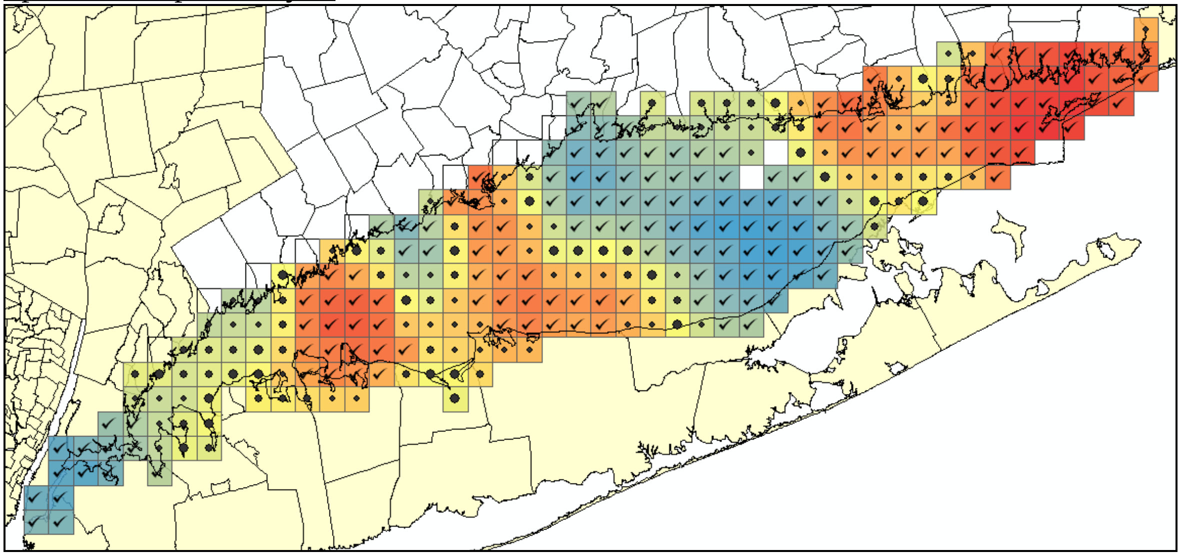
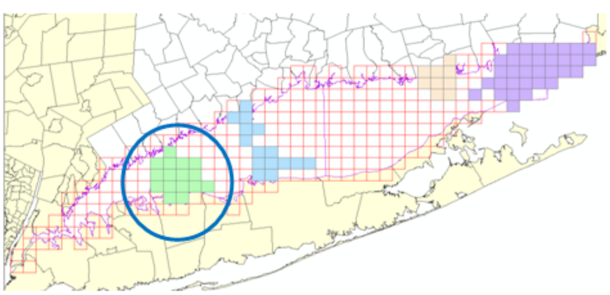


Figure 9: Spatial prioritization spatial analysis results. Z-scores (Colors: Warms = High values, Cool = Low); P-scores (Graphics: 0-20% = Check; rest w/ increasingly larger dots.

- Participants modify and consolidate exercise results to produce consensus.
- For each High priority region, the participants identify the types of products needed to support management needs identified in the survey and further clarify the explicit management needs of each high priority area.
- Strategize on resources and funding to complete seafloor mapping in high priority areas.
- Compile Workshop findings and action items in report including details on the high priority areas identified (Figure 10).

Western LIS Area 1: (~ 89 square miles)



Western LIS Area 1 Summary:

- CMSP, Monitoring/Research Design, & Regulatory are the top three issues in this area (71.4%)
- The predominant criteria across all issues involve knowledge gaps and significant natural areas. Other criteria suggest interest in use and infrastructure.
- Several comments point to the following specific needs/topics (infrastructure alternatives analysis, reefs, high topographic roughness/species, lobster/fisheries resources, scientific interest)

Issue Listed	# Responses	% Responses	Listed Criteria 1 (per results)	Comment / Description	Listed Criteria 2 (per results)	Listed Criteria 3 (per results)
CMSP	29	27.6%	Knowledge Gaps	All NY waters in LIS	Multiple Use Conflict	Potential Infrastructure
Monitoring / Research Design	25	23.8%	Knowledge Gaps	areas of scientific interest; not enough info to subset further DEP Fisheries Trawl data holes. These are areas in which we clearly need more data and/or they are important ecologically and to any CMSP efforts that may emerge.	Significant Natural Area	<none listed>
Regulatory	21	20.0%	Knowledge Gaps	Information needed to support alternative analyses, application review/evaluation relative to large scale energy infrastructure projects (cables, pipelines, etc.)	Potential Infrastructure	Existing Infrastructure
Resource Management	15	14.3%	Significant Natural Area	better, more refined data required to characterize/understand areas in vicinity of reefs/shoals to enhance management options, protective measures. important lobster/fisheries resources stewardship and SCFWH's (Significant coastal fish & wildlife habitats)	High Use Area	Knowledge Gaps
Impact Assessment	14	13.3%	Knowledge Gaps	High TRI values that are spatially rare in LIS and, based on preliminary empirical analyses, represent spatially rare habitats and associated assemblages of species.	Potential Infrastructure	Significant Natural Area
Evaluate Management Success	1	1.0%				
Total	*105*	*100%*				

Figure 10: Spatial prioritization workshop findings for high priority areas.

5. Post-Workshop Activities
   While the spatial prioritization workshop findings will provide ample evidence of what effort needs to be conducted and where, the real challenge is capitalizing on those findings. Key individuals need to be prepared to craft a strategic plan that develops a marketing approach to raise awareness of the spatial prioritization findings so as to develop support in fulfilling the needs identified. A collaborative report that clearly articulates objectives can be a very powerful tool for building support to realize the current and future mapping needs. Developing a funding strategy that identifies approaches to secure state financial support and Federal in-kind or matching will be imperative.

   One key avenue to pursue is engaging Federal programs actively involved in coastal mapping. The U.S. Army Corps of Engineers, National Oceanic and Atmospheric Administration, Bureau of Ocean and Energy Management, and the US Geological Survey either directly perform coastal mapping or directly support groups that do. Concerted outreach to Federal program offices should be actively pursued to make State requirements known as many of these Federal programs plan collection efforts 3-5 years in advance. Identifying principal contacts in each Federal program and advocating State needs on an ongoing basis with these individuals will improve Federal/State collaborative opportunities and project success.

   Outreach to other groups or consortiums that were not actively engaged in the spatial prioritization effort needs to occur. This may include Non-governmental agencies, academic institutions, or constituent groups. Communication and briefings to senior State agency managers, executive and legislative branches to raise awareness of the challenges that have been identified and building support for filling the gaps.

   Additionally, enough supporting information will have been collected to begin developing detailed scope of work and cost estimates. This planning activity will provide a bottom-up requirements document that can be used to solicit cost proposals or contracting opportunities.

2.3.1 Adaptations and Improvements to the Spatial Prioritization Exercise and Tool

While the spatial prioritization exercise implemented in LIS was very successful, there are several technical modifications which would improve its versatility. In addition, the process should incorporate the unique regional complexities of the state of Washington such as geographic challenges, coastal development and economic industries (e.g. fishing, maritime transportation), and jurisdictional management authorities.

Workshop Participants and Technical Advisors
Careful consideration should be given to the groups and individuals that comprise the Workshop participants, as they will help dictate the future priorities for Washington. Governmental entities that have management oversight over the coastal jurisdiction should be participants (i.e. Tribal Nations, State and Federal agencies), but including other non-regulatory groups such as academic institutions or NGO's may also have great benefit. Academic scientists are technical experts in many seafloor mapping technologies and have collected a large percentage of data along the outer coast. NGO advocacy groups are also heavily engaged in marine conservation and planning, and may provide valuable perspective to the process. Including these groups, in at least some part of the process, has the benefit of improving collaborative opportunities and garnering broader support of the outcomes. One option could be to include them as part of the Technical advisory team.

