U.S. Offshore Wind Synthesis of Environmental Effects Research (SEER) Project

U.S. Pacific Coast Workshop Report on Preconstruction Research Recommendations

November 2022

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Executive Summary

In May 2022, the U.S. Offshore Wind Synthesis of Environmental Effects Research (SEER) project team hosted a stakeholder workshop focused on preconstruction (baseline) research needs for potential floating offshore wind (OSW) energy development on the U.S. Pacific Coast, including California, Oregon, and Washington. Prior to the workshop, the SEER team developed a set of initial synthesized research recommendations that were identified based on a review of relevant, publicly available resources and with advisory group input. The workshop covered three marine life breakout groups on subsequent days to discuss research recommendations related to 1) marine mammals and sea turtles, 2) fish and invertebrates, and 3) birds and bats.

As part of the workshop, over a hundred participants from the public and private sectors provided feedback on various aspects of the initial research recommendations, including associated data and knowledge gaps, benefits/limitations of available methods and technologies, and technological advancements or infrastructure needed to address the recommendation. Approximately 1,000 total comments were received on the workshop MURAL boards and were synthesized in this report. Key takeaways regarding the preconstruction research recommendations from each workshop breakout group are listed as follows.

Marine Mammals and Sea Turtles

- Exposure and Risk Analysis. Greater baseline understanding of marine mammal and sea turtle habitat use and residency is needed to inform exposure and risk to the various potential stressors associated with floating OSW energy development. This analysis includes understanding how marine animals are using and interacting with the habitat, as well as identifying what ecological factors are influencing their behavior patterns.
- Model Development and Validation. Consideration should be given to evaluating existing baseline data, models, and prediction capabilities to help identify species and data collection priorities, with emphasis on the need for data collection to validate model outputs. Rigorous monitoring protocols will need to be in place during OSW energy development to provide the empirical data needed to reduce uncertainties in modeling the various risks.
- Autonomous Monitoring Technologies. A variety of advanced technologies and methods are needed to monitor and mitigate risks to marine mammals and sea turtles, including (1) fixed and mobile passive acoustic monitoring (PAM) as part of a regional network, (2) autonomous underwater vehicles to provide sustained offshore ecological measurements, (3) improved tags that are species-specific and have longer retention times, and (4) technologies that can help monitor and mitigate any entanglement associated with mooring lines.

Fish and Invertebrates

- Existing Data Sets and New Surveys. Information from existing data sets and surveys should be used to better understand baseline fish and invertebrate distributions, as well

as seafloor conditions in areas of potential OSW energy development. Synthesizing existing data will help identify data gaps and define how to fill them, including the potential for new surveys that include expansion into unmapped areas to assess species and map seafloor habitats.

- Sampling and Data Processing Techniques. Improvements to sampling and data processing techniques will allow researchers to gather and analyze large amounts of data more effectively and/or efficiently. For example, potential areas for advancement include publishing a publicly available database of genetic sequences for relevant species to support environmental DNA analysis and developing automated image/video analysis techniques for underwater surveys.
- Modeling Approaches. Models and simulations can help predict ecological response to OSW energy development and understand dispersion and movement patterns of fish and invertebrates. In many cases, the methodology for the models already exists but needs to be applied to the specific context of OSW development in a relevant area. In particular, simulations can help understand larval transport, changes in oceanographic conditions, and other key research questions.

Bats and Birds

- Advances in Technology. Technology advancement and deployment are necessary to monitor bird and bat activity and behavior. Technologies, such as acoustic detectors, visual or thermal video cameras, lidar, radar, and global positioning systems (GPS) or radio tags are often used to monitor bird and bat activity. Near-term research activities include 1) improving existing technology to withstand the harsh offshore environment, 2) miniaturizing tracking technology for small-bodied birds and bats, 3) developing and deploying infrastructure to install monitoring technology, and 4) advancing machine-learning algorithms to efficiently process large data sets.
- Focal Species. Given the lack of baseline data for most species and the uncertainties of how species will respond to the presence of wind turbines, preconstruction monitoring should focus on a broad suite of species considered vulnerable to collision, displacement, or avoidance. Examples include species with flight heights within the rotor-swept area, those that may be potentially attracted to wind turbines, or individuals that commonly use the proposed area for development.
- Covariates. It is important to collect spatial, temporal, weather data, and other ecological factors (e.g., prey availability) associated with the presence or movement of species in an area to assess patterns of activity. These patterns may be useful in relating potential exposure species once facilities are operational.

Based on workshop feedback, SEER developed a final database of over 500 specific research recommendations based on more than 40 resources. In Fall 2022, the full database and a tool with updated synthesized research recommendations were disseminated on Tethys

(https://tethys.pnnl.gov/pacific-offshore-wind-environmental-research-recommendations) to assist with informing future funding opportunities and research programming.

There is a continued need to improve awareness of the potential environmental effects, monitoring technologies, and management strategies for floating OSW energy development on the U.S. Pacific Coast. Coordination of these activities will require the sustained involvement of multiple stakeholders from across sectors. Beyond the baseline considerations discussed in this workshop, future state-of-the-science activities should be planned to consider research needs across wind energy life cycle phases for all relevant wildlife taxa and associated habitat and ecosystem processes.

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Abbreviation and Acronyms

AUV	autonomous underwater vehicle
BIA	biologically important area
BOEM	Bureau of Ocean Energy Management
CEC	California Energy Commission
CDFW	California Deparment of Fish and Wildlife
DOE	U.S. Department of Energy
EMF	electromagnetic field
ESA	Endangered Species Act
MMPA	Marine Mammal Protection Act
NGO	nongovernmental organization
NMFS	NOAA's National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NREL	National Renewable Energy Laboratory
NYSERDA	New York State Energy Research and Development Authority
ODFW	Oregon Department of Fish and Wildlife
OPC	California Ocean Protection Council
OSW	offshore wind
PAM	passive acoustic monitoring
PNNL	Pacific Northwest National Laboratory
ROV	remotely operated vehicle
SEER	U.S. Offshore Wind Synthesis of Environmental Effects Research
USFWS	U.S. Fish and Wildlife Service
WEA	wind energy area
WDFW	Washington Department of Fish and Wildlife

1. Overview

At the direction of the U.S. Department of Energy (DOE) Wind Energy Technologies Office, the National Renewable Energy Laboratory (NREL) and the Pacific Northwest National Laboratory (PNNL) the initiated the U.S. Offshore Wind Synthesis of Environmental Effects Research (SEER) project. The multiyear collaborative effort facilitates knowledge transfer of offshore wind (OSW) energy research from around the world to inform research needs applicable to U.S. waters. Specifically, research is being synthesized related to the understanding and minimization of impacts from OSW energy development on wildlife, habitats, and related environmental processes.

2. Workshop Goals

The SEER team organized the U.S. Pacific Coast workshop with the overall objective of gathering feedback from the OSW and environmental communities regarding recommendations for research needed in the near term (preconstruction) to promote responsible and sustainable OSW energy development on the Pacific Coast (i.e., California, Oregon, and Washington), including monitoring technology that should ideally be developed before construction begins. The team incorporated feedback from existing regional entities to ensure SEER workshop activities were aligned with the needs of the three states and complemented existing regional road maps, research plans, and environmental programs. The intended workshop audience included researchers, state and federal agencies, OSW developers, nongovernmental organizations (NGOs), and other entities who might use these recommendations to help prioritize future research.

The workshop focused on identifying near-term recommendations (next 3–5 years) that will improve the understanding of environmental effects (e.g., wildlife, habitat, and ecosystem processes) from regional OSW energy development on the U.S. Pacific Coast. The workshop brought stakeholders together with the primary goals of (1) reviewing an initial set of environmental research recommendations related to three marine life groups (marine mammals and sea turtles; fish and invertebrates; and bats and birds), (2) identifying additional literature that contain recommendations, and (3) characterizing new recommendations that are not in the public literature.

3. Preworkshop Activities

3.1 Advisory Group

The SEER team formed an advisory group to assist with the Pacific Coast workshop planning activities. Advisory group members included Jason Busch (Pacific Ocean Energy Trust, Garry George (National Audubon Society [Audubon]), Jennifer-Lilah Ise (National Oceanic and Atmospheric Administration [NOAA] National Marine Fisheries Service [NMFS], Delia Kelly (Oregon Department of Fish and Wildlife [ODFW]), Chris Potter (California Department of Fish and Wildlife), Sara Guiltinan and Abby Ryder (Bureau of Ocean Energy Management [BOEM]). From DOE's Wind Energy Technologies Office, Joy Page and Naomi Lewandowski provided

significant input throughout the process. The advisory group met on a monthly basis leading up to the workshop to provide input on workshop goals, invitees, and existing literature resources for the research recommendations database.

3.2 Outreach to Agencies

With respect to the government sector, the SEER team aimed to ensure that workshop outcomes were relevant to the OSW energy regulatory and permitting process across the relevant agencies. Thus, individual calls were held with several of the lead federal and state agencies involved in the permitting process, including BOEM, NOAA, U.S. Fish and Wildlife Service (USFWS), California state agencies (i.e., Ocean Protection Council, Energy Commission, California Department of Fish and Wildlife, Natural Resources Agency, Coastal Commission, and State Lands Commission), Washington Department of Fish and Wildlife, and ODFW). Each agency provided their unique perspectives on environmental priorities associated with Pacific OSW energy development, based on their respective regulatory mandates and purviews.

3.3 Initial Research Recommendations Database

The team compiled a database of existing research recommendations from publicly available resources relevant to the environmental effects of potential OSW energy development on the Pacific Coast. Resources were identified by the SEER team and the workshop advisory group, then reviewed to determine whether they met the criteria developed for inclusion in the database. The SEER team developed the following criteria required for resource inclusion:

- Focused, at least in part, on the OSW energy industry and possibly marine energy (therefore excluding documents that focused solely on terrestrial wind or offshore oil and gas), but some non-OSW methods from onshore may be relevant (e.g., bats, migratory songbirds)
- Relevant to the western United States, including lessons learned from other regions; “relevance” entails either a direct focus on this geography or inclusion of taxa, habitats, and questions germane to the U.S. context
- Clear delineations of research needs, knowledge gaps, or other funding needs or priorities focused on wildlife, habitats, and ecosystem processes
- Resource types include journal articles, workshop reports, technical reports, agency reports, and written comments
- Include research recommendations that are relevant to the offshore component of OSW energy from the wind farm to landfall (offshore to coastal).

After applying the criteria, the team identified a total of 28 resources. See the References section for a list of the resources that were included.

The SEER team reviewed each resource and extracted information related to research recommendations identified in the source. Each research recommendation was specific to the environmental effects of OSW energy. A description of each recommendation was entered into the database with data fields that included:

- Title – a brief description of the research recommendation
- Goal/objectives – a description of the research goal or objective
- Category – the type of information to be obtained from the recommendation (i.e., occurrence, conditions and stimuli, response, consequences, or methodological)
- Spatial scale – options include site-level, multisite, regional, off-site, or not applicable (n/a)
- Temporal scale - the time required for a proposed study to be conducted
- Geographic area - the specific geographic focus
- Focal taxa - general taxonomic category(ies)
- Development phase – options include preconstruction, construction, operations and maintenance, decommissioning, or n/a.

In total, the team identified and described 312 research recommendations in the initial database. This database was then consolidated into a set of 8–14 synthesized recommendations for each marine life group and then shared those recommendations with the workshop invitees prior to the session (Section 4.3). Based on feedback from the workshop, further resources were included in the database following the workshop, such that the final database included 577 research recommendations.

4. Workshop Activities

4.1 Compilation of Invitee List

The team compiled a list of workshop invitees to include experts with knowledge of U.S. Pacific Coast OSW energy development and research associated with its potential environmental effects. Invitees were chosen from both the public and private sectors based on their diverse expertise across marine life groups. The workshop advisory group reviewed the invitee list and provided additional contacts to ensure participation from a range of experts. The final list included 191 individuals, all of whom were invited to the workshop and otherwise included on all workshop communications, in case they were not able to participate in the workshop itself but wanted to stay informed on activities. All workshop invitees were given the opportunity to contribute to pre and postworkshop activities.

4.2 Marine Life Groups

Three broad groups were chosen for workshop activities and breakout sessions based on the major marine life types considered potentially sensitive to OSW energy development activities. Marine life data and analysis in U.S. oceanic regions has historically included (at a minimum) marine mammals, sea turtles, birds, fish, and invertebrates (e.g., California Data Basin 2022; Marine-Life Data and Analysis Team 2022). For the SEER workshop, these marine life types were grouped into three broad categories based on similarities in related research

methodologies and associated expertise, including marine mammals and sea turtles, fish[1] and invertebrates, and bats and birds. Workshop invitees were identified with expertise in each of these areas. Cross-cutting considerations that are relevant to multiple marine life groups, such as habitat and ecosystems, were considered as a part of each marine life breakout session.

4.3 Synthesized Research Recommendations

Within each marine life group, the team developed a shorter synthesized set of research recommendations from all relevant entries in the research recommendations database. To synthesize the database, the recommendations were first filtered by the marine life group and then by development phase to focus only on research needs related to the OSW preconstruction phase. For each marine life group, the SEER team condensed research recommendations into a smaller list, given that numerous recommendations from different sources were similar in nature. The target was to identify approximately 10–20 synthesized recommendations for each marine life group. The SEER team wrote a succinct summary of each synthesized recommendation and used those summaries as the basis for the workshop discussion.

The synthesized research recommendations include the following (ordered by number of votes [in parentheses] received during workshop activities):

Marine Mammals and Sea Turtles

- Collect baseline spatial data on abundance, distributions, and migratory pathways (21)
- Assess primary and secondary entanglement risk associated with OSW energy development (15)
- Analyze synergistic and cumulative effects of multiple OSW farm projects (14)
- Establish baseline sound data to understand noise impacts from OSW development (11)
- Understand habitat use, including critical habitat, to inform OSW development (10)
- Consider vessel traffic associated with OSW development that could result in vessel strikes and disturbance (8)
- Determine marine mammal and sea turtle response to new OSW structures (4)
- Consider onshore and nearshore environmental effects from OSW development (3)
- Investigate potential impacts of floating array cable electromagnetic fields (EMFs) on marine life (2)
- Examine diet composition and prey species for marine mammals and sea turtles (1)
- Determine risk of chemical and toxic pollutants on marine mammals and sea turtles associated with OSW energy development (1)

Fish and Invertebrates

- Understand how OSW energy development will impact fisheries[1] (18)

[1] Note that the focus is on fish species and fisih stocks/populations rather that the fishing industry and associated socioeconomic considerations.

- Determine how the introduction of new structures affects the local habitat and populations (14)
- Gather baseline information for marine life distributions and migratory routes (13)
- Conduct seafloor mapping and biological benthic surveys in OSW energy areas (11)
- Determine effects of trophic interactions (6)
- Understand sediment transport in OSW energy areas and changes to seafloor productivity (5)
- Determine wildlife effects from floating OSW cable systems (4)
- Evaluate risk and impact from chemical contaminants introduced through OSW energy installation, operation, and maintenance (2)
- Study the behavioral response to sound exposure (e.g., baseline, response, measurement) (2)
- Determine sensitivity threshold and effects of EMFs (2)
- Evaluate potential to introduce invasive species (1)
- Catalog the conditions of biofouling on new structures (1)
- Investigate whether heat emitted by OSW energy cables affects benthic communities (1)
- Study impacts of artificial light on photosensitive species (1)

Bats and Birds

- Collect baseline data at the proposed development site during preconstruction to determine habitat use (19)
- Establish methodological standards for evaluating species-specific collision risk with OSW turbines (17)
- Improve understanding of migratory pathways (15)
- Consider cumulative impacts to high-value biological resources (14)
- Develop preliminary population models and sensitivity analyses (12)
- Improve understanding of marine animal distribution (8)
- Assess areas of entanglement risk and develop best management practices (6)
- Identify the distribution of prey resources (5)

4.4 MURAL Platform Exercises

The workshop was divided into three 2-hour breakout groups and was conducted virtually from May 3−5, 2022. The SEER team solicited feedback from workshop participants using MURAL, an online collaboration platform (www.mural.com), which enables multiple users to add comments to an interactive digital whiteboard in real time (Figures 1−3).

