Proceedings of the 2nd National Protected Species Assessment Workshop

Hosted by the National Marine Fisheries Service Southwest Fisheries Science Center and sponsored by the Office of Science and Technology

Edited by Mridula Srinivasan, Stephen K. Brown, Emily Markowitz, Melissa Soldevilla, Eric Patterson, Karin Forney, Kimberly Murray, Eric Ward, Jay M. Ver Hoef, Jessica Redfern, and Tomo Eguchi

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NOAA Technical Memorandum NMFS-F/SPO-198
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Wilbur L. Ross, Jr., Secretary

National Oceanic and Atmospheric Administration
Neil A. Jacobs, Ph.D., Acting NOAA Administrator

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<u>Executive Summary</u>

NOAA Fisheries' Office of Science and Technology organized the second Protected Species Assessment Workshop (PSAW II) in February 2019 at the Southwest Fisheries Science Center in La Jolla, California. Over the course of the three-day workshop, 153 individuals attended in person or remotely via webinar. Workshop participants included students, federal agency scientists, contractors, and managers, as well as researchers from academia.

Similar to the first PSAW (https://spo.nmfs.noaa.gov/sites/default/files/TMSPO172.pdf, keynote speakers headlined each thematic session followed by presentations from NOAA and non-NOAA scientists. Dedicated discussion sessions scheduled at the end of each day facilitated additional conversations on topical questions and emerging themes.

A steering committee composed of NOAA Fisheries Science Center and headquarters (HQ) offices aided overall workshop planning including identification and agreement on thematic areas, keynote speakers, and workshop format. To elicit targeted dialogue on topics of mutual interest and expertise, the steering committee identified three major themes for PSAW II: I) *Survey Design,* II) *Estimating Abundance from Disparate Sources, and* III) *Spatial Prediction of Distribution Shifts*.

PSAW-style workshops are largely directed towards a technical audience, but also provide a macroscopic overview of the latest methods and challenges that data scientists contend with to meet legislative mandates and produce accurate and precise stock or population assessments. However, narrowly focused workshop themes can limit the broader appeal of the subject matter. Thus, there were only 25 talks during PSAW II compared to 49 talks and 18 poster presentations in PSAW I. Also, less than 10% of participants were NOAA managers. Also, since PSAW primarily caters to NOAA scientists and managers, a majority of the attendees were from NOAA.

To some extent, the lengthy partial federal government shutdown preceding the workshop triggered speaker cancellations and affected overall participation. Future workshops could be structured to include subjects of general interest, as well as highly technical topics, which could lead to a broader audience. PSAW theme selections are influenced by the steering committee, participant feedback, and the current scientific or management problems of the day. So, variable attendance and participation should be expected in future PSAWs and is not necessarily a reason to generalize thematic areas.

Presentations covered a range of protected species, such as beaked whales, bearded seals, blue whales, sperm whales, Steller sea lions, harbor seals, rockfish, loggerhead sea turtles, white abalone, Nassau grouper, and smalltooth sawfish. However, the methods proposed and discussed to overcome data quality issues or integrating multiple sources of observational data emphasize the need for creative survey designs and sampling schemes depending on the population metrics being estimated and hypotheses being tested irrespective of taxa. The different studies presented also underscore the need to understand how species are affected by, and respond to, human activities in changing ecosystems where effects may be exacerbated by climate change and the aggregation of stressors that affect species conservation and recovery. Further, as science progresses, management policies and regulatory frameworks need to keep pace with the science and rapidly changing ecosystems.

For the first time, PSAW II marked the organization of multiple short format protected species science training sessions in conjunction with the main workshop. An online survey conducted during workshop registration allowed the steering committee to choose the five most popular topics for training. Ultimately, dictated by NOAA Fisheries instructor availability, four ½ day training sessions were held on February 11. Approximately 80 individuals attended the training sessions with at least 20 participants in each session.

In another first, the keynote speakers headlining each of the three thematic sessions were not from NOAA, allowing the influx of fresh perspectives on the latest technical solutions to address complex natural resource data types and variable data quality.

PSAW II culminated with a summary and wrap-up session to consider future topics and workshop structure. Participants greatly enjoyed the training sessions and recommended similar but multi-day sessions to allow maximum immersion in the topic and practice new methods or analyses. Participants also suggested adopting a hybrid structure in future PSAWs, which would feature a mix of specific technical topics and broader themes to attract a diverse audience. Also, the addition of lengthier training sessions is likely to increase participation from different disciplines.

<u>Introduction</u>

In February 2019, NOAA Fisheries' Office of Science and Technology (ST) sponsored and organized the second Protected Species Assessment Workshop (PSAW II) with the support of a formal steering committee. The steering committee was composed of representatives from the Science Centers and Headquarters Offices (Appendix 1). PSAW is an ST flagship event held biennially at different Science Centers or regions across the country to share the latest scientific advancements in protected species assessments, encourage local participation, and promote scientific exchange across NOAA Fisheries' vast research enterprise.

The Southwest Fisheries Science Center (SWFSC) generously hosted PSAW II, providing extensive logistical and staff assistance throughout the three-day event. Further, with assistance from the Scripps Institute of Oceanography (SIO)-affiliated SWFSC faculty, separate training sessions were held on the SIO campus on February 11 ahead of PSAW II to accommodate a large number of participants.

PSAW II marked the first time that dedicated training events taught by NOAA Fisheries scientists and organized for protected species scientists and students were offered. Based on a poll conducted during online workshop registration from June-October 2018, NOAA Fisheries' scientists identified five topics. These included: 1*) Introduction to programming in R*, 2) *Time Series Analysis*, 3) *Mapping and (some) advanced spatial tools in R*, 4) *Developing Forecasting Models for Fisheries Time Series with R*, and 5) *Movement Modeling* (See Appendix 2 for topic descriptions and instructor information). Concurrent training sessions were organized on February 11 at various locations on the SIO campus. Due to logistical issues, training topic # 1 was canceled. All training sessions were equally popular, with at least 20 participants in each of the four training sections. Each session was half a day long, which limited the amount of time for practical sessions.

PSAW II officially started on February 12. An estimated 153 attendees participated in-person or remotely via webinar. Participants were from NOAA Fisheries, outside federal institutions (e.g., Bureau of Ocean Energy Management, US Navy), and students, researchers, and faculty from SIO, which is co-located with the SWFSC. It is possible that local SWFSC staff, interns or SIO students at SWFSC attended various portions of the workshop but did not register or sign in and were unaccounted for in the final tally.

As with the previous PSAW, the steering committee served as the PSAW II planning team with overall coordination provided by ST staff. The steering committee was convened in early February 2018 and was instrumental in identifying workshop themes, providing feedback on keynote speaker selections, and workshop structure. Usually the steering committee is also responsible for reviewing abstract submissions and identifying selections for oral, poster, or speed presentations. This year, the limited abstract submissions precluded any formal review process and selection of presentation formats (see Agenda in Appendix 3).

The workshop was divided into three thematic sessions:

1) (Day 1, Feb 12) **Survey Sampling Design** — dealt with exploring the importance of randomization in survey design and optimizing surveys to collect data from species or habitats of interest. (Total presentations: 7 including the keynote)
2) (Day 2, Feb 13) **Estimating Abundance from Disparate Data Sources** — focused on sharing important concepts and methods for estimating abundance from a variety of data sources differing in quality (e.g., missing data or opportunistic data) and observation platform (e.g., ships, unmanned systems, manned aircraft, shore, acoustics, tagging). (Total presentations: 14 including the keynote)
3) (Day 3, Feb 14) **Spatial Prediction of Distribution Shifts** —focused on assessing changes in species densities and range shifts using the multitude of data available from telemetry, moored passive acoustic monitoring units, shipboard or aerial surveys, or fisheries dependent or independent data. (Total presentations: 7 including the keynote)

The next few sections provide highlights from each session, abstracts, and discussion notes.

Day 1: February 12, 2019

PSAW II – Another Step Forward for Protected Species Science

(Invited Speaker) Richard Merrick

Chair, Scientific Advisory Committee and NOAA Fisheries Scientist Emeritus

Former Chief Science Advisor and Director of Scientific Programs

Dr. Richard Merrick (NOAA Fisheries Scientist Emeritus) provided the opening remarks at PSAW II, setting the tone and vision for advances in protected species science. On the state of protected species science, Dr. Merrick commented on the need for science communicators to represent our science better, as many science stories are not told, or are not disseminated widely or well. He also stated that management offices are not fully prepared to use the information coming out of assessments, including climate impacts. Scientists need to be more proactive in working with managers to integrate scientific information into decision-making.