Prioritization Tool
The following are a number of factors requiring guidance from the Technical Advisory Team in order to develop an optimum spatial prioritization approach customized to capture unique needs or situations in Washington.

The tool used for LIS did not allow for data entry via the data viewer, rather the information was collected via Adobe Acrobat form. The results were then consolidated and then imported into a geographic information system (GIS). However, data entry by the participants would be dramatically facilitated if the prioritization tool was entirely integrated into one process. We propose the improvements to the web-based data viewer which will provide functionality that facilitates the selection of grid cell blocks and the input of ranking criteria by participant. The tool would allow the spatial selection of one to many grid cells, with a drop down list of the requested criteria information. Additionally, the tool would provide dynamic updates of previously input information to provide a current status of completion. Explicit access controls would be put in place so that only registered pre-selected individuals are allowed to input updates, but which also allow a user to save the current session so that future updates or revision could be made at a later time.

One additional modification worth considering is limiting the total number of participant input selections, through the use of "tokens". Each participant can be allocated a fixed number of tokens which they can place on the map based on the perceived need for information in a given grid cell. This function allows participants to spread the tokens evenly on grid cells until they are consumed, or stack multiple tokens in a given cell to increase its weighting. The number of tokens available can be dynamically tracked in the tool to provide a current accounting of the number remaining for use. The purpose of the token concept is to force participants to strategically rank the seascape based upon perceived priority. The alternative is to allow participants to score each grid cell. If the later approach is chosen, there may be some benefit to requiring each participant to rank every grid cell in the AOI, thereby forcing the participants to capture the management need and priority of each cell. This condition was not enforced in LIS, and many cells were left unranked. It was assumed in these cases that the cells had very low priority and no management need.

Determining the optimum grid cell size for inputting spatial prioritization data by participants requires some advanced consideration. The grid cells need to be at sufficient size to capture the fine scale granularity of a given location, but not so small that the sheer number of cells overwhelms the participant's ability to complete the task. In the case of LIS, the AOI was 3,341 km^2 in size and a 4x4 km^2 grid cell size was chosen as optimum. This translated to a cell matrix of 308 cells.

The Washington outer coast AOI is 16,659 km^2. Unlike LIS, where the AOI depth range extended from 0 to 80 meters, Washington AOI depths range from 0 to 400 fathoms. One approach would be to analyze seafloor complexity to identify areas of greater relief, and presumably greater habitat complexity. It is assumed that the coast, embayments, river systems, shelf edge, and canyons would be highlighted. A finer resolution cell matrix could be fit to these locales, and large cell matrix fit to the remaining areas.

Potentially there are other factors which could influence the outcome of the spatial prioritization process. One in particular that may be difficult to overcome is the parochial interests of each of the participants. Each of the participants will be requested to query, consolidate and then input the priorities of their respective agency or group. A given agency may have one or more groups that are assigned a participant to represent their priorities. One should assume that the spatial prioritization results of any given group are skewed to reflect their respective jurisdictional authority geography and needs. For example, it is assumed a coastal county would prioritize areas within their County boundaries higher than non-County locations. The same could be said of any other participant group whose jurisdictional oversight does not extend to the extent of the entire AOI. It may be difficult to overcome this bias other than by statistical techniques that normalize for jurisdictional area and adequate representation among different decision makers and stakeholders.

2.3.2 Defining the Way Forward

The results of the Spatial Prioritization process will help identify and guide future efforts. In the case of LIS, the findings were a critical driver for planning logistics, developing collaborations, and formulating a budget to accomplish the objectives.

Developing a Scope of Work and detailed project planning for LIS was instrumental in helping to explicitly define seafloor mapping products and the technical approaches to address the products needed. Examples of these are provided below. Given the level of detail in the LIS Scope of Work, it is not provided in its entirety here, but can be made available upon request. However, the executive summary does provide salient details on the approach.

LIS Scope of Work Executive Summary

EXECUTIVE SUMMARY

The following Scope of Work represents an important milestone to successfully complete Seafloor Mapping of Long Island Sound. A project of this size has many challenges including but not limited to a large geographic project area, a diverse assemblage of collaborators, disparate past and present research activities, limited financial resources, and outcomes that are generally identified, but not explicitly defined. This document serves to provide the preliminary construct to more completely identify, define, organize and guide subsequent efforts.

The scientists from the collaborative consortiums which crafted this document represent a distinguished collection of experts that were able to reach consensus and identify the fundamental requirements needed to address the scientific and management objectives. The recommendations represent a range of activities designed to support the following outcomes identified in the August 2011 Prioritization Workshop:

- Key data sources required:
  - Bathymetry and backscatter
  - Biological and Physical Observational and sampling data
- Key derived products:
  - Geology
  - Benthic Habitats Characterization
  - Topography (e.g. Slope, Rugosity, and other relevant topographic metrics)

However, these components merely provided a broad description of the exact products needed, which the team subsequently further defined in developing this Scope of Work. The finalized list of products recommended to the Steering Committee, and described in detail later in this document, include:

- Acoustic Intensity (Section 6.0) - Acoustic intensity products are able to depict valuable properties about the composition, roughness, and texture of the seafloor to provide meaningful information to managers about the distribution and composition of seafloor habitats.
- Seafloor Topography (Section 7.0) - Seafloor topography products showing bathymetry and terrain relief are able to depict important features and seafloor changes to better explain physical, geological, and ecological processes.
- Benthic Habitat and Ecological Processes (Section 8.0) - Maps depicting seafloor habitats and their ecological communities are critical for many environmental management, conservation, and research activities, and for the growing focus on coastal and marine spatial planning. Such maps depict either

separately or in combination the spatial distribution and extent of benthic habitats classified based on physical, geological, geomorphological, and biological attributes and the benthic communities that reside in the mapped habitats. Additionally, maps can be produced that depict ecological process across the sea floor.

- Sediment Texture and Grain Size Distribution (Section 9.0) - Mud, sand, and gravel dominated areas provide very different habitats and the main grain size often determines many seafloor characteristics. Therefore grain size composition and sediment texture of the seafloor are essential elements of any habitat classification and detailed knowledge of grain size distribution is the basis for many management decisions.
- Sedimentary Environments (Physical) (Section 10.0) - Besides grain size the stability and suitability for different habitats for various species depend on the dominating sedimentary environment characterized by processes such as erosion, deposition, and transportation. Mapping and understanding these processes in detail is important for understanding habitats as well as their potential to change.
- Sedimentary Environments (Chemical Inorganic) (Section 11.0) - Detailed knowledge of sedimentary environments will assist resource managers in better understanding sediment accumulation, long-term contaminant loading and distribution, and age and distribution/stability of various benthic habitats.
- Sedimentary Environments (Chemical Organic) (Section 12.0) - In order to preserve and protect coastal and estuarine environments an understanding of the historic and pre-historic conditions is required to better assess the impact of anthropogenic activities. A scientific documentation of long- and short-term environmental changes will facilitate decision making for conservation and remediation solutions of marine and estuarine resources. Chemical and organic analyses obtained from sediment sampling especially sediment cores can provide quantitative measurements to evaluate changes and the health of ecosystems.

And

- Physical and Chemical Environments (Section 13.0) Products that depict the distributions and variability of environmental characteristics like temperature, salinity, dissolved oxygen and bottom stress are central elements of habitat classification. They are also important to wise regulation and planning for dredging and other engineering activities in the coastal ocean.