The SEER team organized each breakout group's MURAL board into five overarching sections to guide participants through the workshop exercises. Section 1 included the workshop agenda, instructions on using MURAL, and a practice exercise wherein participants were asked to add their name and affiliation on a sticky note to a map. Section 2 provided background information on the SEER effort and links to the SEER educational research briefs, public webinar recordings,

and preliminary database of research recommendations. Section 3 listed the sources used to compile relevant research recommendations, and asked participants to identify any additional sources the SEER team should consider. Section 3 also provided the summarized list of research recommendations, and asked participants to identify any missing recommendations. Additional research recommendations were gathered from workshop participants and are documented in the following sections but were not discussed individually as part of the workshop activities.

Before beginning MURAL Section 4 (the main focus of the workshop), the SEER team asked workshop participants to vote on their top three priorities for the initial research recommendations identified earlier to discuss in further detail during the workshop. Five to six of the research recommendations were discussed during each day of the workshop, depending on how much time was available. During Section 4, facilitators asked participants to respond to the following four questions for each of the initial research recommendations:

- Does the research recommendation accurately represent the need?
- What are the data and knowledge gaps associated with this recommendation?
- What are the methods or technologies available to address the recommendation? What are the benefits and limitations of each?
- What technological advancements or infrastructure are needed to address the recommendation?

Workshop participants, and those unable to attend, were later invited to provide additional feedback on the recommendations not covered during the workshop.

Finally, MURAL Section 5 highlighted next steps and acknowledgements.

4.5. Compiling Workshop Feedback

Information from each of the three MURAL boards (i.e., marine mammals and sea turtles; fish and invertebrates; and bats and birds) is summarized in the following sections. The original comments for each recommendation are available on the MURAL boards at the links provided in the following sections. In addition to summarizing the responses to each question, the SEER team synthesized key takeaways from each breakout group. The structure for describing the information in the following sections is the same for each breakout group. The "Description" section for each research recommendation includes text that the SEER team developed ahead of the meeting; the text under each question is a summary of the input provided by the attendees (e.g., clarifying input, removing redundancy, etc.) with the original wording preserved where possible.

5. Breakout #1: Marine Mammals and Sea Turtles

Figure 1. Humpback whales in Monterey Bay National Marine Sanctuary Photo credit: NOAA

5.1 Key Takeaways

The team reviewed all feedback from the marine mammal and sea turtle breakout group and developed the following key takeaways as a synthesis across research recommendations.

- **Exposure and Risk Analysis.** Greater baseline understanding of marine mammal and sea turtle habitat use and residency is needed to inform exposure and risk to the various potential stressors associated with floating OSW energy development. Baseline information needs include understanding how animals are using and interacting with the habitat, including identifying what ecological factors are influencing their behavior patterns.
- **Model Development and Validation.** Consideration should be given to evaluating existing baseline data, models, and prediction capabilities to help identify species and data collection priorities, with emphasis on the need for data collection to validate model outputs. Rigorous monitoring protocols will need to be in place during OSW energy development to provide the empirical data needed to reduce uncertainties in modeling the various risks.
- **Autonomous Monitoring Technologies.** A variety of advanced technologies and methods are needed to monitor for and mitigate risks to marine mammals and sea turtles, including (1) fixed and mobile passive acoustic monitoring (PAM) as part of a regional network, (2) autonomous underwater vehicles to provide sustained offshore ecological measurements, (3) improved tags that are species-specific and have longer retention times, and (4) technologies that can help monitor for and mitigate any entanglement associated with mooring lines.

5.2 Overview of Participation

The marine mammal and sea turtle breakout group was held on May 3, 2022. Aside from the organizers, 37 participants attended the webinar (see Table A-1 for names and affiliations). In addition to the workshop organizers, participant affiliations included federal agencies, state agencies, government-sponsored research organizations (both U.S. and international), nonprofit organizations, environmental NGOs, environmental consultants, OSW energy developers, and universities. Most participants were from the U.S. Pacific region, but there were also several participants from other U.S. regions and Europe.

5.3 Summary of Feedback

A total of 333 comments were received on the marine mammals and sea turtles MURAL board from participants either during or after the workshop (Figure 2). The following numbers of responses were received for each workshop activity: (1) additional sources (21 comments), (2) additional research recommendations (26 comments), (3) the five research recommendations prioritized for discussion during the workshop (246 comments), and (4) additional research recommendations that received feedback after the workshop (37 comments).

Figure 2. Screenshot of Breakout #1 MURAL board. A high-resolution version of the screenshot is available to download here.

Participants provided several additional resources for the database including published articles, workshop reports, public comments on BOEM's leasing activities, new and ongoing research projects, lab highlights, and data layers (see Appendix A.3).

Prior to the workshop, the team synthesized a list of 11 recommendations for preconstruction research for marine mammals and sea turtles. The summary of these recommendations can be found in Section 4.3. Further, a series of comments (26) were received from workshop participants to identify additional research recommendations (see Appendix A.4). For example, the impacts of climate change were mentioned in several comments and the need to model

these impacts on migration/feeding changes. For baseline studies, the need for winter occurrence/density data was highlighted, given how limited winter surveys are across species. Also, the need for baseline body condition, health metrics, and energetics was identified. There were several suggestions to change "spatial data" to "spatiotemporal data" to encompass the seasonality and temporal variability in animal distributions. Numerous comments identified methods for addressing research recommendations, many of which were captured in the follow-on exercises.

Participants voted on which of the initial synthesized recommendations should be prioritized for discussion. Five recommendations were discussed in depth during the workshop based on voting and are described in the following subsections (Synthesized Recommendations A–E). Other recommendations were not discussed but received some comments from workshop participants that are also documented here (Synthesized Recommendations F–K); note that these comments represent the feedback of just a few individuals and not the larger group. The 11 research recommendations for marine mammals and sea turtles including input from the workshop participants are summarized next. The "Description" section for each research recommendation includes text that the SEER team developed ahead of the meeting; the text under each question is a summary of the input provided by the attendees (e.g., clarifying input, removing redundancy, etc.) with the original wording preserved where possible.

Synthesized Recommendation A. Collect Baseline Spatial Data on Abundance, Distributions, and Migratory Pathways

Description of the synthesized topic as developed by the SEER team:

- Basic biological data are lacking for a number of whale species (e.g., humpback, fin, gray, minke, North Pacific right whales) and sea turtles (e.g., leatherback) that are migrating, feeding, and/or breeding in the area and how their distribution changes in response to dynamic environmental variables.
- Increase understanding of marine animal distributions and sensitivities to determine where and when interactions are most likely or present highest risk to species to inform OSW "smart siting."
- Expand what is known about migratory pathways and potential disruption of along-shore movement, including the high use of the shelf and shelf break as both a foraging area and migratory corridor.
- Sources identifying this recommendation include Aylesworth et al. (2019); California joint state letter (2022); Flick et al. (2021); Liebezeit et al. (2021); California Energy Commission (CEC) (2021); ODFW (2020a,b); NMFS (2022); Pacific Fishery Management Council (PFMC) (2021); Southall et al. (2021); Maxwell et al. (2022).

Does this research recommendation accurately represent the need?

- The recommendation should include evaluating existing data and models to help identify species priorities.
- The temporal component is also important (e.g., seasonality).

- Still need to understand the dynamic interactions between distribution/abundance with both seasonal and environmental variability, including climate change in dynamic environmental variables.
- Need to better understand how animals are using and interacting with the habitat, as well as what ecological factors are influencing their behavior patterns.
- Need to consider including deep-diving offshore foraging seals, sea otters, and haulout sites.
- Need to consider including predatory/prey interactions.
- This topic overlaps with "habitat use" topics.

What are the data and knowledge gaps associated with this recommendation?

- Habitat use has a comparatively greater information need and should include residence times and environmental drivers of changes in habitat use.
- It is challenging to get robust data that reduce uncertainty in the face of interannual variability; climate change may affect use of prior data to predict.
- Basic biological data are not necessarily "lacking," depending on locations or species of interest. There are a lot of data—in some cases it may not be practical to collect the amount of data we would like to have.
- Consider modeling and prediction capabilities based on existing data, with emphasis on validating model outputs.
- Accessibility to data collected as wind energy developers start doing surveys.
- Understand current spatial and temporal dynamics well enough to estimate preconstruction threats and stressors (e.g., strikes, entanglements) for context in adding additional stressors; ability to quantify cumulative impacts.
- Collation and integration across multiple platforms with existing data.
- More representative temporal occurrence needed for various species, including winter surveys for all species.
- Fine-scale foraging behavior needed.
- Population composition of small cetaceans and pinnipeds.

What are the methods or technologies available to address the recommendation? What are the benefits and limitations of each?

- Photo-identification methods to assess residency in areas to determine exposure and risk.
- New autonomous technologies for data collection (e.g., autonomous underwater vehicles (AUVs): a con is that they are probably expensive and different from the past so hard to compare with older studies; a pro is that they provide access to data when hard to do in-person work.
- Autonomous, long-duration observing instruments (e.g., acoustics from moored instruments, gliders, drifters).

- Tagging: a benefit is movement and residence time; a con is high cost .
- Maximize existing data sets and noninvasive methods prior to considering invasive tagging.
- Passive acoustic monitoring:
    - Develop PAM regional network.
    - Determine occurrence seasonally for calling individuals; relatively inexpensive
    - Benefits include presence time series; however difficult/expensive to measure distance and direction of animals. Another advantage is that it can be paired with lots of other methods (e.g., tagging, visual surveys), and is relatively low cost.
    - PAM from autonomous gliders and fixed hydrophones. Con: only detects vocalizing individuals; pro: cheaper than aerial surveys.
- Environmental DNA to identify presence of species that may not be seen in surveys.
- High-definition aerial surveys/satellite surveys, including aerial flyover for visual surveys in nearshore and shoreline.
- Visual survey: gold standard for density; con: expensive, weather-dependent.
- In terms of modeling, Navy is funding a new NMFS model to extrapolate summer data to winter based on environmental variables.

What technological advancements or infrastructure are needed to address the recommendation?

- More autonomous collection methods to cover times when surveys are difficult to do with people on the water.
- While new technology may be an option (e.g., PAM on AUVs), traditional existing methods would meet the need: visual, PAM, tagging.
- Artificial intelligence data processing of large data sets from AUVs including gliders
- Repository for data with standards for data and metadata.
- Funding to analyze data that are collected.
- Funding for integration of data from multiple platforms.
- Need better at-sea instrumentation for observations for turtles and whales. Cannot rely on boat-based and aerial surveys; need digital acoustic recording tags (DTAGs) specific to species; need streamlined permitting to carry out this work.
- Satellite tags with longer retention rates.
- Better data storage, power sources, etc. for long-term coverage and redundancy.
- A way to process and store large photographic data sets from aerial work to analyze the data within a reasonable time frame.
- Use of citizen science to identify calls within large data sets (e.g., sound recordings).
- Existing standardized methods to produce PAM data products that can be compared/contrasted across habitats and regions; including propagation and other modeling techniques.

- Coordination for an integrated PAM network development, including multiple platforms, existing sources and new ones across agencies and academia.
- Satellite imagery (find whales from space): https://www.bas.ac.uk/media-post/monitoring-whales-from-space/.

Synthesized Recommendation B. Assess Primary and Secondary Entanglement Risk Associated With OSW Development

Description of the synthesized topic as developed by the SEER team:

- Assess entanglement risks to marine mammals and sea turtles listed under the Endangered Species Act (ESA) and/or protected under the Marine Mammal Protection Act (MMPA) during activities to support OSW projects.
- Distinguish between primary entanglement in project equipment (e.g., mooring lines, dynamic interarray power cables) and secondary entanglement in debris (e.g., derelict fishing gear) ensnared on project equipment.
- Map the multiple entanglement sources documented on the U.S. West Coast and then assess elevated risk areas to inform best management practices or mitigation measures.
- Consider different mooring line configurations, materials, and even colors.
- Develop monitoring and maintenance technologies to minimize entanglement risk, such as robotic mooring line and cable cleaning.
- Sources identifying this recommendation: CEC (2021); NMFS (2022); ODFW (2020 a,b); Maxwell et al. (2022).

Does this research recommendation accurately represent the need?

- Assess may be too strong a term. We can likely "model" the risk but without empirical field data there will be high uncertainty. Unclear as to how much confidence we can have in this question during the preconstruction phase.
- Need to model the risks—including interarray cables and moorings. Modeling movements of marine debris and derelict gear would be helpful to understand risks at different places in the water column and different locations.
- Models will provide the best approach until arrays are in place, for both primary and secondary entanglement.
- Outcomes can inform best management practices or design changes to cable depth, spacing, etc. to minimize risk.
- No need to specify ESA and MMPA—all sea turtles and marine mammals fall under at least one of these at present; not just ESA-listed species: gray whales and pinnipeds are at risk, too.
- We need to also advance technologies and methods to monitor for and mitigate this risk in time for the first floating installations. Model uncertainty will be high until we have empirical data, so we need to have protocols in place to proactively address this potential cause of mortality and injury of protected species.

- Secondary entanglement is a key concern in Oregon; lot of work being done with fishery management to reduce risk.
- Given the diameter of cables, entanglement is not the only risk. Need to consider injury by collision.
- Entanglement mitigation technologies: lights, pingers, others—effectiveness at alerting animals to presence of infrastructure.
- What is the baseline risk? What is the elevation of risk caused by OSW?
- Highly visible line colors (for detection by people monitoring infrastructure or by marine life).
- Add the risk for tertiary entanglement. Tertiary entanglement is "when an animal is already entangled, then the entangled gear becomes entangled in the mooring gear."
- Need to assess healing and survival from injuries.
- What is likelihood of entanglement occurring? We need to start by quantifying "how much gear is lost?"
- Less about healing/survival (an entanglement is a take regardless of outcome) and more about how many individuals are entangled in independent stocks: what percent of each population, what is the distribution of that population, how does that increase risk of secondary and tertiary entanglement?

What are the data and knowledge gaps associated with this recommendation?

- No data are available on how much gear is lost in the Pacific. This is important information needed to assess the risk of secondary entanglement.
- Determine if risk of the current situation with derelict gear and marine debris differs significantly from the risk associated with OSW—there is already a baseline risk.
- There are data on derelict fishing gear—NMFS and California Ocean Protection Council (OPC) have both done some work on understanding this.
- Advocate for alternative fishing gear (i.e., ropeless) and assess environmental impacts/risks to all fisheries.
- What are optimal depths for interarray cables considering animals/entanglement risk and other factors like fisheries interactions?
- Fine-scale and local marine mammal behavior in wind energy areas (WEAs)
- Drift patterns of lost/abandoned fishing gear—overlap with WEAs?
- Energetics of stress and behavioral response to disturbance; how does this affect individual vital rates and scale up to population?
- Current entanglement hotspots.
- Mitigation and deterrence effectiveness.
- Clear information on operations and equipment to be used; this needs to be communicated so we can assess risk.
- Behavior of large whales around floating infrastructure.