Abstract

NOAA's 2019 Protected Species Assessment Workshop (PSAW) II continued the tradition of progressive protected species science that can be traced through the three "Guidelines for Assessing Marine Mammal Stocks" workshops forward to PSAW I. In this respect, I suggested the attendees remember three key challenges to improved assessments. First, NOAA scientists assess populations from multiple taxonomic groups (some protected and some harvested) from the same ecosystems. With this in mind, we must adopt an ecosystem-based approach to surveys and assessments. Secondly, the quality of our assessments is challenged by the effect climate change has on distribution and abundance; only through understanding of the importance of ecosystem covariates, can we predict distribution and abundance. As NOAA's climate vulnerability assessments have shown, many of our species (e.g., from cod to right whales) will be impacted both directly and indirectly by a warming, more acidic ocean. Finally, we need to develop new and better ways of educating and informing our management partners in the ways changing marine systems will impact the distribution and abundance of our trust species. This information will allow managers to support a regulatory culture that is more resilient and adaptable to a changing ocean climate.

Theme I: Survey Sampling Design

Session Chair: Jay Ver Hoef

Summary

Dr. Dale Zimmerman followed with a keynote address on model-based sampling designs within the statistical data collection framework. He discussed the commonly used probability-based model designs, as well as highlighted the pros and cons of space-filling and optimal designs (more suited for computer simulated data). Six presentations followed the keynote, covering a range of topics within the overarching theme of Survey Sampling Design. Topics covered include: 1) exploring preferential sampling in species distribution models, where spatial process of interest and the locations chosen for sampling are conditionally dependent on modeled covariates and can accommodate citizen-based scientific data; 2) using modified unequal random stratified design to estimate a relative abundance index for a rare and endangered species (smalltooth sawfish); 3) improving prediction of dynamic blue whale distributions off the U.S. west coast using multi-model ensembles and high resolution environmental data; 4) allocating survey effort to improve power to detect trends for species with low capture probabilities based on 10-year photo-ID data from Cuvier's beaked whales in the Navy's Southern California Anti-submarine Warfare Range (SOAR) off San Clemente Island, California; 5) estimating abundance of widely dispersed populations of harbor seals in Alaska by optimizing survey designs through prioritizing sampling sites based on effort type and high/medium proportion of harbor seals; and 6) implementing a randomized hierarchical design to estimate bycatch in commercial fisheries in Alaska despite sampling challenges.

Abstracts

Model-Based Sampling Design: An Exhibition

(Keynote Speaker) Dale Zimmerman

Professor, Department of Statistics and Actuarial Science, University of Iowa

Inferences for spatial data are affected substantially by the spatial configuration of the network of sites where measurements are taken. After a brief overview of probability-based and space-filling designs, the "model-based" approach to spatial sampling design is featured. In this approach, a spatial random field model is proposed for the data and a design is sought that optimizes a criterion measuring how suitable the design is for making inferences about selected parameters of the model, or alternatively, for predicting unobserved values of the phenomenon of interest under the model. Designs that are optimal or near-optimal are exhibited for criteria that emphasize, in turn, a good estimation of the model's mean parameters, good estimation of the model's variance-covariance parameters, and good prediction of unobserved values. It is shown that, in general, these designs outperform probability-based and space-filling designs.

Session I Talks

1. Preferential Sampling in Species Distribution Models

Paul Conn[1], James Thorson[1,2], Devin Johnson[1], and Marc Kery[3]

[1]NOAA Fisheries' Alaska Fisheries Science Center, Marine Mammal Lab, [2]NOAA Fisheries' Northwest Fisheries Science Center, [3]Swiss Ornithological Institute

Species distribution models often make the implicit assumption that locations chosen for sampling and animal abundance at those locations are conditionally independent given modeled covariates. However, this assumption may be violated when survey effort is non-randomized, leading to preferential sampling. We develop a hierarchical statistical modeling framework for detecting and alleviating the biasing effects of preferential sampling in spatial distribution models fitted to count data. The approach works by specifying a joint model for population density and the locations selected for sampling and specifying a dependent correlation structure between the two processes. Using simulation, we show that moderate levels of preferential sampling can lead to large (e.g. 40%) bias in estimates of animal density and that our modeling approach can considerably reduce this bias. In contrast, preferential

sampling did not appear to bias inferences about parameters informing species-habitat relationships (i.e. slope parameters). We demonstrate our approach using aerial survey counts of bearded seals (*Erignathus barbatus*) in the eastern Bering Sea and to occupancy data from peregrine falcons in the French Jura mountains.

2. **Developing a Relative Abundance Index for Rare Species using A Priori Information with Random and Subjective Sampling: A Case Study of Smalltooth Sawfish, *Pristis pectinata***

John Carlson and Andrea Kroetz

NOAA Fisheries' Southeast Fisheries Science Center

Efficient sampling design in field studies is important for economic and statistical reasons. Assessing the distribution and abundance of rare species over a broad area is a difficult task because of the low probability of finding specimens in random samples, whereas nonrandom sampling may lead to statistical problems. Smalltooth sawfish, *Pristis pectinata*, is currently listed as endangered under the Endangered Species Act. An important component of monitoring the recovery of this species is establishing long-term baseline trends in abundance. Prior to their listing, very little information was available on abundance or habitat use. Data from public encounters, primarily recreational fisherman, was used to design an abundance survey for smalltooth sawfish. Fixed areas (areas sampled multiple times over many years) were established based on high encounters of sawfish reported to the National Sawfish Encounter Database and previous captures. The survey was later expanded to include random samples taken within subregions while in the field based on habitat type (red mangroves) and depth (shallow water). The fixed area sampling (~70 samples per year) was compared with the random sampling effort (~100 samples per year). Fixed sampling was significantly more efficient. Smalltooth sawfish were captured in 18% of the fixed samples and in 4.6% of the random samples. These indices of abundance were then analyzed using a Bayesian hierarchical framework to estimate a single time series of relative abundance. Estimates of process error show the indices performed reasonably well for smalltooth sawfish abundance and indices' process standard deviation estimates were similar.

3. **Dynamic Ensemble Models to Predict Blue Whale Distributions and Ship Strike Risk in Near Real-Time**

Briana Abrahms[1], Steven J Bograd[1], Elizabeth Becker[2], et al.

[1]NOAA Fisheries' Southwest Fisheries Science Center, [2]Institute of Marine Science, University of California Santa Cruz

Blue whales (*Balaenoptera musculus*) are listed as endangered under the U.S. Endangered Species Act due to population depletion from commercial whaling. In the eastern North Pacific, ship strikes remain the largest threat to the recovery of this protected species. Static management approaches along the U.S. West Coast are being implemented to direct traffic into designated shipping lanes, yet whale distributions are dynamic and may shift in response to changing environmental conditions, necessitating the integration of dynamic management approaches. We developed a dynamic, near real-time blue whale distribution model with the aim to mitigate ship strike risk. We examined potential changes in predictive skill by developing distribution models a) using daily surface and subsurface variables from a data-assimilative regional ocean model (ROMS) compared to monthly remotely-sensed environmental data, and b) using an ensemble modeling approach with multiple datasets (satellite tags and ship surveys) and methods (Generalized Additive Mixed Models and Boosted Regression Trees) compared to a single-model approach. We evaluated candidate models using multiple metrics and training/testing datasets, including a large compilation of independent sightings data. Use of high spatiotemporal resolution environmental data, including subsurface variables improved predictive performance of dynamic blue whale distributions (AUC 0.95 vs. 0.86). Further, multi-model ensembles showed increased performance over single models and predicted blue whale distributions with high accuracy. Dynamic, high-resolution species distribution models with strong predictive performance are a valuable tool for targeting management needs in near real-time. This general approach is readily transferable to other species and spatial management needs.

4. **Power to Detect Trends in a Low-Capture-Probability Population**

K. Alexandra Curtis[1], Jeffrey Moore[2], Erin A. Falcone[3], Greg Schorr[3] , Jay Barlow[2], David J. Moretti[4], and Erin Keene[3]

[1]Ocean Associates, Inc. under contract to NOAA Fisheries Southwest Fisheries Science Center, Marine Mammal and Turtle Division, [2]NOAA Fisheries Southwest Fisheries Science Center, Marine Mammal and Turtle Division, [3]Marine Ecology and Telemetry Research, [4]Naval Undersea Warfare Center Division

Information on demographic rates (e.g., survival and recruitment), can often provide important insights for the management of human impacts on protected resources. Mark-recapture approaches (e.g., photo identification or flipper tagging) provide the most common basis for estimating vital rates in cetaceans and sea turtles and may also provide important information on abundance and trend for species that are poorly sampled by visual transects, such as beaked whales. However, low capture probability and variable capture probability among occasions can reduce precision and increase bias in estimates. Motivated by a 10-year photo-identification study of Cuvier's beaked whales (*Ziphius cavirostris*) in the Navy's Southern California Anti-submarine Warfare Range (SOAR) off San Clemente Island, California, we conducted a power analysis to assess the probability of detecting a decreasing trend in the number of individual animals using SOAR. We simulated a range of scenarios for population growth rate, temporal capture heterogeneity (including seasonal and annual effects), and sampling effort. Our results show that we currently have very low power to detect a 3% or 7% per annum decline in the number of individuals using SOAR. Increasing within-year effort improves power. Extending the time series improves power faster per unit effort, but also corresponds to a greater total decline in abundance, pointing to a tradeoff between efficiency and urgency. Advancing analytical methods that incorporate multiple marks may be the most cost- and time-effective means of improving precision and thus power for low-capture-probability populations.

