WEST COAST

Entanglement Science Workshop

August 25 – September 3, 2020

SUMMARY AND THEMES OF DISCUSSION

THANK YOU

Workshop co-hosts and planning partners are grateful for the contributions of presenters, panelists and participants, whose research, experience, and perspectives supported a robust exchange of ideas and thoughtful dialogue. We also appreciate the support of two consulting firms, Resource Logic and Ross Strategic, in the development and execution of the workshop.

The West Coast Entanglement Science Workshop was a collaborative effort, made possible by the time and contributions of the following workshop steering committee members:
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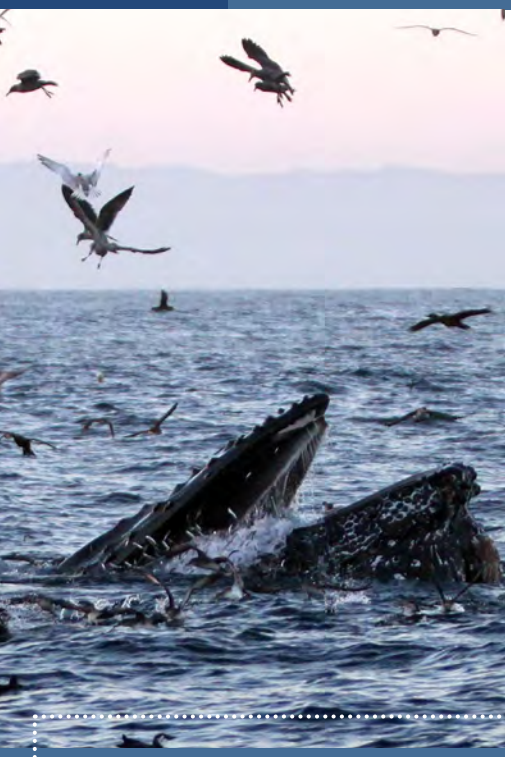
EXECUTIVE SUMMARY

Workshop goals and sponsorship

The West Coast Entanglement Science Workshop was the first comprehensive coastwide convening of U.S. West Coast states focused on the best available science to address whale and sea turtle entanglement in fixed gear fisheries. The workshop provided a unique opportunity to bring together fishery managers, researchers, fishing industry and stakeholders to learn about cutting edge research, share experiences and ideas, and engage in cross-disciplinary dialogue to identify opportunities for science to inform management. Structured as a five-part series of virtual modules between August 25th and September 3rd, 2020, the workshop featured 29 presentations and 8 interactive panel discussions and convened over 190 participants. The workshop engaged a variety of perspectives, geographies and stakeholder groups in a robust dialogue that was well received by participants, presenters and panelists. The outcomes from this workshop will help inform the development of management measures to address marine life entanglements and guide future investment in research and data collection.

The workshop was co-hosted by The Nature Conservancy and the California Ocean Protection Council, in partnership with the National Oceanic and Atmospheric Administration (NOAA Fisheries), Pacific States Marine Fisheries Commission (PSMFC) and the California, Oregon and Washington Departments of Fish and Wildlife.



The progress that has been made, as well as the work that still lies ahead, underscore the essential role of science in understanding marine life entanglements and enabling managers and industry to identify management solutions that meet conservation and fishery goals.

Background and workshop development

Incidental entanglement of marine species in fishing gear and marine debris is a global conservation problem that recently intensified off the U.S. West Coast. Since 2014, the number of reported and confirmed large whale entanglements in U.S. West Coast fixed gear fisheries has increased dramatically. In response, managers, scientists, fishing industry and other stakeholders mobilized to understand and respond to the problem. Significant investments by the California Ocean Protection Council[1], The Nature Conservancy, state and federal governments, fishing industry, research organizations and other partners have catalyzed an expansive and impressive body of cutting-edge research that has positioned the U.S. West Coast as a leader in the science of entanglement risk. This research is focused on understanding the rates and impacts of entanglements and the factors that influence entanglement risk. At the same time, California, Oregon and Washington have made progress developing management frameworks that address entanglement risk — particularly in the commercial Dungeness crab fishery. In coordination with NOAA Fisheries, the U.S. West Coast states have been working to develop Conservation Plans to address the implications and requirements of the Endangered Species Act (ESA) and the Marine Mammal Protection Act (MMPA).

The progress that has been made, as well as the work that still lies ahead, underscore the essential role of science in understanding marine life entanglements and enabling managers and industry to identify management solutions that meet conservation and fishery goals. The West Coast Entanglement Science Workshop was designed as a critical intermediary step to take stock of the best available science, think strategically about near-term opportunities to incorporate available science into management responses, and identify priorities to guide future scientific advancements.

Throughout the course of the workshop, research presentations and panel discussions covered the following topics:

- Management frameworks for entanglement risk
- Forecasting and monitoring marine species dynamics
- Understanding fishing dynamics
- Understanding metrics for entanglement science
- Social and economic dimensions of managing entanglements
- Overcoming barriers to gear innovations
- Understanding and framing risk and tradeoff decisions

The workshop was intended as a stepping off point for further exploration of the science-management interface and a catalyst for additional collaboration in pursuit of the shared goal of thriving marine life and thriving fisheries. Workshop resources, such as agendas and presentation recordings can be found on the West Coast Entanglement Science Workshop webpage, hosted by the California Ocean Protection Council.

[1] California Ocean Protection Council Strategy for Protecting Whales and Sea Turtles & Ensuring Thriving Fisheries: Reducing the Risk of Entanglement in California Fishing Gear, November 2019 https://opc.ca.gov/webmaster/ftp/pdf/agenda_items/20191113/Item6_Appendix-A-Whale-and-Sea-Turtle-Strategy-Final.pdf

Key Themes of Discussion

While workshop discussions were dynamic and wide-ranging, three overarching themes emerged across all five workshop modules.

1. Participants across sectors emphasized a shared dual goal of thriving marine life and thriving fisheries
2. There are opportunities to leverage the considerable scientific advances made to date to improve near-term decision making while continuing to enhance scientific tools over time
3. There are clear priorities for additional research, expanded data collection and enhanced collaboration

These themes, along with several related sub-themes, are summarized below and further explored through the specific summaries prepared for each workshop sessions. A detailed summary of the potential next steps and key information needs identified over the course of the workshop is included on page 37.

1. Participants across sectors emphasized a shared dual goal of thriving marine life and thriving fisheries

Science is the engine of an adaptive management framework

Marine life entanglement in fishing gear is a complex and dynamic challenge along the U.S. West Coast and requires the use of the best available science, and the continued improvement of that science, to support the development and implementation of adaptive management solutions. Workshop participants described a long-term vision of moving from reactive to proactive management strategies and the importance of real-time information and predictive models to enable an adaptive response to entanglement risk. The group emphasized the critical role of science in understanding the complex dynamics of marine life, fisheries and changing environmental conditions; learning and evolving over time; and enabling adaptive approaches that produce the greatest reduction in entanglement risk with minimal impact to the fishery.

Managing entanglement risk requires a multi-pronged strategy

To address the many facets of risk associated with marine life entanglements, participants emphasized the need for a suite of tools to address risk and achieve both conservation and fishery goals. A successful strategy will include better monitoring and reporting of marine life entanglements, enhanced entanglement response capabilities, the collection and integration of real time data streams, the development and validation of interpretive and predictive models, and the development of efficient, economically viable gear innovations.

There is no one-size fits all solution

All three U.S. West Coast states emphasized a dual goal of thriving marine life and thriving fisheries in addressing the shared challenge of whale and sea turtle entanglement in fishing gear. While sharing a common goal and management challenge, participants described significant differences in management frameworks, fishery characteristics and the dynamics of co-occurrence and risk in different areas along the U.S. West Coast. Thus, the appropriateness and effectiveness of specific management measures will be different for states, regions, fishing seasons, segments of the fleet, and environmental conditions.

Photo NOAA MMHSRP (Permit #18786)

2. There are opportunities to leverage the considerable scientific advances made to date to improve near-term decision making while continuing to enhance scientific tools over time

Environmental conditions are a significant driver of marine life entanglements

Several workshop presentations underscored the significance of ecosystem and climate conditions as drivers for entanglement risk (due to climate effects on the prey base) and the complexity of the functional links between oceanographic conditions, whale behavior and fishing dynamics—particularly under changing ocean conditions. Participants highlighted the need to integrate ecosystem information (e.g., through forecasting models and ecosystem indicators) in a way that helps predict and respond to the ways in which environmental factors influence entanglement risk.

Models and observational data streams work hand in hand to help us make better decisions

Participants reflected on the significant progress that has been made in understanding entanglement risk and discussed the complementary linkages between observational data and models. Together, these tools assist with understanding the complex dynamics of entanglement risk, identifying uncertainties and information needs, and considering the costs and benefits of different management strategies. Additionally, these data streams and tools create feedback loops that inform model improvements, refine data collection strategies and guide the iteration of management approaches over time.

Models are valuable tools that can be further strengthened over time

Workshop participants expressed a sense of excitement with the progress and potential for models to inform management of entanglement risk but also acknowledged limitations with the accuracy and precision of models and model outputs. While a number of next steps were identified to improve models, particularly in partnership with industry, participants also emphasized that models do not need to be perfect in order to be useful. The group described the importance of leveraging the data streams and models currently available, with recognition of their strengths and weaknesses, while continuing to improve these tools over time.

3. There are clear priorities for additional research, expanded data collection and enhanced collaboration

A more nuanced understanding of risk is essential

Workshop discussions continually reinforced the multifaceted and nuanced nature of risk. Participants discussed the value of more clearly articulating the concept of risk and described several different aspects of risk related to marine life entanglements, including:

- the risk of entanglement based on the proxy of co-occurrence between whales and fishing activity;
- the relative risk of entanglement based on the specific behavior of marine life (e.g., feeding strategy, forage base) and the configuration and use of fishing gear;
- the risk to individual whales based on the severity of injuries resulting from an entanglement; and
- the risk to whale populations and sub-populations relative to abundance and population status.

Social and economic information is relatively under-developed and merits greater prioritization

Workshop participants felt that while significant progress has been made with understanding the dynamics of marine species, much less is known about the dynamics of fishing activity and the social and economic characteristics of the fishery. The group expressed a strong desire for prioritizing investment in social and economic data collection and modeling in order to better understand the drivers and needs of the fishery and evaluate the costs and benefits of different management measures to the fleet.

Management and data strategies need to be objective driven and cost effective

Workshop participants emphasized the importance of finding cost effective solutions to entanglement risk. This includes considering the costs of monitoring and data collection, the costs of management measures and gear innovations, and the distribution of these costs. Participants also emphasized the importance of building management frameworks and supporting data systems that are affordable and realistic over the long term, particularly given the resource limitations of stage agencies.

It is important to prioritize investment in data collection and research

Over the course of the workshop, participants identified a number of information needs and opportunities to improve data collection and modeling efforts. The group discussed the overarching need to improve monitoring of marine life, fishing activity, environmental conditions and entanglements. The term monitoring is used throughout the report to reflect this broad range of information needs and encompass a range of data collection strategies (e.g., systematic surveys, remote sensing, in-situ monitoring). While a variety of specific data needs were identified, group also emphasized the importance of making strategic investments in new research by prioritizing key information needs and linking information streams to management objectives. Participants described priority information needs as those that improve our ability to:

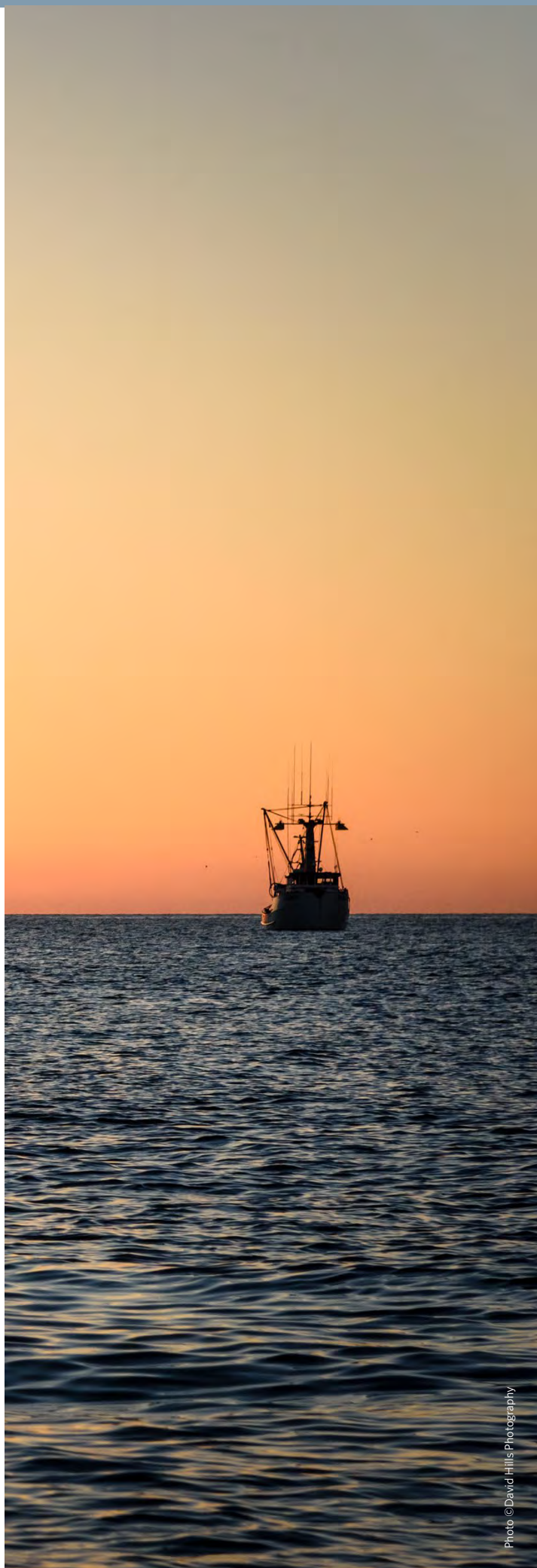
- make better use of existing information (e.g., combining datasets, increasing temporal and spatial resolution);
- evaluate the effectiveness of management measures relative to management objectives, including quantifying benefits to whales and the social and economic impacts to fisheries of different management approaches;

- understand the relationship between co-occurrence and entanglement risk, including the details of how fixed gear fisheries operate, the mechanics of how whales become entangled, and the impacts of entanglement to individuals, stocks, and distinct population segments (DPS);
- understand and predict risk in real-time (e.g., through monitoring and forecasting whale and fishing behavior);
- develop successful gear innovations that are economically viable for the fleet and have demonstrated benefits to whales; and
- understand how environmental factors influence entanglement risk.

Collaboration is key for continued progress

Workshop participants described marine life entanglements as an "all hands on deck" issue and highlighted the importance of collaboration in facilitating continued progress. Participants shared their enthusiasm for further expanding active communication and collaboration among fishermen, managers, scientists and other stakeholders, and identified several valuable near-term opportunities, including:

- improving entanglement detection, reporting and documentation by leveraging the presence of groups already on the water, such as commercial and recreational fishermen, recreational boaters, whale watch companies and research vessels;
- engaging the fishing industry to help fill data gaps and design effective monitoring and data collection programs;
- expanding dialogue between industry, researchers and managers to test assumptions, improve models, develop effective gear innovations, and facilitate a more robust evaluation of the benefits and impacts of management measures;
- improving the consistency of science communication by updating publicly available scientific products, resolving inconsistencies and adequately documenting research limitations and caveats; and
- building on existing state and federal collaborative frameworks to expedite the learning process, share data and information, and find efficiencies through coordination and leveraging resources.



INTRODUCTION

Purpose and Objectives

The West Coast Entanglement Science Workshop convened fishery managers, researchers, fishing industry and non-governmental organization (NGO) stakeholders around the issue of marine life entanglements. Specifically, the workshop was designed to identify opportunities for best available science to inform near-term development of whale and sea turtle entanglement mitigation strategies and adaptive management of entanglement risk along the U.S. West Coast.

The workshop featured presentations by researchers and targeted discussions with invited managers, scientists, industry and stakeholders, and reflected the following objectives:

- Review and preview the best available science on understanding, preventing, and reducing entanglement risk in U.S. West Coast fixed-gear fisheries. This research spanned the range of marine species of management concern (humpback whales, blue whales, leatherback sea turtles), including monitoring and forecasting species movements, oceanographic and forage conditions, socioeconomics, fishing dynamics, and management strategy evaluation.
- Identify near-term opportunities to apply best available science to management frameworks, including Conservation Plans in commercial Dungeness crab fisheries, as well as possible use in additional U.S. West Coast fixed-gear fisheries.
- Identify research needs to improve application of available science to management frameworks and opportunities for improved coordination and collaboration across U.S. West Coast states and among researchers, managers, fishing industry and NGOs.
- Discuss opportunities to overcome barriers to gear innovation through a special session on gear innovation.