In addition to the product sections, the Scope of Work also identifies project Coordination, Management, and Reporting constructs to guide partner interaction and implementation as well as a Data Management component to address the proper storage, organization and data access functions.

At this stage it will be incumbent upon the Steering Committee to provide additional guidance as to the priority and perceived necessity of these elements before progressing to the next phase. Based on this guidance the next steps, Cost and Technical Proposals and Pilot Project commencement, will explicitly define how, when, cost, cross-collaboration, and the level of effort needed to deliver the needed products.

Project Planning

As a compendium to the Scope of Work, detailed planning activities were conducted to design a work flow (Figure 11) so as to coordinate the range of activities needed to provide the seafloor mapping products. The following provides a conceptual task-oriented diagram of the LIS effort.

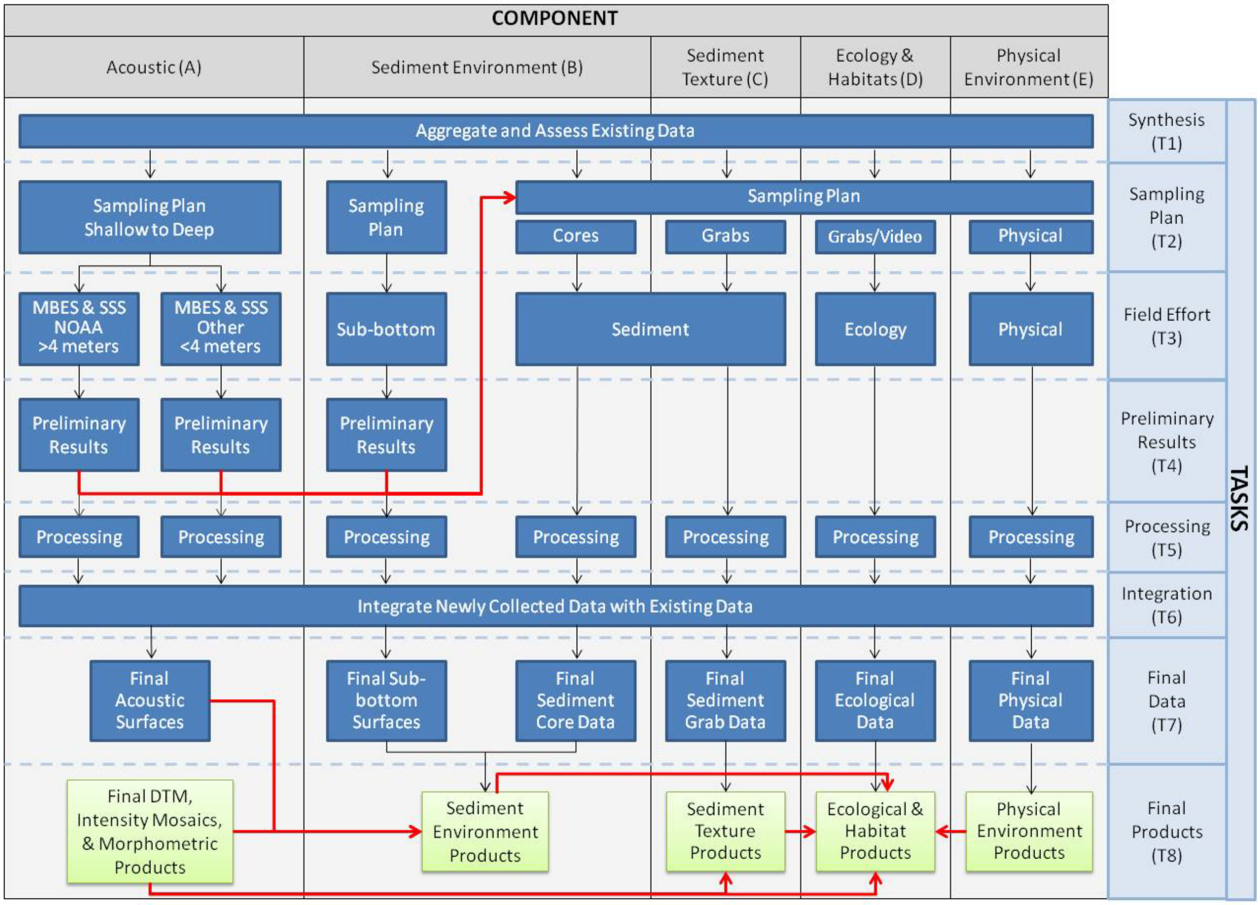


Figure 11: LIS seafloor mapping workflow design.

3.0 Evaluation of Key Ecological Surveys

Seabirds, and deep-sea corals and sponges are impacted, both negatively and positively, by ocean activities, such as fishing, resource extraction, transportation and renewable energy development. A sound understanding of their distribution, abundance, movements, and connections to other ecosystem components is needed to minimize the potential impacts of coastal management decisions and encourage positive interactions.

The study area extends along the outer Pacific coast of Washington from Cape Flattery to the Columbia River and from shore to the 400 fathom isobath. This area was chosen by the Washington Department of Ecology, because it is expected to have the greatest number of potential conflicts among human activities and environmental conservation. This area is the same as the area of interest identified in section 2.1 of this report (Figure 2).

We compiled a list of data sets with information on seabirds, and deep sea corals and sponges within the study area. The collection was made from conversations with coastal resource managers and regional seabird and coral experts, and queries of peer-reviewed journals and grey literature. For deep-sea corals we examined metadata within the NOAA Deep Sea Coral Research and Technology Program database. For each data set we compiled key metadata and mapped the distribution of observations. In some circumstances digital data for the location of data was not readily available, and for these data sets we generated generalized footprints using information contained in methodological narratives or available as maps within publications.

3.1 Seabirds

We operationally define seabirds as all avian species regularly sighted over marine waters. Given this definition, most species in the following taxonomic orders are considered seabirds: Charadriiformes (gulls, terns, auks, phalaropes), Pelecaniformes (gannets, pelicans, and cormorants), and Procellariiformes (shearwaters, fulmars, petrels), but other orders are included as well.

We identified 26 different surveys which collected information on seabirds in the study area and we identified an additional 8 surveys which collected shore-based surveys, including breeding colony surveys, outside of the study area (Appendix A). Surveys are grouped into four categories: pelagic (effort greatest further than 8km from shore), nearshore (effort greatest within 8km from shore), shore-based, and telemetry. The surveys were performed by an assortment of state and federal agencies, academic institutions and non-governmental organizations. The location, timing, duration and methods of data collection varied greatly among surveys. Figure 12 shows the locations of where at-sea data were collected and Appendix A provides basic metadata for each survey, such as which years and months observations were made, the type of sampling design used and which measurements were collected. We did not map shore-based or telemetry surveys and refer the reader to the contact list in Appendix A if spatial information for these surveys is needed.