5. **Optimizing Aerial Survey Design for Harbor Seals in Alaska.**

Josh London, Peter L. Boveng, and Jay M. Ver Hoef

NOAA Fisheries' Alaska Fisheries Science Center

Harbor seals (*Phoca vitulina*) in Alaska encompass one of the largest geographic ranges of any pinniped species. Harbor seals are, for the most part, non-migratory and relatively local in their habitat use. Thus, they are uniquely positioned to provide insight into coastal marine ecosystem health. Harbor seals are also one of the marine mammal species in Alaska most likely to overlap with human activities and development. Sustained monitoring of harbor seal populations in Alaska has been a priority for the NOAA Alaska Fisheries Science Center dating back to the mid-1990s. Traditional aerial survey efforts focused on intensive surveys in one of five regions that rotated each year. This approach provided detailed information on local area harbor seal counts but estimates of trend were only possible on decadal intervals. In recent years, reduced funding has necessitated adjustments to the survey design and allocation of aerial survey effort that emphasize efficiency while maintaining the long-term monitoring dataset. With this in mind, and a desire to improve the timely understanding of trends, a new survey design was developed. Since 2008, survey effort has been spread throughout the state of Alaska in any given year. Sites with historically high numbers of seals are prioritized and regions of conservation or management concern can be emphasized to match available funding. Prior to 2008, the survey effort would often require 4-6 aircraft and 8-10 biologists in the field. More recent survey efforts have relied on one or two aircraft. The extensive long-term dataset prior to 2008 has provided key information that allows us to make informed decisions regarding survey effort. Combining critical telemetry deployments with the development of new statistical techniques has resulted in estimates of abundance and trends for nearly all the 12 recognized stocks.

6. **Implementation of Statistically Rigorous Sampling Designs under Adverse Conditions: Monitoring the Federal Groundfish Fisheries off Alaska**

Jennifer Cahalan

Pacific States Marine Fisheries Commission

Alaska has an extensive groundfish fisheries observer program that collects data to meet a wide range of management and research needs. The North Pacific Groundfish Observer Program (Observer Program) deploys over 400 observers annually under authority granted to NOAA Fisheries by the Magnuson-Stevens Fishery Conservation and Management Act, the Endangered Species Act, and the Marine Mammal Protection Act. The Program must meet multiple sampling objectives for a variety of data users, with an overarching goal of collecting representative data over the range of fishing operations occurring in the Alaska EEZ. Commercial fishing vessels are imperfect sampling platforms. Despite the sampling challenges encountered on vessels that are actively engaged in commercial fishing, the Observer Program can implement a complex, statistically rigorous sample design. We achieve this, in part, by including observer workflow as an integral component of the sample design. Data collections are randomized at each level of sampling and sample fractions differ both between and within layers of the sampling hierarchy. As a result, bycatch estimation follows the same hierarchy, incorporating those design elements into the estimation process. Recently with the advent of new technology, we have incorporated electronic monitoring (EM) into our sampling design, combining EM-collected and observer-collected data to generate bycatch estimates. This presentation describes how the North Pacific Observer Program is able to implement this randomized hierarchical sampling design under the adverse conditions presented by commercial fishing operations and the implications of this design on the estimation of bycatch.

Discussion

Participants and presenters raised a wide variety of questions on the complexity of establishing optimal survey designs. Some key points from the discussion session are highlighted below.

- Participants discussed the merits of optimizing sampling design vs. choosing a simple random sampling design to overcome logistical challenges. There are obvious tradeoffs between estimating abundance vs. trends and the challenges of zero-inflated data (missing or no data). Sampling rare species can yield a lot of ‘zero’ observations, which is valid for abundance but not for estimating trends. For estimating trends, it could be important to sample frequently the first year and the 10th year if the variance is not a major consideration, and preferably all areas where animals are likely to occur. The coefficient of variation (CV) remains a common metric for deciding sampling design for specific species or projects. Further, clustering samples in space and time is helpful for tackling variability. Bayesian sampling designs are particularly useful for capturing uncertainty better and for parameter estimation.

- When it comes to addressing climate impacts and shifting species distributions, sampling both low- and high-density areas are pivotal. For example, low priority sites for harbor seals in Alaska should be sampled over time and not ignored in a long-term sampling plan. Right whale surveys are also a good example of this challenge: the survey design has been changed over time to accommodate observed animal distribution shifts. But adopting adaptive sampling can be challenging when dealing with multiple species. It can also be challenging because of budget or protocol constraints. Further, time series data are critical for documenting both changes in abundance and species distributions as evident with the adaptive right whale survey design employed by the Northeast Fisheries Science Center.
- Power analyses can be useful for conducting protected resources surveys. For example, it was useful for developing harbor porpoise surveys in the northeast to ensure they were conducted often enough to detect trends. Also, power analysis was useful for tagging work when only a certain number of tags were available to develop inferences about species movements. Setting up passive acoustic monitoring for vaquita is another scenario where power analyses were used to optimize survey design by determining how many instruments were needed to detect vaquita presence.
- Regarding the utility of integrating acoustics data with visual mark-recapture data, it is important to first establish the value of acoustic detections and which parameters would be targeted and estimated. Long term trends in abundance can be assessed by combining three data sets: broad-scale passive acoustic monitoring (PAM), fine-scale acoustics data, and visual mark-recapture. PAM can be useful for estimating density with low variation, but is less useful for determining how many animals were impacted by noise or other disturbance, as it often does not provide individual-level data.
- For rare species, such as smalltooth sawfish, study area conditions, low rate of occurrence, and incomplete map data affect the ability to adopt strict randomized survey designs. In the future, eDNA methodologies could be a useful input in population assessments and refining survey design.

Day 2: February 13, 2019

Theme II: Estimating Abundance from Disparate Data Sources

Session Chair: Kimberly Murray

Summary

Dr. Andrew Royle provided the keynote presentation and helped line up the succeeding 13 talks in Session II on *Estimating Abundance from Disparate Data Sources*. He spoke about the value of using spatial-capture-recapture (SCR) modeling for integrating multiple large-scale seasonal/annual movement datasets from the same population. New analytical tools are needed because many of our traditional assessment approaches and recovery targets may be insufficient in a changing climate. There are two typical modes of integration – individual and species-distribution models.

Session speakers covered the following topics essential to the assessment toolbox: 1) using a hierarchical framework to combine multiple models (nested or integrated) for assessing species distributions, trends, and extinction risk forecasting; 2) integrating visual survey data (spatial) with passive acoustic data (temporal) from moored recorders in the Gulf of Mexico to develop habitat models for multiple odontocetes; 3) obtaining more precise estimates of abundance and directly estimating surface availability bias by integrating passive acoustic and visual data and accounting for both horizontal and vertical animal movement with a focus on deep diving beaked whales; 4) developing methods to improve abundance estimate precision for Cuvier's beaked whales combining passive acoustic drifter data with additional datasets and addressing biases related to observation platforms and animal dive behavior; 5) continuing challenges of addressing bias when combining acoustic and visual survey data to estimate beaked whale abundance; 6) developing a standardized workflow for all Science Centers to process and analyze passive acoustic data and integrate with concurrent visual survey data using the R programming platform; 7) using a Bayesian posterior approach in conjunction with an age-structured population model that incorporates mark-recapture pup survivorship data and pup counts to estimate western Distinct Population Segment (DPS) Steller sea lion abundance; 8) studying the effects of ocean conditions on western Steller sea lion survival using a Bayesian integrated female-only population model that improves precision and reduces bias in abundance estimates; 9) using close-kin mark-recapture (e.g., parent offspring pairs and siblings) to estimate abundance without having to genetically recapture the same individual; 10) employing Multivariate Auto Regressive State-Space (MARSS) models to produce qualitative threat analysis for two river herring species; 11) assessing ESA-listed rockfish long-term population growth rate using MARSS models that overcome various time series data challenges such as multiple surveys, regulatory changes, and missing data; 12) analyzing population status of Nassau grouper in the Cayman Islands using a combination of tagging studies and video-capture; and 13) identifying sentinel sites based on spatio-temporal synchrony for hake, northern anchovy, and sardines in different oceanographic regimes by integrating empirical dynamic modeling and Taken's theorem to inform future California Cooperative Oceanic Fisheries Investigations (CalCOFI) surveys.