The workshop was co-hosted by The Nature Conservancy and the California Ocean Protection Council, in partnership with the National Oceanic and Atmospheric Administration, Pacific States Marine Fisheries Commission and the California, Oregon and Washington Departments of Fish and Wildlife.

Workshop Structure

The West Coast Entanglement Science Workshop convened over 190 participants in a five-part series of virtual modules between August 25th and September 3rd and featured 29 science and management presentations and 8 interactive panel discussions. Below is an overview of the topics explored in each respective workshop module.

MODULE 1: Tuesday, August 25th
9:00 am – 1:00 pm

- Management frameworks for entanglement risk
- Forecasting and monitoring marine species dynamics (Part I)

MODULE 2: Thursday, August 27th
9:00 am – 1:00 pm

- Forecasting and monitoring marine species dynamics (Part II)
- Understanding fishing dynamics

MODULE 3: Tuesday, September 1st
9:00 am – 12:00 pm

- Understanding metrics for entanglement science
- Social and economic dimensions of managing entanglements

MODULE 4: Tuesday, September 1st
2:00 pm – 4:00 pm

- Special Topic: Overcoming barriers to gear innovations

MODULE 5: Thursday, September 3rd
9:00 am – 1:00 pm

- Understanding and framing risk and tradeoff decisions
- Synthesis and next steps

Orientation to Session Summaries

The structure and organization of this document mirrors the workshop agenda and includes a separate summary for each of the 8 topical sessions listed above. These summaries are intended to provide a succinct overview of the ideas and perspectives shared and the key themes of each discussion. These summaries do not represent a comprehensive transcript and are not intended to convey consensus opinion or formal recommendations. A detailed compilation of potential next steps and key information needs identified over the course of the workshop is also included following the specific session summaries.

All workshop materials are available on the workshop webpage, hosted by the California Ocean Protection Council. These include agendas for each module, as well as abstracts, presentation slides and video recordings for all workshop presentations. Agendas and presentation abstracts are also included in the appendix of this summary.

WORKSHOP WEBPAGE:
www.opc.ca.gov/west-coast-entanglement-science-workshop/

LIST OF ACRONYMS

AIS	Automated Information System
DPS	Distinct Population Segment
EM	Electronic Monitoring
ESA	Endangered Species Act
MMPA	Marine Mammal Protection Act
MSE	Management Strategy Evaluation
NGO	Non-governmental organization
NOAA	National Oceanic Atmospheric Administration
PBR	Potential Biological Removal
PSMFC	Pacific States Marine Fisheries Commission
RAMP	Risk Assessment and Mitigation Program
VMS	Vessel Monitoring System

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WORKSHOP MODULES

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Management frameworks for entanglement risk

OBJECTIVE: Provide a shared frame of reference for the workshop by reviewing the trajectory of entanglement science and management response and sharing contextual information about each state's progress and approach.

Management Presentations

Through a series of four short talks, presenters provided an overview of their respective management frameworks, shared insights into the similarities and differences along the coast and identified key information needs. Links to presentation slides are provided for each presentation.

- **Dan Lawson, NOAA Fisheries, West Coast Regional Office** (Presentation)
- **Heather Hall, Washington Department of Fish and Wildlife** (Presentation)
- **Caren Braby, Oregon Department of Fish and Wildlife** (Presentation)
- **Sonke Mastrup, California Department of Fish and Wildlife** (Presentation)

Themes of Discussion

Marine life entanglement is a complex and long-term challenge

The entanglement of humpback whales, blue whales and leatherback sea turtles in fishing gear is a serious and complex issue. Presenters discussed the multiple facets of marine life entanglements including legal and conservation implications; industry considerations around access, markets and the economic health of the fishery; and public and political interests to avoid harm and mortality to marine species. Given ecosystem changes and increasing abundance for some humpback whale populations, marine life entanglements are a long-term challenge that must be addressed to ensure healthy marine ecosystems and thriving fisheries. While the Dungeness crab fishery has been the focus for much of the work to date, presenters emphasized that the issue is much broader, involving all fixed gear fisheries along the U.S. West Coast.

Photo ©Julia O'Hern | Sea Goddess Whale Watch

Legal Frameworks for Marine Life Entanglements

Depending on the species involved, marine life entanglements may require management responses under the Endangered Species Act (ESA) and the Marine Mammal Protection Act (MMPA). The ESA provides a framework for conserving and protecting endangered and threatened species and their habitats. The aim of the MMPA is to prevent marine mammal species and stocks from diminishing to the point that they are no longer a significant and functioning part of their ecosystems, and restore their populations to sustainable levels. For humpback whales, the most commonly entangled protected marine species along the U.S. West Coast, entanglements fall under the purview of both laws. Below are several important concepts for how humpback whale entanglements are evaluated under these laws.

- **Stocks —** Under the MMPA, humpback whales are treated as one stock along the U.S. West Coast: the California/Oregon/Washington stock. This stock is comprised of the whales that feed or migrate off the U.S. West Coast.
- **Potential Biological Removal —** Under the MMPA, potential biological removal (PBR) levels are established at the stock level. The PBR reflects the maximum number of animals that may be removed by human activities each year while allowing the respective stock to reach or maintain its optimum sustainable population.
- **Distinct Population Segments —** The ESA assigns humpback whales to distinct population segments (DPS) based upon their breeding area of origin. Humpback whales from three DPS are found along the U.S. West Coast: Central America, Mexico and Hawaii. Each DPS is assessed to consider if the population is threatened or endangered.

States are seeking to develop proactive and adaptive management solutions

To date, California, Oregon and Washington have taken a similar approach in their response to managing entanglement risk. All three states have formed multi-stakeholder whale entanglement working groups and have been working to develop regulations that include changes to fishing seasons, reduced pot limits, depth and area restrictions, gear use, and improved gear marking. The states have also strengthened programs for the retrieval of lost and abandoned gear and supported the testing of gear innovations. Ultimately, all three states are seeking to address entanglements in a proactive and adaptive way by developing a toolbox of management measures that can be used in response to new information and changing conditions. In California, managers and working group members developed and piloted the Risk Assessment and Mitigation Program (RAMP), an adaptive framework that evaluates entanglement risk based on various factors (e.g., entanglements, distribution and density of marine life populations, ocean and forage conditions, and fishing dynamics) to inform an appropriate management response. Based on the piloted RAMP, the California Department of Fish and Wildlife developed regulations to implement the program as a real-time, risk-based management model. The RAMP is an example of an adaptive management framework and underscores the need for strong, real-time science inputs.

Science is the path forward for addressing entanglement risk

There has been a significant amount of work over the past few years to understand marine life entanglements, including forensic review of entanglement incidents, data collection and monitoring, modeling, and testing gear innovations. While this work demonstrates the complexity of the problem, it also reinforces that science is central to figuring out why entanglements occur and how NOAA Fisheries and the U.S. West Coast states should respond. In particular, science will inform:

- the fundamental framework and design of management measures;
- the development of dynamic and adaptive management tools that allow for evolution and iteration in response to new information; and
- the design of monitoring programs to track risk in real-time, assess the effectiveness of management measures and understand the impacts to industry and fishing communities.

Continued development of scientific information will improve management capabilities

Presenters identified a number of science inputs needed to support post-hoc analysis of entanglements and accurately project entanglement risk into the future. Specifically, managers need a better understanding of:

- the dynamics of how whales and sea turtles become entangled in fishing gear;
- how and why entanglement risk can change within and between seasons;
- species abundance, migratory pathways and habitat use (e.g., depth/time distribution) of whales along the coast;
- the abundance and genetic structure of whale populations, particularly for specific humpback whale DPS;
- the social and economic aspects of reducing entanglement risk, including the impacts of potential management responses to different segments of the fleet;
- the environmental factors that influence whale, sea turtle and fishing behavior;
- ecological indicators suitable for predicting entanglement risk; and
- potential gear modifications that are effective and economically viable for the fleet.

Presenters discussed the overarching need to improve monitoring of marine life, fishing activity, environmental conditions and entanglements; both through systematic surveys as well as through passive and autonomous data collection programs. In particular, the group highlighted the need for unbiased data on whales, turtles and fishing activity in the more remote areas of the coastline, and more autonomous and cost-effective methods for long-term monitoring. A final aspect of the group's discussion was the challenge of evaluating the effectiveness of new regulations and gear configurations. While new reporting requirements will provide additional insights, a clear understanding of cause and effect is needed to assess beyond simple correlation between entanglement incidents and the numerous factors that may influence entanglement risk (e.g., fishing effort, management measures, environmental conditions).

Photo by Andrea Holien from Pexels

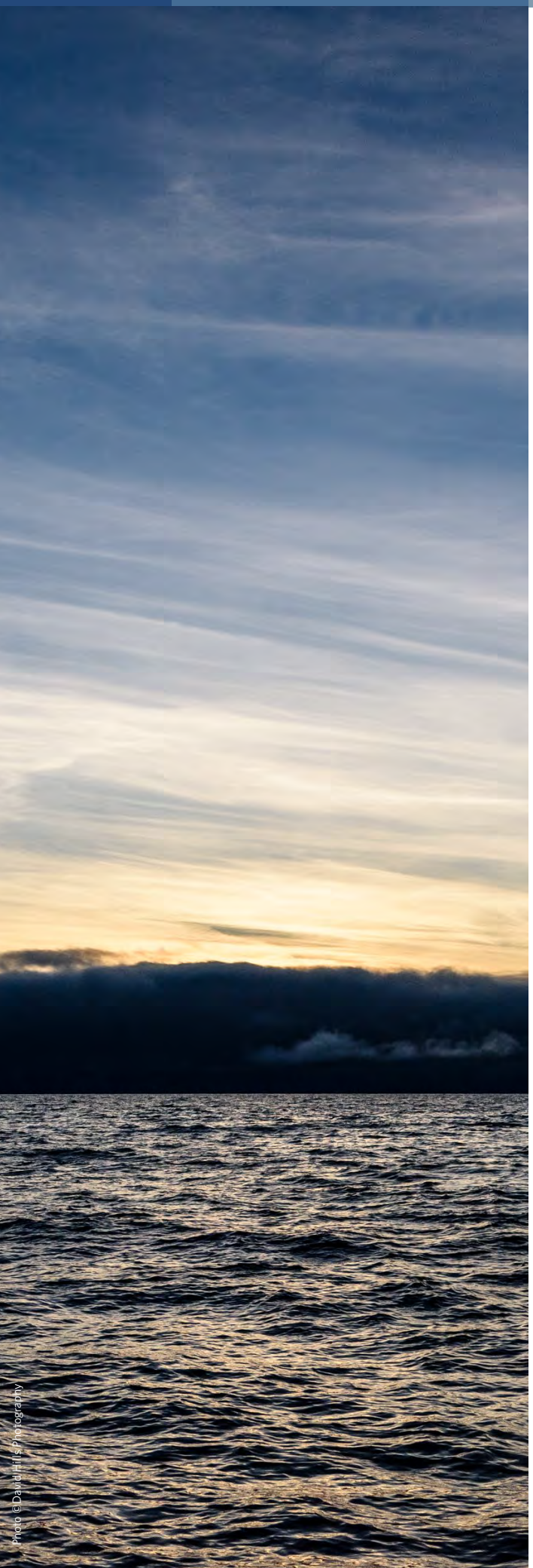


Photo © David Hall Photography

There is a strong history of coordination along the U.S. West Coast

California, Oregon and Washington have jurisdiction for managing the Dungeness crab fishery in state and adjacent federal waters, with coastwide coordination through the Pacific States Marine Fisheries Commission and Tri-State Dungeness Crab Committee. This provides a strong framework for multi-agency coordination and a shared vision to align management across the region. Presenters emphasized their commitment to finding win-win solutions that address marine species conservation goals while ensuring thriving fisheries along the U.S. West Coast.

Marine life entanglement is a shared problem though each state has unique challenges

While all three states are seeing a similar pattern of increasing marine life entanglement reports, presenters described how the nature of the problem differs along the coast.

- The majority of entanglements are reported off the coast of California, making it an inherently bigger challenge. California also has additional state-level mandates driving their response including the California Endangered Species Act and Marine Life Management Act.
- Oregon accounts for a fairly small number of reported entanglements. However, given the lower population centers along the coast, there is not the same ability to monitor and report entanglements. Oregon's location between Washington and California also introduces additional complexities with aligning seasons and management measures.
- Entanglements are rarely reported in Washington, which makes them more difficult to predict and understand. Washington has the smallest coastline and the smallest Dungeness crab fleet of the three states, and also has a tribal sharing agreement for Dungeness crab which results in a unique management structure and influences seasons and closed areas.

The majority of reported entanglements are not attributed to a specific gear type or fishery; when gear type and set location are known, most are attributable to California fixed gear. Presenters emphasized that while the scale of the problem varies along the coast, entanglements are a shared problem, particularly as climate and ecosystem change influence the distribution and dynamics of whales and fishing activity. Additionally, the number of entanglements is not the only factor that influences the severity of the problem. For example, entanglements can have different impacts to the health of different humpback whale DPSs.

Photo ©Scott Benson

Forecasting and monitoring marine species dynamics

OBJECTIVE: Explore the information streams and models that help us understand the dynamics of marine species (e.g., movement and time/space distribution of whales and turtles).

Science Presentations

This session began with a series of short presentations highlighting research efforts underway to help understand marine species dynamics and entanglement risk. Links to presentation slides and abstracts are provided for each presentation.

- **John Calambokidis, Cascadia Research Collective —** Insights into entanglements from whale population monitoring (Presentation | Abstract)
- **Karen Lohman and Scott Baker, Marine Mammal Institute, Oregon State University —** Genetic population assignment of humpback whales in the eastern North Pacific (Presentation | Abstract)
- **Daniel Palacios, Marine Mammal Institute, Oregon State University —** Analytical development of whale satellite tagging data to inform critical knowledge gaps off the U.S. West Coast (Presentation | Abstract)
- **Leigh Torres, Marine Mammal Institute, Oregon State University —** Identifying co-occurrence between whales and fishing effort in Oregon to reduce entanglement risk (Presentation | Abstract)
- **Scott Benson, NOAA Fisheries, Southwest Fisheries Science Center —** Monitoring leatherback entanglement risk on the U.S. West Coast (Presentation | Abstract)
- **Jaime Jahncke, Point Blue Conservation Science —** Changes in abundance and timing of migration of whales in central California (Presentation | Abstract)
- **Karin Forney, NOAA Fisheries, Southwest Fisheries Science Center —** Dynamic humpback whale models for evaluating and mitigating entanglement risk along the U.S. West Coast (Presentation | Abstract)
- **Briana Abrahms, NOAA Fisheries and University of Washington —** WhaleWatch 2.0: Downscaled blue whale habitat models along the U.S. West Coast (Presentation | Abstract)
- **Jarrod Santora, NOAA Fisheries and University of California, Santa Cruz —** Ecosystem science for monitoring and mitigating entanglement risk (Abstract)

Themes of Discussion

Environmental factors influence marine species behavior and entanglement risk

Presenters and panelists reflected on the research presented and the significant progress that has been made in understanding the recent increase in marine life entanglements and the factors that contribute to entanglement risk. One of the central themes emerging from this research is the influence of environmental factors and climate events on the distribution, migration and behavior of marine species.

- The recent trend of warmer water has significantly impacted the timing of whale migrations, with early arrival of whales to California occurring during warmer water, non-productive, years.
- There are a number of environmental factors that influence the distribution and behavior of marine species including sea surface temperature, upwelling patterns, hypoxia, and the distribution and abundance of forage species.
- The feeding ecologies and habitat use patterns of different species results in different responses to environmental change and varying degrees of habitat compression (i.e., the reduction and/or concentration of available habitat).