- Real-time satellite detection of whales—but challenging due to cloud cover and cost of satellite images.

What are the methods or technologies available to address the recommendation? What are the benefits and limitations of each?

- Lean on models already developed for assessment of entanglement in fishing gear— can apply animal distribution models to overlap assessment with OSW gear.
- Regarding models of entanglement risk, need much better information on array cabling structure/types/density before these will be too realistic.
- Model risk by gear and depth.
- Inform optimization of cabling and mooring equipment and configurations, but also need to have some assumptions to model.
- Coast Guard has tools for assessing movement of objects in the water.
- Use accelerometry tags to assess movement near underwater structures (e.g., gear, lines, etc.).
- Primary and secondary entanglement can be addressed as a worst case by agent-based models, but there is no way to monitor or measure at sea until arrays are in place.
- Unmanned underwater vehicles/remotely operated vehicles (ROVs) for infrastructure inspection—expensive, time investment.
- Suction cup accelerometer tags—fine-scale and local foraging behavior; expensive and need vessel time and researchers to apply.
- BOEM and NOAA's National Centers for Coastal Ocean Science are currently developing a 3D simulator to assess the risk of primary and secondary entanglement in whales and sea turtles; PNNL and NREL involved.
- Are deterrents available that would be effective for Pacific species?
- Robots that can "walk" the anchor lines to detect ensnared material; gyrocompasses on lines to detect unusual motions (from drag).

What technological advancements or infrastructure are needed to address the recommendation?

- Advance technologies that can help monitor for and mitigate (remove) marine debris, including at depth, in a cost-effective way (e.g., load sensors, remote vehicles, camera systems).
- Monitoring and maintenance technologies are needed to identify and respond quickly to any entangled gear, including tertiary entanglement of a whale trailing gear from elsewhere.
- Are there advances in fishing gear that can preserve the primary function of the gear while actively fishing but will degrade to not entangle animals when lost or abandoned?
- Automated tools to explore lines for snagged gear.
- More remote monitoring capabilities with redundancy and sufficient to allow for long-term deployment without much maintenance.

- Gear/animal simulation approaches to inform design, risk assessment, etc.
- Cost-benefit analysis for reduction of risk.
- Data storage for underwater visual monitoring.
- Remote detection of entanglement events (e.g., load sensors on mooring lines)
- Regarding entanglement risk models, recognize that our ability to model entanglement risk posed by floating wind infrastructure will be somewhat limited without empirical data from monitoring for incidences of marine debris ensnarement on that infrastructure. May be able to establish some sense of risk level during the preconstruction phase, but there will need to be a rigorous monitoring protocol in place following construction to inform our assessment of risk and enable us to adaptively manage if needed. From an NGO perspective, we should not wait to see if an entanglement occurs before developing the technologies and methods needed to detect and remove marine debris or detect an entangled animal. Serious injury or mortality associated with OSW development may serve as a barrier to progress so we need to be proactive in addressing this issue.
- Use of aerial systems (satellites?) to detect marine debris in surface waters.
- Model drift patterns of lost gear (from existing information—state DFW that collect derelict gear) and simulations—and overlap with WEAs.

Synthesized Recommendation C. Analyze Synergistic and Cumulative Effects of Multiple OSW Farm Projects

Description of the synthesized topic as developed by the SEER team:

- Analyze synergistic and cumulative impacts of multiple OSW projects to high-value biological resources, including reasonably foreseeable impacts, climate change, atmospheric cycles (El Niños, Pacific Decadal Oscillations), and an ecosystem approach.
- Assess and minimize impacts of multiple lessees engaging in site assessment at same time.
- Model potential cumulative impacts of OSW projects under present and future ocean conditions on living marine resources, their habitats, and oceanographic processes (particularly upwelling).
- Consider that climate change is already shifting marine life distributions and may also alter atmospheric cycles in unknown ways; modeling analysis will need to account for scenarios.
- Sources identifying this recommendation: Cullum et al. (2021a, b); Liebezeit et al. (2021); NMFS (2022); California joint state letter (2022).

Does this research recommendation accurately represent the need?

- Impact of OSW on lower trophic levels for marine mammals and sea turtles.
- Climate change—there is a tendency to add impacts of OSW on top of climate change, but we also need to consider how OSW will reduce impacts of climate change.

- Displacement and effects on other areas (e.g., increase pressure from competition if species move into other areas).
- Best we can do is to "describe" not "analyze" at this time due to limited data availability.
- Also consider existing threats/cumulative impacts and how OSW interacts with those.
- What is the energetic cost of loss of habitat? Both lost energetic value and cost of moving to new space.
- Cumulative impacts should also include all sound sources, including non-OSW ones (e.g., shipping). In other words, what does OSW contribute to the anthropogenic sound field?
- Cumulative impacts of site characterization activities (multiple surveys).
- Focus should be on ecological- and population-level concerns.
- What do you mean by "high-value" biological resources? We could remove "high value" from the language. Thumbs down on "high value"!
- Modeling is valuable but should always be coupled with validation.

What are the data and knowledge gaps associated with this recommendation?

- Vessel traffic (including fishing vessels) data are limited and needs to be improved, especially for non-automatic identification system (AIS) carrying vessels to help assess contribution of OSW vessel traffic.
- A gap is our mechanism for assessing National Environmental Policy Act—it may be useful to assess this in other ways, too.
- Residency data, acoustic cue rates, habitat use data are needed.
- Regional risk maps that identify areas of risk across distributions to identify temporal and spatial areas of risk --> cumulative impacts.
- Sound propagation characteristics at the OSW site.
- How marine mammals respond to large infrastructure in habitat.
- Need to assess physiological impacts of disturbance at multiple spatial and temporal scales, including stress, reproductive capacity, body condition. These factors vary with demographic context (age, sex, reproductive state), which is hard to collect from most cetacean populations. Suggest using accessible study populations that can be a representative model system.
- Potential for displacement and where marine life would displace to.
- What are the risks of wind wakes altering upwelling? Would that alter the availability of prey base?
- Understanding prey variability is needed. Animals are more tolerant and resilient when in better nutritive state.
- Will buildout of multiple OSW displace fishing effort and translate to increased risk to species?

What are the methods or technologies available to address the recommendation? What are the benefits and limitations of each?

- Scotland is working on a cumulative effects framework for assessing impacts on marine mammals: https://www.ceh.ac.uk/our-science/projects/cumulative-effects-framework-key-ecological-receptors
- To consider ecosystems, climate change, future conditions, etc., we need to develop good models and validate those models.
- Ongoing studies of abundance, distribution, and population health will be useful in assessing changes over time.
- Population Consequences of Multiple Stressors/Population Consequences of Disturbance modeling.
- BOEM is currently supporting bioenergetics model development for North Atlantic right whales. Additionally, DOE and BOEM are funding the Wildlife and Offshore Wind (WOW) project that includes the Sea Mammal Research Unit Population Consequences of Multiple Stressors/Population Consequences of Disturbance model development for OSW.
- But we need data to populate these models!
- Greatest gaps are among sea turtles. Need more focus there.
- Few studies and no ongoing monitoring. Low population numbers need to be considered and risks, especially in southern California waters are vital.
- Some injury thresholds exist at either individual or population level; need to be integrated into cumulative impact assessments.
- Use long-term data sets (e.g., Newport Hydro Line) and expand those monitoring efforts coastwide to attempt to separate natural variability, climate change, and OSW impacts.

What technological advancements or infrastructure are needed to address the recommendation?

- Long-term monitoring will help verify and inform models and adapt to risks.
- This is a synthesis of information from assessment of other risks—need to have reasonable understanding of the projects likely to occur and good models for synthesis.
- Must also include adaptive management and determination of actions when the anticipated effects are worse than predicted.
- Integration of monitoring into operations and maintenance of wind farms—use of the platforms of opportunity.
- Across all federal agencies, an integrated framework on "how" to address cumulative effects is needed. Especially in terms of Council on Environmental Quality definitions.
- PAM can provide seasonal data on natural and anthropogenic sounds. Further analysis can look at response if any is detectable.
- Further development of predictive models to understand when/where marine life is.

Synthesized Recommendation D. Establish Baseline Sound Data To Understand Noise Impacts From OSW Development

Description of the synthesized topic as developed by the SEER team:

- Baseline data on noise levels are needed in OSW energy areas, with "control" sites for future monitoring, to understand OSW-related noise levels (including from geophysical surveys) that could impact biologically significant behaviors (e.g., foraging, migrating, resting, reproduction).
- Understand how sound propagation differs based on local site characteristics.
- Identify baseline vocalization behavior, including seasonality and acoustic characteristics.
- Develop year-round, long-term and near-real-time PAM (e.g., NMFS/BOEM OSW PAM framework).
- Sources identifying this recommendation: Aylesworth et al. (2019); California joint state letter (2022); NMFS (2022); ODFW (2020 a, b); Southall et al. (2021); Maxwell et al. (2022).

Does this research recommendation accurately represent the need?

- Start the research recommendation with a question then develop a monitoring program to address that question.
- Include what standardized time-series data products are needed to establish baseline understanding and disturbances.
- "Examine marine mammal vocalization behavior" is very vague—need a more specific question to answer.
- Does this topic not really fall in part under "Baseline Occurrence"?
- Need to have specific questions and set up methods to answer them rather than generically monitor.
- Add seismic survey concern; currently used but possibly higher frequency or increased spatial extent due to OSW.
- Need to address physiological and behavioral thresholds of response to different noise levels and sources. When does noise become a problem?
- Add baseline data on noise produced by OSW and what frequencies.
- Understand the contributors to the soundscape (bio, physical, man-made) to understand future changes.
- Identify time frame appropriate for establishing baseline understanding and OSW monitoring (5 years prior to installation?).

What are the data and knowledge gaps associated with this recommendation?

- Habitat use varies by season and year—challenges with predictions and averaging data over multiple years; other projects show the difficulties with this variability, plus there would be potential changes with climate change.
- Better understanding of the demographic nature of vocalizations. For example, like for North Atlantic right whales, mother/calf pairs don't vocalize very much in S calving areas. This is important if you are trying to use acoustics to assess potential impacts.

- Noting that some questions may be hard to get enough data for statistically robust outcomes—need to be strategic in data collection to ensure data will reduce uncertainty at the end of studies.
- Determine call rates, function, and timing for as many species as possible.
- See sea turtle studies by Popper, Hawkins, etc.
- Marine mammal vocalization behavior: understanding vocal repertoire and call rates (and variation in call rates with different behaviors).
- For floating OSW, construction will likely involve dynamic positioning vessels for cable laying. What is the sound level associated and are there timing restrictions on cable laying that would be appropriate to minimize impact?
- Behavior response studies on sea turtles.
- How many West Coast areas off California, Oregon, Washington could be surveyed with seismic at same time?
- Need to determine better auditory profiles for underwater hearing in sea otters and pinnipeds.
- There are also behavioral response studies and lots of Navy work on marine mammals in this regard.
- Are deterrent methods available/effective? Once construction starts it is difficult to stop so having methods in place is important.
- Determine how noisy OSW infrastructure is during operation.

What are the methods or technologies available to address the recommendation? What are the benefits and limitations of each?

- Acoustic data are large data sets—need ways to share, store, analyze—need funding for analysis not just collection of data.
- BOEM and NOAA are supporting the ADRIFT study using drifting acoustic buoys.
- BOEM funded a study by the Naval Underwater Research Lab to collect empirical data on high-resolution geophysical survey sound sources.
- Fecal, blow, biopsy sampling to assess stress response to noise exposure.
- Lots of great automated approaches, artificial intelligence, etc. for streamlining analysis, but require funding and partnerships; can piggy-back on existing networks/data management and archive efforts (NOAA/Integrated Ocean Observing System/NMFS Southwest Fisheries Science Center/international/etc.).
- Fixed and mobile PAM to develop baseline profile; artificial intelligence/algorithm to detect and plot marine mammal sound detection.
- PAM network integrated with other observations most effective; PAM alone can't get at behavioral response.
- Use citizen science to identify vocalizations in large data sets. Then use artificial intelligence to scan the data to identify missing vocalizations from the whole data set using local vocalizations.

- Two to three shallow-water broadband sampling listening stations currently being established by partners in Morro Bay; deep station(s) are needed to augment, and confirm sites are best suited to provide the long-term monitoring needed for OSW
- Similar work in Europe: JONAS; JOMOPANS; COMPASS; MarPAMM.

What technological advancements or infrastructure are needed to address the recommendation?

- Monitoring systems that are very robust, have redundancies, and can operate for long term with minimal maintenance; also high data storage or satellite transmission of data.
- Might consider data standardization and a repository for data and metadata for all projects.
- Need further support and development of artificial intelligence options to analyze large acoustic data sets.
- Need behavioral response studies on sea turtles.
- Need an integrated (multiplatform) PAM network that includes near-real-time options
- There are some AUV, glider, etc. technologies that could be further developed.
- PAM network started, needs to evolve (perhaps expand) to meet OSW and other emerging management needs.
- Sustained funding for data collection, gear maintenance, and analysis, and data management/archiving.
- Need for formal partnerships (network/effort) across PAM researchers to encourage open data and combined efforts to provide synthesized data products.
- Determine setup for acoustic monitoring around OSW facilities (e.g., where to place PAM).
- Noninvasive tags that can collect ambient sound, heart rate, and accelerometry data.

Synthesized Recommendation E. Understand Habitat Use, Including Critical Habitat, To Inform OSW Energy Development

Description of the synthesized topic as developed by the SEER team:

- Delineate biologically important areas (BIAs) for whales and sea turtles and any other areas that are most important ecologically.
- Encourage further synthesis and analysis of data to identify potential additional hotspots and areas of significance for marine life to inform “smart siting”.
- For example, research is needed on killer whales, beaked whales, fin whales, and minke whales, and there is a need to delineate BIAs for those species.
- Sufficient resources and time should be allocated to carry out analyses on a fine enough scale to inform marine planning decisions.
- Sources identifying this recommendation: BOEM (2021); Aylesworth et al. (2019); Cullum et al. (2021a, b); Liebezeit et al. (2021); Maxwell et al. (2022).

Does this research recommendation accurately represent the need?

- Critical habitat is a specific term in law—your bullets are focused on BIAs—do you have a recommendation on critical habitat, too?
- Include other whales in research needs; e.g., fin whales were also in BIA study already published.
- Does critical habitat refer to legally/government-defined or some other definition?
- Is it even possible to identify BIAs for some of those species?
- Residency of individual whales should be considered to better understand exposure and risk.
- This work should not overly consider knowledge gained from studies in California when extrapolating to Northern California Current region. Oceanographic process and prey are different in the Northern California Current so need to be regionally specific.
- What about potential habitat (e.g., otters)?
- Believe this topic should be integrated with "Baseline." Then rely on new BIAs plus what ongoing monitoring can say about climate mediated change to these BIAs. We saw this in Southern California where BIAs based on older data were not used extensively by baleen whales, or at least resident time was relatively low based on tagging data.
- How to adapt/update BIAs or important habitat delineators under changing ocean conditions
- "Critical habitat" carries a regulatory definition. Recommend replacing this term with BIAs or some other similar term.
- Effect of climate change on shifting the locations of essential habitats.
- If this recommendation becomes specific to important habitat areas: what about marine-protected areas, reserves, etc.?
- Perhaps you need to better describe the difference in short-term and spatial resolution to differentiate this from baseline data recommendation.
- For highly mobile species, need for international collaboration as species may move outside of U.S. waters.
- Add haulout sites.

What are the data and knowledge gaps associated with this recommendation?