Abstracts

Movement Assisted Localization from Acoustic Monitoring Studies

(Keynote Speaker) J. Andrew Royle[1], Nathan J. Hostetter[2]

[1]USGS Patuxent Wildlife Research Center, [2]University of Washington, School of Aquatic and Fishery Sciences

Acoustic monitoring is widely used to study resource selection and movement of fish, turtles, and marine mammals. A key objective of acoustic monitoring studies, including both active acoustics (telemetry) and passive acoustic monitoring, is the estimation of acoustic source locations – a process referred to as localization. Localization is essentially statistical triangulation, which can be done when signals are obtained from an array of sensors so that potentially multiple detections of the same signal are possible. Localization may be based on simple detection history information (the pattern of sensors at which detections occur) and auxiliary information on the time delay of arrival at different sensors, or signal strength. Existing approaches to localization from operational acoustic arrays lack generality and make inefficient use of the data obtained from acoustic monitoring -- for example, by requiring multiple simultaneous detections in order to localize a source. One important source of information lacking from current localization methods is that derived from the underlying movement process. Intuitively, the location of an individual at time *t-1* and even at time *t+1* should be informative about the location of the individual at time *t*, regardless of whether it was observed. We develop a method of localization from acoustic telemetry which integrates standard methods of localization with an explicit model of movement. This leads to improved precision of localizations and therefore improved inferences about movement, resource selection, and other spatial processes. We discuss the extension of movement assisted localization to passive acoustic systems. This is a challenging problem because passive acoustic detections do not provide direct information about individual identity, and therefore extending the model to accommodate uncertain identity is necessary. Finally, we address an emerging problem of some importance in marine monitoring: integration of incidental sighting data with

structured capture-recapture data. Movement-assisted localization provides an integrated modeling framework for incidental sighting data, because it provides a characterization of the population of movement trajectories with which incidental observations must be linked.

Session II Talks

7. **Improved Understanding of Fisheries & Ecosystems from Noisy and Disparate Data**

Mark Scheuerell, Eric Ward, and Elizabeth Holmes

NOAA Fisheries' Northwest Fisheries Science Center

Our understanding of natural history phenomena has grown remarkably over time, due largely to advances in the ways we collect and analyze data. Remote sensing platforms now allow us to observe systems over larger spatial and temporal extents, with finer resolution, than ever before. Our ability to sequence entire genomes is transforming our views on diseases and evolutionary pathways. Citizen science programs can provide supplemental monitoring of a wide range of plants and animals. Coincident with these improvements in data collection, we have witnessed a rapid expansion of quantitative approaches for identifying processes from patterns. Improvements in statistical models and numerical algorithms, coupled with better software and hardware, allow us to extract more meaningful information from our data in less time. These include analyses of individuals (e.g., movement tracking) to communities (e.g., inter-species interactions) to landscapes (e.g., joint species distributions). Using examples from a large body of collaborative research, we highlight several developments and applications of new quantitative tools that have markedly enhanced not only our understanding of past conditions, but also our ability to forecast future outcomes.

8. **Cetacean Population Monitoring Integrating Visual and Acoustic Observations**

Kaitlin E. Frasier[1], Lance P. Garrison[2], Melissa S. Soldevilla[2], and John A. Hildebrand[1]

[1]Scripps Institution of Oceanography, [2]NOAA Fisheries' Southeast Fisheries Science Center

The oceanic Gulf of Mexico (GoMx) provides habitat for sperm whales, beaked whales, and a variety of delphinids. This region is also one of the most highly impacted marine habitats in the world in terms of anthropogenic activity. Habitat models are needed to understand marine mammal distributions and to mitigate impacts. Shipboard and aerial line-transect visual surveys are the standard methods for estimating abundance and describing the distributions of cetacean populations in the GoMx. Visual surveys conducted by the National Oceanic and Atmospheric Administration's (NOAA's) Southeast Fisheries Science Center (SEFSC) between 2003 and 2014 provide broad spatial coverage of the Gulf region as snapshots in time. Fixed-location passive acoustic monitoring (PAM) provides a complementary modality for cetacean monitoring by employing acoustic sensors nearly continuously over long periods to record animal presence in the proximity of monitored locations. Since 2010, Scripps Institution of Oceanography (SIO) and NOAA SEFSC have been recording cetacean presence using seafloor-mounted High-frequency Acoustic Recording Packages (HARPs) at five sites in the GoMx. These instruments record odontocete echolocation activity in local habitats across seasons and years. We discuss habitat models for GoMx odontocete species developed using these complementary data sources. This approach integrates visual survey data, which provide excellent spatial resolution, with acoustic monitoring data capable of providing excellent temporal resolution. This approach could support conservation and management of GoMx cetacean populations by developing more comprehensive understanding of temporal and spatial species distribution trends instead of using either data type individually.

9. **Integrating Passive Acoustic and Visual Data Collected During Standard Line Transect Surveys to Refine Population Estimates and Estimate Availability Bias**

Doug Sigourney, Danielle Cholewiak, Annamaria DeAngelis, and Debra Palka

NOAA Fisheries' Northeast Fisheries Science Center

Passive acoustic technology offers a valuable opportunity to collect information on the diving behavior of several cetacean species. Applying passive acoustic technologies towards estimating the density and abundance of marine mammal populations is still in early the stages, and these data have not often been integrated with visual sightings data. Combining these two sources of information has the potential to decrease bias and increase the precision of abundance estimates. We developed a method to integrate passive acoustic data with visual line transect data to estimate abundance and availability bias. We adopt a Bayesian state-space approach to analyze multiple time series of clicking events collected from an acoustic towed hydrophone array. Our method estimates the number of animals that have transitioned between a clicking state and a non-clicking state and can be used to correct for the number of animals that may have been available to both the visual team and the acoustic array. We combine this method with a conventional distance sampling analysis of the visual data to estimate total abundance. This method adjusts for availability bias at the surface to get an unbiased estimate of abundance. An estimate of surface availability can also be calculated. We tested this method with a series of simulations. We also provide a case study by applying the model to data on beaked whales collected in the northwest Atlantic in 2013.

10. **Estimating Abundance for Beaked Whales from Drifting Acoustic Recorders and Other Data Sources**

Jeff E. Moore and Jay Barlow

NOAA Fisheries' Southwest Fisheries Science Center

Deep diving cetaceans are less amenable than many other species to abundance estimation from visual line-transect survey methods because of the limited time they spend at the surface. Passive acoustic survey methods (PAM) are an alternative for obtaining larger samples of detections; however, large datasets and appropriate analytical frameworks have not been employed for estimating abundance from PAM data except under special circumstances, and ancillary datasets are often required. In summer/fall of 2016, the Southwest Fisheries Science Center conducted a 40-day cruise dedicated to collecting PAM data for deep diving species throughout the California Current using drifting acoustic spar buoy recorders (DASBRs). Here, we focus on data for Cuvier's beaked whale, *Ziphius cavirostris*. Cuvier's beaked whales were detected during 870 out of ~111,000 2-minute sound files obtained during 377 recording days from 22 DASBRs that drifted over a combined ~5000 km. The analysis follows a point-transect distance-sampling framework, with the key inference being the estimation of a distance-detection function, but several ancillary data sources are needed for the analysis. The independent datasets we used included: visual sightings data for estimating group size; dive data to estimate mean dive depth, which is used in combination with our detection bearing angles to find the horizontal distance of detections from the DASBRs; and dive data to estimate mean dive duration, which feeds into a g(0)-like estimation parameter. We provide estimates of Cuvier's beaked whale population size that are considerably more precise than previous estimates based on visual sightings data. However, the estimation is sensitive to potential data biases that we are currently attempting to address and are eager to discuss after this workshop.

11. **Can we Combine Visual and Acoustic Estimates of Beaked Whale Abundance?**

Jay Barlow and Jeff E. Moore

NOAA Fisheries' Southwest Fisheries Science Center

The acoustic estimate of Cuvier's beaked whale (*Ziphius cavirostris*) abundance from the above study (N=7,300, CV= 0.15) is greater than but within the confidence intervals of 7 previous visual estimates of abundance for that species (N=2,700-5,700, CV= 0.59-0.67) and is considerably more precise. For this species, it is tempting to accept this new survey methodology and to use the new estimates to continue the prior time series. However, new methods often have different biases than the previous methods, and superficial agreement of estimates does not prove that the methods are truly comparable. Here we examine in detail

some of the assumptions of the new and old methods and propose tests of those assumptions to provide greater assurance that estimates from disparate data sources can legitimately be combined. The new survey method has application beyond Cuvier's beaked whales, and we also explore the possibility of combining time series from visual and acoustic surveys to monitor other hard-to-survey species (Baird's beaked whale, sperm whales, dwarf & pygmy sperm whales, and a group of 5 beaked whale species in the genus *Mesoplodon*). For all species (including Cuvier's beaked whale) we need more information on how the effective probability of detection varies with range, to precisely estimate abundance using point-transect methods. An example is given of using a spatial array of multiple hydrophone recorders to estimate detection range for Cuvier's beaked whales in the Catalina Basin. The same approach could be used to develop models of detection probability for the other species.