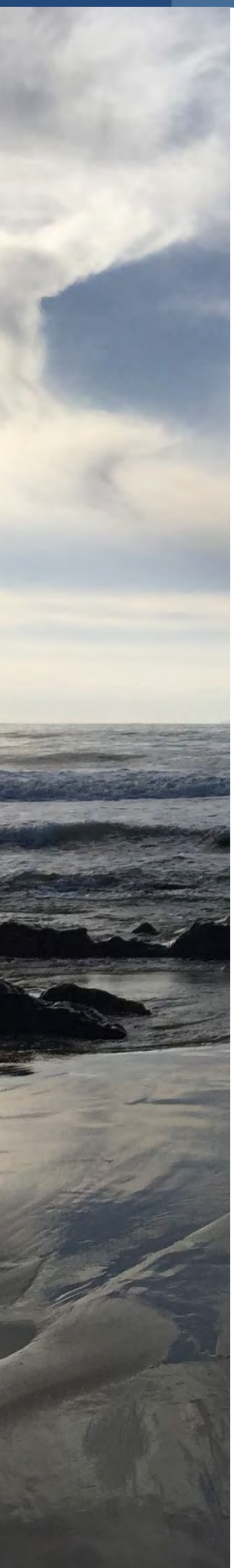
It is important to understand the abundance and population structure of marine species

Presenters and panelists discussed the importance of better understanding whale and sea turtle populations and translating that understanding into corresponding management metrics. This is particularly complex for humpback whales given the different feeding and breeding population designations under the MMPA and ESA. Specifically, the group discussed the importance of regular adjustments to PBR limits in response to new stock assessments and the need to better understanding the abundance and distribution of humpback whale DPS on U.S. West Coast feeding grounds. This information will help managers understand the different areas being used by each DPS and facilitate finer scale spatial management to protect threatened and endangered sub-populations.

We need to better understand the implications of co-occurrence and entanglement risk

Entanglement risk is a complex and highly nuanced topic. Presenters and panelists identified several key factors that influence entanglement risk beyond the spatial overlap of whales and fishing activity and outlined a number of information needs to better understand the dynamics of entanglement risk.

- **Co-occurrence is not a static predictor of risk.** The spatial and temporal behavior of whales is variable, and thus the entanglement risk associated with co-occurrence is also highly variable. For example, whales behave differently when feeding versus migrating and present different feeding behaviors in response to different forage conditions. These behavioral differences may leader to greater, or lesser, entanglement risk.
- **The mechanics of how whales become entangled in fishing gear is an important element of entanglement risk.** Better understanding the interaction between whales and fishing gear will help identify the risk associated with co-occurrence and will also support the development of gear innovations.
- **The impacts of entanglement at the individual, stock and DPS level are not well understood.** Understanding the severity of impacts at these different levels will support appropriate management responses under the MMPA and ESA.



There is a sense of promise and reluctance with models

The group expressed a sense of excitement with the progress and potential for models to inform management of entanglement risk but also acknowledged limitations with the accuracy and scale of models and model outputs. Presenters described how models are useful tools for some things but not for others. In particular, models are helpful to bring together and extrapolate from different datasets, explore risk and uncertainty, identify key data gaps and limitations, and improve our understanding of complex systems. The group described models as an evolving tool that improves over time and discussed the importance of understanding the strengths and weakness of models and gathering additional information to test, validate and improve models. There was also particular interest in integrating different datasets (e.g., to capture additional complexities and validate models), combining models (e.g., merging fishing and marine species dynamics models), and testing model assumptions as valuable next steps.

Models can help us learn from the past and anticipate the future

Presenters and panelists discussed three different ways that models can be used to understand entanglement risk and inform regulatory and non-regulatory management strategies.

- **Hindcast analysis —** models can use historical whale and fishing data to explore the potential effects of different management scenarios.
- **Risk assessment —** models can integrate and makes sense of different data streams to identify the conditions that may indicate increased risk and explore the potential outcomes of different interventions.
- **Predictive models —** models can be used to forecast whale and fishing conditions and produce risk predictions that can be used to inform or trigger a preventative response.

Real-time management and predictive models are the long-term goal

Presenters and panelists emphasized the role of environmental conditions in entanglement risk and the need to integrate ecosystem science in a way that allows for predictive and responsive management as conditions change. The group felt that while models are still in the development phase, they are a fundamental piece of moving from reactive to proactive management. This includes real-time management and the ability to predict co-occurrence and entanglement risk and respond through regulatory and non-regulatory pathways. Panelists described the analogy of tornado watches and tornado warnings and identified near-term opportunities to employ a tornado watch approach by providing the fleet with voluntary alerts under high-risk conditions.

The group identified the following next steps and specific data needs to support these goals.

- Improve monitoring and real-time information streams, including expanded use of passive and/or autonomous data streams to ensure long-term data collection is affordable and reliable.
- Fill key knowledge gaps about ecosystem dynamics, including the connections between entanglements and specific environmental drivers; the functional links between oceanography, prey and whales; and a more comprehensive understanding of whale and forage distribution throughout the year.
- Develop regional and spatially explicit environmental indicators to enhance our ability to predict forage conditions, incorporate climate projections in a meaningful way, and link indicators with predictive models and monitoring programs.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Understanding fishing dynamics

OBJECTIVE: Explore the information streams and models that help us understand the dynamics of fishing activity (e.g., time/space distribution of fishing effort) and consider specific information needs to improve management of entanglement risk.

Science Presentations

This session began with a series of short presentations highlighting several research efforts underway to collect, compile and use fishery data to understand and address entanglement risk. Links to presentation slides and abstracts are provided for each presentation.

- **Blake Feist, NOAA Fisheries, Northwest Fisheries Science Center —** Using landings and vessel monitoring system data to model fixed-gear fishing activity and its relationship to whale entanglements off the U.S. west coast (Presentation | Abstract)
- **Owen Liu, NOAA Fisheries, Northwest Fisheries Science Center —** Vertical line estimation for the Dungeness crab fishery (Presentation | Abstract)
- **Cotton Rockwood, Point Blue Conservation Science —** Co-occurrence of whales and Dungeness crab-pot fishing gear in north-central California (Presentation | Abstract)
- **Kathi George, The Marine Mammal Center —** Pelagic Data Systems Solar Logger Case Study (Presentation | Abstract)

Themes of Discussion

A strong, quantitative understanding of whale and fishing gear co-occurrence is key

Presenters and panelists discussed the importance of understanding fishery dynamics to help understand co-occurrence with whales and turtles. Specifically, it is important to understand:

- the spatial distribution of U.S. West Coast fisheries with sufficient resolution on where fishing activity is occurring;
- the intensity of fishing effort, and in particular, the number of vertical lines in the water given that gear is the point of interaction with whales and sea turtles; and
- how distribution and fishing effort changes over time and the ecosystem factors that drive or influence that change.

Information on fishing activity can help address entanglement risk

In addition to understanding co-occurrence, robust information streams on the distribution and intensity of fishing activity can help managers design and implement management measures to minimize entanglement risk. Specifically, this information can enable managers to:

- assess entanglement risk in real-time and respond quickly;
- develop and deploy tactical management measures that minimize risk without unnecessarily curtailing fishing effort;
- utilize and enforce spatial restrictions (e.g., area and depth closures);
- understand the benefits and impacts of different management measures; and
- support the consideration and achievement of other management objectives for U.S. West Coast fixed gear fisheries (e.g., safety at sea, efficiency, market access).

Multiple information streams help paint the full picture

The primary information streams on fishing activity include logbooks (Oregon and Washington), landing tickets, and positional data through Automated Information System (AIS) and Vessel Monitoring System (VMS) for a subset of vessels. There is interest in emerging electronic technologies such as solar loggers to fill information gaps and provide more detailed and real-time data. Presenters and panelists described the value of multiple information streams to help paint the full picture and cross-validate individual information streams, particularly because certain data streams, such as VMS, do not have full and/or representative coverage of the fleet. The group also emphasized the importance of logbooks to anchor the data and reflect the trends and on-the-water realities of fishing activity. All three states expressed a desire for more real-time data on fishing activity, while also noting a need to better understand how to effectively use fishing effort data to reduce entanglement risk.

U.S. West Coast states are in a good position to develop electronic monitoring programs

Presenters and panelists described the interest and need for electronic monitoring (EM) across all three states. The group described EM in the context of video and positional monitoring, and identified several opportunities and lessons learned to facilitate the development of effective EM programs.

- Establishing goals for EM programs is an important first step in order to a) distinguish between the information needed and the management objectives the information will support and b) identify the most appropriate data collection tools.
- Communication and coordination among the states will support the development of complementary programs and facilitate learning and data sharing among agencies.


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- Industry members and stakeholders are important partners for developing, designing and implementing EM programs in order to ensure targeted information is gathered efficiently, effectively, and with minimal burden on the industry.
- It is important to consider the costs of EM programs to the industry as well as the costs to agencies associated with data collection, analysis, storage, and maintaining data privacy and security.
- Learning from past experience with EM on the U.S. West Coast will shorten the learning curve and allow states to take advantage of existing EM capabilities and infrastructure, such as those offered by PSMFC.

There is a need for expanded collaboration among managers, scientists and industry

Presenters and panelists reflected on how collaboration among scientists, managers, industry and other stakeholder groups has greatly improved understanding of fishery dynamics and co-occurrence and highlighted the need for continued and expanded collaboration. Specific near-term opportunities include:

- engaging fishermen to better understand fishing data and ground truth the assumptions being used in data extrapolation, data interpretation and modeling;
- gathering additional input from the fleet to ensure the human dimensions of the fishery and co-occurrence dynamics are appropriately reflected;
- communicating with the fleet about how fishing activity data will be used for research and management purposes and the procedures for ensuring confidentiality and privacy;
- improving coordination and collaboration among state agencies, federal agencies and research institutions through data sharing agreements and data standardization; and
- addressing challenges, limitations and priorities with more real-time fishing data such as transmission, processing and data confidentiality.

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Understanding the metrics for entanglement

OBJECTIVE: Explore the information streams provided through entanglement science (e.g., entanglement rates and impacts) and consider application to monitoring and evaluation.

Science Presentations

This session began with a series of short presentations highlighting efforts underway to monitor, report, study and respond to marine life entanglements. Links to presentation slides and abstracts are provided for each presentation.

- **Doug Sandilands, SR3 Sealife Response, Rehabilitation and Research —** Information collected during large whale entanglement response (Presentation | Abstract)
- **Jenn Tackaberry, Cascadia Research Collective —** Re-sights & survival of entangled humpbacks & other large whales within the CA-OR-WA region using photo-id & long-term life history data (Presentation | Abstract)
- **Dan Lawson, NOAA Fisheries, West Coast Regional Office —** Serious injury and mortality of U.S. West Coast whale entanglements (Presentation | Abstract)

Themes of Discussion

Entanglement science helps us understand the challenge

Information about marine life entanglements is gathered from several sources including entanglement reports, data collected during entanglement response, and population studies that collect photo identification, scar rates and genetic information. Together, these information streams provide insights into the frequency and distribution of entanglements and inform estimates of serious injury and mortality. These insights support assessment of management responses and provide critical context for interpreting other data streams and modeling entanglement dynamics.

There is still a lot to learn about marine life entanglements

Presenter and panelists reflected on the significant progress that has been made to identify and characterize marine life entanglements and discussed four key knowledge gaps.

- **Unreported and unconfirmed entanglements —** Entanglements are rarely observed, rarely reported and even more rarely well documented. Thus, the rates of reported entanglements are not representative of the total number of entanglements. Additionally, scar studies indicate that the incidence of entanglements may be more broadly distributed coastwide than the distribution of entanglement reports, where reports are more concentrated in regions with greater marine and coastal activity.
- **Severity and impacts of entanglement —** The short-term and long-term effects of sub-lethal entanglements are not well understood. Linking scar studies and confirmed entanglements by photo identification can help fill these information gaps and provide insight into the influence of time of year and entanglement duration on survival.
- **Assigning entangled gear to specific fisheries —** It can be challenging to identify the source of entangled gear when recovered gear does not have distinguishing markings or characteristics. There are efforts underway improve gear marking in the Dungeness crab and other fixed gear fisheries.
- **Relative impacts of entanglements to different DPS —** Expanding photo identification efforts in Oregon and Washington combined with genetic sampling will provide a better understanding of the distribution of different DPS along U.S. West Coast.

Improving understanding and outcomes of entanglements will require a coordinated effort

Presenters and panelists emphasized the need for an expanded and coordinated entanglement response effort and identified two important steps for better understanding entanglements and improving entanglement outcomes.

- Increase the number of people on the water to monitor, detect and report entanglements – Given the cost of expanding on-the-water monitoring capabilities, the group discussed the importance of leveraging the presence of groups already on the water, such as commercial and recreational fishermen, recreational boaters, whale watch companies and research vessels. Providing training and developing citizen science programs can improve coastwide entanglement detection and reporting, and the quality of information collected.
- Improve the capacity and timeliness of entanglement response to support improved entanglement outcomes and provide important data – Timely entanglement response helps to reduce the rates of serious injury and mortality and provides valuable data, including photo identification and biopsies that are important for better understanding the impact rates of different DPS. The group discussed the challenge of timely entanglement response given the distribution of response teams along the coast. Increasing the number of trained responders, integrating trained responders with research cruises, establishing a pool of on-call responders, and encouraging reporters to stay with the whale until the response team arrives were all identified as helpful solutions.

Information on gear configuration and use will improve our understanding of entanglements
Presenters and panelists discussed the value of integrating additional information about fishing practices to improve our understanding of entanglements. Gaining a better understanding of gear configuration and use (e.g., relative frequency, spatial distribution, seasonal patterns) will help scientists and managers interpret information gathered from entanglement reporting and response and support the development of effective gear regulations and gear innovation. Additionally, exploring the strategies that fishermen have been employing to mitigate and avoid entanglements will aide in the interpretation of data and inform the evaluation of which practices are most effective.

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Social and economic dimensions of entanglements

OBJECTIVE: Explore social and economic information streams and consider how they might be utilized and improved to inform management decisions.

Science Presentations

This session began with a series of short presentations to frame the social and economic dimensions of entanglement risk and share recent and ongoing research efforts. Links to presentation slides and abstracts are provided for each presentation.

- **Shannon Davis, The Research Group and Gil Sylvia, Oregon State University —** Economic impacts of proposed regulations for whale entanglement avoidance (Presentation | Abstract)
- **Rachel Seary, NOAA Fisheries, Southwest Fisheries Science Center —** Developing socio-ecological indicators to evaluate management strategies to mitigate whale entanglement risk within the Dungeness crab fishery (Presentation | Abstract)
- **Carrie Pomeroy, University of California at Santa Cruz —** Social and economic considerations for addressing U.S. West Coast entanglements (Presentation | Abstract)

Themes of Discussion

There is a need to better understand the costs and benefits of management measures

Presenters and panelists described a shared goal of thriving whale and sea turtle populations and thriving fisheries. To achieve this goal, managers need to understand the amount of risk reduction and the extent of fishery impacts that correspond to specific management measures. The group felt that while a significant amount of work has been done to understand the impacts and risks of entanglements to whales, there is a lack of understanding about impacts to the fishery. Presenters and panelists emphasized the need to prioritize social and economic data collection so that the needs of industry members and fishing communities can be better represented when considering the costs and benefits of different management strategies. Scientists

have been making progress incorporating social and economic considerations when modeling risk and tradeoffs, thus the capabilities exist to begin investigating impacts, both retrospectively and prospectively, as new data is collected.

The group also discussed the tradeoffs between entanglement risk and impacts to fisheries. Better understanding the impacts of entanglement to different DPS will provide a more nuanced understanding of risk as both the probability of an entanglement occurring and the relative severity of population-level impacts. This understanding will position managers to evaluate management alternatives based on the potential risk reduction to different whale populations relative to the impacts to the fishery.

A number of factors influence social and economic outcomes for the fleet

Fisheries are complex social-ecological systems that evolve and change over time. There are a number of factors to consider when assessing the social and economic health of the fleet, including stability, vulnerability, equity and cultural values. The health of the fishery also has far-reaching impacts to individuals, families, businesses and communities. Evaluating the socioeconomic impacts of different management measures requires an understanding of the complexity and context of the fishery, its individual members, and associated supply chain. The group identified several important considerations for evaluating social and economic impacts.

- **The diversity of the fleet —** Fisheries are diverse and thus the impacts of management measure will be different for the fishery as a whole, certain segments of the fleet, and specific individuals.
- **The dynamics of the fishery —** The dynamics and nuances of how the fishery operates influences costs and benefits. For example, the discussion highlighted the importance of the late spring and summer Dungeness crab fishery despite the smaller volume and participation levels compared to other seasons.
- **Individual and cumulative stressors —** Management actions may add additional stress to the fishery including changes to access and opportunity, safety at sea, and the ability of younger fishermen to be successful.
- **The resiliency of the fleet —** The extent to which different individuals are able to adapt to change influences social and economic impacts, such as the ability to participate in other fisheries or employment sectors.
- **The costs of management measures —** Incremental and cumulative costs influence the economic viability of different management measures and gear modifications.

It is important to approach social and economic data collection strategically

Presenters and panelists emphasized the need for a dedicated effort to improve social and economic data streams and shared excitement about scientists, managers and industry members working together to address this data gap. The group discussed the importance of taking a strategic and targeted approach to data collection that leverages shared resources, utilizes the most appropriate methods, and gathers information that directly support decision making. This strategic approach would enable us to:

- target and prioritize the most important information needs by framing key questions and linking data collection, analysis, application and evaluation;
- scale data collection approaches in a way that reflects the diversity of the fishery;
- integrate diverse sources of information and ground truth the interpretation of data and associated assumptions; and
- capture a broader understanding of the fleet's needs to inform risk and tradeoff analysis and support the achievement of other management objectives for the fishery.