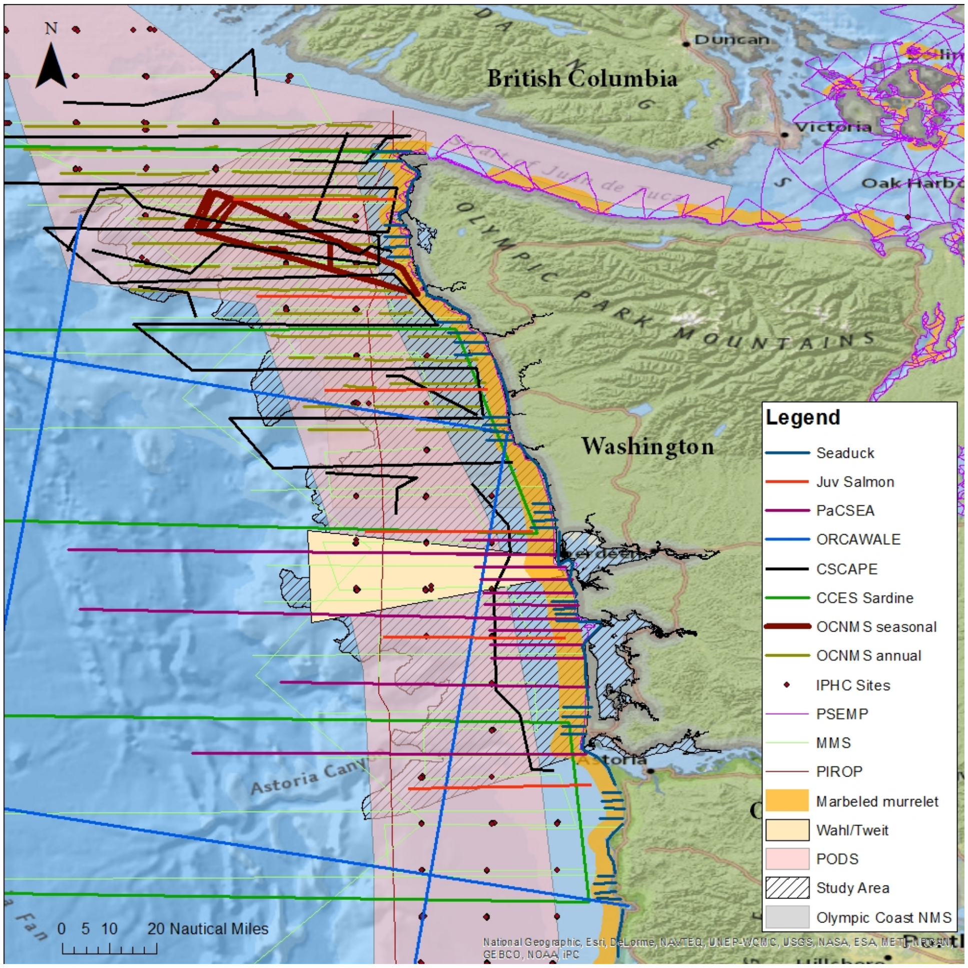


Figure 12: Map of at-sea visual surveys along outer Pacific coast of Washington and the study area.

3.1.1 Available seabird surveys

Twelve pelagic surveys collected or collect seabird observations across very large areas (>5000 square kilometers) to determine coarse-scale offshore patterns of occupancy and abundance, and most extend to the north and/or south of the study area providing regional context. It was common for collections of agencies and organizations to survey together to leverage resources and share costs. Marine mammals, sea turtles and physical variables (e.g. chlorophyll, sea surface temperature) were commonly recorded on these surveys.

Most pelagic surveys collected information over multiple years, although not necessarily consecutively. Their spatial distribution represents a patchwork of effort (see Figure 12) with some areas more heavily surveyed than others, such as in the Olympic Coast National Marine Sanctuary (OCNMS), and some areas surveyed sparsely, such as Astoria Canyon. Visual observations were collected from boats or planes using long nonrandom strip transects, generally running perpendicular to shore or at specific systematically placed point stations. Transects ranged from 25 km to hundreds of kilometers long and were spaced from 5 km to 125 km apart. They were surveyed annually or during several targeted months of the year. In the case of the International Pacific Halibut Commission (IPHC) survey, point stations were regularly spaced approximately 20 km apart and were surveyed annually.

Most nearshore surveys were accomplished with transects that ran parallel to shore along the entire outer coast. These surveys focused effort on species which are generally concentrated closer to shore (e.g. marbled murrelets, seaducks), although for all surveys except one, they collected information on any observed seabirds and marine mammals. The majority of nearshore observations are part of the ongoing multi-agency Marbled murrelet survey (Raphael et al. 2007) which focuses effort from May to July and is conducted annually. It uses a rigorous sampling protocol and is the only survey we found that employs a probabilistic design. The subsample of surveys conducted in the Grays Harbor Focal Area by PaCSEA can also be considered a nearshore survey.

We found seven telemetry surveys which tracked birds along the outer coast of Washington (Appendix A). Unlike the pelagic and nearshore at-sea surveys, the telemetry surveys track individual seabirds over time using data loggers or satellite transmitters. Four studies tracked black-footed albatross (*Phoebastria nigripes*; Fernandez et al 2001, Hyrenbach et al. 2002, Kappes et al. 2010), short-tailed albatross (*p. albatrus*; Suryan et al. 2007) and pink-footed shearwaters (J. Adams, pers. comm.) from individual seabirds caught at the Northwestern Hawaiian Islands, the Aleutian Islands and off of Chile, respectively. Three studies tracked common murres (*Uria aalge*; J. Adams, pers. comm.), double-crested cormorants (*Phalacrocorax auritus*; Courtot 2012) and sooty shearwaters (*Puffinus griseus*; Adams et al. 2012). All telemetry studies except one were conducted from May to October, which is similar to the temporal distribution of at-sea visual surveys.

We searched for shore-based surveys which focused on breeding colonies or mortality at sea and found 8. Both types of surveys have direct connections to the study area. A comprehensive catalog of seabird colonies along the outer coast of Washington was prepared by Steven Speich and Terrence Wahl in 1989. The catalog summarized data collected from multiple investigators from 1792 to 1982 on the location, size, and species composition of colonies for 16 species of seabirds. The report is available online from the National Wetlands Research Center. In 2010, WDFW started the process of updating the catalog, by creating a spatial database of old colonies, entering data on colonies since the catalog was published, and conducting new surveys of seabird colonies. More current information on the WDFW project is on their project webpage.

Extensive monitoring of breeding and behavior exists on offshore islands, such as Tatoosh Island and Destruction Island, and along the outer coast for a selection of species of conservation or management concern. These monitoring studies include observations on tufted puffins, commom murres, cormorants, Leach's and Fork-tailed storm-petrels, Glaucous winged gulls and snowy plovers (J. Parrish, pers. comm., S. Pearson, pers. comm., Parrish 1995, Good 2002, Hamel et al. 2008). Most past and current effort is devoted to observations over land, but a tufted puffin population study on Tatoosh Island monitored counts of birds on the water. The National Wildlife Refuges in and adjacent to the study area support many of these surveys and conduct their own wildlife monitoring on refuge islands (L. Sollmann, pers. comm.).

A comprehensive monitoring program devoted to recording seabird mortality along the outer coast of the study area is organized by the Coastal Observation and Seabird Survey Team (COASST). COASST is a distributed network of citizen scientists (i.e. nonprofessional volunteers) that has collected information on bird mortality along Washington's beaches since 1999. The use of trained citizen scientists allows data to be collected throughout the year although there are fewer records in the winter months and over much greater area than would be possible from professional scientists alone.

3.1.2 Evaluation

Our evaluation is focused on how surveys can be used to identify important areas for seabird nesting, feeding and migration in the study area. These important areas are commonly used by other states to plan ocean activities in ways which mitigate impacts to seabirds (e.g., Rhode Island special Area Management Plan, Massachusetts Ocean Plan, California Marine Life Protections Act Initiative) and were identified as key needs for effective spatial planning during a technical workshop conducted by Washington in 2010 (Hennessey and the State Ocean Caucus 2011). Survey data can also provide a baseline of spatially and temporally explicit occupancy, abundance, habitat-use and mortality that can later be used to assess impacts of new ocean uses.