12. **Putting Passive Acoustic Data to Work: Developing a Standardized, Open-Source Approach to Automated Analysis of NOAA Fisheries PAM Data**

Shannon Rankin, Taiki Sakai, and Frederick Archer

NOAA Fisheries' Southwest Fisheries Science Center

Passive acoustic monitoring (PAM) has shown great potential for cetacean population assessment, a central responsibility of NOAA Fisheries, including density estimation and habitat modeling. This application requires competence in cetacean detection, classification, and localization, and a streamlined process to apply acoustic detections to population assessment methods. However, Science Centers have generally pursued different approaches to the processing and analysis of that data, severely limiting reproducibility and comparability of results. SWFSC is currently developing a series of open-source software packages that can be used by all Centers to efficiently process and analyze passive acoustic data. Built on the open source, multi-platform language R, these three packages will consist of: (1) functions to extract acoustic metadata, integrate it with ancillary data, and generate summaries and output for downstream analyses (PAMr, in development), (2) a powerful and systematic method for cetacean species classification using passive acoustics (BANTER, complete), and (3) a package for the coordination of acoustic cetacean population assessment tools (PAMde, FY19). Our approach in the development of PAMde is to provide an integrated platform that will incorporate available methods while remaining flexible as the field matures in the future. PAMde will be developed along three paths: (1) applying acoustic data to existing R packages (e.g. MRDS in Distance), (2) integrating existing methods into R (e.g. habitat modeling), and (3) encouraging development of novel population assessment methods. Ultimately, the analytical advancements provided by BANTER, PAMr, and PAMde will allow for efficient, standardized results that can be quickly produced with minimal human intervention.

13. **Estimating Sea Lion Abundance from Aerial Surveys and Capture-Recapture Data**

Devin Johnson and Lowell Fritz

NOAA Fisheries' Alaska Fisheries Science Center

Assessing the total abundance of sea lions can be challenging since the adult portion of the population is only partially observable during the year. Only pups are reliably available for counting at rookeries during summer months. Thus, stock assessment for sea lions in Alaska has been determined as a multiple (~4.5x) of the current year's pup counts. This multiplier was initially determined as the ratio of pups to adults and juveniles in a population that is at a stable age distribution. Although this method is easily applied, it can give misleading results if the population is not at a stable age distribution. As an alternative to this overly simplified multiplier, we propose a new methodology based on population reconstruction using pup abundance and survival information obtained from capture-recapture data. Although adults are not reliably available for rookery abundance surveys, uniquely marked animals can be observed throughout adulthood to determine an age-specific survival schedule, which can be used to determine a survivorship curve. By forward projection of past pup abundance estimated from aerial surveys, the number of adults alive in the current year can be estimated without the assumption of stable age distribution. Moreover, the method accounts for the more volatile nature of pup abundance versus adult abundance. A Monte Carlo version is used to assess the error of estimation as well, which is unavailable using the multiplier method.

14. **Modeling the Effects of Ocean Conditions on Survival in the Western Stock of Steller Sea Lions within a Bayesian Integrated Population Model**

Amanda J. Warlick[1], Sarah J. Converse[2], and Devin S. Johnson[3,4]

[1]University of Washington, [2]USGS Washington Cooperative Fish and Wildlife Research Unit, [3] University of Washington, School of Aquatic and Fisheries Sciences, [4]NOAA Fisheries' Alaska Fisheries Science Center, Marine Mammal Laboratory

Integrated population models that combine disparate data sources can improve the precision of abundance estimates and demographic rates through the simultaneous analysis of the state of a population and the dynamic processes that underlie that state. We present an integrated population model for the western stock of Steller sea lions (*Eumetopias jubatus*) that combines rookery counts and capture-recapture data, thereby allowing robust inference about factors influencing age-specific survival. Rookery counts from aerial surveys provide information relevant to the estimation of abundance, while age-specific survival estimates are estimated from capture-recapture data using a multi-event model that accounts for uncertainty in female reproductive status. We investigated the potential effects of local and large-scale

oceanographic conditions on pup and juvenile survival using several indices, including upwelling, sea surface temperature, the Pacific Decadal Oscillation, and the Arctic Oscillation. Model results will advance efforts to identify the causes of regionally divergent population trends. This framework also has the capacity to provide much-needed updated abundance estimates and improve predictions of population viability, the selection of recovery actions, and inform the upcoming five-year review of the ESA listing for this stock.

15. **Close-Kin Methods to Estimate Census Size and Effective Population Size**

Robin S. Waples

NOAA Fisheries' Northwest Fisheries Science Center

Close-kin mark-recapture (CKMR) uses genetic methods to identify close relatives, which are then analyzed in the standard capture-mark-recapture (CMR) statistical framework to estimate adult census size (N). Unlike traditional CMR, it is not necessary to capture the same individuals more than once to apply CKMR; instead, the method relies on the fact that genes are shared naturally among close relatives through Mendelian inheritance. In the CKMR framework, close relatives (parent-offspring pairs (POPs) or siblings) are considered "recoveries." In the first large-scale application of CKMR, Bravington *et al*. (2016 Nature Communications 7:13162) produced an estimate of $N \approx 2 \times 10^6$ for southern bluefin tuna (*Thunnus maccoyii*) that was both larger than expected and much more precise (CV = 17%) than had been possible with traditional methods. This result, which was obtained using POPs identified by 26 microsatellite loci, has attracted a great deal of interest globally. Furthermore, the ready availability of many thousands of SNP loci, even for non-model species, opens the possibility of also using siblings to increase precision. However, the extension of CKMR to incorporate siblings introduces several complexities, not the least of which is that there is already a widely used method based on siblings to estimate effective population size (Ne) or the effective number of breeders per year (Nb). I review the CKMR methodology for POPs and siblings and discuss factors that can affect bias and precision of the estimates, including changes in survival and fecundity with age; selectivity in sampling; overdispersed variance in reproductive success; skewed sex ratio; skip breeding; persistent individual differences; and population subdivision. I show that siblings from different cohorts can be used to estimate N, whereas siblings from the same cohort estimate Nb. Because precision depends on the number of close-kin pairs identified, robust estimates for large populations will require extensive sampling efforts. This project was made possible by an International Science Fellowship from NOAA Fisheries that supported a 2-month visit by RSW to Hobart in 2017 to collaborate with colleagues from CSIRO.

16. **Use of Multivariate Autoregressive State-Space Models to Assess the Extinction Risk of a Data-Limited Anadromous Species**

Kiersten L. Curti[1] and Tara Trinko Lake[2]

[1]NOAA Fisheries' Northeast Fisheries Science Center, [2]NOAA Fisheries' Greater Atlantic Regional Office

River herring (alewife and blueback herring), two anadromous fish species found along the Atlantic coast from the Gulf of St. Lawrence, Canada, to the southeastern US, were petitioned to be listed under the Endangered Species Act (ESA) in 2011. River herring are managed at the state level through the Atlantic States Marine Fisheries Commission and, due to their life history, should ideally be assessed and managed by individual river systems. However, river herring data quality varies among river systems, creating limitations for assessment models. Furthermore, river herring are highly migratory with most of their life history spent in the marine environment, yet few coastwide indices are available. To assess the extinction risk for the ESA status review, Multivariate Autoregressive State Space (MARSS) models were developed to combine these disparate data sets and assess trends at the coastwide level as well as trends by stock complexes that were identified through genetic analysis. The probability of extinction could not be assessed because threshold population levels are not available for either species. Instead, population growth rate estimates from the MARSS analyses were used to assess whether each stock complex was significantly increasing, decreasing or stable. However, the use of the term stable, while accepted in the scientific community, was problematic in the realm of an ESA status determination when challenged in court. The challenges associated with this approach as well as paths forward will be discussed.