The group also discussed the importance of considering the costs and benefits of different data collection strategies and the ability of agencies and industry to cover those costs. The consideration of costs also extends to the nature of the management scheme used to address entanglement risk and ensuring the necessary resources are available to support data intensive management strategies.

Identifying barriers to gear innovation

OBJECTIVE: Identify barriers to the development of gear innovations in U.S. West Coast fixed gear fisheries and explore opportunities to overcome barriers and prioritize future investments.

Framing Presentations

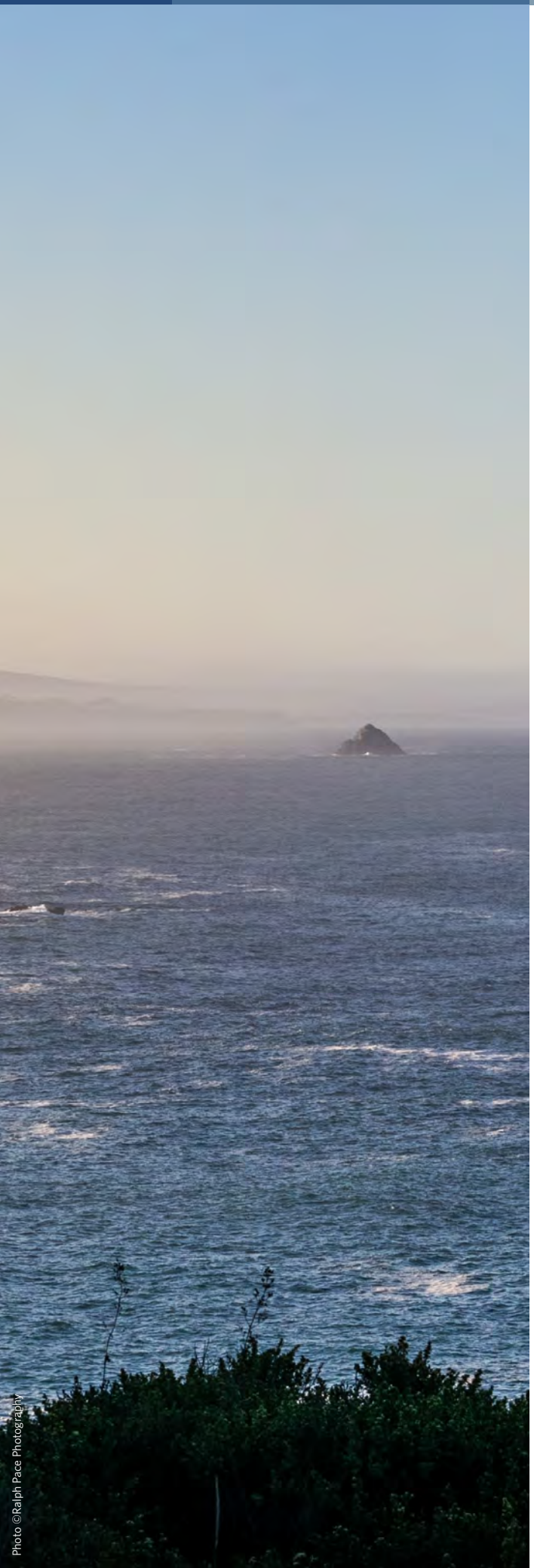
This session began with two short presentations to frame the panel's discussion.

- **Fran Recht, Pacific States Marine Fisheries Commission** (Presentation)
- **Dan Lawson, NOAA Fisheries, West Coast Regional Office** (Presentation)

The first presentation provided a short summary of recent efforts to test innovations for fixed gear fisheries on the U.S. West Coast and included information on:

- best management practices developed by each state's entanglement working group;
- current and proposed regulations in each state regarding fixed gear configurations;
- gear innovation discussions at two previous workshops; and
- fishermen-led gear testing conducted to date.

Details on the workshops and gear tests are available on the PSMFC website. Despite these efforts, testing of innovations has not occurred at sufficient scale to demonstrate success in meeting the operational needs of fishermen or effectiveness at reducing entanglement risk to whales.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The second presentation introduced six categories of potential barriers to gear innovation:

- **Regulatory (R) –** barriers created by existing and future regulatory structures;
- **Feasibility (F) –** skepticism about the feasibility of operating new gear;
- **Cultural (C) –** resistance to innovation due to cultural factors;
- **Incentives (I) –** unclear or inadequate incentives for innovation;
- **Effectiveness (E) –** uncertainty about the effectiveness of new ideas to reduce risk; and
- **Unintended Consequences (U) –** potential for of creating unintended consequences.

Considerations for Successful Gear Innovation

Through exploring barriers and opportunities for gear innovation, panelists identified several important crosscutting considerations to support the development of successful innovations:

Gear innovations need to be economically viable and have a demonstrated benefit

Panelists emphasized that in order to reduce barriers to adoption, gear innovations need to be operationally efficient and economically viable for the fleet, and have a tangible, demonstrated benefit to whales. Proposals will be more favorable to the fleet when cost neutral to implement.

A better understanding of how the fishery operates could advance innovations

The group discussed the value of educating managers, scientists and gear innovators about how the fishery operates and what it takes for new gear to be operationally efficient and economically viable. Providing financial support for gear development (e.g., grants, subsidies) would further facilitate the industry's ability to engage in developing and testing new gears.

Filling data gaps will help to inform and prioritize gear innovations

Panelists discussed several challenges to gear innovation and identified three key information needs to help overcome those barriers.

- Improving socioeconomic information—including the short-term and long-term costs of gear development, continued entanglement and market factors—will provide a better understanding of the costs and benefits of new gears.
- Establishing baselines and meaningful metrics for entanglement will enable us to evaluate the effectiveness of gear innovations and measure relative risk reduction.
- Information on whale behavior and the mechanics of how whales become entangled is critical to pinpoint and prioritize successful innovations.

There is no one size fits all solution

The group identified a number of factors to consider when assessing the appropriateness and effectiveness of different gear innovations including seasons, geographic regions, segments of the fleet, environmental conditions, management frameworks and enforcement capabilities.

Be aware of shifting entanglement risk or creating new challenges

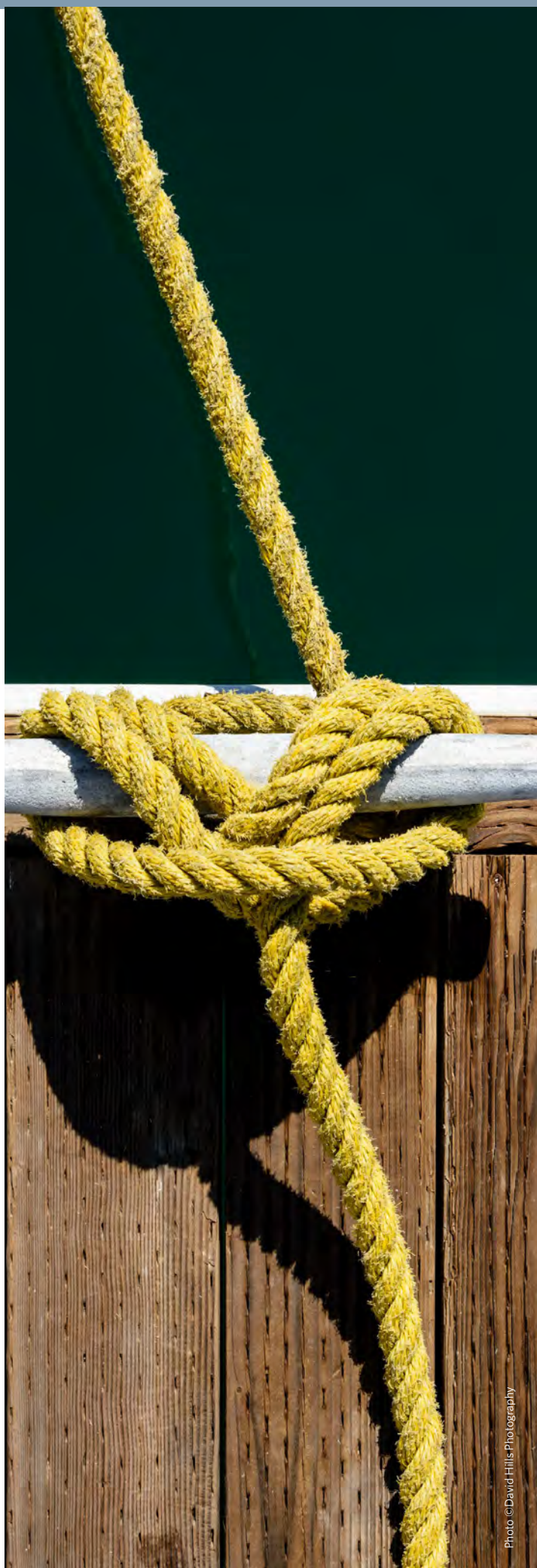
Panelists discussed the need to be aware of any unintended consequences associated with new gears such as shifting entanglements or bycatch to new species, changing the dynamics of entanglement frequency and mortality, or creating new challenges such as safety and lost gear.

Move forward by taking small steps and learning as you go

The group discussed the value of approaching gear innovation in a stepwise and coordinated fashion in order to learn through experimentation and invest in the most promising gears. Panelists also suggested starting simple, focusing on low tech solutions, exploring innovations that minimize injury, and the importance of gear marking for evaluating effectiveness.

Barriers and Solutions for Specific Gear Innovations

The panel also explored the barriers and solutions associated with three specific types of gear innovations: longlining pots/traps, weak line/weak links (e.g., yale grip sleeves), and pop-up gear (e.g., time delayed or triggered on demand).
A summary of this discussion is provided on the next page.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Summary of barriers and solutions for specific gear innovations

LONGLINING POTS/TRAPS

Barriers/Limitations	Solutions/Benefits
• The start of the season is too hectic for longlining traps given major effort pulse (R, C, F, U) • Longlining traps are currently prohibited for the Dungeness Crab fishery due to gear conflict and enforcement concerns (R, C, U) • There is concern that groundlines could introduce new risks for some whales (E, U) • Environmental barriers (e.g., sedimentation, tides, storms) could result in stuck gear (F, U) • Longlining traps may require the use of heavier line and may result in more sever entanglements, particularly if unobserved (F, E, U)	• Longlining traps may help maintain similar catch levels and could increase detectability of entanglements in areas where there is good monitoring • Waiting until the spring to implement would avoid the initial effort pulse • Use of smaller/collapsible pots could help smaller boats operate safely and lower costs • Float bag technology on the middle trap(s) may reduce the stress of multiple pots on one line • Longlining pots could be implemented for specific portions of the fishery (e.g., deeper water) • Starting with small steps (e.g., 1-2 traps/line) provides an opportunity to evaluate and learn • Longlining traps could be combined with other ideas (e.g., pop-up gear, Yale grips, and RFID technology for enforcement)

YALE GRIPS/WEAK LINES

Barriers/Limitations	Solutions/Benefits
• There may not be sufficient resistance to break the line (E) • It is difficult to test effectiveness due to the relatively small number of entanglements (E, R) • Use of yale grips may increase gear loss (e.g., as a result of sedimentation in pots) (F, E, C, U) • Weak links near the buoy may result in the loss of buoys from entanglements, which can reduce gear identification and detectability (R, E)	• Yale grips could be relatively easy for fishermen to implement compared to other changes • Yale grips can minimize the use of knots/spices to help keep the line from snagging on whales • Using yale grips in deeper areas with less sedimentation would reduce the risk of stuck gear • Combining yale grips with longlining traps could provide sufficient resistance for gear to break • Yale Grips, if periodically placed on the line, could serve as identifying markers

POP-UP GEAR WITH DELAY OR DEMAND SYSTEMS

Barriers/Limitations	Solutions/Benefits
• Testing pop-up gear out of season may be a barrier (no other major regulatory barriers) (R) • There are concerns about gear conflicts, increased lost gear, enforceability of other regulations, and the considerable expense of pop-up gear (R, F, C, U) • Pop-up gear would require hard buoys to accommodate submersion pressure (F, C) • Pop-up gear may move/drift after deployment, which may also result in the loss of efficiency if gear cannot be hauled in a straight line (F, C)	• Pop-up gear can be developed by addressing one obstacle at a time (e.g., 1st is it fishable? 2nd is it reliable? 3rd is it detectable (virtual gear marking)?) • Testing in low complexity situations (e.g., late season, small areas) is a good way to begin • In the future, virtual gear marking would be detectible on a plotter • Funding initiatives and data collection can be organized • Coupled with longlining traps, pop-up gear could be grappled up if lost

OTHER POTENTIAL GEAR IDEAS

	Solutions/Benefits
	• Explore line profiles of floating vs. neutral buoyancy line relative to whale feeding behavior

Understanding and framing risk and tradeoff decisions

OBJECTIVE: Explore models that help us "put it all together" to understand the overlap in marine life and fishing dynamics, consider and predict risk, and explore tradeoffs.

Science Presentations

This session began with a series of short presentations highlighting several tools being developed to help evaluate the risks and tradeoffs of different management approaches. Links to presentation slides and abstracts are provided for each presentation.

- **Karin Forney, NOAA Fisheries, Southwest Fisheries Science Center —** Assessing humpback whale entanglement risk off California and Oregon (Presentation | Abstract)
- **Jameal Samhouri, NOAA Fisheries, Northwest Fisheries Science Center —** Chasing the moving target of sustainability: understanding tradeoffs between fisheries and conservation goals in a changing ocean (Presentation | Abstract)
- **Chris Free, University of California Santa Barbara —** Crabs, HABs and humpback whales: balancing tradeoffs in the California Dungeness crab fishery (Presentation | Abstract)
- **Burton Shank, NOAA Fisheries, Northeast Fisheries Science Center —** Entanglement risk modeling for North Atlantic right whale from the lobster fishery (Presentation | Abstract)

Themes of Discussion

Models are a tool to inform decision making

Risk and tradeoff models are flexible tools that can be used to evaluate different management approaches based on numerous management objectives. Presenters and panelists explained that these tools aren't designed to produce specific decisions; rather they synthesize and integrate large amounts of data and

provide meaningful information to support decision making. Modeling tools such as Management Strategy Evaluation (MSE) have a long history in fisheries management and have proven to be a useful tool for addressing other management challenges such as preventing overfishing. For marine life entanglements, these models help us to explore ideas, consider tradeoffs and find the right balance between reducing entanglement risk and minimizing impacts to the fishery.

Models allow us to make science-based decisions in the face of uncertainty

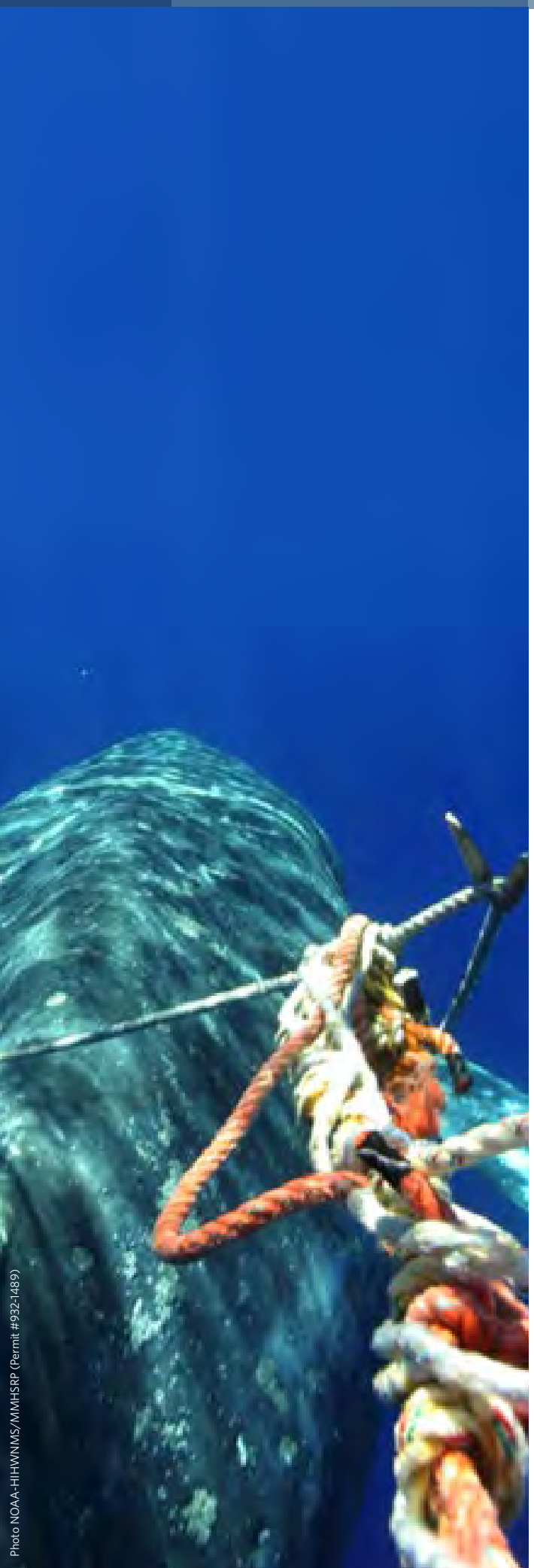
Models are a particularly helpful tool in the face of uncertainty. They can draw useful insights from limited information, such as exploring relative risks when determining absolute risk is not possible. These models can also be adapted over time to incorporate additional complexities and provide more precise insights as new information becomes available. Presenters and panelists described a number of ways that models can improve our ability to manage entanglement risk. Models allow us to:

- bring together different data sets in a complementary way and incorporate new information over time;
- uncover and test assumptions about the dynamics of different systems and interactions;
- guide the evaluation of benefits and impacts with different management approaches and different combinations of management measures;
- explore relationships and patterns, such as the differential impacts of different factors over time and the conditions that make tradeoffs more or less severe;
- pinpoint uncertainties and priority data gaps by testing assumptions, exploring similarities and differences in model projections, and comparing the outcomes of different models; and
- learn through the process of building models, iterating and targeting research efforts.