- See updated BIA effort for cetaceans to be available end of 2022 (e.g., Calambokidis et al. 2019).
- BIAs are *some* but not *all* of the important areas for marine mammals.
- Need occurrence data in data-poor areas like area north of Point Conception up to southern Monterey Bay National Marine Sanctuary.
- Need more data on habitat use for different species.
- Emphasize BIAs for more species and to more fully represent habitat function.
- BIAs may change under changing ocean conditions—harder and harder to protect static areas.

- Need to prioritize species of interest for special habitat use like BIAs and critical habitat. Hard to consider all in a practical way.
- Quality of habitat can be assessed in many ways other than residence in time and space. A good additional metric is body condition to reflect foraging success. Suggest photogrammetry using unmanned aerial vehicles.

What are the methods or technologies available to address the recommendation? What are the benefits and limitations of each?

- There is an *Aquatic Mammals* issue that focuses on BIAs and the cetsound website has maps for cetaceans, with an update in progress.
- Models that incorporate multiple studies are usually valuable for assessing sensitive or important habitats for species.
- BIAs (being updated now, will be available by end of 2022) and critical habitat designations exist.
- Modeling with oceanographic factors to indicate habitat features that create BIAs: needs sightings + ecosystem data, groundtruthing, continued data input, and adjustment.
- All national marine sanctuaries have status and trends, including habitat, published within their "Condition Reports." Marine protected areas may have similar evaluations and reports that would be relevant.
- Photo identification, unmanned aerial vehicle, noninvasive suction cup tags, focal follows.

What technological advancements or infrastructure are needed to address the recommendation?

- Integration of data from multiple data platforms and different tags that already exist to validate existing models.
- Need models that will be predictive in different conditions, including climate change scenarios; also helpful to predict in "real time" like the blue whale work by Hazen's labto inform fisheries activities.
- Improve ability to integrate more data than just NMFS surveys in assessing areas of importance, which are the main data used.
- Advancement of PAM data for habitat models—integrating data from various platforms (PAM network?).

Synthesized Recommendation F. Determine Marine Mammal and Sea Turtle Response to New OSW Structures

Description of the synthesized topic as developed by the SEER team:

- Understand collision potential between new OSW structures and marine organisms.
- Identify marine organism responses and local community changes due to new in-water structures, including potential prey attraction and implications for foraging habitat.

- Investigate conditions associated with avoidance or attraction.
- Sources identifying this recommendation: ODFW (2020a, b); Southall et al. (2021); Maxwell et al. (2022).

Does this research recommendation accurately represent the need?

- Think about effects on populations, not just individuals (like the Population Consequences of Disturbance model).
- Also think about effects at multiple scales—close by (e.g., attractant effect) as well as various distances (e.g., acoustic effects).
- Impacts on local/fine-scale movements around infrastructure.

What are the data and knowledge gaps associated with this recommendation?

- Don't know what's there now; don't know how organisms respond to installation and presence of structures. Massive data gaps across lots of taxa!

What are the methods or technologies available to address the recommendation? What are the benefits and limitations of each?

- Visual (vessel-based) surveys.
- Acoustic (fixed- and mobile-platform) surveys.
- Suction-cup accelerometer tags.
- There's a lot of overlap here with other research recommendations (in terms of methods/tools/techniques); it should just be clarified that all studies/data collection can be done for multiple purposes and should be combined as much as possible to reduce stress from research!

What technological advancements or infrastructure are needed to address the recommendation?

- Better machine learning/deep learning for automated analysis of survey data (mostly acoustic, but hopefully visual in the future).

Synthesized Recommendation G. Consider Vessel Traffic Associated With OSW Energy Development That Could Result in Vessel Strikes and Disturbance

Description of the synthesized topic as developed by the SEER team:

- Support research and analysis of risk and impacts of vessel strikes to marine mammals and sea turtles, including ESA-listed species, in waters between the WEA and shore.
- Research that informs measures to reduce the risk of vessel strikes, avoid injury, and minimize potential disturbance during geophysical survey operations.
- Development of near-real-time dynamic management tools (e.g., Whale Alert).

- Example species: southern resident killer whale; blue, fin, gray, humpback, sei, sperm whale; North Pacific right whale; Guadalupe fur seal; non-ESA-listed marine mammals; Pacific leatherback sea turtle.
- Sources identifying this recommendation: NMFS (2022); OPC (2020); Maxwell et al. (2022).

Does this research recommendation accurately represent the need?

- Would characterize as increased risk from vessel traffic—it's already well-established that vessels create risk from strikes and noise/disturbance.
- Research is also fairly well established on reducing lethal strikes: speed limits. New research should focus on technology for real-time detection to alert mariners to slow down and avoid areas.

What are the data and knowledge gaps associated with this recommendation?

- Data gaps linked to baseline distribution/habitat use patterns.
- Depth of foraging and migrating whales on the West Coast.

What are the methods or technologies available to address the recommendation? What are the benefits and limitations of each?

- Suction-cup accelerometer tags: fine-scale movements of whales, depth, speed, etc.
- Acoustic monitoring + visual monitoring for baseline information; ability to detect through PAM depends on whales vocalizing.

What technological advancements or infrastructure are needed to address the recommendation?

- Real-time detection capability and communication—app to create geofencing around whale hotpots, send alert directly to boaters in the area.
- Digital aerial surveys + PAM and artificial intelligence/algorithm program to detect whale presence.

Synthesized Recommendation H. Consider Onshore and Nearshore Environmental Effects From OSW Energy Development

Description of the synthesized topic as developed by the SEER team:

- Understand potential effects on marine life from OSW development that may include infrastructure onshore and nearshore such as port development, subsea interconnection, and/or transmission expansion.
- Link these effects to the offshore impact analyses.
- Sources identifying this recommendation: American Bird Conservancy (2021); California joint state letter (2022).

Does this research recommendation accurately represent the need?

- Need more detail about potential impacts from nearshore/onshore development—noise, benthic disturbance, vessel traffic?

What are the data and knowledge gaps associated with this recommendation?

- Nearshore distribution and habitat use of small cetaceans and pinnipeds.
- Possibly include EMF effects here from cable/subsea interconnection.
- Baseline noise and vessel traffic in ports/nearshore.
- Use of inshore areas (estuaries, bays) by small cetaceans (harbor porpoises) and pinnipeds.
- Impacts on prey species at every life stage (e.g., larval fish/crabs—EMF and benthic disturbance—impact juveniles, fewer adults available as prey?).

What are the methods or technologies available to address the recommendation? What are the benefits and limitations of each?

- Species composition and abundance: aerial surveys, PAM, shore-based observations.
- Lab and field-based EMF studies.

What technological advancements or infrastructure are needed to address the recommendation?

- No responses.

Synthesized Recommendation I. Examine Diet Composition and Prey Species for Marine Mammals and Sea Turtles

Description of the synthesized topic as developed by the SEER team:

- Examine diet composition and primary prey species, particularly in/near planned OSW areas.
- Evaluate changes in ecosystem and prey conditions in OSW development areas.
- Consider potential upwelling impacts from OSW development on ecosystem and prey.
- Sources identifying this recommendation: NMFS (2022); Southall et al. (2021); California joint state letter (2022).

Does this research recommendation accurately represent the need?

- Not just in OSW areas, but regionwide (would changes cause shift in presence/abundance within OSW areas).
- Add prey density needs (how much prey needs to be present to forage).

What are the data and knowledge gaps associated with this recommendation?

- Prey for small cetacean species; habitat drivers for most large whale species (especially fin whales).

What are the methods or technologies available to address the recommendation? What are the benefits and limitations of each?

- Prey sampling, fecal samples, breath samples, isotopic analysis.
- Net tows, water column samples, sonar (prey density).

What technological advancements or infrastructure are needed to address the recommendation?

- Models integrating distribution and abundance data, ecosystem information.

Synthesized Recommendation J. Investigate Potential Impacts of Floating Array Cable Electromagnetic Fields (EMFs) on Marine Life

Description of the synthesized topic as developed by the SEER team:

- Consider potential impacts of EMFs from dynamic or buried cables on marine animal sensory systems and movements (e.g., some sea turtles and theoretically for some cetaceans).
- Sources identifying this recommendation: NMFS (2022); State of Maine (2021).

Does this research recommendation accurately represent the need?

- Floating cables also pose an entanglement risk—are EMF cables more or less risky?

What are the data and knowledge gaps associated with this recommendation?

- Marine mammal response to EMF.

What are the methods or technologies available to address the recommendation? What are the benefits and limitations of each?

- No responses.

What technological advancements or infrastructure are needed to address the recommendation?

- No responses.

Synthesized Recommendation K. Determine Risk of Chemical and Toxic Pollutants on Marine Mammals and Sea Turtles Associated With OSW Energy Development

Description of the synthesized topic as developed by the SEER team:

- Understand risk of chemical and toxic pollutant runoff (e.g., fuel, oil, or other hazardous materials spills) into the water from increased vessel traffic and shoreside activities that can affect the health of marine mammals and sea turtles.
- Consider chemical leaks or use of biocides to control growth of marine organisms that may pollute the ecosystem and harm prey.

- Assess potential impacts and recommend measures to prevent or contain accidental spills to minimize any possible adverse impacts of leasing activities on the environment.
- Sources identifying this recommendation: NMFS (2022); California joint state letter (2022).

Does this research recommendation accurately represent the need?

- No responses.

What are the data and knowledge gaps associated with this recommendation?

- Length of time vessels will be transiting to or in WEAs.
- Baseline health metrics.
- Effectiveness of biocides/chemicals to control growth of marine organisms (worth even using them?).

What are the methods or technologies available to address the recommendation? What are the benefits and limitations of each?

- Fecal and breath samples, stranding network reports (necropsy results especially).

What technological advancements or infrastructure are needed to address the recommendation?

- No responses.

6. Breakout #2: Fish and Invertebrates

Figure 3. Yelloweye rockfish. Photo Credit: NOAA Fisheries

6.1 Key Takeaways

The team reviewed all feedback from the fish and invertebrates breakout group and developed the following key takeaways as a synthesis across research recommendations.

- **Existing Data Sets and New Surveys.** Information from existing data sets and surveys should be used to better understand the baseline fish and invertebrate distributions, as well as seafloor conditions in areas of potential OSW energy development. Synthesizing existing data will help identify data gaps and define how to fill them, including the potential for new surveys that include expansion into unmapped areas to assess species and map seafloor habitats.
- **Sampling and Data Processing Techniques.** Improvements to sampling and data processing techniques will allow researchers to gather and analyze large amounts of data more effectively and/or efficiently. For example, potential areas for advancement include publishing a publicly available database of genetic sequences for relevant species to support environmental DNA analysis and developing automated image/video analysis techniques for underwater surveys.
- **Modeling Approaches To Understand Baseline and Response.** Models and simulations can help predict ecological response to OSW energy development and understand dispersion and movement patterns of fish and invertebrates. In many cases, the methodology for the models already exists but needs to be applied to the specific context of OSW development in a relevant area. In particular, simulations can help understand larval transport, changes in oceanographic conditions, and other key research questions.

6.2 Overview of Participation

The fish and invertebrates breakout discussion took place on May 4, 2022. Aside from organizers, there were 37 participants in the breakout session (see Table B-1 for names and affiliations). In addition to the workshop organizers, participant affiliations included federal agencies, state agencies, government-sponsored research organizations (both U.S. and international), nonprofit organizations, environmental NGOs, and environmental consultants. Most participants were from the U.S. Pacific region, but there were also several participants from other U.S. regions and Europe.

6.3 Summary of Feedback

A total of 311 comments were received on the fish and invertebrates MURAL from participants during and after the workshop (Figure 4). This workshop was focused on the ecological aspects of fish and invertebrate populations, habitats, and biology, and not focused on the fisheries aspects. As such, research recommendations about the fishery industry and socioeconomic effects were not considered in this workshop.

Feedback was solicited from workshop participants through a series of prompts for each synthesized research recommendation. A summary of the feedback for each recommendation is provided in the following sections. The "Description" section for each research recommendation includes text that the SEER team developed ahead of the meeting; the text under each question is a summary of the input provided by the attendees (e.g., clarifying input, removing redundancy, etc.) with the original wording preserved where possible. See Appendix B for more detail on individual responses received on the MURAL board for fish and invertebrates.

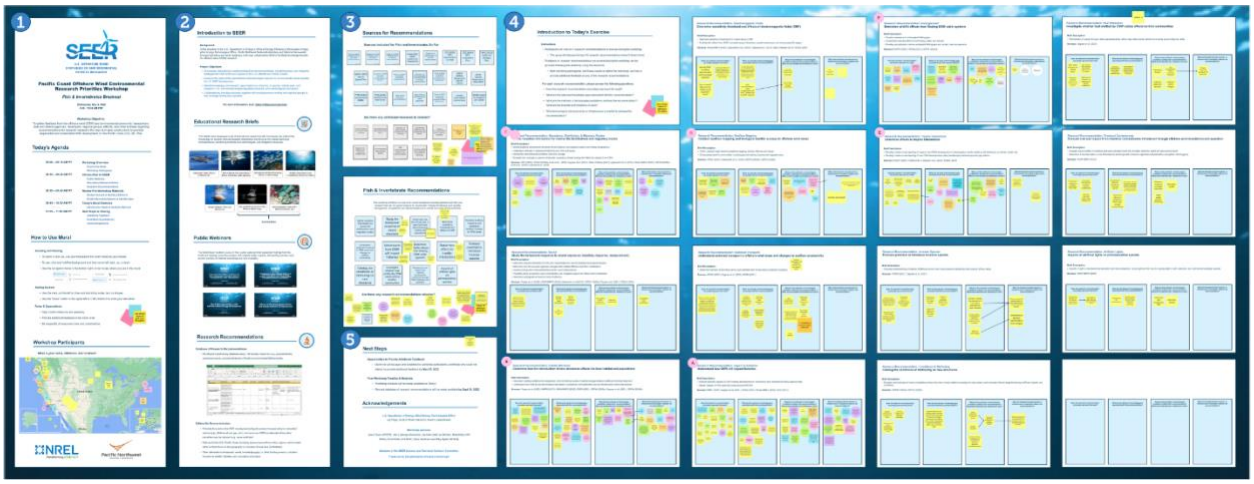

Figure 4. Screenshot of Breakout #2 MURAL board. A high-resolution version of the screenshot is available to download here.

Seven additional resources were recommended by workshop participants for inclusion in the database, such as published articles, reports, and state plans (see Appendix B.3).

Using recommendations provided in the literature, the team synthesized 14 research recommendations related to fish and invertebrates and OSW on the Pacific Coast. A preliminary description of each recommendation was created using information gathered through the literature. The summary of these synthesized research recommendations can be found in Section 4.3. During the workshop, participants expanded on the initial research recommendation to provide additional details about the topic description, knowledge gaps, suggested methodology, and required technology or infrastructure to address each research recommendation.

Six of the 14 initial synthesized research recommendations were discussed in depth during the workshop (Synthesized Recommendations A–F). The six recommendations for discussion were selected based on voting by the participants during the workshop. For the remaining eight recommendations (Synthesized Recommendations G–N) that were not discussed during the workshop, participants were asked to provide written comments after the workshop. Note that these comments may represent the feedback of just a couple of individuals and not the larger workshop group. The 14 research recommendations for fish and invertebrates including input from the workshop participants are summarized as follows.

Synthesized Recommendation A. Understand How Offshore Wind Energy Development Will Impact Fisheries[2]

Description of the synthesized topic as developed by the SEER team:

- Analyze potential impacts of OSW energy development on commercial and recreational fishing opportunities.
- Assess impacts on fish spawning and early life stages.
- Sources identifying this recommendation: CEC (2021); Degraer et al. (2021); NMFS (2022); PFMC (2021).