17. **Estimating Rockfish Abundance with MARSS**

Nick Tolimieri[1] Elizabeth Holmes[1], Greg Williams[1], Dayv Lowry[2], and Bob Pacunski[2]

[1]NOAA Fisheries' Northwest Fisheries Science Center, [2] Washington Department of Fisheries and Wildlife

The data available for population viability analysis (PVA) are often fragmented and from multiple, disparate data sources. Multivariate autoregressive state-space (MARSS) models allow one to combine surveys with different gears and across different sites for estimation of PVA parameters, and allow one to implement replication, which reduces the variance-separation problem and maximizes informational input for mean trend estimation. Even data that are fragmented with unknown error levels can be accommodated. Here, we present a case study that estimates long-term trends of rockfish in Puget Sound, WA based on citizen science scuba surveys, a fishery-independent trawl survey, and recreational fishery surveys affected by baglimit reductions. The best-supported models indicated that the recreational and trawl surveys tracked different, temporally independent assemblages that declined at similar rates (an average -3.8 to -3.9% per year). The scuba survey tracked a third increasing (an average 4.1% per year) and temporally independent assemblage. Three rockfishes (bocaccio, canary, and yelloweye) were listed in Puget Sound under the ESA at the time of the analysis (canary was subsequently delisted based on genetic data). These species are associated with deep water, which the recreational and trawl surveys sample better than the scuba survey. All three ESA-listed rockfishes declined as a proportion of recreational catch between the 1970s and 2010s, suggesting that they experienced similar or more severe reductions in abundance than the 3.8–3.9% per year declines that were estimated for rockfish populations sampled by the recreational and trawl surveys.

18. **Let Me Count the Ways: Combining Video Counts and Mark-Recapture to Monitor Recovery of the Endangered Nassau Grouper (*Epinephelus striatus*)**

Lynn Waterhouse[1], Brice Semmens[1], Christy Pattengill-Semmens[2], and Croy McCoy[3]

[1]Scripps Institution of Oceanography, [2]Reef Environmental Education Foundation (REEF), [3]Department of Environment, Cayman Islands

In 2001, a spawning site for Nassau grouper (*Epinephelus striatus*) was rediscovered by fishermen on the Island of Little Cayman. It was estimated to have between 7,000 and 8,000 fish, making it the largest known aggregation in the Cayman Islands. Nassau grouper form spawning aggregations at specific times of year to reproduce, making them easy targets for exploitation and prone to experiencing levels of overharvesting. Following two years of exploitation, it was estimated that approximately 2,000 fish remained. Since 2003, the government has implemented various forms of protections, leading up to permanent multifaceted legislation in 2016. At the same time, the Grouper Moon Project, a collaborative effort between Reef Environmental Education Foundation (REEF), the Cayman Island Department of the Environment, and various research institutions, has worked to provide the government with science to evaluate management strategies. In order to quantitatively estimate population size, video transects and scuba diver-based tagging studies have been conducted. Here we present results from Little Cayman and Cayman Brac fitted in a Bayesian state-space model to estimate population recovery over time.

Identifying Spatial Scales and Synchrony in Dynamics with Empirical Dynamic Modeling from the CalCOFI Ichthyoplankton Survey

Peter Kuriyama[1,2] and Brice Semmens[2]

[1]NOAA Fisheries' Southwest Fisheries Science Center, [2]Scripps Institution of Oceanography

Empirical dynamic models are a group of nonparametric models that have proven to provide accurate out-of-sample predictions and identify causal relationships in marine and terrestrial ecosystems. Here, we apply simplex, smaps, and time delay embedded Gaussian processes to the CalCOFI dataset, an ichthyoplankton survey in the California current which began in 1951, to identify synchrony in the dynamics of species and groups of species. Specifically, we seek to identify the spatial scales of synchronous dynamics and identify regime shifts in real time.

Discussion

Participants and speakers discussed common themes of dealing with disparate data sources, data quality issues, and associated trade-offs with integrating multiple data sources to address complex conservation problems. Key discussion points are enumerated below.

- Data synthesis using disparate data sources can help highlight gaps and biases in the different methodologies employed. Using multiple observation platforms can yield valuable scientific data but can be expensive. Additionally, over time, using the same method is preferred to not jeopardize a time series. The challenge is to modernize data collection without compromising long-term data sets.
- Data integration needs to account for differences in variance with weighting methods (lower variance model has a stronger effect on ensemble modeling, so weighting is needed), but the challenge is to optimize model selection and evaluate model performance. Models with very low variance are not ideal as the variance is often underestimated in modeling due to sources of variability being left out.
- Data for age-specific vital rates for any species would be helpful for improving close-kin mark-recapture methods, especially for challenging species like salmon. Close-kin mark-recapture methodology is flexible but has some constraints - covariates need to be chosen carefully and some guesswork is required about the true population size to ensure that sampling intensity will be sufficient to provide the desired level of precision.
- We need to consider implementing quantitative listing criteria developed by Boyd et al. 2016 (https://onlinelibrary.wiley.com/doi/full/10.1111/conl.12269) rather than relying on qualitative criteria for endangered species listings.
- Movement models are already complex so using spatial-capture-recapture (SCR) models can be difficult when you have no information on individual identity. However, some

assumptions can be made for low-density populations, although less feasible in other situations.

- Bias corrections for visual surveys are well-advanced (diving and sightings condition corrections still result in negative bias in abundance estimates), but acoustic bias correction is still in its infancy. There are benefits and shortcomings of using just visual or acoustic sampling. For example, visual estimates can be imprecise for developing correction factors and distance sampling techniques tend to underestimate true abundance. Alternatively, variance is low when acoustic sampling is employed largely due to increased observations or acoustic sensors. In the future, simultaneous visual and acoustic surveys might be an approach worth testing to overcome biases in estimating the true abundance.
- Beaked whales can be undetected even if close or directly below the acoustic sensor due to echolocation directionality. There are challenges and potential biases for estimating abundance of cryptic species, such as beaked whales, for both standard visual survey methods and acoustic estimates derived from drifting buoys using point-transect methods. Spatial autocorrelation is another factor to consider in deciding the analytical framework for estimating Cuvier's beaked whale abundance from acoustic and visual datasets.

Day 3: February 14, 2019

Theme III: Spatial Prediction of Distribution Shifts

Session Chair: Jessica Redfern

Summary

Dr. Maunder in his keynote address spoke about the problems of equating catch-per-unit-effort (CPUE) with abundance and the usefulness of certain spatiotemporal models to reduce bias in fisheries-dependent data caused by variability in fishing effort and vertical/horizontal distribution of fish populations in space and time.

In the final session of PSAW II, the topics covered in the 6 talks were: 1) identifying potential outplanting sites within the Southern California Bight and northern California based on fine- and broad-scale modeling of historical and current white abalone distributions at different scales using multiple fisheries-dependent and independent datasets; 2) predicting multiple cetacean species distributions during an anomalous warm year (2014); 3) developing forecasts of bowhead whale habitat suitability/preference in fall foraging range in changing Arctic conditions and evaluating whether modeled prey from an ocean biophysical model can improve habitat models; 4) moving towards dynamic ocean management through the development of predictive habitat models, wherein species tagging and observer data are combined with static, surface, and subsurface environmental data and ultimately, into an ecoinformatics tool for the drift gill net fishery in the California Current; 5) evaluating ensemble modeling using eastern Pacific blue whales as a case study to integrate multiple species distribution models (SDMs) for the same species in the same region to account for different strengths and weakness of each of the individual models; and 6) estimating eastern north Pacific loggerhead turtle demographic parameters, such as vital rates and residency patterns, to better mitigate a diverse suite of fisheries threats.

Abstracts

Spatio-Temporal Modelling of Fishery-Dependent Data: It's Difficult

(Keynote Speaker) Mark Maunder

Stock Assessment Program, Inter-American Tropical Tuna Commission

Fishery-dependent data appears to be a valuable source of information for estimating the spatial distribution of protected species. However, its interpretation is not that simple. The premise that catch-per-unit-effort (CPUE) is proportional to abundance is compromised by a range of factors including change in the efficiency of the fleet, changes in target species, environmental cycles and trends, dynamics of the population, dynamics of the fishing fleet, and management measures, among others. Of interest to this workshop is the proportion of the population that is vulnerable to the fishery, which depends on the horizontal and vertical distribution of fish. This distribution can depend on size, gender, stage, etc. The impact on the relationship between CPUE and abundance depends on the overlap in spatial distribution of the fishing fleet and the fish population and how it changes over time. Spatio-temporal models can be used to limit the bias caused by these changes. Spatio-temporal models fill in empty space/time cells or augment cells with low sample sizes by sharing information across space and time. There are many different types of spatio-temporal models available, and the method that you choose is generally less important than the assumptions that you make. These methods work well when cells are missing at random, but can be problematic if cells are missing on the edges, in clumps, or areas where the habitat makes fishing difficult. Using covariates may help reduce bias caused in these situations. When using covariates, it is important to separate the effects into density and catchability, because density is used for estimating abundance indices and spatial distribution. The analyses might require adding a fourth dimension to time and horizontal space. This fourth dimension could be spatial (e.g. depth) or related to a characteristic of the species (e.g. age, length, gender, stage), which is important for stock assessment models that use age or size composition data. The methods used to model the fourth dimension will depend on correlation within the fourth dimension and with the other dimensions. Spatio-temporal models can be extended in other ways, such as using multispecies models to account for targeting and combining information from different fleets. However, many issues remain. Spatial patterns are complex, particularly with fishery-dependent data, and they differ among stocks. Correlation changes with space and time and are anisotropic. Finally, catchability has a big impact on fishery-dependent data and needs to be considered.