There are many opportunities to improve models

Presenters and panelists discussed the limitations of the models presented and identified opportunities to further improve the precision, accuracy and utility of these tools. While different models have different limitations, the group also discussed the inherent limitation of all models in that they are, by necessity, a simplification of the dynamic and intricate nature of complex problems. Panelists expressed a dual sense of excitement and reluctance with models and identified a number of opportunities for improving these models, including:

- evaluating and validating models to identify strengths, weaknesses and sensitivities;
- engaging fishermen and stakeholders to establish objectives, develop metrics to track achievement of objectives, and test assumptions;
- collecting and integrating additional information on whale dynamics such as wintertime distribution and finer scale information on migration and distribution;
- collecting and integrating additional information about the social and economic dynamics of the fishery;
- expanding modeling efforts to Oregon and Washington to reflect region-specific dynamics and management frameworks; and
- expanding the range of future environmental states to be considered given the influence of environmental conditions on entanglements and the potential for future conditions to be considerably different than those observed in the past.



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Understanding the dynamics and socioeconomics of the fleet is an important next step

Presenters and panelists discussed the importance of incorporating additional social and economic information into models to reflect the complex socioeconomic relationships in the fishery. Scientists described several ongoing efforts to weave in different socioeconomic factors, and the importance of feedback from the industry to make sure the dynamics of the fleet are accurately reflected. The group highlighted several important social and economic aspects of the fishery that would be helpful to better understand, including:

- the heterogeneity of the fleet, including how that may influence fishing dynamics (e.g., different fishing and business strategies, participation in other fisheries) and how benefits and impacts of different management measures are distributed across the fleet;
- downstream impacts and implications, including how processors, supply chains and markets change in response to different management strategies; and
- the different costs associated with managing entanglement risk, including the cost of different management responses, the cost of data collection and monitoring, and how those costs are distributed within and among the industry and management agencies.

Photo ©Scott Benson NOAA ESA (Permit #15634)

Synthesis and next steps

OBJECTIVE: Reflect on regional and fishery-specific science needs and identify opportunities for improved collaboration and coordination among and across U.S. West Coast partners.

Themes of Discussion

In this final session, panelists reflected on the information and insights provided over the course of the workshop to identify information needs, near-term and long-term priorities, and opportunities for collaboration. Below is a summary of key themes from the group's discussion.

Existing science provides actionable information that will improve over time

Panelists reflected on the significant progress that has been made with understanding the dynamics of entanglement risk and expressed excitement with the potential to apply this information now and in the future. The group discussed the value of filling data gaps and improving models but also emphasized that scientific tools don't need to be perfect in order to be useful. Leveraging the volume of information currently available, with recognition of its strengths and weaknesses, allows us to respond to the immediacy of the challenge. Specifically, the group discussed how existing information is already informing state-specific management frameworks and the development of conservation plans and incidental take permits.

As information streams and models become more refined, they will become increasingly powerful tools and will enable us to make progress on several key aspects of a successful entanglement risk management strategy.

- **Evaluating the effectiveness of our management frameworks —** Models can be used as a framework for tracking and assessing the impacts of management strategies and specific management measures and will allow us to learn and adapt over time.
- **Taking a more surgical approach —** Learning more about the dynamics of whales and fisheries and improving our ability to understand risk and tradeoffs will allow us to become increasingly strategic and tactical in our management approach.
- **Building confidence and support —** Gaining additional insights and validating models and assumptions will increase our confidence in the appropriate management actions and build support with the industry and stakeholders.

There are several near-term opportunities to improve models

Panelists discussed the importance of developing strategies to continue improving models and identified a number of key next steps, including:

- continuing to evaluate the specific strengths, weaknesses and sensitivities of different models and pinpointing coastwide and regional information needs;
- integrating additional datasets to make the best use of existing and future information;
- engaging stakeholders to inform model design and improve assumptions about how the fishery operates; and
- integrating the increasing population trends of humpback whales along the U.S. West Coast and exploring the implications of these trends on entanglement risk and whale population dynamics.

There are critical gaps in our understanding of marine species dynamics

Panelists identified a number of next steps to build on existing research and improve our understanding of marine species dynamics, including:

- defining specific information needs and the necessary spatial and temporal resolution in order to target additional research, such as information on early/late season abundance and finer scale distribution of humpback whales (e.g., inshore/offshore, DPS);
- conducting additional research on the severity of entanglements to better understand the consequences of entanglements to whale populations and inform our evaluation of management measures and gear innovations;
- improving observational data streams and enhancing our ability to monitor, report and document entanglements;
- updating and reconciling inconsistencies with publicly available scientific products; and
- updating abundance estimates for humpback whale populations and specific DPS.

We need better social and economic information to support the goal of thriving fisheries

Panelists emphasized the need to prioritize social and economic data collection and modeling efforts to better understand the needs of the fishery, evaluate the costs and benefits of different management measures, and consider the distribution of costs and benefits among individuals and different segments of the fleet. The group felt that it was important to include the industry in the design of social and economic data collection systems.

Gear innovations are an important part of the solution

While the information and models presented during the workshop advance our ability to avoid and manage the co-occurrence of whales and fishing activity, the group discussed the importance of gear innovation to finding long-term solutions. Gear innovations will be an important aspect of economically viable fisheries by allowing the industry to fish safely in the presence of whales. Panelists suggested that providing gear innovators with a better understanding of how the fishery operates and offering funding for industry members to engage in gear testing will advance the development of effective gear solutions for the fleet.

Photo ©Ralph Pace Photography

A strategic approach to research efforts will make the best use of limited resources

Panelists discussed the importance of approaching new research efforts in a targeted and coordinated manner to make the best use of limited resources. Specific suggestions included:

- establishing clear management objectives to make strategic investments in data collection and model improvements, and evaluate the achievement of management objectives;
- developing cost effective research strategies that leverage existing resources and expertise; and
- improving observational data streams and documentation of entanglements by enlisting additional collaborators, such as researchers and fishermen.

Collaboration and communication are key to making forward progress

Panelists reflected on the benefits of the collaborative frameworks already in place along the U.S. West Coast and shared their enthusiasm for further expanding active communication and collaboration among fishermen, managers and scientists. The group felt that inclusive, iterative dialogue is central to continued progress and identified two key opportunities to further advance collaboration.

- **Expand engagement with the industry —** The group emphasized the importance of involving industry in science and management efforts, and expanding opportunities for dialogue among managers, scientist, industry and other stakeholders. Specifically, panelists suggested involving fishermen, processors and fishing communities in the development of scientific tools and leaning on the industry more heavily through the Tri-State Dungeness Crab Committee process to identify and share best practices and develop pragmatic, non-regulatory ways to reduce entanglement risk.
- **Increase information sharing among states —** The group emphasized the importance of a coordinated approach to addressing entanglement risk along the U.S. West Coast and the need to continue improving communication and coordination. Increasing information sharing with states, tribes and research groups will allow the states to share good ideas, learn from each other's experience and find efficiencies.

Photo Lyman- NOAA HIHWNMS/MMHSRP (Permit #18786)

Summary of opportunities and information needs

Over the course of the workshop, participants identified a number of concrete opportunities and information needs to inform science and management efforts. This section organizes and synthesizes the high-level next steps and information needs captured in the preceding session summaries. The following list does not represent consensus or convey any prioritization. The purpose of this compilation is to provide an organized list of ideas for further reference and consideration.

Take action on near-term opportunities to integrate scientific advances into management

- Provide opportunities for industry to identify and share best practices and develop pragmatic, non-regulatory ways to reduce entanglement risk through the Tri-State Dungeness Crab Committee
- Consider the use and/or expansion of informal and voluntary alerts during high-risk conditions (e.g., tornado watch) in response to forecasting models and ecosystem indicators
- Assess opportunities to use fishing effort data to reduce entanglement risk
- Identify opportunities to integrate ecosystem science to improve prediction capabilities
- Prioritize adjusting PBR limits based on new abundance estimates

Prioritize development of cost-effective monitoring and real-time information streams

- Expand the use of passive/autonomous data collection
- Address the challenges, limitations and priorities with more real time fishing data such as transmission, processing and data confidentiality
- Leverage existing eyes on the water, especially in remote areas by providing training and developing citizen science programs
- Improve the capacity and timeliness of entanglement response by increasing the number of trained responders, integrating trained responders with research cruises, and encouraging reporters to stay with the whale until the response team arrives
- Establish clear goals and coordinate approaches for developing EM programs (among states, with industry and stakeholders), and leverage lessons learned and available resources from other EM programs on the U.S. West Coast

Continue to improve the precision, accuracy and utility of models

- Further identify and test assumptions and clearly communicate the strengths, weaknesses and sensitivities of models
- Gather additional information to test, validate and improve models, including integrating different data sets, models, and additional information on whale and fishing dynamics
- Pinpoint coastwide and regional information needs to improve models
- Expand the consideration of social and economic dimensions
- Integrate whale population trends and explore implications of these trends on entanglement risk and whale population dynamics
- Expand the range of future environmental states/conditions to be considered
- Engage fishermen and stakeholders to establish objectives, develop metrics, inform model design and test assumptions

Continue to advance gear innovations as an important aspect of a long-term solution

- Continue to improve gear markings
- Establish baseline metrics to evaluate the effectiveness of gear innovations
- Educate managers, scientists and gear innovators about how the fishery operates and what is needed for new gears to be economically viable and operationally efficient
- Provide financial support to facilitate the industry's ability to engage in gear testing

Develop a strategic data collection strategy based on clear management objectives

- Establish clear management objectives and metrics for evaluating entanglement risk to guide strategic investments in data collection, inform model improvement, assess the costs and benefits of management measures, and evaluate the achievement of management objectives
- Expand opportunities for dialogue among managers, researchers, industry and other stakeholders to inform data collection strategies and tools, including how data on fishing activity will be used
- Engage fishermen to help scientists better understand, interpret and ground truth data and test assumptions
- Identify key questions and define specific information needs and the necessary spatial and temporal resolution in order to target additional research
- Link data collection, analysis, application and evaluation to inform future data needs
- Reconcile inconsistencies with publicly available scientific products and adequately document limitations and caveats
- Leverage existing resources/expertise and additional collaborators to develop cost effective research strategies
- Improve coordination and collaboration among state agencies, federal agencies and research institutions through data sharing agreements and data standardization

Detailed digest of specific information needs identified in workshop discussions

MARINE SPECIES

Finish painting the picture for marine species dynamics

- Abundance, migratory pathways and habitat use of whales along the coast
- Comprehensive understanding of whale and forage distribution throughout the year (e.g., early/late season abundance, inshore/offshore distribution)
- Abundance, distribution and genetic structure of whale populations, particularly for specific humpback whale DPS
- Functional links between oceanography, prey and whales
- Variability in spatial and temporal behavior of whales (e.g., feeding v. migrating, behavior in response to different forage conditions)

FISHERIES

Gather additional information on fishing activity and the human dimensions of entanglement risk (i.e., complexity and context of the fishery, individual members, and supply chain)

Fishing activity / operations:

- Spatial distribution and intensity of fishing activity in U.S. West Coast fixed gear fisheries, especially the number of vertical lines in the water
- Change in distribution and fishing effort over time and the ecosystem factors that drive or influence that change
- Real-time data on fishing activity
- The specific gear configurations that are being used (frequency, distribution) and the factors that influence gear choice and how gear is deployed (e.g., region, season)
- The strategies fishermen have been using to mitigate and avoid entanglements and which practices appear most effective.

Social and economic dimensions:

- Heterogeneity/diversity of the fleet (segments, geographies, different fishing and business strategies, participation in other fisheries)
- Distribution of benefits and impacts of different management measures across the fleet
- Resiliency of the fleet (as a whole, among sectors and individuals), and the individual and cumulative stressors that influence resiliency
- Downstream impacts and implications to processors, supply chains and markets
- Dynamics of how the fishery operates (e.g., socioeconomic factors that influence distribution and density of effort)

ENTANGLEMENTS

Pinpoint the dynamics of how entanglements occur and the associated risks

- Dynamics and mechanics of how whales and sea turtles become entangled in fishing gear (to inform management and gear innovation)
- How any why entanglement frequency and risk changes within and across seasons
- Clear understanding of cause and effect (to evaluate the effectiveness of management measures and gear innovation)
- Severity and implications of impacts at different levels (individual, stock, DPS), and the short term and long-term effects of sub-lethal entanglements
    - Link scar studies and confirmed entanglements by photo identification
    - Expand photo identification efforts in Oregon and Washington and combine with genetic sampling

ECOSYSTEM

Expand understanding of how environmental factors influence whale and fishing behavior, and entanglement risk

- Connections between entanglements and specific environmental drivers
- Regional, spatially explicit environmental indicators suitable for predicting entanglement risk
    - Link indicators with predictive models, monitoring and management frameworks
- Incorporate climate projections in a meaningful way

COSTS

Collect information to assess costs on multiple levels

- The costs associated with managing entanglement risk, including the cost of management responses and gear modifications
- The cost of data collection and monitoring programs
- The costs of not effectively addressing entanglements (to the industry and markets) compared to market benefits of minimizing entanglements
- How costs are distributed within and among the industry and management agencies, and the ability to absorb those costs
- The costs of the overarching management system (making sure necessary resources are available to support data intensive management strategies)

APPENDIX A: WORKSHOP AGENDA

West Coast Entanglement Science Workshop Agenda

The purpose of the West Coast Entanglement Science Workshop is to Identify opportunities for best available science to inform near-term development of whale and sea turtle entanglement mitigation strategies and adaptive management of entanglement risk along the West Coast. The workshop will be held as a 5-part series of virtual modules between August 25 – September 3. Participation in all modules is encouraged, but not mandatory.

Workshop Objectives:

- Review and preview the best available science on understanding, preventing, and reducing entanglement risk in West Coast fixed-gear fisheries;
- Identify near-term opportunities to apply best available science to management frameworks;
- Identify research needs to improve application of available science to management frameworks and opportunities for improved coordination and collaboration; and
- Discuss opportunities to overcome barriers to gear innovation through a special session on gear innovation.

MODULE 1:

TUESDAY, AUGUST 25TH
9:00 AM – 1:00 PM

9:00 – 9:20 am
Welcome and introductions

- Paige Berube, California Ocean Protection Council
- Jenn Humberstone, The Nature Conservancy
- Dan Lawson, NOAA Fisheries, West Coast Regional Office
- WebEx orientation: Dana Stefan, Ross Strategic

9:20 – 10:15 am
Management frameworks for entanglement risk
OBJECTIVE: Provide a shared frame of reference for the workshop by reviewing the trajectory of entanglement science and management response and sharing contextual information about each state's progress and approach.

Moderator:

- Paige Berube, California Ocean Protection Council

Presenters:

- Dan Lawson, NOAA Fisheries, West Coast Regional Office
- Heather Hall, Washington Department of Fish and Wildlife
- Caren Braby, Oregon Department of Fish and Wildlife
- Sonke Mastrup, California Department of Fish and Wildlife
- Q&A/Discussion

10:15 – 10:30 am BREAK

10:30 am – 1:00 pm
Forecasting and monitoring marine species dynamics
OBJECTIVE: Explore the information streams and models that help us understand the dynamics of marine species (e.g., movement and time/space distribution of whales and turtles).