The abundance and distribution of seabirds at sea largely depends on where they breed and/or feed. Many seabirds use inshore and offshore areas adjacent to nests for feeding, mating, preening and rafting. The distribution of nesting colonies along the outer coast is well documented and information is available for both current and historical distributions through the Washington Department of Fish and Wildlife (WDFW). In Oregon, Suryan et al. (2012) noted that there was less known about crevice/burrow-nesting species, and this gap is likely applicable in Washington as well since surveys are similar. They also noted that it would be prudent to consider both occupied colonies and currently unoccupied habitats in evaluating potential impacts of human activities. Historical distributions can provide information on potential nesting habitats. Species-specific information on foraging distances, such as from the BirdLife Seabird Foraging Database, has been used to predict the distribution of seabirds at sea in relation to nesting sites (RSPB 2012, Lascelles 2008). In addition, tracking studies can identify pathways and link nesting sites to foraging areas, and many of the National Wildlife Refuges (e.g. Flattery Rocks NWR, Copalis NWR, Grays Harbor NWR) were chosen in part to protect seabird nesting sites and adjacent critical habitats (USFWS 2007).

All seabird breeding surveys in the study area are selective in the species, times and/or places they monitor. This selective approach provides a sound understanding of a particular subset of the targeted seabird population in the study area, and greater statistical power to detect changes in abundance, occupancy and timings. Corresponding data are frequently used to provide context for changes observed in larger-scale surveys and can be used to infer changes in the whole population.

Pelagic and nearshore at-sea visual surveys can identify important feeding areas for most species off the coast of Washington at coarse spatial scales. Telemetry data is also available for several species and shows patterns of occupancy at much greater spatial and temporal resolution than at-sea visual surveys.

Visual observations provide a means of measuring seabird populations at sea that are easily designed, low cost and are capable mapping seabird populations across a range of spatial scales. However, these observations can be biased by seabird attraction to ships, bird size, weather and bird behavior. They are also not appropriate to identify or study of nocturnal patterns and behaviors. For instance, small petrels, such as Leach's Storm petrel (which breeds along the Olympic coast), are nocturnal during the breeding season and will likely to be under-represented in visual surveys. Tracking, vocal activity (Mougeot and Bretagnolle, 2000) and radar (Bertram et al. 1999) data can successfully monitor seabirds such as petrels at night.

The spatial distributions and frequency of collections for most pelagic surveys is adequate to assess patterns of occupancy and abundance across coarse spatial and temporal scales, 10 km to 100 km and years to decades, respectively. Better spatial resolution is provided by nearshore surveys such as the Marbled Murrelet survey, the OCNMS seasonal survey and within the Grays Harbor focal area targeted by PaCSEA. The Marbled Murrelet Survey provides observational data for all species, except gulls, within 8 km of shore and covers all state waters.

When all years of surveys are combined, the greatest amount of effort was in the northern of the Olympic Coast National Marine Sanctuary (OCNMS) and offshore of Willapa Bay and Grays Harbor (Figure 12). After 2008, less area was surveyed in OCNMS and relatively more area was surveyed outside of the Sanctuary near Grays Harbor and Wilapa Bay (Figure 13).

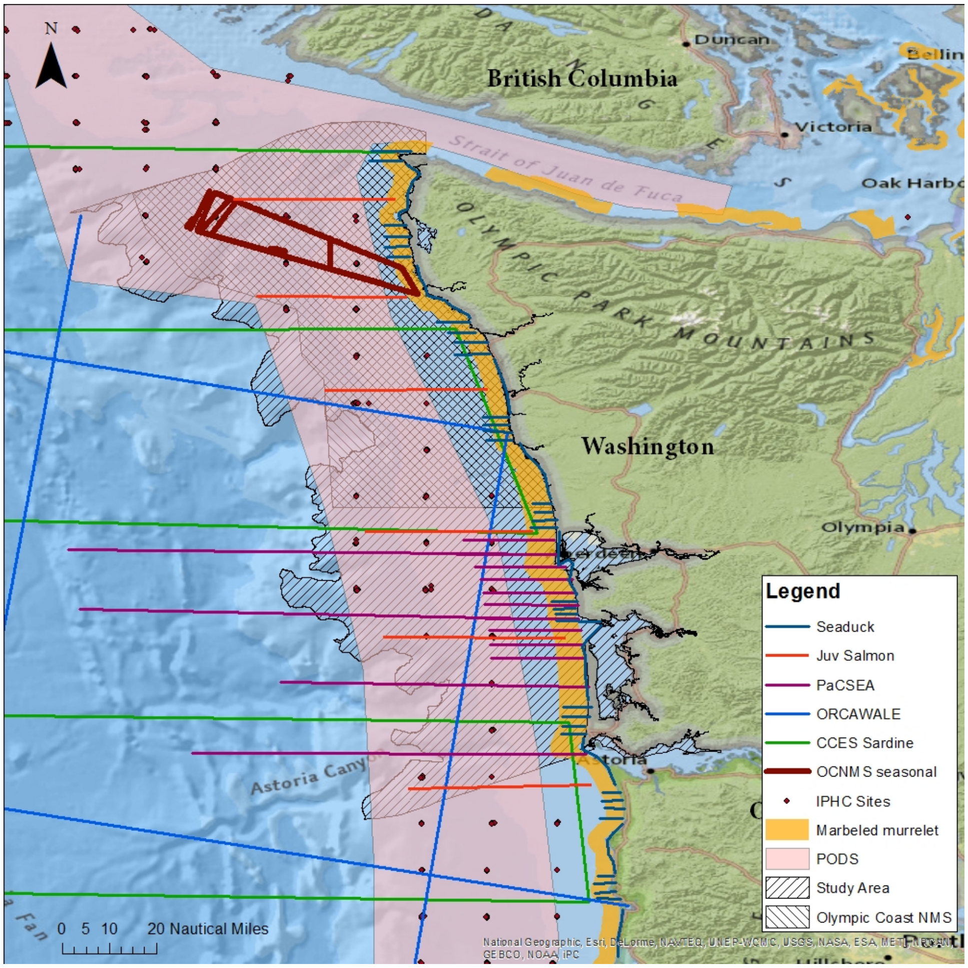


Figure 13: Distribution of seabird surveys in the study from 2008 to 2013.

Marine planning must consider seabird surveys performed throughout the year, because seabird distributions change seasonally. For instance, Suryan et al. (2012) noted in their assessment of Oregon bird data that the threatened Marbled murrelet may disperse more broadly over the continental shelf (Day 2006) and may shift southward during the non-breeding season (Strong 1999; Henkel 2004), and species assemblages may be very different during the non-breeding season when species like Cassin's Auklet, Rhinoceros Auklet, and Northern Fulmars, migrate into the region to feed.

In most areas the majority of at-sea surveys are collected annually during the breeding season because of better weather and many targeted species are more effectively sampled during their breeding season. However, there are a few surveys, such as the NMFS Juvenile Salmon and PaCSEA surveys, that collect consistent at-sea observations several times a year within the study area. These surveys provide information to assess seasonal distributions during the breeding and non-breeding seasons and address the entire study area at coarse spatial scales, with most effort near Grays Harbor (Figure 14). In addition the seaduck survey targets the months of February and March and complements the marbled murrelet survey which is performed during the breeding season. Data collected during the non-breeding season are in jeopardy since, the future of the NMFS juvenile salmon survey is uncertain (J. Zamon, pers. comm.) and the PaCSEA survey will end soon.