Does this research recommendation accurately represent the need?

- Develop understanding of secondary production, spawning habitat, and nursery habitat.
- Potentially reframe this as impacts to "fish and invertebrate species" to avoid the socioeconomic and management implications associated with "fisheries".
- What is the expected effect if fishing is excluded in the OSW energy area?
- Does OSW energy development comply with National Environmental Policy Act environmental justice regulations.
- What is the economic reliance of ports and communities?
- What externalities are introduced? (e.g., do fishers need to travel further to access fisheries?)
- Develop better understanding of how changing climate will affect the interactions between OSW and fish distributions.
- Determine if predators will congregate near the structures, and if so, the potential effect on fish populations.
- Sources identifying this recommendation: CEC (2021); Degraer (2021); NMFS (2021); PFMC (2021); Responsible Offshore Development Alliance (RODA) (2021).

What are the data and knowledge gaps associated with this recommendation?

- Understanding of impacts at different life stages.
- There is good knowledge about the local effects, but less is known about how that translates to population dynamics at the stock level.
- The types of fishing restrictions within OSW areas.
- The types and designs of mooring that will be used.
- Behavior of fish in early life stages.
- Do OSW areas create different food availability and sources for fish?
- Fishing sectors at different ports and their vulnerability to OSW development.
- Levels of bycatch during OSW installation and operation.

[2] Note that the focus is on fish species and fisih stocks/populations rather that the fishing industry and associated socioeconomic considerations.

- Limited understanding of natural variability in fish stock, which may lead a tendency to relate OSW pressures to changes in stock rather than natural variability or climate change.

What are the methods or technologies available to address the recommendation? What are the benefits and limitations of each?

- Seek input from all potentially impacted fishing sectors.
- NMFS Northwest Fisheries Science Center groundfish bottom trawl survey data could be used.
- Biophysical larval transport/dispersal model.
- Leverage NMFS stock assessments
    - Benefits: standardized, long time series data.
    - Challenges: limited to some habitats, random annual selection within a pool of stations.
- Fish tagging or various tracking technologies
    - Benefits: works well for large predators.
    - Challenges: may not be acceptable to fishing communities.
- Hydroacoustics
    - Benefits: works well for small, pelagic species.
- Midwater seines
    - Benefits: works well for small, pelagic species.
- Standardizing data collection methods (e.g., use same Before-After-Control-Impact [BACI] methods) across different wind energy areas to better understand cumulative impacts.
- Evaluate ecosystem services including food supply (e.g., as done by sanctuaries).
- Compare larval dispersal model outputs with genetic analysis, otoliths/statoliths.
- Population dynamics model (leveraging stock data)
    - Benefits: can consider large spatial scale
    - Challenges: a lot of data are needed
- Construct participation networks by using infoMap community detection algorithm.
- Simulation modeling of effects to resource surveys.
- Computational models of fishing gear when fished
    - Challenges: may not be developed for all gear; may not be groundtruthed.

What technological advancements or infrastructure are needed to address the recommendation?

- Environmental DNA: expand methods for more groundfish; create libraries for relevant species; pair with traditional sampling to ground-truth the methodology.
- Regional network of receivers to detect tagged fish, allowing detection among farms and across different habitat grounds.
- Co-locating sensors on long-term mooring across a strategic network.

- Noninvasive technologies, such as video imaging.
- Advance the capabilities of spatially explicit assessment models.

Synthesized Recommendation B. Determine How the Introduction of New Structures Affects the Local Habitat and Populations

Description of the synthesized topic as developed by the SEER team:

- Document existing conditions for comparison with monitoring results and habitat changes related to OSW development.
- Understand how OSW structures influence recruitment, connectivity, and settlement around OSW farms and anchors in the pelagic zone and on the sea bottom.
- Sources identifying this recommendation: Degraer et al. (2021); NMFS (2022); ODFW (2020 a, b; Popper et al. (2022); RODA (2021); Washington Department of Fish and Wildlife (WDFW) (2017).

Does this research recommendation accurately represent the need?

- Understand how new structures affect oceanographic processes (circulatory and thermal changes) and larval transport.
- Determine how OSW effect water stratification and primary production.
- Understand the linkage mechanisms that cause OSW structures to influence the abundance and distribution of fish.
- Determine how new organisms interact with the ocean environment, including water filtering capabilities and organic matter stored in biomass.
- Determine how species interactions during the initial deployment stage affect long-term community development around the structures.
- Evaluate differences and similarities between effects of floating structures and fixed-bottom structures to facilitate knowledge transfer, as applicable.

What are the data and knowledge gaps associated with this recommendation?

- Baseline data for all habitat components and populations of interest
    - Baseline benthic community structure and variation.
- Understanding characteristics of OSW infrastructure; where they exist and what ecosystems exist there.
- The process between settlement and recruitment are not well-known.
- Colonization rates and species at different levels in the water column.
- Larval distribution from estuarine to offshore areas.
- Determine sampling design that pairs best with each research area.
- Determine thresholds and criteria that indicate a significant change from the baseline such that changes to the project are required.
- Maintenance of biofouling and how it affects community change.
- Indicators to characterize habitat and assemblages.

- How to transfer knowledge from offshore infrastructure to OSW-specific understanding.
- Effect of climate change on fisheries.
- Understanding how cables interact with the sea bottom during tidal cycles and weather events.
- Floating structure effects on vertical mixing.
- Feedback of how organisms affect environment and environment affects organisms.
- Methods to mitigate negative impacts that are identified postconstruction.

What are the methods or technologies available to address the recommendation? What are the benefits and limitations of each?

- Acoustic Doppler profiles to understand local oceanographic conditions.
- Underwater video and images (including benthic surveys and fish trap camera surveys).
- Benthic trawls in soft sediment areas.
- Regional Ocean Modeling System linked to OSW scenarios to assess changes in pelagic habitat.
- Use indicator species that represent large part of communities, conduct detailed research there, then upscale.
- Biophysical larval transport and dispersion models run with and without OSW structures.
- Environmental DNA to characterize changes in species assemblages over time.
- Synthesis of economic and port infrastructure data for potentially affected fisheries.

What technological advancements or infrastructure are needed to address the recommendation?

- High-spatial-resolution hydrodynamic models.
- Buoy network with environmental and ecological sensors.
- Automated image analysis with machine learning.
- Autonomous holographic camera to image plankton in the field.
- Individual-based modeling to link larval and adult dispersal with OSW farms and essential fish habitat.
- Environmental DNA—develop a publicly available database of genetic sequences; complete further validation of environmental DNA methodology.
- Docking stations for AUV and ROV (wave-powered).
- Mechanisms to share proprietary data collected by developers (geophysical, geotechnical, meteorological ocean).

Synthesized Recommendation C. Gather Baseline Information for Marine Life Distributions and Migratory Routes

Description of the synthesized topic as developed by the SEER team:

- Identify baseline distributions of marine life and habitat, including the location and timing of migrations.
- Understand changes in the species distributions over time and space.
- Identify the environmental conditions that drive change.
- Evaluate how changes in species distribution caused by climate change will affect the impacts from OSW.
- Sources identifying this research recommendation: OPC (2020); ODFW (2020a); Cook et al. (2021); Degraer et al. (2021); State of Maine (2021); Aylesworth et al. (2019); NMFS (2022); ODFW (2020b); Flick et al. (2021); WDFW (2017); CEC (2021).

Does this research recommendation accurately represent the need?

- Improve understanding of baseline oceanographic conditions, and how they interact with species distributions including larval life stages.
- Characterize how measurements of abundance fit within baseline data collection.

What are the data and knowledge gaps associated with this recommendation?

- Identify priority species for monitoring.
- Migratory routes for invertebrates in addition to fishes.
- Access to high-quality environmental parameters for species distribution models.
- Understand whether oceanographic change may alter upwelling and larval distribution of fish and invertebrates.
- Understanding how the wind-wake effect influences Ekman dynamics and upwelling/downwelling.
- Current biogeography of species and predicted distribution with climate change.
- Migration and stock status of international and transboundary species.

What are the methods or technologies available to address the recommendation? What are the benefits and limitations of each?

- Tagging highly migratory species.
- Collect long-term data sets to incorporate natural variability and climate change.
- Benthic camera surveys.
- Fish trap surveys.
- Environmental DNA.
- Acoustic Doppler profilers.
- Fish tagging with moored buoy network.
- Fish surveys.
- Environmental modeling to predict movement patterns and transboundary migration.
- Population genetic studies, otolith studies; Fourier-transform near infrared spectroscopy (FT-NIRS) for otolith aging; otolith chemistry for anadromous species.

- Unmanned aeries surveys.
- Food web models.

What technological advancements or infrastructure are needed to address the recommendation?

- Telemetry network and data sharing.
- Increased scientific staffing.
- Strategic network of co-located sensors.
- Improvement in remote sonar monitoring (e.g., Deepwater Echo Integrating Marine Observatory System [DEIMOS]).

Synthesized Recommendation D. Conduct Seafloor Mapping and Biological Benthic Surveys in Offshore Wind Areas

Description of the synthesized topic as developed by the SEER team:

- Obtain updated, high-resolution seafloor mapping data for OSW areas.
- Characterize benthic communities including ground truthing of previously mapped areas
- Sources identifying this recommendation: Aylesworth et al. (2019); PFMC (2021); ODFW (2020a, b).

Suggested additions to this recommendation:

- Standardize a characterization scheme for seafloor sediment type.
- Expand surveys to characterize the extent of unique features if and when they are identified.
- Conduct long-term surveys to monitor changes that progress over longer time horizons (>10 years).
- Evaluate coral larval dispersal.
- Define the goal of the survey before conducting habitat mapping.

What are the data and knowledge gaps associated with this recommendation?

- Data sets are sporadic, especially in off-the-path areas.
- Identify locations of deep-sea coral, sponge reefs, pockmarks, cold seeps.
- Surveys that include nearshore landing areas as well as OSW farm areas.
- Shell mounds reports are lacking in southern California.
- Recovery rates of different types of habitats.
- Assessment of seafloor habitat and the types of anchors suitable for that substrate.

What are the methods or technologies available to address the recommendation? What are the benefits and limitations of each?

- Data sharing of bathymetry from commercial and recreational data.

- Leverage existing data from Coastal and Marine Ecological Classification Standard [CMECS], other partnerships for seafloor mapping, and vessels of opportunity.
- Video imagery (360 degree) with automated image processing.
- Video AUV.
- ROV with environmental DNA sampling (similar to NOAA's Explorer).

What technological advancements or infrastructure are needed to address the recommendation?

- Machine learning and artificial intelligence for data processing.

Synthesized Recommendation E. Determine Effects of Trophic Interactions

Description of the synthesized topic as developed by the SEER team:

- Develop a better understanding of impacts from OSW development to bioenergetics, benthic feeding, fish behaviors, and lower trophic life.
- Develop a better understanding of how OSW developments alter predator/prey relationships and populations.
- Sources identifying this recommendation: Degraer et al. (2021); RODA (2021); WDFW (2017).

Suggested additions to this recommendation:

- Consider lower trophic species, such as phytoplankton and zooplankton.
- Link how the artificial reef affects secondary production.
- Determine keystone species at each tropic level; identify trophic levels of most concern.
- Develop understanding of physical-biogeochemical-ecosystem effects of OSW.

What are the data and knowledge gaps associated with this recommendation?

- Spatial relationship between nursery areas and offshore distribution.
- Distribution and abundance of small forage fishes.
- Behavioral patterns of fish.
- Adaptive management strategies for fisheries.

What are the methods or technologies available to address the recommendation? What are the benefits and limitations of each?

- Fish tags to understand fish behavior.
- Underwater cameras to understand fish behavior.
- Stable isotope analysis:
    - Benefits: can identify trophic level, model interactions, cost-effective.
    - Challenge: large sample sizes required for best results.
    - Can couple with genetics to understand connectivity.
    - Can combine with pulse chase experiments.

- Ecosystem model.

What technological advancements or infrastructure are needed to address the recommendation?

- In situ experimental tools, mesocosms, and controlled environments.

Synthesized Recommendation F. Determine Wildlife Effects From Floating Offshore Wind Cable Systems

Description of the synthesized topic as developed by the SEER team:

- Conduct assessment of entangled fishing gear.
- Understand potential effects from floating cables and failures.
- Develop procedures to remove entangled fishing gear and protect marine organisms.
- Sources identifying this recommendation: ODFW (2021a); RODA (2021); WDFW (2017).

Suggested additions to this recommendation:

- Consider all marine debris, not just fishing gear.
- Determine the biofouling and ecosystem effects of floating cables.
- Understand whether floating cables change water column stratification and impact primary production.
- Determine if the potential for debris entanglement increase within an OSW array.
- Specify the problem in more detail by describing the realistic cables depths.

What are the data and knowledge gaps associated with this recommendation?

- What fishing gear gets entangled? Where it gets entangled? How gear behaves underwater?
- System design, including mooring design, when and where will cables be buried.
- Does wildlife entanglement potential change during different life stages.
- Effects of severe weather on floating cables.

What are the methods or technologies available to address the recommendation? What are the benefits and limitations of each?

- Underwater cameras.
- Oceanographic models to determine hot spots for potential entanglement and how these locations relate to fishing grounds.
- AUVs or ROVs with manipulator arms for removal of entangled gear.

What technological advancements or infrastructure are needed to address the recommendation?

- Methods for monitoring mooring entanglement and maintenance needs through remote sensing.

- Sensors on floating cables for monitoring.
- Biodegradable fishing gear.
- Marking fishing gear to determine its origin.
- Robotics for monitoring and mitigation.

Synthesized Recommendation G. Study the Behavioral Response to Sound Exposure (Baseline, Response, Measurement)

Description of the synthesized topic as developed by the SEER team:

- Determine acoustic thresholds for fish and invertebrates and conduct behavioral response studies.
- Determine how the acoustic signature changes with multiple OSW farm installations
- Develop a long-term instrumented field site for sound observations.
- Feasibility study to examine sounds minimization and mitigation options for fish and invertebrates.
- Determine propagation of sounds in local conditions.
- Sources identifying this research recommendation: Popper et al. (2021, 2022); NMFS (2022); Aylesworth et al. (2019); ODFW (2020a); RODA (2021).

Suggested additions to this recommendation:

- Identify which species have the potential to be impacted and focus initial effort on managed species.

What are the data and knowledge gaps associated with this recommendation?

- Species-specific noise sensitivity.
- Species-specific mechanisms for sound detection.
- Characterization of background noise.

What are the methods or technologies available to address the recommendation? What are the benefits and limitations of each?

- In-situ passive acoustic monitoring.
- Laboratory experiments.

What technological advancements or infrastructure are needed to address the recommendation?

- Automated data processing methods.

Synthesized Recommendation H. Determine Sensitivity Threshold and Effects of Electromagnetic Fields

Description of the synthesized topic as developed by the SEER team:

- Determine sensitivity threshold for marine life and EMF.

- Evaluate the effects from EMF in predator-prey interactions, spatial awareness, and during early life stages.
- Sources identifying this research recommendation: Aylesworth et al. (2019); Degraer et al. (2021); NMFS (2022); RODA (2021); State of Maine (2021).

Suggested additions to this recommendation:

- Identify EMF-sensitive species.
- Identify a framework, if possible, to transfer lessons learned between species and locations.
- Determine if there are population-level effects.

What are the data and knowledge gaps associated with this recommendation?

- How do EMFs affect species that spawn nearby?
- How do EMFs affect sharks and rays?
- How could EMF affect salmon and their migratory senses?
- How do EMFs affect species in short and long term?
- How do EMFs affect different life stages for nearby species?
- Information about cable configurations and characteristics of EMF.