Moderator:

- Dan Lawson, NOAA Fisheries, West Coast Regional Office

Presenters:

- John Calambokidis, Cascadia Research Collective
- Karen Lohman and Scott Baker, Marine Mammal Institute, Oregon State University
- Daniel Palacios, Marine Mammal Institute, Oregon State University
- Leigh Torres, Marine Mammal Institute, Oregon State University
- Scott Benson, NOAA Fisheries, Southwest Fisheries Science Center

Panelists:

- Caren Braby, Oregon Department of Fish and Wildlife
- George Bradshaw, Commercial Fisherman, CA
- Jaime Jahncke, Point Blue Conservation Science
- Victoria Knorr, Washington Department of Fish and Wildlife
- Sonke Mastrup, California Department of Fish and Wildlife
- Brian Nolte, Commercial Fisherman, OR
- Larry Thevik, Commercial Fisherman, WA
- Andrea Treece, Earth Justice

MODULE 2:

THURSDAY, AUGUST 27TH
9:00 AM – 1:00 PM

9:00 – 9:15 am
Welcome back

- Dan Lawson, NOAA Fisheries, West Coast Regional Office
- WebEx orientation: Dana Stefan, Ross Strategic

9:15 – 10:45 am
Forecasting and monitoring marine species dynamics (continued)
OBJECTIVE: Explore the information streams and models that help us understand the dynamics of marine species (e.g., movement and time/space distribution of whales and turtles).

Moderator:

- Dan Lawson, NOAA Fisheries, West Coast Regional Office

Presenters:

- Jaime Jahncke, Point Blue Conservation Science
- Karin Forney, NOAA Fisheries, Southwest Fisheries Science Center
- Briana Abrahms, NOAA Fisheries / University of Washington
- Jarrod Santora, NOAA Fisheries / UC Santa Cruz

Panelists:

- Caren Braby, Oregon Department of Fish and Wildlife
- John Calambokidis, Cascadia Research
- Elliott Hazen, NOAA Fisheries, Southwest Fisheries Science Center
- Victoria Knorr, Washington Department of Fish and Wildlife
- Sonke Mastrup, California Department of Fish and Wildlife
- John Mellor, Commercial Fisherman, CA
- Tim Novotny, Oregon Dungeness Crab Commission
- Larry Thevik, Commercial Fisherman, WA

10:45 – 11:15 am BREAK

11:15 am – 1:00 pm
Understanding fishing dynamics
OBJECTIVE: Explore the information streams and models that help us understand the dynamics of fishing activity (e.g., time/space distribution of fishing effort) and consider specific information needs to improve management of entanglement risk.

Moderator:

- Kate Kauer, The Nature Conservancy

Presenters:

- Blake Feist, NOAA Fisheries, Northwest Fisheries Science Center
- Owen Liu, NOAA Fisheries, Northwest Fisheries Science Center
- Cotton Rockwood, Point Blue Conservation Science
- Kathi George, The Marine Mammal Center

Panelists:

- Dan Ayres, Washington Department of Fish and Wildlife
- Caren Braby, Oregon Department of Fish and Wildlife
- Dave Colpo, Pacific States Marine Fisheries Commission
- John Corbin, Commercial Fisherman, OR
- Lisa Damrosch, Morning Star Fisheries, CA
- Sonke Mastrup, California Department of Fish and Wildlife
- Larry Thevik, Commercial Fisherman, WA

MODULE 3:

TUESDAY, SEPTEMBER 1ST 9:00 AM – 12:00 PM

9:00 – 9:15 am
Welcome back

- Dan Lawson, NOAA Fisheries, West Coast Regional Office
- WebEx orientation: Tess Wendel, Ross Strategic

9:15 – 10:30 am
Understanding the metrics for entanglement
OBJECTIVE: Explore the information streams provided through entanglement science (e.g., entanglement rates and impacts) and consider application to monitoring and evaluation.

Moderator:

- Ryan Bartling, California Department of Fish and Wildlife

Presenters:

- Doug Sandilands, SR3 Sealife Response, Rehabilitation and Research
- Jenn Tackaberry, Cascadia Research Collective
- Dan Lawson, NOAA Fisheries, West Coast Regional Office

Panelists:

- Caren Braby, Oregon Department of Fish and Wildlife
- Gerry Hemmingsen, Commercial Fisherman, CA
- Victoria Knorr, Washington Department of Fish and Wildlife
- Sonke Mastrup, California Department of Fish and Wildlife
- Larry Thevik, Commercial Fisherman, WA
- Justin Viezbicke, NOAA Fisheries, West Coast Regional Office

10:30 – 10:45 am BREAK

10:45 am – 12:00 pm
Social and economic dimensions of entanglements
OBJECTIVE: Explore social and economic information streams and consider how they might be utilized and improved to inform management decisions.

Moderator:

- Carrie Pomeroy, University of California at Santa Cruz

Presenters:

- Shannon Davis, The Research Group and Gil Sylvia, Oregon State University
- Rachel Seary, NOAA Fisheries, Southwest Fisheries Science Center
- Carrie Pomeroy, University of California at Santa Cruz

Panelists:

- Richard Axelson, Commercial Fishermen, CA
- Caren Braby, Oregon Department of Fish and Wildlife
- Cari Brandberg, Living Pacific Seafood; Chelsea Rose Seafood, OR
- Heather Hall, Washington Department of Fish and Wildlife
- Sonke Mastrup, California Department of Fish and Wildlife
- Susan Rotwein, Commercial Fishermen, CA
- Jameal Samhouri, NOAA Fisheries, Northwest Fisheries Science Center
- Gilbert Sylvia, Oregon State University
- Larry Thevik, Commercial Fisherman, WA

MODULE 4:

TUESDAY, SEPTEMBER 1ST 2:00 PM – 4:00 PM

Special Topic: Gear Innovation Barriers & Opportunities
The goal of this special topic session is to outline and discuss ideas for how to potentially overcome barriers that may be hindering the development of gear innovations in U.S. West Coast fixed gear fisheries. These barriers may be specific to certain innovations and fisheries or acting more broadly. This discussion will ultimately aim to help managers and stakeholders develop "plans" to incorporate these ideas into strategic frameworks and/or priorities for investment in and evaluation of future gear innovation efforts that may have fishery specific and non-fishery specific implications.

Specifically, this session will:

- Engage experts and key stakeholders in a discussion of obstacles and solutions facing the design and implementation of gear innovations, specifically and/or in general, that could be used to help address the US West Coast entanglement issue (and beyond).
- Summarize the state of gear innovation and important barriers on West Coast (and beyond) from various perspectives of attendees.
- Focus on identifying and discussing the barriers for some innovations that are already at the forefront of ideas that are being considered for further development.
- Discuss specific opportunities to complement gear innovation with other wants/needs/interests of the fishery, and vice versa.

2:00 – 2:15 pm
Welcome and introductions

- Dan Lawson, NOAA Fisheries, West Coast Regional Office
- WebEx orientation: Tess Wendel, Ross Strategic
- Fran Recht, PSMFC, background work on gear innovation

2:15 – 2:45pm
Identifying barriers to gear innovation
OBJECTIVE: Clearly identify and characterize barriers to gear innovation.

Examples:

- Regulatory (current structure and purpose, law enforcement)
- Feasibility (cost, technical, practical)
- Cultural (resistance to change traditions and current practices, "social" interaction fishing with/around each other, fleet diversity)
- Incentives (uncertainty about them, how will they be realized, creation of negative ones)
- Effectiveness (will it work, how will we know/evaluate)
- Unintended consequences (can we think ahead?)

2:45 – 4:00 pm
Reviewing barriers and solutions to specific gear innovation
Using a matrix of identified barriers, systematically review specific gear innovation ideas that are being considered for use on the U.S. West Coast. Review the pros/cons and identify/discuss the barriers and ideas for overcoming them with a goal of trying to find paths forward to innovation. Ideas for specific innovations include:

- Longlining traps
- Yale grips/weak lines
- Pop-up gear with delay or demand systems
- Other ideas that connect to gear innovation from the panel discussion

Moderators:

- Dan Lawson, NOAA Fisheries, West Coast Regional Office
- Lauren Saez, NOAA Fisheries, West Coast Regional Office
- Fran Recht, PSMFC, Whale entanglement project

Panelists:

- Dan Ayres, Washington Department of Fish and Wildlife
- Caren Braby, Oregon Department of Fish and Wildlife
- Ryan Bartling, California Department of Fish and Wildlife
- Zed Blue, Commercial Fisherman, WA
- Larry Thevik, Commercial Fisherman, WA
- John Corbin, Commercial Fisherman, OR
- Calder Deyerle, Commercial, Fisherman, CA
- John Mellor, Commercial Fisherman, CA
- Dick Ogg, Commercial Fisherman, CA
- Sheila Garber, Englund Marine, OR
- Sean Hayes, NOAA, NE Fisheries Science Center
- Steve Johnson, CDFW Law Enforcement
- Doug Sandilands, SR3 Sealife Response, Rehabilitation and Research
- Geoff Shester, Oceana, CA

MODULE 5:

THURSDAY, SEPTEMBER 3RD
9:00 AM – 1:00 PM

9:00 – 9:15 am
Welcome back

- Dan Lawson, NOAA Fisheries, West Coast Regional Office
- WebEx orientation: Tess Wendel, Ross Strategic

9:15 – 11:00 am
Understanding and framing risk and tradeoff decisions
OBJECTIVE: Explore models that help us "put it all together" to understand the overlap in marine life and fishing dynamics, consider and predict risk, and explore tradeoffs.

Moderator:

- Jenn Humberstone, The Nature Conservancy

Presenters:

- Karin Forney, NOAA Fisheries, Southwest Fisheries Science Center
- Jameal Samhouri, NOAA Fisheries, Northwest Fisheries Science Center
- Chris Free, University of California Santa Barbara
- Burton Shank, NOAA Fisheries, Northeast Fisheries Science Center

Panelists:

- Caren Braby, Oregon Department of Fish and Wildlife
- Mike Conroy, Pacific Coast Federation of Fishermen's Associations
- Heather Hall, Washington Department of Fish and Wildlife
- Sonke Mastrup, California Department of Fish and Wildlife
- Penny Ruvelas, NOAA Fisheries, West Coast Regional Office
- Gilbert Sylvia, Oregon State University
- Larry Thevik, Commercial Fisherman, WA
- Justin Yager, Commercial Fisherman, OR

11:00 – 11:30 am BREAK

11:30 am – 1:00 pm
Synthesis and next steps
OBJECTIVE: Reflect on regional and fishery-specific science needs and identify opportunities for improved collaboration and coordination among and across West Coast partners.

Moderator:

- Paige Berube, California Ocean Protection Council

Panelists:

- Caren Braby, Oregon Department of Fish and Wildlife
- John Calambokidis, Cascadia Research Collective
- Heather Hall, Washington Department of Fish and Wildlife
- Jenn Humberstone, The Nature Conservancy
- Karin Forney, NOAA Fisheries, Southwest Fisheries Science Center
- Jon Gonzalez, Pacific Seafood
- Sonke Mastrup, California Department of Fish and Wildlife
- Penny Ruvelas, NOAA Fisheries, West Coast Regional Office
- Jameal Samhouri, NOAA Fisheries, Northwest Fisheries Science Center
- Larry Thevik, Commercial Fisherman, WA
- Justin Yager, Commercial Fisherman, OR

APPENDIX B: PRESENTATION ABSTRACTS

MODULE 1 ABSTRACTS (Tuesday, August 25th | 9:00 am – 1:00 pm)

Insights into entanglements from whale population monitoring

J Calambokidis, KR Flynn, A Wall, J Tackaberry, and D Sandilands

Monitoring of populations of humpback, blue, and gray whales (especially the Pacific Coast Feeding Group or PCFG) along the US West Coast has been conducted using a variety of approaches including long-term photo-identification since the 1980s by Cascadia Research and other collaborating groups. This research has served as the basis for abundance estimates of these populations as well as insights into their status, trends, and stock structure. This information has also been important in understanding some of the causes and the impacts of entanglements on these populations.

We examine several aspects of whale population monitoring along the US West Coast and the insights they provide into the entanglement issue. This includes:

1. Updated population estimates and trends of humpback, blue, and gray whales along the US West Coast and how these interact with entanglement risk
2. Studies of entanglement scars on humpback whales along the US West Coast and how scaring rates compare to known areas of documented entanglements
3. Insights into the population units of whales in different region and DPS status (for humpback whales) and insight into the risk of entanglements
4. Role of research in documenting entanglements and proposed study to integrate population monitoring, information on whale fishery overlap, documentation of entanglements, and disentanglement response into future surveys
5. Whale diving and feeding behavior from observations and tag deployments and insights into dynamics of entanglement

Genetic population assignment of humpback whales in the eastern North Pacific to Distinct Population Segments

Karen Lohman[1], Debbie Steel[1], Dawn R. Barlow[1], John Calambokidis[2], Bruce Mate[1], Daniel M. Palacios[1], Leigh G. Torres[1], and C. Scott Baker[1]
[1] Marine Mammal Institute and Department of Fisheries and Wildlife, Oregon State University, 2030 SE Marine Science Drive, Newport, Oregon 97365, USA
[2] Cascadia Research Collective, 218½ West Fourth Avenue, Olympia, Washington 98501, USA

Humpback whales migrate annually from spatially and genetically differentiated winter breeding grounds, or Distinct Population Segments (DPS), to shared summer feeding grounds (Baker et al. 2013). Recent increases in the entanglement of humpback whales on feeding grounds off the US West Coast have led to conservation concerns for individuals thought to belong to the Mexico DPS, considered threatened under the US ESA, and the Central America DPS, considered endangered under the US ESA (Bettridge et al. 2015, NOAA 2019). An accurate understanding of feeding ground use by each DPS is important for geographic assessment of entanglement risk and allocation of individual mortality events from areas of mixing. To this end, standardized DNA profiling (microsatellite genotypes, mtDNA haplotypes and sex) was conducted for 765 biopsy samples representing 666 individuals collected off the West Coast of North America representing fifteen years of sampling effort (2002–2019). These DNA profiles were compared to a large reference database including DNA profiles from the breeding grounds of the four recognized North Pacific DPS during the SPLASH study in Bayesian assignment testing (Baker et al. 2013).

Spatial assessment of the population assignments produced showed latitudinal trends of decreasing assignment probability to Central America with increasing latitude and increasing assignment probability to the Hawaii with increasing latitude. Individuals with assignment to Mexico were found across a wide range of latitudes along the US West Coast. Beta regression Generalized Additive Models (GAMs) assessed the relationships between each sample's proportional assignment to the four North Pacific DPS relative to latitude/longitude, sea surface temperature, year, and month. GAMs had high deviance explained and latitude was a highly significant predictor variable in all DPS models. Further analyses are underway to improve the spatial population assignment models and the assignment accuracy to the Mexico DPS.

Analytical development of whale satellite tagging data to inform critical knowledge gaps off the US West Coast

Daniel M. Palacios, Oregon State University

For the last three decades, Oregon State University (OSU) has been deploying Argos-monitored satellite tags on baleen whales off the US West Coast to collect data on movement and habitat use for these species in this important feeding ground. As the technology has matured, its potential use as an operational tool for effective monitoring of whale populations is coming to fruition, as exemplified by recent projects that OSU has conducted on behalf of the US Navy since 2014 as part of their regulatory compliance with Letters of Authorization issued by the National Marine Fisheries Service (NMFS). A retrospective analysis of OSU's cumulative datasets has the potential to generate critical baseline knowledge about whale distribution and movement, important areas of aggregation, and habitat preferences off the West Coast at spatial and temporal scales not possible with other survey methodologies. Currently, OSU holds satellite tracking datasets for these four species of baleen whale – gray whales: years 2005 (n=17), 2009 (n=18), 2012 (n=9), and 2013 (n=6); humpback whales: years 2004–2005 (n=14) and 2016–2019 (n=67); blue whales: years 1994-2008 (n=104) and 2014–2017 (n=90); and fin whales: years 2004–2006 (n=2) and 2014–2018 (n=31). In addition to acquiring tracking data to inform whale distribution and movement, since 2016 OSU has been using advanced tags that also report dive depth, duration, and feeding activity. Thus, with our more recent datasets we also have the ability to characterize diving behavior and its variability at daily, weekly, and monthly timescales.