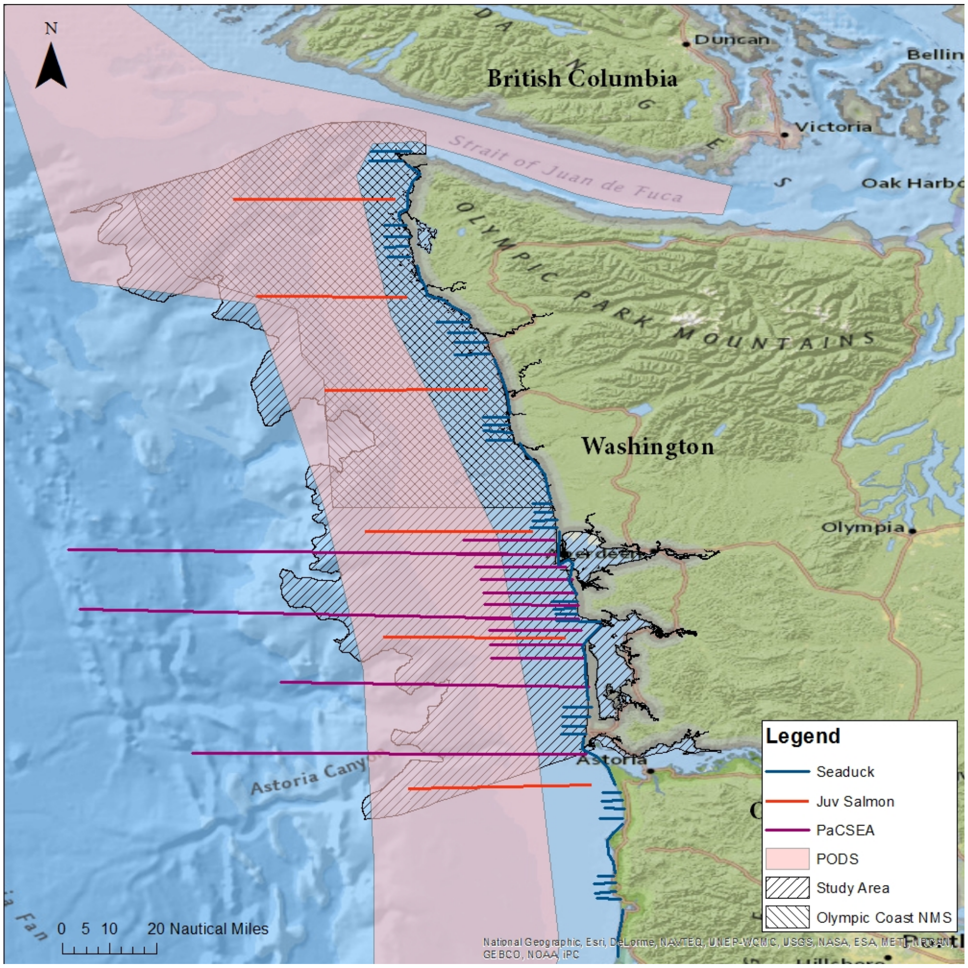


Figure 14: A map of surveys performed in the study area during the non-breeding season.

Persistence and long-term (decadal) averages of occupancy and abundance are commonly used to identify important seabird areas for marine planning. Variability is implicitly incorporated by recommending adaptive management and revision at defined time intervals under the assumption new data will be available and show new patterns. This approach provides a means for integrating long-term seasonal and decadal variance into a marine plan, but does not integrate temporal variance at shorter time scales. Since seabird distributions change at shorter temporal scales (hours to days to weeks) due to variability in weather and prey fields, a particular area may have many birds at one moment and none in another, and consequently may be appropriate for a particular human activity at one moment and not in another. To assess pelagic patterns of occupancy and abundance at spatial scales less than 10 km or at temporal resolutions less than months 1) new finer-scale visual seabird surveys can be acquired, 2) predictive models can be used to predict seabird distributions from remotely sensed biophysical parameters, and 3) telemetry data can be compiled and analyzed to identify patterns in tracked species.

Telemetry offers a relatively new method of identifying important nesting and feeding areas and detecting global migration routes (Burger 2008, BirdLife International 2012). When many birds are tracked, the data can be used to accurately identify persistent hotspots of activity and connectivity among different habitats and managed areas. In addition the loggers limit sampling bias associated with attraction to vessels and can assess patterns between life history and movements. Adams et al. (2012) provide a good example of applying telemetry to identify important distributional patterns of sooty shearwaters off the coast of Washington. Their work identifies at-sea distributions across a large area at spatial and temporal resolutions unattainable by existing visual surveys. We did not find other telemetry surveys that have attempted to compile tracks and identify hotspots for areas within the study area.

Tracking data can also be used to track movements and identify migration corridors, although we did not find any research which explicitly identified and delimited at-sea migration routes off Washington. Many tracks are needed before making inferences from telemetry data to ensure observed patterns are representative of a population and not a selection of individual behaviors (BirdLife International 2009). Further, since some species undergo ontogenetic habitat shifts, a representative sample size for all age classes and seasons is desirable.

Generally individual at-sea surveys have a patchy distribution and are discontinuous in time. The value of at-sea visual surveys can be extended by compiling datasets and/or applying predictive modeling. A growing number of studies use data compiled from multiple surveys to extend the spatial and temporal footprints of inference and to increase the resolution of discernible patterns. In addition, the Royal Society for the Protection of birds recommends compiling data to reduce the weaknesses associated with any specific datasets, such as age, coverage or certainty (RSPB 2012). Cullinan (2001) and Sydeman et al. (unpublished) used information from at-sea and breeding colony surveys, and expert judgment within a non-quantitative framework to identify important bird areas in the Pacific Northwest. These studies present hotspots from records of occurrence and relative abundance for specific species. Sydeman et al. (unpublished) also compiled hotspots for multiple species to identify hotzones. Nur et al. (2011) applied a quantitative approach to compile surveys and identify hotspots on the West Coast. They standardized and merged surveys and used predictive modeling to develop continuous predictions of species occurrence, persistence and biodiversity. Given the discontinuous nature of at-sea surveys, predictive modeling serves as a useful tool to fill in spatial and or temporal gaps and provide objective estimations of uncertainty.

There has been recent interest in compiling datasets to support integrative assessments. The BirdLife managed Global Procellariiform Tracking Database and the Tagging of Pacific Predators (TOPP) database are two large collections of seabird tracking surveys. They serve as a central store for seabird tracking data from around the world and aim to help further seabird conservation work. A future project to be undertaken by the USGS Western Ecological Research Center will compile distinct telemetry studies along the U.S. west coast, including those found during this inventory (J. Adams, pers. comm.). Researchers at the USGS Pacific Science Center compiled numerous pelagic at-sea surveys in the North Pacific Pelagic Seabird Database (NPPSD). Most of the data compiled for Washington in the database was provided by Glen Ford and was originally a dataset compiled for the Mineral Management Service (J. Piatt, pers. comm.). The Ocean Biogeographic Information System Spatial Ecological Analysis of Megavertebrate Populations (OBIS SEAMAP) offers another repository of spatially referenced marine mammal, seabird and sea turtle observations data from across the globe, including Washington.

In addition to identifying important bird areas, seabird surveys provide useful information to monitor seabird populations over time and identify impacts from human activities; both are important aspects of marine planning. Long-term monitoring programs are useful to marine planning because they can show baseline patterns of distribution and abundance before changes to human activities, and to assess any impacts after changes to human activities. They can also assess impacts from decadal oscillations which are thought to alter seabird populations and are informative for forecasts associated with climate change (Sydeman et al. 2013).