What are the methods or technologies available to address the recommendation? What are the benefits and limitations of each?

- In-situ field telemetry studies to track animals around EMF.
- EMF modeling studies based on cable characteristics.

What technological advancements or infrastructure are needed to address the recommendation?

- Commercial off-the-shelf magnetometers.

Synthesized Recommendation I. Understand Sediment Transport in Offshore Wind Areas and Changes to Seafloor Productivity

Description of the synthesized topic as developed by the SEER team:

- Determine whether wind energy farms could interfere with the process of sediment transport.
- Sources identifying this research recommendation: Degraer et al. (2021); PFMC (2021); RODA (2021).

Suggested additions to this recommendation:

- Will the presence of multiple anchors from floating wind turbines influence the process of sediment transport enough to impact infauna assemblages, biogeochemical processes within the sediment, and the overall seafloor productivity?

What are the data and knowledge gaps associated with this recommendation?

- Need hydrodynamics throughout the whole water column, especially near the bottom.

- Sediment grain size in OSW areas.
- Infauna assemblages, taking into account natural variability.
- Biogeochemical processes within the sediment at OSW areas.
- Understanding of trophic levels and food webs that could be affected.

What are the methods or technologies available to address the recommendation? What are the benefits and limitations of each?

- Sediment core and grab samples
    - Challenge: time- and labor-intensive.
- Suspended sediment monitoring: satellite imagery.
- Suspended sediment sampling: optical backscatter point or acoustic backscatter.
- Bed load or suspended load samplers.
- Flume studies.

What technological advancements or infrastructure are needed to address the recommendation?

- No responses provided.

Synthesized Recommendation J. Evaluate Potential To Introduce Invasive Species

Description of the synthesized topic as developed by the SEER team:

- Develop understanding of impacts to OSW on non-native species habitat use and invasion of new areas.
- Sources identifying this research recommendation: Degraer et al. (2021); WDFW (2017).

Suggested additions to this recommendation:

- Develop list of non-native species at risk for settling around OSW turbines.
- Understand what role non-native species will occupy and if they will replace native species.
- How could the mechanisms for non-native species introduction be avoided?

What are the data and knowledge gaps associated with this recommendation?

- Invasiveness potential of non-native species.
- Locations of existing populations of non-native species.
- Means and distance of non-native species.

What are the methods or technologies available to address the recommendation? What are the benefits and limitations of each?

- Environmental DNA to identify the presence of non-native species.
- Scrape samples with good taxonomical expertise.
- Underwater imagery (still and video).

What technological advancements or infrastructure are needed to address the recommendation?

- Genetic representation of non-native species in public repository.
- Autonomous image identification for species.

Synthesized Recommendation K. Catalog the Conditions of Biofouling on New Structures

Description of the synthesized topic as developed by the SEER team:

- Evaluate archived data of marine installations when they were newly installed to catalog the rate, extent, and character of early-stage conditions.
- Sources identifying this research recommendation: ODFW (2020a, b).

Suggested additions to this recommendation:

- Identify species diversity and successional stages.
- Identify relevant marine installations in similar conditions to OSW areas.
- Determine if climate change is shifting baselines for biofouling communities.

What are the data and knowledge gaps associated with this recommendation?

- Are the conditions and timelines at OSW structures comparable to those of surrogate industries? For example, taking into account the effects of climate change, including poleward distribution shifts, water chemistry, etc.

What are the methods or technologies available to address the recommendation? What are the benefits and limitations of each?

- Artificial reef monitoring systems
    - Challenge: requires good taxonomical expertise and/or genetic barcoding of samples.
- Scrape samples
    - Challenge: requires good taxonomical expertise and/or genetic barcoding of samples.
- Literature review and especially monitoring reports.

What technological advancements or infrastructure are needed to address the recommendation?

- Representation of genetic biofouling species in public sequence libraries.

Synthesized Recommendation L. Investigate Whether Heat Emitted by OSW Cables Affects Benthic Communities

Description of the synthesized topic as developed by the SEER team:

- The transfer of energy through cables generates heat, which may influence the benthic community surrounding the cable.
- Sources identifying this research recommendation: Degraer et al. (2021).

Suggested additions to this recommendation:

- How does heat dissipate away from the cable?

- What impacts to benthic organisms are expected, if any?
- What organisms might be impacted, if any?

What are the data and knowledge gaps associated with this recommendation?

- Physiological and behavioral effects of heat on benthic organisms at different life stages.
- Characterization of heat emission and dissipation per type of cable and sediment type.

What are the methods or technologies available to address the recommendation? What are the benefits and limitations of each?

- Lab studies.
- Field measurements of heat emissions and dissipation.
- Sediment profile imagery.
- Sediment grab/core samples.

What technological advancements or infrastructure are needed to address the recommendation?

- Thermal or infrared sensors to measure heat emissions, if they are not available.

Synthesized Recommendation M. Evaluate Risk and Impact From Chemical Contaminants Introduced Through Offshore Wind Installation, Operation, and Maintenance

Description of the synthesized topic as developed by the SEER team:

- Evaluate risk and effect of chemical and toxic pollutant runoff on the health of marine ecosystems.
- Determine if chemical leaks or use of biocides to control growth of marine organisms will pollute the ecosystem, harming prey.
- Sources identifying this research recommendation: NMFS (2022).

Suggested additions to this recommendation:

- What can be learned and leveraged from surrogate industries?
- Identify all potential sources of chemical contaminants.
- What are the potential trophic web implications?

What are the data and knowledge gaps associated with this recommendation?

- Physiological effects of biocides on nontarget species.
- Threshold of chemical contaminant exposure to trigger irreversible and/or harmful effects (species and life-stage specific).
- How much dilution is expected in the relevant environments.

What are the methods or technologies available to address the recommendation? What are the benefits and limitations of each?

- Literature review of surrogate industries.
- Water quality sensors.
- Laboratory studies.

What technological advancements or infrastructure are needed to address the recommendation?

- No responses provided.

Synthesized Recommendation N. Impacts of Artificial Light on Photosensitive Species

Description of the synthesized topic as developed by the SEER team:

- Impacts of light to photosensitive demersal and infaunal species, including those that bury to varying depth in soft substrate and photosensitive pelagic species.
- Sources identifying this research recommendation: NMFS (2022).

Suggested additions to this recommendation:

- Characterize the penetration of turbine artificial light into the water column (i.e., determine the depth).
- Determine how much light, if any, reaches the seafloor.

What are the methods or technologies available to address the recommendation? What are the benefits and limitations of each?

- Characterize which species are photosensitive.
- What is the behavioral and physiological response of sensitive species to artificial light?

Methods and technologies to address this recommendation:

- Underwater light sensors (e.g., photosynthetically active radiation).
- Laboratory studies.

What technological advancements or infrastructure are needed to address the recommendation?

- No responses provided.

7. Breakout #3: Bats and Birds

Figure 5. Brown Pelicans along the Oregon coast. Photo Credit: Roy W. Lowe/ USFWS

7.1 Key Takeaways

The team reviewed all feedback from the bats and birds breakout group and developed the following key takeaways as a synthesis across research recommendations.

- **Advances in Technology.** Technology advancement and deployment are necessary to monitor bird and bat activity and behavior. Technologies, such as acoustic detectors, visual or thermal video cameras, lidar, radar, and GPS or radio tags are often used to monitor bird and bat activity. Near-term research activities include 1) improving existing technology to withstand the harsh offshore environment, 2) miniaturizing tracking technology for small-bodied birds and bats, 3) developing and deploying infrastructure to install monitoring technology, and 4) advancing machine-learning algorithms to efficiently process large data sets.
- **Focal Species.** Given the lack of baseline data for most species and the uncertainties of how various species will respond to the presence of wind turbines, preconstruction monitoring should focus on a broad suite of species considered vulnerable to collision, displacement, or avoidance. Examples include species with flight heights within the rotor-swept area, those that may be potentially attracted to wind turbines, or individuals that commonly use the proposed area for development.
- **Covariates.** It is important to collect spatial, temporal, and weather data, as well as data on other ecological factors (e.g., prey availability), associated with the presence or

movement of species in an area to assess patterns of activity. These patterns may be useful in relating potential exposure of species once facilities are operational.

7.2 Overview of Participation

The bat and bird breakout session was held on May 5, 2022. Aside from NREL and PNNL staff, 39 participants joined the webinar, representing government agencies, academia, consultants, and NGOs (see Appendix C-1 for names and affiliations). Most participants were from the U.S. Pacific region, but there were several participants from other U.S. regions and Europe.

7.3 Summary of Feedback

A total of 313 comments were received on the bat and bird MURAL from participants during the workshop (Figure 6, Appendix C-2). The following numbers of responses were received for each workshop activity: additional sources (15 comments), additional research recommendations (40 comments), the five research topics prioritized for discussion during the workshop (258 comments), and additional research topics that received feedback after the workshop (0 comments).

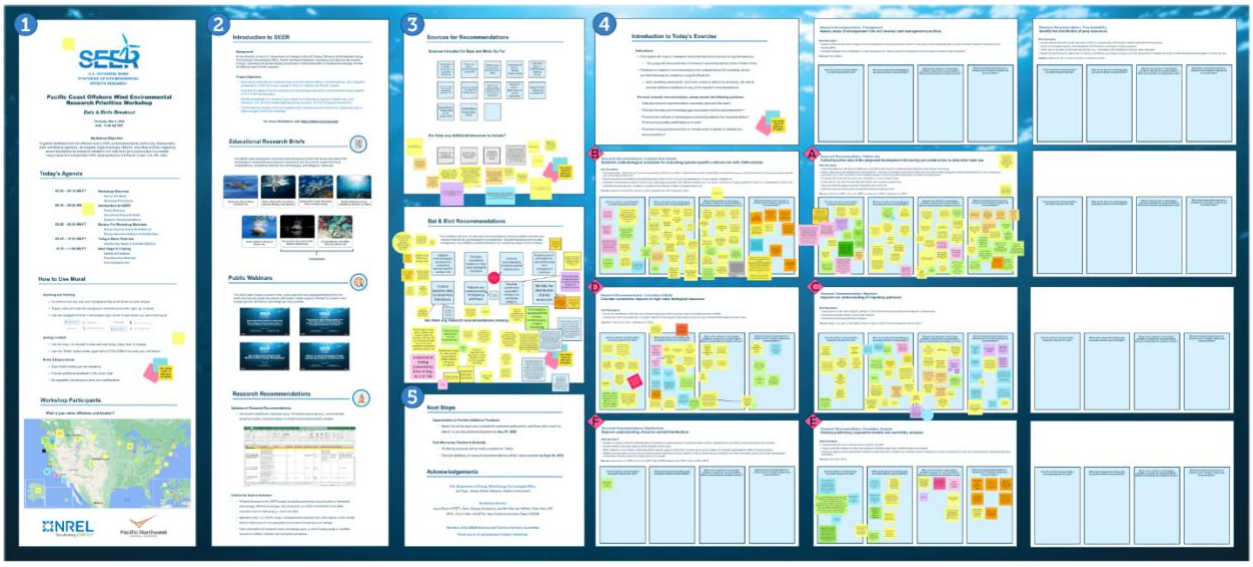

Figure 6. Screenshot of Breakout #3 MURAL board. A high-resolution version of the screenshot is available to download here.

Prior to the workshop, the team synthesized a list of eight broad recommendations for preconstruction research for bats and birds. The summary of these synthesized research recommendations can be found in Section 4.3. Participants provided additional reports and publications to include in the research database (see Appendix C-3). They also provided several suggestions for research recommendations that can be grouped into two categories: 1) those that were outside the scope of this workshop (i.e., focused on construction or operational phases), and 2) those that are similar to or related to the eight synthesized topics. There were a few comments highlighting the need to develop the analytical tools and monitoring technologies to use during various phases of development.

Participants voted on which of the initial synthesized recommendations to prioritize for discussion. Five of the eight recommendations were discussed in depth during the workshop based on voting and are described in the following sections (Synthesized Recommendations A–E). Three recommendations were not discussed during the workshop group discussions nor did they receive comments after the workshop (Synthesized Recommendations F–H). Feedback on the five recommendations discussed during the breakout group is also summarized. Full details on the feedback received during the breakout group discussion is available on the MURAL board link. The "Description" section for each research recommendation includes text that the SEER team developed ahead of the meeting; the text under each question is a summary of the input provided by the attendees (e.g., clarifying input, removing redundancy, etc.) with the original wording preserved where possible.

Synthesized Recommendation A. Collect Baseline Data at the Proposed Development Site During Preconstruction To Determine Habitat Use

Description of the synthesized topic as developed by the SEER team:

- Understand patterns of bat activity and habitat use in the offshore environment to assess the likely interactions with OSW.
- Assess habitat use of nonbreeding birds among years to 1) examine links between distribution and habitat use over winter to better understand potential displacement, and 2) link nonbreeding populations using OSW areas back to their breeding colonies to understand potential population-level effects of displacement.
- For species that breed near the study area, collect data on colony location and size.
- Collect data on rare marine birds to determine habitat use to establish baseline data.
- Determine potential hotspots and areas of significance for marine life.
- Determine avian use during winter and determine potential foraging grounds.
- Sources identifying this research recommendation: Cook et al. (2021); Hein et al. (2021); Leirness et al. (2021); Liebezeit et al. (2021).

Does this research recommendation accurately represent the need?

- Depending on species present, include breeding season.
- Baseline activity and presence of bats may not correlate with operational activity or mortality.
- Temporal and weather patterns are important.
- Understand drivers of habitat use, not just the patterns of use; this includes prey availability, oceanographic and atmospheric conditions, etc.
- Include common species, not just rare marine birds.

What are the data and knowledge gaps associated with this recommendation?

- Timing and distribution of shorebird nesting and bat roosting activity relative to cable landing sites.
- Movement data for species that are too small for tags.
- Accurate flight heights across seasons.

- Understanding variation in bat activity by species, age, and sex.
- Do bats echolocate in the offshore environment?

What are the methods or technologies available to address the recommendation? What are the benefits and limitations of each?

- Altimetry tags, lidar, and other technologies to estimate flight height.
- Boat and plane surveys.
- GPS tags.
- Acoustic monitors, particularly for bats.
- Motus receiving stations.
- Radar.

What technological advancements or infrastructure are needed to address the recommendation?

- GPS tags for smaller animals.
- Acoustic detectors that enable detection from greater distances.
- Machine-learning algorithms.
- Motus receiving stations.
- Transmitter development to get three-dimensional (3D) locations.
- Statistical methods to pair with data from various technologies.

Synthesized Recommendation B. Establish Methodological Standards for Evaluating Species-Specific Collision Risk With OSW Turbines

Description of the synthesized topic as developed by the SEER team:

- Use empirical data, collected at each site and incorporating wind and wave conditions, seabird behavior state, detailed flight characteristics by season, and turbine features to inform species-specific risk to bird-turbine collision risk.
- Quantify exposure and vulnerability at proposed development areas to inform siting and risk assessments; focus on species of greatest risk.
- Understand characteristics of seabird movement (e.g., flight height and speed) under different conditions (e.g., time of day, commuting vs. foraging, weather) and relate to our understanding of collision risk.
- Use behavioral responses (e.g., attraction or avoidance) to wind farms in models to evaluate collision risk.
- Sources identifying this research recommendation: Aylesworth et al. (2019); Cook et al. (2021); Liebezeit et al. (2021); American Bird Conservancy (2021).

Does this research recommendation accurately represent the need?

- Ensure this applies to more than seabirds and include other species of birds (e.g., shorebirds, migratory birds) and bats.