The answer to the question of how West Coast fisheries can reduce entanglement risk is evidently by reducing spatial and temporal overlap between whales and fishing activity. This is not a simple task, however, considering the high variability in oceanographic conditions, forage resource abundance, and whale behavior from year to year. Ultimately, a dynamic ocean management approach is well-suited for this task, although the implementation of such an approach is data-intensive and follows three development phases: 1) conduct basic science to fill critical data/information gaps (i.e., quantitative characterization of the cumulative tracking data to derive parameters such as timing, movement rates, home range, and vertical use of the water column); 2) use these results to develop intermediate data products (i.e., predictive habitat models to forecast whale distribution and density from oceanographic conditions); and 3) conduct risk assessment modeling using the intermediate data products as input, to develop decision support tools to be used by managers. Additionally, strategic acquisition of additional tagging data in the future would allow for continued monitoring and for iterative improvement of the data products developed in phases 1-3. Finally, given the presence of three NMFS-identified Distinct Population Segments (DPS) of humpback whales off the West Coast, the implementation of these phases ideally should be done at the DPS level for this species to the extent possible.

Identifying co-occurrence between whales and fishing effort in Oregon to reduce entanglement risk

Leigh Torres[1], Kelly Corbett[2], Troy Buell[2], Scott Baker[1], Caren Braby[2], Solène Derville[1], Amanda Gladics[3], Craig Hayslip[1]
[1] Marine Mammal Institute, Oregon State University
[2] Oregon Department of Fish and Wildlife
[3] Oregon Sea Grant

Increased whale entanglements along the US West Coast in Dungeness crab fishing gear are causing significant concern among managers, researchers, fishermen, and the environmental community in Oregon; entanglements threaten both whale populations and the stability of the crab fishery and coastal communities. First convened in 2017, the Oregon Whale Entanglement Working Group developed recommendations to reduce entanglement risk, including the high priority of supporting future research to better document whale distribution in Oregon waters. In progress since early 2019, this research project

aims to fill this data gap and link an improved understanding of whale distribution patterns in Oregon with fishing effort to develop maps of entanglement risk, which managers can use to spatially manage fishing effort more effectively. Data on whale presence/absence in Oregon waters is collected using standardized distance sampling methods during four monthly surveys aboard USCG helicopters along set tracklines in four different coastal regions of Oregon. The goal is to conduct these four survey tracklines monthly for two full years, beginning February 2019. To-date we have conducted 51 surveys and recorded 206 sightings of 10 different cetacean species. Additionally, when humpback whale aggregations are observed, boat-based field operations occur to collect photo-ID and biopsy data to improve individual and population assignment to Distinct Population Segments (DPS).

Species distribution models (SDM) will be generated using this presence/absence data in relationship to oceanographic and topographic data. Other complementary datasets on baleen whale occurrence in Oregon waters will contribute to this SDM calibration and validation process including vessel-based survey data and opportunistic sightings reported by citizen scientists. We have also developed an extensive outreach program to engage various ocean-users (e.g., commercial and recreational fishermen, USCG personnel, tugboat captains, tour operators) to collect opportunistic whale sightings using the mobile app Whale Alert. Predictive maps of whale distribution patterns in Oregon derived from the SDMs will be spatially overlaid with layers of crab gear fishing effort generated by the Oregon Department of Fish and Wildlife (ODFW) to identify areas of elevated risk of whale entanglement. This project will improve our knowledge of whale space-use patterns in Oregon and develop maps of co-occurrence with fishing effort. Understanding when and where whales overlap with the fishery would allow discrete and targeted management actions, potentially including spatio-temporal fishery closures, to maximize effectiveness and minimize burden to fishermen. Furthermore, our network of project collaborators is strong, transparent, and broad including engaged fishermen and ODFW managers. Already we have communicated effectively between groups: fishermen often inform scientists on the locations of whale aggregations, and scientists have in-turn informed managers on locations and behavior of whales who then advise the fishery on recommended, voluntary gear placement to reduce entanglement risk.

Monitoring leatherback turtles in nearshore US west coast waters

Scott Benson, NOAA Fisheries, Southwest Fisheries Science Center

Endangered leatherback turtles *(Dermochelys coriacea)* that originate from nesting beaches in the western Pacific occur seasonally (June-November) in US west coast shelf waters for foraging. We have used genetics, telemetry, aerial surveys, and habitat sampling to inform key questions about population structure, movements, abundance, trends, and foraging habitat. Multi-year telemetry studies have identified key foraging areas in shelf waters off central California and shelf/slope waters off Oregon/Washington. A steep, long-term declining trend has been documented at the largest nesting beaches in western Pacific (Papua Barat, Indonesia) and a similar declining trend in abundance is evident at a vital central California foraging area. As a consequence of its endangered status, leatherback turtle critical habitat was designated off central California and Oregon/Washington in 2012.

Unlike large whale species, leatherbacks are cryptic, therefore, monitoring presence and distribution is a significant challenge. Telemetry studies and aerial surveys have been useful for monitoring presence and movement within nearshore central California foraging areas to inform potential management actions and mitigate entanglement risk. Biological indicators recorded during our surveys can also be useful proxies for presence of leatherbacks. For example, leatherbacks primarily consume brown sea nettles *(Chrysaora fuscescens)* in neritic central California waters and surface aggregations of brown sea nettles can be observed during aerial surveys.

MODULE 2 ABSTRACTS
(Thursday, August 27th | 9:00 am – 1:00 pm)

Changes in abundance and timing of migration of whales in central California

Kaytlin Ingman[1,2], Ellen Hines[1], Piero Mazzini[1], Nadav Nur[2], Cotton Rockwood[2], and Jaime Jahncke[2]
[1] Estuary & Ocean Science Center, SFSU
[2] Point Blue Conservation Science

We document changes in the annual sightings and timing of humpback *(Megaptera novaeangliae)* and blue whale *(Balaenoptera musculus)* migration around the Farallon Islands, California. We hypothesized that changes in the timing of migration off central California were driven by local oceanography, regional upwelling, and basin-scale climate conditions. Using 24 years of daily whale counts collected from Southeast Farallon Island, we developed negative binomial regression models to evaluate trends in local whale sightings over time. We used linear models to assess trends in the timing of migration, and to identify potential environmental drivers. Wind-driven upwelling and overall productivity in the California Current System is driven by atmospheric circulation that is influenced by basin scale climate patterns: the El Niño Southern Oscillation, the Pacific Decadal Oscillation, and the North Pacific Gyre Oscillation. We used the timing model to predict entanglement risk. Humpback whale sightings significantly increased over the study period, but blue whale counts did not though there was variability across the time series. Breeding migration (departure time) for all species showed little to no change, whereas migration towards feeding areas (arrival time) occurred earlier for humpback and blue whales. Timing was significantly influenced by both local variables (upwelling, temperature) and a basin wide climate index (El Niño). Earlier arrival time without concomitant earlier departure results in longer periods when blue and humpback whales are present in the Gulf of the Farallones. We maintain that these changes have increased whale exposure to pot and trap fishery gear off the central California coast during Spring, elevating the risk of entanglements. Humpback entanglement rates were correlated with increased counts and early arrival in central California. Actions to decrease the temporal overlap between whales and pot/trap fishing gear, particularly when whales arrive earlier in warm or El Niño years, would likely decrease the risk of entanglements.

Fine-scale spatial models capture changes in humpback whale distribution associated with the 2014–2016 marine heat wave along the U.S. West Coast

Karin A. Forney[1], Jessica V. Redfern, Samuel M. Woodman, Elizabeth A. Becker, Jarrod A. Santora, Isaac Schroeder.
[1] Marine Mammal & Turtle Division, Southwest Fisheries Science Center, NOAA

As our understanding of climate impacts on the marine environment has grown, so has our recognition that approaches to managing anthropogenic impacts on marine species must explicitly take into account shifts in species distributions associated with episodic and longterm climate changes. For marine mammals, species distribution models (SDMs) that include dynamic habitat predictors have become an essential tool for managing impacts of naval activities, fisheries, vessel traffic, and underwater sound. Off the U.S. West Coast, a 2014–2016 marine heatwave led to pronounced shifts in the distribution of marine species, which in turn caused a dramatic increase in entanglements of humpback whales, *Megaptera novaeangliae*, in nearshore fixed-gear fisheries. Robust humpback whale SDMs have been extensively developed and validated for the broader California Current Ecosystem, but the resolution of these models (10 km) was too coarse to provide reliable distribution data in the nearshore regions, where fixed-gear fisheries operate. We have, therefore, adapted the previous SDMs that examined broad-scale interannual cetacean distributions to create a dynamic finer-scale (3 km) model that captures seasonal patterns of whale occurrence in

nearshore habitats across 15 years from 2005–2019. Using independent data sets to validate the model, we demonstrate its ability to capture seasonal and interannual whale distribution shifts, particularly associated with the 2014–2016 marine heatwave. This model provides a foundation for two separate studies that examine whale entanglement risk (Redfern et al., in prep) and socio-economic tradeoffs associated with entanglement risk reduction (Samhouri et al., in prep) for various potential management approaches to reduce whale entanglements along the U.S. West Coast.

WhaleWatch 2.0: a dynamic ensemble model to predict daily blue whale distributions along the West Coast in near real-time

Briana Abrahms, Heather Welch, Stephanie Brodie, Michael Jacox, Elizabeth Becker, Steven J. Bograd, Ladd Irvine, Daniel Palacios, Bruce Mate, Elliott L. Hazen

In this presentation I introduce WhaleWatch 2.0, a predictive spatial management tool that helps scientists and managers evaluate the most likely times and places that blue whales will be present along the U.S. West Coast in order to mitigate risk of interaction with human activities. We integrated a long-term satellite tracking dataset on 104 blue whales with data-assimilative ocean model output to predict daily, year-round habitat suitability for blue whales at 10x10 km resolution along the U.S. West Coast. We evaluated candidate models using multiple metrics and training/testing datasets, including the largest compilation of independent blue whale sightings data to date. The final model had strong predictive skill, resulting in daily, year-round predictions of blue whale habitat suitability in the CCE that accurately captured the whales' migratory behavior and shifts due to anomalous environmental conditions. Daily, coastwide blue whale predictions are publicly available and operational in near-real time, and can be found at coastwatch.pfeg.noaa.gov/projects/whalewatch2/about_whalewatch2.html.

Dynamic, high-resolution species distribution models with strong predictive performance such as this are valuable for targeting management needs in near real-time. After introducing the WhaleWatch 2.0 tool, I present a brief case study on its application to management of ship strikes to blue whales in the Southern California Bight, where metrics derived from this tool for ship strike risk assessment are currently operational. Our aim is to expand its application for entanglement risk assessments by providing blue whale distribution information for the entire coast at daily, monthly, or seasonal timescales as needed. Since whale distributions are dynamic and have been shown to shift in response to changing environmental conditions, integration of this information into management is valuable.

Advancing development of regional management strategies that incorporate ecosystem oceanography to mitigate whale entanglements along the U.S. West Coast

Jarrod A. Santora, NOAA Fisheries, Southwest Fisheries Science Center, Fisheries Ecology Division; University of California Santa Cruz

We will present an overview of a new website that describes the development and of an ecosystem oceanography toolbox for understanding and communicating attributes underlying whale entanglements along the U.S. West Coast. The website provides information describing the process for conducting seasonal assessment and contains data on relevant indicators for monitoring ecosystem conditions (dynamic time series and maps). Monitoring forage species (krill, anchovy) distribution and the area of cool surface temperatures provides supporting information for understanding upwelling ecosystem conditions and monitoring impacts from warming events (e.g., marine heatwaves). Specifically, we developed the habitat compression index (HCI) to inform regional ecosystem dynamics along the U.S. West Coast. The HCI is a spatial time series that tracks the area of coastal upwelling habitat and is relevant for retroactive and ongoing risk assessments involving whale entanglement. Larger values (e.g., >1SD) indicate expansion

of cool habitat and values less than the mean indicate periods when habitat compressed onshore. Under periods of strong habitat compression (low values) there is an apparent increased risk of increased whale entanglement due to the shrinkage of the coastal upwelling ecosystem, coinciding with the lack of forage used by whales. Our presentation will provide an overview of the HCI and discuss examples on how the index may be integrated with other habitat metrics, especially with respect to bathymetry since fishery management and conservation decisions may be based on setting crab fishing depth restrictions. Additionally, we will discuss how the HCI can be classified according to thresholds (e.g., low, medium and high) to monitor potential entanglement risk. These thresholds will be provided to federal and state resource managers to develop regional management strategies to mitigate whale entanglement risk.

Using landings and vessel monitoring system (VMS) data to model fixed-gear fishing activity and its relationship to whale entanglements off the US west coast

Blake Feist[1], Jameal Samhouri[1], Owen Liu[1], Mary Fisher[1,2] Lauren Saez[3], Karin Forney[4] and Dan Lawson[3]
[1] Northwest Fisheries Science Center
[2] University of Washington
[3] West Coast Regional Office
[4] Southwest Fisheries Science Center

Bycatch of whales in commercial fishing gear poses a global threat to populations and is of particular concern for endangered or threatened whale species. In order for resource managers to effectively minimize the risk of entanglement while ensuring economic well-being in associated fisheries, they need to be able to integrate the dynamics of fishing activity, whale distributions and environmental conditions. Further, the geographic extent over which whales are exposed to commercial fishing gear can be vast, and yet, decisions must often be made at a more local extent. Therefore, we need to develop tools that incorporate the factors that drive entanglements and can be used at relevant spatio-temporal scales for fisheries management in the context of whale entanglements.

In this presentation we describe new, spatially-explicit indices of fishing activity off the US west coast from 2009–2016 for four major pot- and trap-fisheries most commonly implicated in entanglements, and relate that activity to modeled humpback whale species distributions and reported entanglements across the same spatial domain. We use vessel monitoring system (VMS) data informed by port-level landings data to delineate fishing activity hotspots and examine overlap patterns with predicted humpback whale density. Over the full study period for the four fisheries we analyzed, we did not detect marked increases in fishing activity in general or changes in fisheries footprints within areas with historically high mean annual whale densities. However, we observed a clear signal of higher Dungeness crab fishing activity in California in spring of 2016 that is consistent with a high rate of entanglement in that year. Together, our results add to a growing body of work related to bycatch of protected species in otherwise sustainable fisheries and highlight the potential value of novel, spatio-temporal data sources and analyses for reducing human-wildlife conflict in the ocean. Outputs from these models are currently in the next phase of development in order to improve their accuracy at identifying fishing hotspots. These next generation fishing activity models, coupled with dynamic ocean whale density models are being used to simulate various scenarios that can be used by resource managers to test a variety of fisheries management strategies aimed at reducing the risk of entanglements.

A Vertical Line Model for the West Coast Dungeness Fishery

Owen R. Liu, National Research Council Postdoctoral Fellow, Northwest Fisheries Science Center

Entanglement of large whales in fishing gear is a complex environmental problem. Managing entanglement risk requires an understanding of both the biological and economic dynamics of whales and fisheries. Much recent research has focused on the environmental drivers of whale distributions over space and time, but substantially less attention has been paid to the spatial dynamics of fisheries. Focusing on the Dungeness crab fishery in California, this research attempts to address the need to better understand the distribution of fishing effort over time. Specifically, using satellite-derived vessel positions combined with fishery landings data, we developed a model of the number of fishing lines in the water over space and time, which we term a vertical line model.

While not a replacement for current approaches to understanding and managing whale entanglements, results from the vertical line model can be used as an additional source of information when assessing the potential impacts of alternative management approaches to reduce entanglement risk. For example, the model provides a spatial view of hotspots of fishing line density, as well as an assessment of how these hotspots change over time. When combined with predictive models of whale distributions, the model can be used to help assess relative entanglement risk across space. In the future, extensions from this model could be used in predictive models of how fishing pressure might change in response to management measures.

Preliminary analysis on "Co-occurrence of whales and Dungeness crab-pot fishing gear in the north-central California National Marine Sanctuaries."

Cotton Rockwood[1] and co-authors
[1] Point Blue Conservation Science

One of the primary remaining human impacts on large whales is entanglements with fishing gear. In recent years the number of entangled whales has increased along the U.S. West Coast. Records show the vast majority of entanglements occur in trap/pot fishing gear with most reports occurring off California. We used 10 years (2008–2017) of crab pot and whale distribution data collected on the Applied California Current Ecosystem Studies (ACCESS) cruises. We modeled crab pot and whale densities in relation to climate, oceanography, and bathymetry. We estimated co-occurrence by calculating the product of whale and pot densities and used it as a proxy for entanglement risk. Average risk for all years and months showed different patterns for blue and humpback whales. Since whale prey is expected to be compressed close to shore in warm water years, we compared averages of May risk between warm and cold years. Warm years showed higher risk that was more concentrated close to shore. To examine the accuracy of our modeled entanglement risk in predicting entanglements, we compared our predictions to observed entanglements for the study region. We scaled our index so that the maximum predicted risk aligned with the greatest number of entanglements observed in any month of our study period. On an annual basis, our predictions aligned well with observed entanglements. Overall, the predictions captured the significant rise in entanglements in 2016–17, though 2015 was under-predicted. With improved modeling driven by expanded data, our approach can offer important insights into how to mitigate whale entanglement.