COASST surveys dead, beached birds to monitor mortality patterns, causes of death, chronic and catastrophic pollution and seasonal occurrence of seabirds (e.g., Camphuysen and van Franeker 1992). COASST uses citizen scientists and their data are able resolve patterns of seabird mortality and abundance at scales unattainable from professional scientists alone and are also capable of providing real-time information. The IPHC survey provides a complementary dataset to assess impacts of fishing on seabirds at-sea, but data are obtained once a year and at approximately 30 discrete sites in the study area.

3.1.3 Summary and Future Directions

Information on seabirds in the study area has been collected using at-sea visual surveys, seabird tracking and shore-based surveys, and these surveys provide robust datasets showing seabird distributions at coarse spatial resolutions. More work is needed to assess distributions at fine spatial scales in pelagic waters and across different seasons. In the future, gaps in spatial and temporal coverage may increase, since funding for some surveys is uncertain and some surveys are scheduled to end.

Each individual survey is a snapshot of the targeted seabird community and will be constrained by the spatial extent, methods and timing of observations. To assess distributions across the entire study area, assessments which compile multiple surveys are effective. The recent work to compile multiple surveys into a standardized framework, such as those by Nur et al. (2011) and Sydeman et al. (unpublished), and telemetry studies by Adams et al. (2012) will be useful for marine planning, because they offer robust assessments of seabird assemblages and distribution patterns, and provide information at spatial and temporal scales, better than individual surveys alone.

Future research to support marine planning should consider integrating diverse datasets (e.g. at-sea censuses, shore-based censuses, tracking, existing important bird areas) to identify key marine areas for management and conservation purposes, because they can yield complementary perspectives on habitat use and suitability.

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3.2 Deep Sea Corals and Sponges

The National Oceanic and Atmospheric Administration's (NOAA) Deep Sea Coral Research and Technology Program has been conducting an ongoing effort to collect and disseminate available information on the locations of deep sea coral and sponge observations as well as information about their biology and ecology. This multi-year effort has led to the development of a spatial database containing approximately 200,000 records. This database contains approximately 24,000 records of deep sea coral and sponges from the Washington coast.

We identified ten distinct datasets with information on deep sea corals in the study area and within the NOAA Deep Sea Coral Research and Technology Program database (Appendix B). Some of these datasets are individual surveys while others are compilations of many surveys.

Observations from the ten surveys span the entire coast from Astoria canyon adjacent to Oregon to the northerly edge of the US exclusive economic zone abutting Canadian waters (Figure 15). All observations are at least 8 nm from shore and in depths greater than 50 m; consequently there is no information on deep-corals and sponges within state waters, defined by 3 nm from shore. Metadata in the database was minimal and we extracted as much relevant information as possible. For additional information we encourage requests to be sent directly to the data contacts. The Deep Sea Coral National database can be obtained upon request from the Data Manager for the Deep Sea Coral Research and Technology Program (Dan Dorfman, dan.dorfman@noaa.gov)

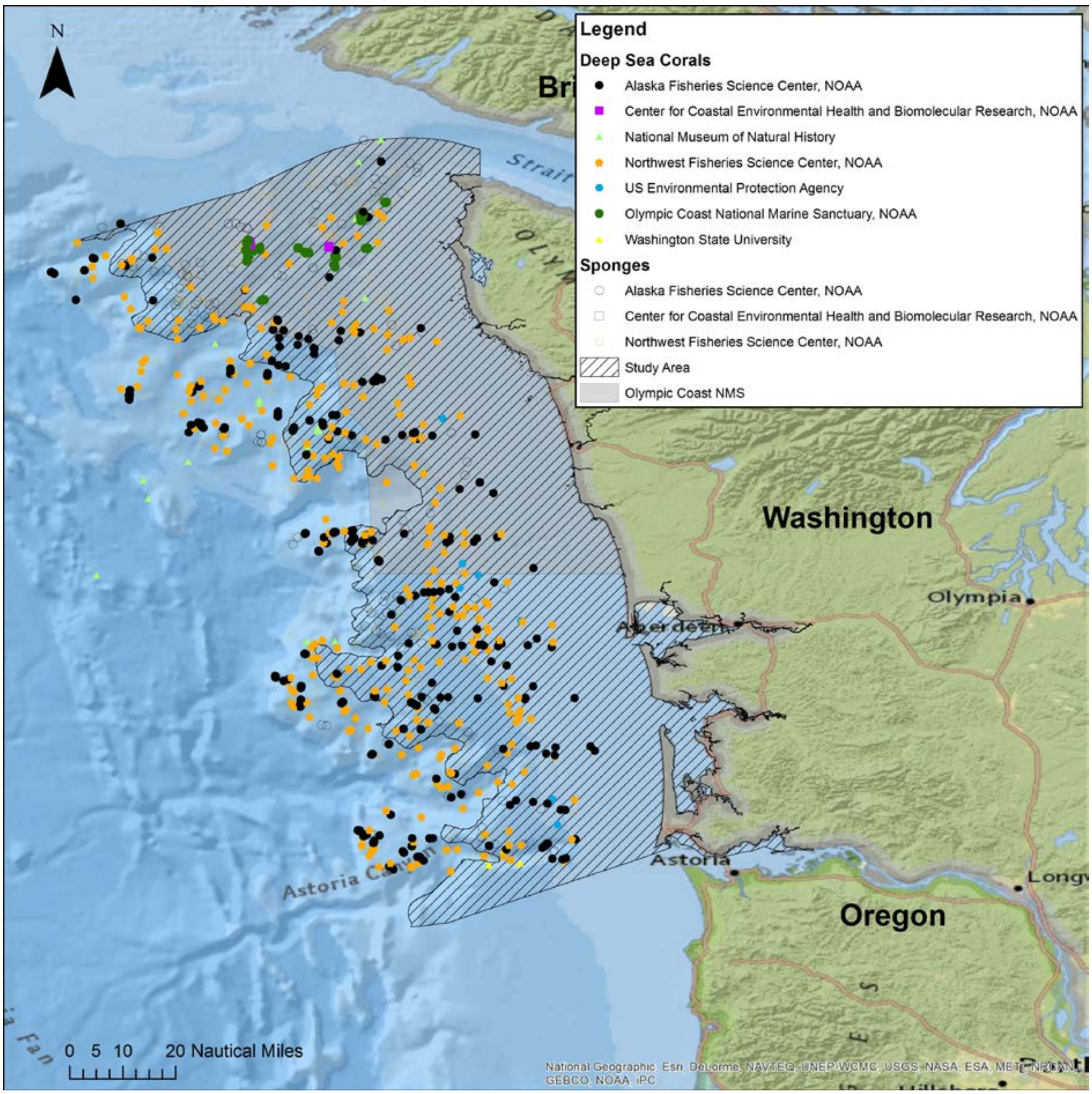

Figure 15: Map showing the distribution of deep sea coral and sponge observations which have already been incorporated into the Deep Sea Coral Research and Technology Program's National Observations Database.

3.2.1 Available Deep Sea Coral and Sponge Surveys

NOAA National Marine Fisheries Service (NMFS) has conducted bottom trawl surveys off the Pacific coast (including Washington) for several decades. From the early 1970's until 2001, the Alaska Fisheries Science Center conducted a triennial survey of demersal fishes on the continental shelf, from Cape Flattery, WA to Point Conception, CA. During that time frame, NMFS also conducted several surveys in addition to the Groundfish Bottom Trawl Survey effort on the continental slope. Invertebrates, including corals and sponges, were recorded, albeit inconsistently, throughout the time period. Starting in 1998, the Northwest Fisheries Science Center took responsibility for bottom trawl surveys off the coast of Washington, Oregon and California. They began with an annual slope (i.e., 100-700 fm) survey of demersal fishes, and extended the survey to the shelf (i.e., 30-100 fm) in 2002. In 2003, the survey was again extended south of Pt. Conception to the Mexican maritime boundary. The purpose of this survey is to provide data for assessment purposes on the distribution and abundance of commercially important west coast groundfish; however, invertebrates are also recorded in the catch. Identification of invertebrates in the catch was intermittent in early years, but has been fairly consistent since 2001. This survey offers the most comprehensive geographic coverage for "trawlable" habitats on the Washington shelf and slope (to 700 fm).