- Assess how collision risk changes with weather condition (e.g., is collision risk higher in bad weather/poor visibility conditions).
- Are there differences in potential collision risk between fixed-bottom and floating wind turbines?

What are the data and knowledge gaps associated with this recommendation?

- Validate model assumptions and the ability to effectively predict risk.
- Determine whether there are differences in risk/exposure between fixed-bottom and floating wind turbines.
- Accurate flight height data.
- What lighting requirements from U.S. Coast Guard may be modified to reduce attraction?
- Data on how animals perceive and respond to wind turbines.
- Variation in risk related to age classes, breeding vs. nonbreeding seasons.
- Need population or abundance estimates to put risk into context.
- Data from winter and in poor weather/oceanic conditions.

What are the methods or technologies available to address the recommendation? What are the benefits and limitations of each?

- Motus receiving stations with a large number of tagged individuals of various species.
- Lidar and cameras on aerial surveys to determine flight height.
- Altimeter tags for flight height.
- GPS tags for flight speed.
- Human observations.
- Radar for flight height.
- Radar paired with cameras.
- Radar paired with acoustic detectors.
- Machine-learning algorithms for processing and analyzing data.

What technological advancements or infrastructure are needed to address the recommendation?

- Thermal video and acoustic detectors capable of species identification.
- Tags for small-bodied animals.
- Drones.
- Collision detection systems for validating models.
- Stable platforms/buoys to support technologies (e.g., radar).
- Advances in remote-sensing, machine-learning algorithms.

Synthesized Recommendation C. Improve Our Understanding of Migratory Pathways

Description of the synthesized topic as developed by the SEER team:

- Expanding what is known about migratory pathways is instrumental in appropriate siting and management of leased areas.
- Evaluate the potential impacts to trans-Pacific migrants.
- Characterize the timing and pathways of migrants.
- Sources identifying this research recommendation: WDFW et al. (2017); ODFW (2020b); American Bird Conservancy (2021); PFMC (2021).

Does this research recommendation accurately represent the need?

- Need to characterize the number of migrants to establish take estimates.
- Migration should also include nearshore and onshore bird and bat movement.
- Need to understand environmental factors influencing migration patterns to help make predictions to other locations or into the future.
- Understand arrival and departure altitudes and setbacks of wind turbines.

What are the data and knowledge gaps associated with this recommendation?

- Migratory pulses.
- Landscape-scale models that predict migration of birds and bats using weather variables.
- Tracking studies with large sample sizes leveraged by data sharing/open data where possible.
- Migratory routes for passerines are unknown because of constraints in technology.
- Are bats using the Pacific offshore for migration?
- Migratory pathways for different age classes and sexes.
- Establish sampling grid for systematic surveys (e.g., North American Bat Monitoring Program).

What are the methods or technologies available to address the recommendation? What are the benefits and limitations of each?

- GPS tags.
- Ebird data to get a handle on timing of migratory pulses.
- Couple radar with cameras to assist in identifying species.
- State space movement models for Motus data.
- Radio telemetry for small-bodied animals.
- Next Generation Weather Radar (NEXRAD) weather radar and birdcast or batcast offshore migration.
- Validation of the Cornell migration dashboard.
- Simultaneous acoustic monitoring of bats onshore, nearshore, and offshore to compare patterns.

What technological advancements or infrastructure are needed to address the recommendation?

- Motus receiving stations.
- Large number of tagged individuals.
- NEXRAD coverage into the offshore environment.
- Transmitters that can be detected on radar.
- A grid of upward-facing cameras deployed throughout the area would provide information on birds and bats .
- Smaller transmitters with better battery life and good 3D location resolution.
- Transmitters that integrate location data with collection of other types of data (e.g., weather).
- Development of analytical methods and calibration data to develop 3D location estimates from Motus receiving stations.
- Expand temporal sampling for the North American Bat Monitoring Program to cover more time periods.

Synthesized Recommendation D. Consider Cumulative Impacts to High-Value Biological Resources

Description of the synthesized topic as developed by the SEER team:

- Ensure full consideration of the high-value biological resources and the cumulative impacts of multiple projects on wildlife.
- Analyze and model the potential and cumulative impacts of initial projects under present and future ocean conditions before approving lease areas.
- Sources identifying this research recommendation: Cullum et al. (2021a, b); Liebezeit et al. (2021).

Does this research recommendation accurately represent the need?

- Include common species; rare species may present greater risk, but they are more difficult to study.
- Displacement of birds feeding in an area leading to increased energetic costs, increased competition, and the potential effects on breeding .
- Clearly define cumulative effects; For example, does it only cover wind energy development or other human activities, such as fishing or oil/gas, and/or climate change?
- Establish range-wide monitoring approaches for OSW instead of site-specific studies.
- Need to assess impacts for species that may use multiple OSW Call Areas.

What are the data and knowledge gaps associated with this recommendation?

- What are the cumulative effects on prey base and is that from natural variability, climate change, or OSW development?
- How to address this issue in difficult-to-study species or areas.
- Need to fill gaps in baseline population vital rates.

- Energetic costs of avoidance/diversion, factors into cumulative impacts in a variety of ways.
- How does risk vary with different numbers and configurations of turbines?
- How does displacement and barrier effects change population vital rates?
- What is the nature of these interactions (e.g., additive, antagonistic, synergistic, etc.)? If a species exhibits avoidance, then other impacts are likely to be mitigated.

What are the methods or technologies available to address the recommendation? What are the benefits and limitations of each?

- Various modeling approaches exist, but data to populate the models are lacking.
- Long-term population surveys to observe population-level effects.
- Need population models and sensitivity analyses to identify key new studies to fill gaps, then refine models over time.
- Species status assessment analyses.
- This is a huge topic that requires understanding of population demography, individual level effects, and how to scale individual effects to individual fitness and then to population consequences. Might be better to refine this category to focus specifically on trying to scale up from individual- to population-level effects.

What technological advancements or infrastructure are needed to address the recommendation?

- Fatality estimates for OSW turbines.
- Coastwide avian productivity monitoring data.
- Data sharing from monitoring efforts.
- Data standardization and transparency.
- Ability for year-round monitoring of populations.
- Better multiscale statistical models to aggregate impacts.

Synthesized Recommendation E. Develop Preliminary Population Models and Sensitivity Analyses

Description of the synthesized topic as developed by the SEER team:

- Collect demographic data to develop robust population estimates.
- Conduct sensitivity analyses and other gap analyses to identify key gaps where additional data are most needed.
- Assess the degree to which displacement/collision may affect population viability and use sensitivity analysis to highlight key areas of uncertainty that need to be addressed when quantifying population-level effects.
- Sources identifying this research recommendation: Cook et al. (2021).

Does this research recommendation accurately represent the need?

- In addition to displacement/collision effects, there are increased disturbance effects that have energetic costs that might ultimately influence reproduction and survival.

What are the data and knowledge gaps associated with this recommendation?

- Population processes (e.g., density dependence, dispersal).
- Coordinated large-scale trend monitoring onshore for birds and bats.
- Understanding the fitness consequences of OSW effects to individuals (for nonlethal effects, such as displacement).
- Differences in juvenile and adult survival.

What are the methods or technologies available to address the recommendation? What are the benefits and limitations of each?

- Long-term data sets to inform change in prey availability over time.
- Careful statistical design of Motus telemetry studies.
- Mark-recapture studies.
- Color marking for survival and dispersal.
- Genetics.

What technological advancements or infrastructure are needed to address the recommendation?

- Motus receiving stations for onshore and offshore.
- Drone aerial survey methodologies for nesting seabird colonies.
- Big data analytics.
- Advanced tags for small-bodied animals.
- Integrated population models that include multiple data streams (e.g., trend, reproduction, survival) and that include covariates, such as disturbance and mortality.
- Fleet of upward-facing cameras to provide "point count" snapshot data for population estimation and migration passage.
- Sufficient resources to invest heavily in year-round tracking technologies (geolocators/GPS) to assess the impacts of movement/migration and/or exposure at the population level.

Synthesized Recommendation F. Improve Understanding of Marine Animal Distribution

Description of the synthesized topic as developed by the SEER team:

- Research is needed to identify and delineate areas of importance to marine organisms to determine where and when interactions are most likely or present the highest risk to species.
- Are bats present and how does presence relate to weather and time of year?

- Better integration of how climate is influencing shifts in species ranges and distributions; consider not just current ranges, but predicted ranges based on different climatic scenarios.
- Modeling analyses need to account for and evaluate possible distribution scenarios related to El Niños, Pacific decadal oscillations, and other atmospheric cycles that can alter oceanographic processes and spatially shift zones of high productivity or hypoxia.
- Sources identifying this research recommendation: Aylesworth et al. (2019); Cook et al. (2021); ODFW (2020b); Liebezeit et al. (2021); State of Maine (2021).

Synthesized Recommendation G. Identify the Distribution of Prey Resources

Description of the synthesized topic as developed by the SEER team:

- Identify baseline distribution of prey resources to inform our understanding of the drivers of seabird distributions and movements.
- Assess the unintended impacts, including impacts to the food chain, and access to existing resources.
- Collect data on variables that birds are responding to (e.g., zooplankton or fish availability) to improve model predictions.
- Review existing literature on seabird diet, by species, to identify key prey species and gaps, such that assessments of changes in prey due to OSW development are focused on the right prey taxa.
- Sources: WDFW (2017); Cook et al. (2021); Leirness et al. (2021).

Recommendation H. Assess Areas of Entanglement Risk and Develop Best Management Practices

Description of the synthesized topic as developed by the SEER team:

- Research efforts should invest in mapping multiple entanglement sources documented on the U.S. West Coast and then assess elevated risk areas identified through the mapping exercise.
- Develop best management practices.
- Distinguish between direct entanglement in project equipment (e.g., mooring lines) and entanglement with fishing gear ensnared on project equipment.
- Sources: ODFW (2020a).

8. Outcomes

This workshop gathered substantial feedback on research recommendations associated with the preconstruction phase of Pacific Coast OSW energy development in California, Oregon, and Washington. A total of 113 external participants were involved across the three workshop breakout groups, and provided approximately 1,000 total comments on the MURAL boards. Based on workshop feedback, the SEER team updated the research recommendations database. The database includes over 40 existing resources and more than 500 research

recommendations related to preconstruction, postconstruction, and maintenance, as well as decommissioning phases; the workshop focused primarily on the preconstruction recommendations only but other development phases should be further considered in future efforts. The team then synthesized the individual research recommendations into broad overarching topics to provide an overview of what is included in the database. Both the full database and synthesized research recommendations are available on the Tethys website to facilitate dissemination across interested stakeholders (https://tethys.pnnl.gov/pacific-offshore-wind-environmental-research-recommendations).

There is a continued need to improve awareness of the potential environmental effects, monitoring technologies, and management strategies for floating OSW energy development on the U.S. Pacific Coast. Coordination of these activities will require the sustained involvement of multiple sectors, including state and federal government, NGOs, industry, and tribal stakeholders. Beyond the baseline considerations discussed in this workshop, future state of the science activities should be planned to consider research needs across wind energy lifecycle phases for all relevant wildlife taxa and associated habitat and ecosystem processes.

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Appendix A – Breakout Group 1 (Marine Mammals/Sea Turtles) Details

A.1 Participant List

#	Name	Affiliation
1	Hayley Farr	PNNL
2	Rebecca Green	NREL
3	Mark Severy	PNNL
4	Frank Oteri	NREL
5	Cris Hein	NREL
6	David Weller	NOAA NMFS Southwest Fisheries Science Center
7	Bill Gorham	OCEAN
8	Abigail Ryder	BOEM
9	Michelle St Martin	USFWS
10	Michelle Fogarty	Equinor
11	Casey Clark	WDFW
12	Jess Stocking	WDFW
13	Desray Reeb	BOEM
14	James Morris	NOAA NCCOS
15	Casey Dennehy	Washington Department of Ecology
16	Andrew Johnson	MarFishEco Fisheries Consultants
17	Shannon Rankin	NOAA NMFS Southwest Fisheries Science Center
18	Colleen Weiler	Whale and Dolphin Conservation
19	Delia Kelly	ODFW
20	Joe Haxel	PNNL
21	Leigh Torres	Oregon State University
22	Jay Staton	CDFW
23	Naomi Lewandowski	DOE
24	Saffia Hossainzadeh	California Energy Commission
25	Andrea Copping	PNNL
26	Tina Fahy	NOAA NMFS West Coast Region
27	Lindsey Peavey Reeves	National Marine Sanctuary Foundation
28	Francine Kershaw	Natural Resources Defense Council
29	Sarah Courbis	Advisian
30	Jason Busch	Pacific Ocean Energy Trust
31	Stef Stavrakas	USFWS
32	Dave Mellinger	Oregon State University
33	Margarita McInnis	CDFW
34	Cheryl Strong	USFWS
35	Joy Page	DOE
36	Alexander Gilliland	Marine Scotland Science
37	Chip Johnson	U.S. Navy

#	Name	Affiliation
38	Kristen Hislop	Environmental Defense Center
39	Manuel Castellote	NOAA NMFS Alaska Fisheries Science Center
40	Scott Pearson	WDFW
41	Ali Carter	American Clean Power
42	Jessica Watson	ODFW

Table A-1. Breakout 1 Participants.

A.2 Detailed Feedback

All feedback received on the Marine Mammal and Sea Turtle Breakout MURAL board, including additional resources, additional research recommendations, and commentary is available here.

A.3 Additional Resources Identified by Participants

Abrahms, B., Hazen, E. L., Aikens, E. O., Savoca, M. S., Goldbogen, J. A., Bograd, S. J., Jacox, M. G., Irvine, L. M., Palacios, D. M., and Mate, B. R. 2019. Memory and resource tracking drive blue whale migrations. *Proceedings of the National Academy of Sciences*, *116*(12): 5582–5587.

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A.4 Additional Research Recommendations Identified by Participants

Following were additional research recommendations for marine mammals and sea turtles that were identified by workshop participants:

- Seasonality/temporal variability very important especially for construction phase.
- Propagation modeling to provide context for regular and “new” noise inputs.
- Modeling for migration/feeding changes with climate change.
- Maybe “spatiotemporal data,” since distributions vary by day, season, decade...
- Produce standardized long-term spectral averages (LTSAs) and anomalies to compare vessel and construction noise inputs against usual vessel inputs, event-based and seasonal wind noise inputs, etc.
- How little information is available about the floating offshore wind operations. As I understand it, much of this technology is still in development, making it very hard to assess impacts or even what impacts we should be concerned about. Also, the scale of these operations and facilities needs to be emphasized more. Not just the size of the turbines and arrays, but also the shore-based support and associated environmental damage.
- And increased noise—link to baseline sound data, model increases from vessel traffic.
- Energetics?
- Cumulative impacts with sea-level rise, fishing, etc.
- For baseline, winter occurrence/density really limited and emerging data need.
- As bigger picture could include Population Consequences of Disturbance and other methods to understand potential for population-level impacts.
- Recently seen interest in understanding effect on the California Current.
- Baseline body condition/health metrics.
- Substrate vibration.
- Specifics for small cetaceans (population size/abundance; social groups and existence of localized/regional populations).
- Determine geographic extent of impacts from different stressors.
- Water column use (three-dimensional behavioral maneuverability) while foraging to assess collision/entanglement risk.
- Winter surveys for all species off central California.
- Existing threats and connection to environmental changes/drivers.
- Making a note here about deep-diving offshore seals—not an issue on East Coast and something that may need attention.
- Examine far-field effects tens or even hundreds of kilometers from a site (from noise, chemical pollution, etc.).
- Pinniped migration routes (northern and Guadalupe fur seals, northern elephant seals) and overlap with proposed wind energy areas
- Upwelling.
- Downwelling baseline conditions.
- Comparison of East Coast and West Coast systems.