Pelagic Data Systems Solar Logger Case Study

Kathi George, Whale Entanglement Response and Prevention Manager, The Marine Mammal Center

In 2019, a pilot project was initiated in California to utilize solar loggers (from Pelagic Data Systems) on commercial Dungeness crab vessels and whale watch vessels to collect and analyze fishing dynamics and whale concentration data. I will highlight the technology used, data analysis conducted, and the challenges and opportunities that solar loggers present. Additionally, I will call attention to proposed regulations for electronic monitoring, and how solar logger technology fits the requirements.

MODULE 3 ABSTRACTS
(Tuesday, September 1st | 9:00 am – 12:00 pm)

Documentation of Large Whale Entanglements by Trained Responders — A Rare Opportunity to Learn about the Problem of Entanglement and Inform Management Efforts Towards Prevention and Mitigation

Doug Sandilands[1], John Calambokidis[2], Kiirsten Flynn[2] and Jenn Tackaberry[2]
[1] SR3 Sealife Response Rehab & Research
[2] Cascadia Research Collective

Reports of large whale entanglements provide a rare opportunity to gain insight into how whales became entangled, in what gear they became entangled, the effects the entanglement has on large whales including wounds, impediments to normal behavior and long-term health effects. Additionally, documentation collected during a response can identify the whale as an individual providing information on the whale's life history. This information is rarely collected during public reports. In fact, using scarring images taken during entanglement responses and follow up during large whale research efforts, we know that public reports represent an extremely small fraction of the total entanglements occurring.

There will be a focus on the analysis of gear removed from entangled whales and how systematic documentation of the whale during the entanglement can allow inference of how and in what part of the gear the whale became entangled. In the coming years, these and future case studies will provide data that can inform fisheries and fisheries managers working to modify gear to prevent entanglements and mitigate the severity of entanglements to ensure that their efforts target strategies with the best chance of succeeding.

Re-sight and survival of entangled humpback whales within the California, Oregon, and Washington region using photo-identification and long-term life history data

Jenn Tackaberry, John Calambokidis, Elana Dobson, and Kiirsten Flynn | Cascadia Research Collective, Olympia, WA 98501

The recent uptick of entanglements along the coast of California, Oregon, and Washington (US West Coast) since 2015 has provided an opportunity to assess the re-sight rates of entangled humpback whales. We used photo-identification images collected from entangled animals, to examine sighting history prior to entanglement as well as after entanglement using longitudinal catalogs and life-history data (from both Cascadia and Happywhale). This information can be used to better inform management, models, and estimates of serious injury and mortality unique to the West Coast. We established a group of "control" whales seen in the same region and similar time period as the entangled whale to serve as a basis of comparison for the sighting history of entangled whales.

Key findings included:

1. Resightings of entangled whales were lower than the "control" whales.
2. Resightings of entangled whales were less likely when the region the gear was set were different than where the entangled whale was reported.
3. Entangled whales tended to have shorter histories of sightings prior to entanglement than the "control" whales possibly reflecting that entangled whales tended to be younger animals.
4. The resighting of whales post entanglement generally correlated with the original Serious Injury score assigned by NOAA with more seriously entangled whales less likely to be resighted than those with non-serious entanglements.

While the increase in entanglements along the US West Coast has been fairly recent, these findings show the value of photo-identifications of entangled whales and will dramatically increase our understanding of entanglements and survival with additional years of data.

Analysis of U.S. West Coast Large Whale Entanglement Serious Injury and Mortality Assessments

Dan Lawson and Lauren Saez, NMFS West Coast Region Protected Resources Division

All three U.S. West Coast States that manage commercial and recreational Dungeness crab fisheries are developing Conservation Plans under the Endangered Species Act to guide management of their Dungeness crab fisheries to minimize the risks of entangling ESA-listed species, including large whales. To help States to make informed assumptions about the potential impacts of entanglements on individuals and on populations, NMFS WCR has conducted analysis of serious injury and mortality (SI/M) assessed to confirmed whale entanglements reported from the U.S. West Coast. These assessments for each entanglement are conducted by NMFS Southwest Fisheries Science Center under national criteria established to support marine mammal stock assessments. In this presentation, we present summary analysis of the SI/M assessments for 219 confirmed U.S. West Coast whale entanglements reported from 2013–2018.

The results of this analysis illustrate expectations for what the SI/M rates of entangled whales may be in the future for use predicting the population-level impacts of entanglements. In addition, these SI/M rates can be used to generate preliminary expectations for outcomes from entanglements, as they occur, to support in-season management actions or spur implementation of new management measures in advance of a formal determination of SI/M by NMFS through its formal evaluation process. These results also offer a baseline of historic impact rates that can be used to monitor the effectiveness of any management measures or changes in fishing practices that are implemented. It may also be possible this information could be used to help design new management measures that may be expected to reduce the number or severity and outcomes for entanglements based on the type/extent of injuries that have been documented in the past.

Economic Impacts from Oregon Department of Fish and Wildlife Proposed Regulations for Whale Entanglement Avoidance

Shannon Davis, The Research Group and Gil Sylvia, Oregon State University

The Oregon Department of Fish and Wildlife (ODFW) proposed regulations in the Spring 2020 to lower risk of whale entanglements from interactions with vertical gear used in the Dungeness crab fishery. The regulations are intermediary until a final suite of measures are approved in an Endangered Species Act Section 10 incidental take permit (ITP) by the National Marine Fisheries Service. A humpback whale distinct population segment that transits the Oregon Coast is an ESA listed species. The Oregon Coastal Crab Association (an industry group) requested the Oregon Dungeness Crab Commission sponsor a study to determine economic impacts from the proposed regulations. We provide impact result information using an already developed interactive bio-economic model for the fishery. We offer discussions about the consequence of the prescriptive regulations given limited information about fleet capacity utilization. Finally, there is discussion about the procedural approach for gaining approval for an ITP. We advise that the approach will benefit from having a decision support tool in-place during ITP preparation and negotiations.

Developing socio-ecological indicators to evaluate management strategies to mitigate whale entanglement risk within the Dungeness Crab Fishery

Rachel Seary, NRC Postdoctoral Research Associate at NOAA SWFSC

Understanding ecosystem dynamics which lead to increased whale entanglement risk for the Dungeness Crab Fishery has benefited from the development of ecosystem indicators (measures of the status or trends in ecosystem attributes) for the California Current Ecosystem (CCIEA Team, 2020; Santora *et al*., 2020). Management tools used to reduce entanglement risk, for example temporary area restrictions including closures due to harmful algal blooms and marine life concentrations, may have severe socio-economic consequences for stakeholders that must be evaluated at the individual fisher and fishing community level. Our research aims to develop socio-ecological indicators and objectives that could further strengthen the assessment of risk and trade-off of management options if combined with geographic-based ecosystem indicators (i.e., habitat compression and fishing depth limitations). Therefore, we would like to present our preliminary analysis and elicit feedback from the community to aid our progress towards developing socio-ecological indicators for the Dungeness Crab Fishery, specifically related to the state of the whale entanglements issue.

Previous disturbances to the Dungeness Crab Fishery, for example due to the 2015 harmful algal bloom event, demonstrated the large economic and social impacts that temporary closures can have for fishermen and throughout the wider community (Ritzman et al., 2018; Moore *et al*., 2019; K. M. Moore *et al*., 2020; S. K. Moore *et al*., 2020). Thus, this research will begin by investigating whether lost fishing days in the Dungeness Crab Fishery due to closures prompted by whale entanglement risk have an economic impact on the individuals participating in the fishery. This will first focus on direct revenue losses during the 2019 and 2020 crab fishing seasons. Achieving ecosystem-based fisheries management, which successfully reduces whale entanglements, while promoting a healthy Dungeness Crab Fishery, along with other West Coast fisheries, will benefit from combining fishery resource databases with socio-economic indicators that derive knowledge from the fishing community.

Social and economic considerations for addressing West Coast whale entanglements

Carrie Pomeroy, PhD, UC Santa Cruz

Fisheries are complex, integrated social-ecological system. Whale entanglements are one example of the way that social—or human—systems and ecological systems interact. Management measures and other efforts to minimize the risk of such entanglements have feedbacks throughout the social-ecological system, at multiple scales and with varying scope. While the economic costs of management measures to, and required adaptations by, fishermen are of central concern, the social and economic dimensions of managing whale entanglements entail other key considerations as well. These extend beyond fishing per se to shoreside support businesses and communities, other fisheries, and the seafood supply system. Drawing on the Socioeconomic Guidance for Implementing the California MLMA Master Plan, insights gained from service on the California Dungeness Crab Task Force, and ongoing research on the human dimensions of fisheries, this brief talk highlights some of those considerations. The questions and information needs that arise from these can be addressed by integrating available qualitative and quantitative data with the knowledge of fishery participants, other fishing community members and managers. Where information gaps are identified, additional data can be collected and "added to the mix" using appropriate qualitative and quantitative methods. Taken together, the resulting information is useful for more fully evaluating the feasibility, efficacy and implications of management for the fishery and for reducing the risk of unintended consequences for social as well as the ecological system.

MODULE 5 ABSTRACTS
(Thursday, September 3rd | 9:00 am – 1:00 pm)

Assessing humpback whale entanglement risk off California and Oregon

Jessica V. Redfern, Samuel M. Woodman, Jameal Samhouri, Blake Feist, Lauren Saez, Dan Lawson, Karin A. Forney

The increase in humpback whale entanglements off the U.S. West Coast beginning in 2014 is a management concern because these foraging whales belong to breeding populations off Mexico and Central America that are listed as threatened and endangered, respectively, under the U.S. Endangered Species Act. Understanding potential causes and the effectiveness of management measures is crucial for reducing entanglement risk in the future. In our study, we use data on fishing effort derived from PacFIN-informed Vessel Monitoring System (VMS) data and dynamic whale distribution models (see presentation by Forney *et al*.) to estimate the risk of entanglement for humpbacks along the U.S. West Coast from 2009 – 2019. We use historical entanglement observations to validate our risk measure. Our analyses show that the periods of greatest estimated risk during 2014 – 2016 correspond well to the periods of increased observed entanglements. Based on this concordance, we further assess entanglement risk during those years under various hypothetical management scenarios. Specifically, we assessed whether delayed opening and early closures could have reduced the risk of entanglements. While both options reduced risk, our analyses highlight the importance of understanding and managing how fishing effort is redistributed when delayed openings occur. Our analyses also suggest that optimal management solutions are likely to be region specific.

Chasing the moving target of sustainability: understanding tradeoffs between fisheries and conservation goals in a changing ocean

Jameal Samhouri, Briana Abrahms, Blake Feist, Mary Fisher, Karin Forney, Elliott Hazen, Dan Lawson, Owen Liu, Jessica Redfern, Lauren Saez, Sam Woodman

Environmental variability and climate change are twin challenges for achieving conservation goals and sustainable management of natural resources. The role of heatwaves in the ocean has come to light recently as a major type of environmental disturbance, yet their ramifications for social and ecological processes are not well understood. In this study we examine how a marine heatwave (MHW) in the Northeast Pacific affected tradeoffs between conservation goals for two of the region's most iconic species—blue and humpback whales—and sustainability goals for one of the US West Coast's most valuable fisheries—the Dungeness crab fishery. We conducted a retrospective analysis of relative risk of entanglement in fishing gear for blue and humpback whales and relative revenue to the California Dungeness crab fishery from 2009–19 under both status quo management and a broad set of hypothetical, alternative management scenarios. Combining several state-of-the-art models and data sets on whale distributions and fishing vessel movements (fish ticket-informed Vessel Monitoring System data), we found that on average, the MHW period during 2014–18 saw a 20% increase in revenue to the fishery but a doubling or tripling of risk to blue and humpback whales, respectively, compared to 2009–14 and 2018–19.

We use spatial analysis to ask whether delayed openings, early closures, depth restrictions, and fishing effort reduction could have mitigated risk of entanglement while protecting fishing revenues over this same ten-year time period. Examination of these alternative management scenarios shows that the tradeoffs between whale risk and fishery revenue grew more stark during the MHW, with anticipated conservation benefits of management interventions increasing but the expected costs to the fishery escalating even

more. On average, the expected reduction in risk to whales increased by as much as 20% during the MHW period, but the expected decline in revenue to the crab fishery more than tripled in some cases. The tradeoff analysis framework we present here provides a transparent approach for evaluating the effectiveness of management interventions designed to improve the lofty aims of fisheries sustainability while meeting mandates for the conservation of individual species. It also emphasizes that one-size-does-not-fit-all time periods, regions, species, or elements of a fishery, underscoring the importance of multi-criteria decision approaches to navigating these uncharted waters. More generally this case study highlights how conservation concerns and tradeoffs with extractive uses can be exacerbated by extreme climate events and suggests that management solutions that balance across multiple objectives must be robust to environmental variability.

An MSE-based approach for identifying strategies that maximize catch while minimizing whale entanglements and toxin contamination in the California Dungeness crab fishery

Christopher M. Free[1], Lyall F. Bellquist[2,3], Karin A. Forney[4,5], Jenn Humberstone[2], Kate Kauer[2], Owen R. Liu[6], Jameal F. Samhouri[6], Jono R. Wilson[1,2], Lee Qi[1,7], Darcy Bradley[1]
[1] University of California, Santa Barbara,
[2] The Nature Conservancy
[3] Scripps Institution of Oceanography
[4] NOAA Southwest Fisheries Science Center
[5] Moss Landing Marine Laboratories
[6] NOAA Northwest Fisheries Science Center
[7] University of Washington

The California Dungeness crab fishery has suffered several recent shutdowns due to (1) the contamination of crabs with toxins produced by harmful algal blooms (HABs) and (2) the entanglement of whales in crab fishing gear. We developed a management strategy evaluation (MSE) model to simulate these dual threats and measure the ability for current and alternative management strategies to maximize catch while minimizing whale entanglements and the public health risk posed by toxin contamination. Our retrospective model simulates management over the whale and toxin dynamics of the 2014/15 to 2018/19 fishing seasons (5 seasons) using predictions of historical humpback whale distributions (Forney et al. in prep) and historical toxin contamination (Free *et al*. in review). We evaluate both static and dynamic management strategies for minimizing whale entanglements. The static strategies include (1) immediate state-wide gear reductions and (2) fixed closures based on historical migration patterns. The dynamic strategies employ various management actions (i.e., zonal closures or gear reductions) in response to different management triggers (i.e., an observed entanglement or the results of a whale abundance survey). We evaluate the robustness of these strategies under multiple procedures for managing the public health risk of domoic acid contamination (i.e., management actions based on current vs. expanded domoic acid sampling programs). Our preliminary results indicate that immediate gear reductions maximize catch while reducing entanglements to levels similar to or lower than zonal closures across all domoic acid management scenarios. Zonal closures result in more entanglements than expected because they displace fishing effort elsewhere and concentrate overlap between whales and fishing gear. Mid-season gear reductions (i.e., in response to a trigger) are ineffective, because they are generally triggered after effort in this derby fishery has already been greatly reduced.

Development of a software tool for testing management scenarios and quantifying entanglement risk to North Atlantic Right Whales in the American lobster fishery

Burton Shank, NOAA / NMFS / Northeast Fisheries Science Center, Woods Hole, MA

Over the past year, staff at the Northeast Fisheries Science Center and Greater Atlantic Regional Fisheries Office have been developing and using a Decision Support Tool (DST) to approximate the entanglement risk to North Atlantic Right Whales from the American lobster fishery. The DST models entanglement risk as the product of vertical line density, vertical line threat, and whale density at 1Nm and monthly resolution. For a given model run, the users can specify management scenarios that remove or redistribute traps, change trawl configurations, and change numbers and strengths of endlines as well as constrain the spatial domain and fleet examined in the model run with output including estimated decrease in entanglement threat from the management scenario. Trap densities and gear configurations are largely derived from fishery dependent data sources while the spatiotemporal distribution of whales come from aggregated aerial survey data or species distribution models based on survey data.

The third component of risk, "gear threat", quantifies how entanglement threat varies across different gear configurations, which was desirable to include given the variety of gear configurations present throughout the fishery and the hope of addressing entanglement risk by modifying gear. However, quantifying gear threat is very difficult as entanglements are necessarily complex events, are rarely witnessed, and most observed entanglement injuries and mortalities retain little or none of the original gear, making it difficult to know the what the whale actually encountered. Currently, we are quantifying gear threat on a relative scale based solely on rope breaking strength as there is some literature suggesting that stronger ropes tend to result in more severe entanglements. We built the gear threat model from discrepancy between the observed and expected distribution of rope strengths from documented entanglements but can hopefully be improved upon in the future as more data become available.

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