In addition to the fishery independent trawl surveys, NMFS operates an observer program which records by catch on commercial fishing expeditions. Information for coral and sponge observations are expected to be available through this effort, but this information has not yet been incorporated into the Deep Sea Coral Research and Technology Program's National Database. Data from the observer program can be requested from the NOAA Northwest Fisheries Science Center though the following link:
http://www.nwfsc.noaa.gov/research/divisions/fram/observation/data_products/biological_metadata.cfm

In 2003, the US Environmental Protection Agency conducted a benthic grab survey off the Washington coast. The survey is one component of the EPA's Environmental Monitoring and Assessment Program (EMAP). The objective of the EMAP is to monitor the condition of the Nation's ecological resources to evaluate cumulative success of current policies and programs and to identify emerging problems before they become widespread or irreversible. This survey recorded observations of deep sea corals.
Several programs have conducted in situ surveys of benthic habitats off the Washington coast, many of which have noted presence of deep-sea corals and sponges. Some examples are:

- NOAA's Center for Coast Environmental Heal and Biomolecular Research (CCEHBR)
    - Where: Olympic Coast NMS
    - Contact: Peter Etnoyer (peter.etnoyer@noaa.gov)
- NOAA's Olympic Coast National Marine Sanctuary
    - Where: Olympic Coast NMS
    - Contact: Ed Bowlby (Ed.Bowlby@noaa.gov)
- NOAA's Office of Ocean Exploration and Research
    - PI's: Robert Embley (NOAA-PMEL), Waldo Wakefield (NOAA-NMFS), Brian Tissot (WSU Vancouver)
    - Where: Astoria Canyon, 2001
    - Contact: Brian Tissot (tissot@wsu.vancouver.edu)
- Washington Dept. of Fish & Wildlife
    - Where: Various sites
    - Contact: Farron Wallace (wallafrw@dfw.wa.gov)
- Oregon State University and Bureau of Ocean Energy Management
    - Where: Various sites off Oregon and Washington
    - Contact: Sarah Henkel (sarah.henkel@oregonstate.edu)
- NOAA Fisheries, Northwest Fisheries Science Center

    - Where: sponge reef at head of Gray's Canyon
    - Contact: Elizabeth Clarke (elizabeth.clarke@noaa.gov)
- Oceana
    - Where: San Juan Islands
    - Contact: Geoff Shester (GShester@oceana.org)

The Smithsonian's National Museum of Natural History maintains an invertebrate zoology collection which includes deep sea coral observations. The records included in this database come from a wide variety of investigations.

Additional data on deep sea coral and sponges is expected to exist beyond the information identified here. Possible sources include: the Pacific Marine Environmental Laboratory, the University of Washington, Oregon State University and Washington State University, among others. These sources could not be thoroughly investigated within the timeframe available for this project.

3.2.2 Deep Sea Coral Predictive Model

A predictive model of the distribution of deep sea corals off the US west coast has been developed by the Marine Conservation Institute (Guinotte and Davies, 2012). The model predicts where deep sea corals could potentially occur based on physical, chemical, and environmental variables. The model employs a Maxent approach and is developed on a 500m by 500m grid. Individual models were developed for the taxonomic orders Antipatharia and Scleractinia and for suborders Alcyoniina, Calcaxonia, Holaxonia, and Sceraxonia.

3.2.3 Evaluation

Collection dates for the deep sea coral observations date back as far as 1888. Care should be taken to understand the spatial accuracy of older records when evaluating this information. For instance, the location of records prior to 1990 were likely taken from sextant or LORAN readings, both of which have relatively poor positional accuracy compared to current geographic positioning systems.

It should be recognized that coral and sponge distributions are likely greater than shown in the data due to limited surveys and irregular survey effort. Deep sea corals and sponges are widely distributed in the study area and across the Washington coast shelf and slope. However, there are no observations in depths shallower than 50 m and this is likely due to no observation effort at depths shallower than 50 m.

Trawl surveys offer the largest geographic distribution of survey sites. However, it is important to note that these surveys are targeted to avoid areas of high relief and hard substrate in order to minimize gear damage. Instead, these surveys target "trawlable" habitats - areas of silt, sand, mud or low-relief hardbottom. Areas of high reflief and hard substrate are expected to harbor the most significant occurrences of deep sea coral. Surveys which employ ROVs, submersibles or benthic grabs are less frequent in the study area, but are more likely to encounter deep sea corals and sponges on high-relief hardbottom habitat and in many cases target these habitats.

ROV and trawl surveys both represent effective methods for detecting corals and sponges. However, the spatial resolution of ROV surveys is more accurate than trawl surveys, since trawl surveys can be kilometers long and it is not known precisely where corals were caught during a trawl. The information collected represents presence only. Absence of corals during surveys has not been tracked. It is important to note that surveys for deep sea corals and sponges are incomplete and that the database represents the distribution of survey effort and not necessarily the distribution of corals and sponges.

The west coast deep sea coral predictive model likely over predicts the distribution of these corals. This is due to the fact that only coral presence information is available, and the model did not incorporate variables known to limit their distribution (e.g., substrate, current), because they were not available across the entire study region. Sponges are not included in the predictive model.

3.2.4 Summary and Future Directions

Observations and predictions of deep sea corals and sponges in the study area must be used carefully in marine planning, because the absence of a record does not necessarily mean a coral or sponge does not occur. Records generally represent survey effort as much as coral and sponge distribution and available predictions only provide potential habitat and not expected distribution.

Other states have used similar observations and predictions in marine planning because they represent the best available data from which to make decisions. For example, the State of New York has applied the deep sea coral observations database to marine spatial planning by applying the information to direct priority locations for offshore wind farms. Deep sea coral and sponge observations from the NOAA Deep Sea Coral Research and Technology Program database were used alongside other ecological data to help identify significant wildlife areas and identify potential impacts of human activities within designated significant wildlife areas.

The deep sea coral database has also been used to guide marine managed area placement at regional scales. The South Atlantic Fishery Management Council has applied the information in the deep sea coral observations database to support the creation and expansion of a coral habitat area of particular concern off the southern US coast and the deep sea coral observations database is currently being employed as one element of information supporting the west coast essential fish habitat review being conducted by the Pacific Fishery Management Council.

NOAA's Deep Sea Coral Research and Technology Program has recently conducted a three year investigation into the deep sea corals and sponges of the west coast. The investigation was conducted from 2010 to 2013. Several of the datasets listed here are results from that research effort including surveys by CCEHBR, OCNMS, and NWFSC. Objectives for this program were to support the evaluation of essential fish habitat, support the management plans for national marine sanctuaries, and advance our understanding of deep sea coral and sponge biology and ecology. Researchers are currently developing a synthesis of the results of this effort and that report should become available in 2014. This research effort is led by Dr. Elizabeth Clarke. For additional information contact Dr. Clark at elizabeth.clarke@noaa.gov or the Deep Sea Coral Research and Technology Program. Another key contact for deep sea coral information in the study area is Curt Whitmire at curt.whitmire@noaa.gov.

References

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4.0 Appendices

Appendices A and B are Excel spreadsheets and were provided to WDNR at the time of delivery of this report. Contact charles.menza@noaa.gov if you would like these spreadsheets.