Appendix B – Breakout Group 2 (Fish/Invertebrates) Details

B.1 Participant List

#	Name	Affiliation
1	Hayley Farr	PNNL
2	Mark Severy	PNNL
3	Frank Oteri	NREL
4	Rebecca Green	NREL
5	Cris Hein	NREL
6	Katie Pierson	ODFW
7	Jan Vanaverbeke	Royal Belgian Institute of Natural Sciences
8	Lynn Mattes	ODFW
9	Martin Perrow	ECON Ecological Consulting
10	Delia Kelly	ODFW
11	Naomi Lewandowski	DOE
12	Alexander Gilliland	Marine Scotland Science
13	Lysel Garavelli	PNNL
14	James Morris	NOAA NCCOS
15	Brian Owens	CDFW
16	Bill Gorham	OCEAN
17	Tricia Perez	DOE
18	Paul Deaver	California Energy Commission
19	Sharon Kramer	H. T. Harvey & Associates
20	Lenaig Hemery	PNNL
21	Lyndie Hice-Dunton	Responsible Offshore Science Alliance
22	Cotton Rockwood	Point Blue Conservation Science
23	Kerry Griffin	Pacific Fishery Management Council
24	Jay Staton	CDFW
25	Mike Pol	Responsible Offshore Science Alliance
26	Kelly Andrews	NOAA NMFS Northwest Fisheries Science Center
27	Casey Dennehy	Washington Department of Ecology
28	Mark Bagdovitz	USFWS
29	Lindsey Peavey Reeves	National Marine Sanctuary Foundation
30	Abigail Ryder	BOEM
31	Stef Stavrakas	USFWS
32	Steven Degraer	Royal Belgian Institute of Natural Sciences
33	Jessica Watson	ODFW
34	Margarita McInnis	CDFW
35	Christopher Potter	CDFW
36	Andrew Johnson	MarFishEco Fisheries Consultants
37	Kathryn White	Advisian

#	Name	Affiliation
38	Kate Wells	NOAA NMFS West Coast Region
39	Jeff Young	NOAA NMFS West Coast Region
40	Linette Makua	BOEM
41	Elizabeth Clarke	NOAA NMFS Northwest Fisheries Science Center
42	Whitney Roberts	WDFW

Table 2. Table B-2. Breakout 2 Participants.

B.2 Detailed Feedback

All feedback received on the Fish and Invertebrate Breakout MURAL board, including additional resources, additional research recommendations, and commentary is available here.

B.3 Additional Resources Identified by Participants

Dannheim, J., Bergström, L., Birchenough, S. N. R., Brzana, R., Boon, A. R., Coolen, J. W. P., Dauvin, J.-C., De Mesel, I., Derweduwen, J., Gill, A. B., Hutchison, Z. L., Jackson, A. C., Janas, U., Martin, G., Raoux, A., Reubens, J., Rostin, L., Vanaverbeke, J., Wilding, T. A., Wilhelmsson, D., and Degraer, S. 2020. Benthic effects of offshore renewables: identification of knowledge gaps and urgently needed research. *ICES Journal of Marine Science 77*(3): 1092–1108.

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New Jersey Department of Environmental Protection. 2022. Research and Monitoring Initiative (RMI). Available from: https://www.nj.gov/dep/offshorewind/rmi.html.

New York State Environmental Technical Working Group. 2020. State of the Science Workgroup reports. Available from: https://www.nyetwg.com/2020-workgroups. (*Note: While this was a comment from a participant, these sources were already included as resources.)*

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B.4 Additional Research Recommendations Identified by Participants

Following were additional research recommendations for fish and invertebrates that were identified by workshop participants:

- Define the EMF emissions in the context of the local electromagnetic environment.
- Effects of noise from pile driving.
- Model sound propagation from turbines to fish and invertebrate habitats.
- Effects on spawning/nursery habitats.
- Effects of displacement on fisheries; if fishing fleets are pushed out of one area due to OSW they will add competition to other areas.
- Document food web properties before construction of OSW and investigate how it changes after construction.
- Ecosystem effects are crucial to understand: a particular gap is knowledge on the effects/impacts on small forage fishes critical prey for seabirds and marine mammals.
- For impacts to fisheries—consider how fishing effort will change as fish move; can management/quotas be responsive to this?
- Need to identify what questions need to be answered, and design research to answer those questions.
- Changes in ocean (Ekman) dynamics caused by wind farms are predicted to be considerable with large changes in downwelling and upwelling; fundamental to ocean productivity.
- Larval dispersal, larval connectivity for commercial/endangered fish/shellfish species (and consequences on population dynamics) (also for impact to fisheries).
- Local scale is rather well-understood but effects may be manifested at a much larger scale (at least 8-10 times area of wind farm).
- Identify keystone species within the various assemblages.
- A distinction may need to be made between aspects about what data to collect and aspects relating what questions to be answered; both are now included.
- Determining fisheries that will be excluded due to interarray cables, how that differed pressure can impact other areas.
- Determine connectivity and dispersion patterns between natural habitats and OSW.
- Research potential effects on communities from changes in upwelling/mixing due to wind wake effects.
- Plankton impacts are sometimes overlooked.
- Determine at what scale (numbers of turbines, spacing of turbines, etc.) do wind farms affect wind stress/fronts and the downstream effects on upwelling, nutrient delivery, larval transport and survival.

- Understand effects of OSW on larval transport.
- Cooling structure (inverters) impacts.
- Varying scales here (e.g., understanding impacts to fisheries requires gathering baseline conditions.
- Ecosystem impacts of changes on the plankton from offshore wind farm on higher trophic levels.
- Understand how mitigation methods for other species (e.g., mammals) may negatively impact fish and invertebrates (unintended consequences).
- Don't limit the research to the wind farm scale, upscaling to the larger area is needed.
- There is an International Council for the Exploration of the Sea (ICES) Working Group on Marine Benthal and Renewable Energy Developments (WGMBRED) report on what the likely differences between floating and fixed turbines onto the benthos (including demersal and bentho-pelagic fish) are; may be useful to have a look at that.
- Understand cumulative impacts to species across distributions where multiple OSW installations will be operational.
- Adaptations to structure design and to fishing that encourage coexistence.
- Cumulative and regional impacts.

Appendix C – Breakout Group 3 (Bats/Birds) Details

C.1 Participant List

#	Name	Affiliation
1	Hayley Farr	PNNL
2	Frank Oteri	NREL
3	Stephen Ferry	Santa Barbara Audubon Society
4	Cris Hein	NREL
5	Rebecca Green	NREL
6	Sara M Maxwell	University of Washington
7	Brian Owens	CDFW
8	Dan Nolfi	USFWS
9	Roberta Swift	USFWS
10	Roberto Albertani	Oregon State University
11	Delia Kelly	ODFW
12	Abigail Ryder	BOEM
13	Martin Perrow	ECON Ecological Consulting
14	Pasha Feinberg	Pasha Feinberg Consulting
15	Jay Staton	CDFW
16	Scott Pearson	WDFW
17	Michael Whitby	Bat Conservation International
18	Jo Lutmerding	USFWS
19	Jennifer Stucker	Western EcoSystems Technology, Inc
20	Emma Kelsey	U.S. Geological Survey (USGS)
21	Aspen Ellis	University of California Santa Cruz
22	Michelle St Martin	USFWS
23	Joe Liebezeit	Portland Audubon
24	Aonghais Cook	British Trust for Ornithology
25	Erin Adams	USFWS
26	Naomi Lewandowski	DOE
27	Gabe Reyes	USGS
28	Daniel Barton	Humboldt State University
29	Alexander Gilliland	Marine Scotland Science
30	Pam Loring	USFWS
31	Kate Williams	Biodiversity Research Institute
32	Mark Severy	PNNL
33	Robb Diehl	USGS
34	Cheryl Strong	USFWS
35	Jess Stocking	WDFW
36	Joy Page	DOE
37	Matthew McKown	Conservation Metrics
38	Elizabeth Labunski	USFWS

#	Name	Affiliation
39	Thomas Good	NOAA NMFS Northwest Fisheries Science Center
40	Shilo Felton	Audubon
41	Margarita McInnis	CDFW
42	Jason Busch	POET
43	Stef Stavrakas	USFWS
44	Cotton Rockwood	Point Blue Conservation Science

Table C-1. Breakout 3 Participants.

C.2 Detailed Feedback

All feedback received on the Bat and Bird Breakout MURAL board, including additional resources, additional research recommendations, and commentary is available here.

C.3 Additional Resources Identified by Participants

Adams, J., E. C. Kelsey, J. J. Felis, and D. M. Pereksta. 2017. Collision and displacement vulnerability among marine birds of the California Current System associated with offshore wind energy infrastructure (ver. 1.1., July 2017): U.S. Geological Survey Open-File Report 2016-1154, 116 p. Available at https://pubs.usgs.gov/of/2016/1154/ofr20161154.pdf.

Cryan, P. M., and A. C. Brown 2007. Migration of bats past a remote island offers clues toward the problem of bat fatalities at wind turbines. Biological Conservation doi: 10.1016/j.biocon.2007.05.019. Available at https://www.sciencedirect.com/science/article/pii/S0006320707002364.

Johnson, A. F., C. Dawson, M. G. Conners, C. Locke, S. M. Maxwell. 2022. Offshore renewables need an experimental mindset. Science. Doi: 10.1126/science.abo7924.

Kelsey, E. C., J. J. Felis, M. Czapanskiy, D. M. Pereksta, and J. Adams. 2018. Collision and displacement vulnerability to offshore wind energy infrastructure among marine birds of the Pacific Outer Continental Shelf. Journal of Environmental Management. 227: 229 – 247. Available at https://www.sciencedirect.com/science/article/pii/S0301479718309228.

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Menza, C. W., J. Leirness, T. White, A. Winship, B. Kinlan, L. Kracker, J. E. Zamon, L. Balance, E. Becker, K. A. Forney, J. Barlow, J. Adams, D. Pereksta, S. Pearson, J. Pierce, S. Jeffries, J. Calambokidis, A. Douglas, B. Hanson, S. R. Benson, and L. Antrim. 2016. Predictive mapping of seabirds, pinnipeds and cetaceans off the Pacific Coast of Washington. NOAA Technical Memorandum NOS NCCOS 2010. Silver Springs, MD. 96 pp. Doi; 10.7289/V5NV9G7Z. Available at https://repository.library.noaa.gov/view/noaa/9329.

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Ruthrauff, D. R., C. M. Harwood, T. L. Tibbitts, N. Warnock, and R. E. Gill. 2021. Diverse patterns of migratory timing, site use, and site fidelity by Alaska-breeding Whimbrels. Journal of Field Ornithology 92: 156–172. Available at https://onlinelibrary.wiley.com/doi/abs/10.1111/jofo.12365.

Skewgar, E, and S. F. Pearson (Eds). 2011. State of the Washington Coast: Ecology, management, and research priorities. Washington Department of Fish and Wildlife, Olympia, Washington. Available at https://wdfw.wa.gov/publications/01198.

Solick, D. I., and C. M. Newman. 2022. Oceanic records of North American bats and implications for offshore wind energy development in the United States. Ecology and Evolution doi: 10.1002/ece.3.8175. Available at https://onlinelibrary.wiley.com/doi/full/10.1002/ece3.8175.

Suryan, R. M., E. M. Phillips, K. So, J. E. Zamon, R. W. Lowe, and S. W. Stephensen. 2012. Marine bird distribution along the Oregon coast. Northwest National Marine Renewable Energy Center Report no. 2. Corvallis: NNMREC. 26 pp. Available at https://tethys.pnnl.gov/sites/default/files/publications/Suryan_et_al_2012_NNMREC_OR_seabirds.pdf.

C.4 Additional Research Recommendations Identified by Participants

Following were additional research recommendations for bats and birds that were identified by workshop participants:

- Establish methods for documenting collision rates (could also inform our understanding of collision risk, but still an important difference).
- Do cumulative impacts include the displacement of species which have lost foraging areas and are pushed into other areas creating an increased energy cost and increased competition for resources? Including impact on breeding success.
- Garbage and ghost net/gear collection on mooring lines as attraction for marine birds; effectiveness of best management practices.
- Initial minimization measures that might proactively be implemented or accounted for in planning.
- Artificial reef effects and marine birds.
- Analytical methods to integrate site-specific monitoring methods (e.g., Motus, radar, acoustics).
- Collision risk with moving structures.
- Potential links between toxicity of prey items growing on turbines (e.g., mussels) and antifouling materials applied to turbines.

- Technologies that work on floating turbines.
- Improve understanding of marine animal distributions: many of the species that we're concerned about might not be classified as “marine”.
- Develop preliminary population models and sensitivity analyses: fill demography knowledge gaps to build population models and sensitivity analyses.
- Risks of different layouts of vessel lanes and turbines.
- Strategic integration of existing tracking data and collecting new tracking data to fill gaps.
- Improve our understanding of migratory pathways, numbers of individuals, and timing.
- Identify the distribution of prey resources; Does this include marine insects as prey for bats?
- Identify the distribution of prey resources.
- Impacts to migratory shorebirds and passerines which also migrate far offshore.
- Studies in the United Kingdom are looking at the impacts of wind farms on the migration of nonmarine species which pass these structures during migration.
- Bats: Seasonal/migratory activity windows.
- Collect baseline data to determine habitat use and determine which species are present (for bats, at least).
- Collect baseline data to determine habitat use and to understand habitat loss from wind turbine avoidance after construction.
- Technological development to conduct monitoring (e.g., collision monitoring).
- Potential negative interactions are the result of several risk probabilities (overlap in space and time, encountering the object, and injury by the object if encountered); develop the risk model needed to multiply these risk factors; for this type of risk model, we need data on each of the probabilities.
- Collate existing data (at-sea surveys, telemetry, etc.).
- Flight height of birds across weather and seasons; given the dynamic movement (three-dimensional) of floating turbines this is even more important to determine potential collision risk.
- Develop an understanding of the interaction between environmental conditions, time of year, and migration behavior.
- Displacement of species which have lost foraging areas and are pushed into other areas creating an increased energy cost and increased competition for resources.
- Methodological comparisons of survey methods. The Pacific Coast has a nice historical survey data set using methods that would not be used in relation to offshore wind today. It would be helpful to understand how those data compare to newer data sets in terms of things like detectability and species identification rates. Jeff Leirness (NOAA) may have looked at this type of question a bit when he integrated data from different sources into his distribution models, but a focused comparison study might also be helpful.

- Understand ecosystem effects and changing trophic interactions that determine seabird abundance and distribution.
- For some species, this can help to provide a cursory evaluation of species that may be at risk from impacts, but will also be necessary to provide a baseline from which to compare postconstruction data that would help us to understand how the presence of wind development might influence species habitat use.
- Consideration for diving birds and entanglement.
- Timing of migrations and capacity to monitor migration in real time for cessation of turbines.
- Reliable technology to automatically assess blades-wildlife impacts with specie recognition.
- Seasonal interactions both breeding and nonbreeding season.
- Understand timing (seasonality, time of day, etc.) of risk.
- How does collision risk change with changes in ocean state and wind conditions? Sampling often occurs in good conditions for obvious reasons. As a result, sampling during higher wind events is not well-documented.
- Understand appropriate compensatory measures for species in the area; for example, if a wind farm will cause a negative impact on the population which measures can be put in place to help the population.
- Species and timing.
- Understand relationships among bird distributions and wind patterns from climate change.
- Roosting, attraction potential for bats and birds.