Session III Talks

19. **Modeling White Abalone Habitat in the Southern California Bight to Inform Future Outplanting Efforts**

Jordan DiNardo

Scripps Institution of Oceanography

White abalone (*Haliotis sorenseni*) supported an intense commercial fishery in southern California during the 1970s, which closed in 1996. In 2001 white abalone was listed under the Endangered Species Act (ESA), and due to its high risk of extinction, NOAA identified the species as a "Species in the Spotlight" in 2016. Efforts are underway to develop a conservation hatchery and outplanting program to recover the species. To inform outplanting efforts, I modeled broad-scale (17 km) historical (fishery-dependent) and contemporary (fishery-independent) distributions of white abalone habitat using random forest and Maxent, respectively. I projected models to future scenarios in 2050 and 2100 to assess the quality of habitat under climate change. Using Maxent, I developed fine-scale (10 m) models with fishery-independent data. I also conducted interviews with former abalone fishermen who observed white abalone during the fishery. Fishery-dependent and -independent based models revealed differing outcomes of suitable habitat and ensuing effects of climate change. These differences in suitability resulted from differences in the spatial distribution of white abalone between the two data sets. Fine-scale fishery-independent data was limited in its spatial extent, yet in places with enough data, I generated high-resolution suitability maps. These maps along with oral histories from fishermen regarding fine-scale habitat can help guide site selection within broadly suitable geographic regions. This study provides managers with potential areas to outplant that are resistant to climate change, and a framework to design experimental outplanting to adaptively manage a successful recovery effort.

20. **Predicting Cetacean Distribution Shifts in a Changing Climate**

Elizabeth A. Becker[1,2], Karin A. Forney[1,3], Jessica V. Redfern[1], Jay Barlow[1], Michael G. Jacox[4,5], Jason J. Roberts[6], and Daniel M. Palacios[6]

[1]*Marine Mammal and Turtle Division, NOAA Fisheries' Southwest Fisheries Science Center*, [2]*ManTech International Corporation*,[3]*Moss Landing Marine Laboratories*, [4]*Physical Sciences Division, NOAA Research's Earth System Research Laboratory,* [5]*Marine Geospatial Ecology Laboratory, Duke University,* [6]*Oregon State University, Marine Mammal Institute and Department of Fisheries and Wildlife, Hatfield Marine Science Center*

Substantial shifts in distribution as a result of a warming climate have been documented for many marine species, but opportunities to test our ability to forecast such changes have been limited. In 2014, waters in the California Current Ecosystem (CCE) became anomalously warm as an unprecedented marine heatwave spread over the area. The profoundly altered ocean conditions provide a unique opportunity to evaluate whether species distribution models (SDMs) could accurately predict changes in marine mammal distribution during a period with unusually warm ocean temperatures. We constructed SDMs based on sighting and environmental data collected in the CCE from 1991 to 2009 for eight cetacean species with a diverse range of habitat associations. Models predicting species abundance and distribution patterns during 2014 were then compared to actual cetacean survey sighting data collected during 2014 to assess model performance. Model-predicted abundance and distribution patterns showed good concordance with the actual 2014 survey observations and design-based estimates, capturing substantial shifts in the distribution and abundance of some species. Our results indicate that models of cetacean-habitat relationships built on two decades of survey data were sufficiently robust for both cool and warm-temperate species to capture shifts in distribution and abundance under anomalously warm conditions. This is likely because the models were based on long-term survey data collected during periods that encompassed a large range of environmental variation. They also revealed species-specific responses to warming ocean waters, enhancing our understanding of the effects of climate change on cetaceans and other marine predators in the CCE.

21. **Using an Arctic Ocean Ecosystem Model to Improve Bowhead Whale Spatial Distribution Models**

Daniel Pendleton[1], Elizabeth Holmes[2], and Jinlun Zhang[3]

[1]Anderson Cabot Center for Ocean Life, New England Aquarium, [2]NOAA Fisheries' Northwest Fisheries Science Center, [3]Polar Science Center, University of Washington

Our study evaluated the efficacy of utilizing output from a biophysical ocean model to improve the accuracy of species distribution models (SDMs) of bowhead whale habitat in Beaufort Sea, Alaska. Our specific aims were to examine the utility of modeled sea ice and zooplankton and to compare two popular species distribution models, maximum entropy (Maxent) and boosted regression trees (BRT). To study this question, we used a 3D physical-biological model of the Arctic Ocean (BIOMAS, Zhang et al. 2015), which provided estimates of sea-ice thickness, small phytoplankton, zooplankton (bowhead whale prey) and water temperature. Maxent and BRT SDMs were fit using the modeled ocean covariates, bathymetry data, and bowhead whale occurrence records from 1988-2012. Accuracy of spatial distribution models was measured using 'held out' data. We found that the mean predictive performance of SDMs was good, with a mean AUC score of ~0.825. Maxent and BRT SDMs performed similarly. Bathymetry and zooplankton were the most important predictor variables, while modeled sea ice and phytoplankton were poor predictors of bowhead whale habitat after the early to mid- 2000s. Models with modeled zooplankton alone were able to predict bowhead whale locations and highlighted the importance of zooplankton as a predictor. Nonetheless, models with only the static variable bathymetry were slightly more accurate. Our work is a step forward in understanding how modeled prey can be used to improve spatial distribution models, however, operational models will require further investigation of the interplay between static and dynamic environmental covariates.

22. **Dynamic Ocean Management Applications for the Drift Gillnet fishery in the California Current**

Stephanie Brodie[1], Elliott Hazen[2], Heather Welch[1], and Michael Jacox[3,4]

[1]UC Santa Cruz, Institute of Marine Sciences, [2]NOAA Fisheries' Southwest Fisheries Science Center, [3]Physical Sciences Division, NOAA Research's Earth System Research Laboratory, [4]Marine Geospatial Ecology Laboratory, Duke University

Managing for economic and ecological sustainability in marine fisheries often requires novel approaches, such as species distribution models. However, data to build such models for top predators are often sparse and collected using multiple platforms, e.g. fisheries catch, fisheries independent surveys, and telemetry studies. Analytical approaches that synthesize across data types can provide a more holistic understanding of species distributions than a single approach alone. We used tracking and observer data to build species distribution models for three catch and three bycatch species in the California swordfish fishery (catch: swordfish, thresher shark, mako shark; bycatch: California sea lion, leatherback turtle, and blue shark). We also compared models that integrated surface-only satellite environmental data with models that integrated subsurface environmental data, finding that subsurface metrics significantly improved habitat predictions. These species distribution models were integrated into an ecoinformatics tool to support dynamic ocean management – a strategy in which management boundaries change in space and time at scales relevant for animal movement and human use. The operationalized tool provides fishers with daily fishing suitability maps of regions that are better and poorer to fish based on relative bycatch risk and target catch potential. We then used this tool to examine how anomalous ocean conditions influenced catch and bycatch patterns and found dynamic approaches to be 2-10x more efficient than static closures. Dynamic ocean management approaches could be applied to other migratory species for which data are available, and this example emphasizes the utility of integrating multiple data types for marine conservation and management.

23. **eSDM: A Tool for Creating and Exploring Ensembles of Predictions from Species Distribution and Abundance Models**

Samuel Woodman[1], Karin A. Forney[2,3], Elizabeth A. Becker[4], Monica L. DeAngelis[5,6], Elliot L. Hazen[2], Daniel M. Palacios[7], and Jessica V. Redfern[2]

[1]Ocean Associates, Inc., in support of NOAA Fisheries' Southwest Fisheries Science Center, [2] NOAA Fisheries' Southwest Fisheries Science Center [3]Moss Landing Marine Laboratories, [4]Institute of Marine Science, University of California Santa Cruz, [5]NOAA Fisheries' West Coast Regional Office, [6]Naval Undersea Warfare Center, [7]Marine Mammal Institute and Department of Fisheries and Wildlife, Oregon State University, Hatfield Marine Science Center

Species distribution modeling (SDM) in dynamic marine environments has enhanced our ecological understanding, as well as the ability of resource managers to identify and assess potential impacts to protected species at finer spatial scales than traditional methods. However, different data sets or different analytical approaches often yield different modeled results, creating uncertainty and challenges in the decision-making process. For example, there are currently multiple spatial and habitat-based models of blue whale distribution off the U.S. West Coast (Becker et al. 2016, Hazen et al. 2017, Redfern et al. 2017). Assessing spatial distribution shifts from these models is challenging because they predict absolute density, relative density, or probability of occurrence at varying spatial resolutions. One solution to this problem is 'ensemble averaging', whereby the output of multiple models is combined using a weighted or unweighted average. Such ensemble models are often more robust than the individual models. We present eSDM (Ensemble tool for predictions from Species Distribution Models), an R package with a built-in graphical user interface. eSDM allows users to overlay SDM outputs (predictions) onto a single base geometry, create ensembles of these predictions with associated uncertainty via weighted or unweighted averages, calculate performance metrics for each set of predictions and for resulting ensembles, and visually compare ensemble predictions with original predictions. This tool allows users to combine SDM predictions made at different spatial scales, using different data sources, and with different numerical scales to better evaluate spatial uncertainties and make informed conservation and management decisions.

24. **Using Time-Specific Tissue Samples to Assess Shifts in Species Distribution**

Calandra Turner Tomaszewicz[1], Hoyt Peckham[2], Tomo Eguchi[1], Jeffrey A. Seminoff[1]

[1]NOAA Fisheries Southwest Fisheries Science Center, [2]Stanford Center for Ocean Solutions

Understanding and predicting the spatial and temporal distribution of protected species is essential to managing stocks and initiating dynamic management actions that minimize fishery

interactions. Traditional tools such as satellite telemetry, aerial surveys, and models informed from bycatch/interaction events and environmental conditions are extremely useful in guiding dynamic management solutions. Yet these approaches are useful in a short time span. For example, satellite telemetry is limited in attachment time, thus precluding a long-term view of animal movement. Aerial surveys provide snapshots of seasonal and annual presence and density. Here we present a recently developed technique that uses samples collected from stranded animals to recreate multiple, sequential years' worth of long-term and large-scale movement patterns for individuals. Many species have accretionary tissues that continually form annual growth layers, such as humerus from sea turtles, and teeth from odontocetes and pinnipeds. By conducting stable isotope analysis on these layers, shifts in habitat can be tracked over time as each layer forms during a known year and retains a chemical signature of the habitat occupied. Here we share results from North Pacific loggerhead turtles (*Caretta caretta*) that show the estimated timing (year) and corresponding oceanographic conditions for when 33 turtles shifted from the oceanic Central North Pacific to nearshore habitats in the Eastern Pacific. These findings and similar future work can provide complementary insight to on-going research using traditional tools to better understand when, how, and why animals move from one environment to another.

Discussion

As with other sessions, participants and speakers engaged in robust discussions on various aspects of species distribution models, with the predominant focus on developing predictive models under different ocean and climate scenarios whilst constrained by variable data sources and data quality. The key takeaways from this session are listed below.

- Spatio-temporal modeling: General Linear Models, which use data weighting for areas with more data, can yield biased results as fishery effort has preferential sampling (fishermen fish where the fish are most abundant). However, in spatio-temporal modeling, spatial grid sampling methods can correct some bias by filling missing data in grids using information from nearby grids if gaps are uniformly distributed. But when there are big gaps or clusters, the nearest neighbor data may not be applicable. Spatial distribution resolution of data is still being evaluated in situations where GPS coordinates are coarse. An alternative could be to use oceanographic covariates, but limited success has been achieved so far in tuna spatial distribution studies in the eastern Pacific by adding oceanographic variables as covariates in the habitat model. It is tricky to distinguish between catchability and density effects in some cases, e.g., rocky reef habitat may be preferred (or not), but this habitat cannot be trawled due to the potential for gear damage. Fleet data from multiple countries may be combined, such as integrating commercial dolphin observer and marine mammal survey data from the eastern Pacific Ocean to estimate at dolphin index of abundance. Combining data with different spatial coverage and information collected may yield imprecise estimates.

- White abalone habitat modeling: Interviews of prior abalone fishers validated the habitat features used to model abalone presence – helpful to find outplanting sites.
- Predictive cetacean habitat models in a changing climate: Both distribution shifts and changes in absolute abundance were accurately captured when the models were used to make novel predictions on the unusual warm year in 2014. These types of habitat models may help to understand changes in distribution and abundance in a changing climate. Humpback whales in 2014 were concentrated in very nearshore areas, which increased entanglement risk in coastal fisheries - this was not predicted by the models due to their resolution (10 x 10 km, developed using the Regional Ocean Modeling System - ROMS habitat data), which was not fine enough to be effective for coastal entanglement management use. Models that included latitude-longitude as predictors exhibited better explanatory power of the training data for many species, but those models did not necessarily have the best predictive power for the novel year, 2014. Such predictive cetacean habitat models may not be very useful for long-range forecasting (50 years) because of expected changes in species distribution. Bottom-forcing physical changes might be a more reliable measure in the long-term. Although manager needs can vary depending on the conservation problem, shorter-term forecasts and higher resolution models are generally more useful for managers.
- Bowhead whale model: Extrapolating data outside the study area and out of range of oceanographic predictive variables are continuing challenges — both issues can be problematic but extending beyond the study area is a higher concern. Although there were some biases in the data from the early years, all data were used for the modeling effort. Krill and sea ice were not strongly correlated with each other. With decreasing sea ice, other variables, including prey, may carry greater significance. Passive acoustic datasets are available for bowhead whales and were considered initially for habitat mapping but were excluded due to increased complexity and associated uncertainty.
- There is a potential increased risk of loggerhead fisheries interactions with warming waters in the Central North Pacific (CNP) and Eastern North Pacific (ENP). It is rare for juvenile turtles tagged in the western Pacific (near Japan) to cross over to Baja, as most stay in the CNP due to a cold barrier between CNP and ENP. But when a thermal corridor of warm water forms connecting the two parts, turtles can sometimes pass through. For stable isotope analysis, only nitrogen isotopes were considered as carbon isotopes were not informative for pelagic foraging loggerheads. In general, sea turtles might show more adaptive capacity to warming temperatures than anticipated.
- Dynamic ocean management: Barriers to dynamic ocean management are regulatory changes not keeping up or being nimble. Additional challenges are fishery specific and

depend on the duration of gear sets, e.g. mobile vs. fixed gear, and the ability to react to dynamic changes at the timeframe needed to protect the species. In Australia, dynamic ocean management applications are well-supported by regulatory decisions or a framework. Management needs to consider what risk they're willing to take. Explicitly considering risk is required under some legislative mandates, e.g. Magnuson-Stevens Act (MSA), which enables managers to weigh risk vs. benefits in implementing scientific advice. It is difficult to capture all levels and types of uncertainty in spatial models. But criteria are currently being developed for characterizing uncertainty in cetacean density models. In general, uncertainty tends to be underestimated.

Conclusion

PSAW II ended with a feedback session on the organization, structure, and content of PSAW II and proposals for future PSAWs. All participants acknowledged the limited number of presentations received relative to PSAW I and the narrow themes covered. However, the relatively small size promoted a very collegial atmosphere, and allowed individuals to interact directly with peers who had developed R packages, models, or other tools which they were applying in their own research. Like the NOAA Fisheries' National Stock Assessment Workshop, topic and scope are likely to vary between workshop years. People suggested adding an open session to include non-theme conforming topics. Others suggested providing an open session to feature research associated with the host NMFS lab/s, or to have speed talks on cutting edge research, emerging topics, and experimental techniques to improve the diversity of speakers and increase interest.

Future PSAWs could also consider management-friendly topics or policy discussions to attract managers and policymakers. Organizing poster sessions as social events would further increase participant diversity and cross-fertilization of ideas. Using different venues for PSAW workshops would facilitate different science center and regional office staff, as well as associated universities and federal and non-federal research entities, to participate. Moreover, the different venue choices could promote cross-region collaboration and provide opportunities for talented students and early-career researchers to share their work and obtain feedback.

All workshop participants applauded the inclusion of training sessions and emphasized the need for all future PSAWs to include training sessions of longer duration. Since significant effort goes into putting training materials together, protracted training sessions will allow the instructors and trainees to benefit from longer interaction time and hands-on activities.

Opening training sessions to graduate students and postdocs would enable the next generation of scientists to acquire valuable skills, learn about modern tools used to combat conservation threats, and network with professionals. All instructors need travel and resource support, as well as some official and unofficial recognition for services provided. Organizing data hackathons or dedicated sessions to address a common scientific or management problem using training and testing data from one region or multiple regions are other possibilities for future events. Thus, future PSAWs should strive for a combination of open and themed sessions, add speed and poster sessions, and organize full-fledged multi-day training sessions.

Suggestions for future PSAW topics:

1. Analyzing rare species for assessments or bycatch analyses;
2. Quantifying and communicating uncertainty in management applications;
3. Conservation and management planning incorporating movement models;
4. Integrating social sciences and protected species science, including social/economic valuations;
5. Estimating abundance, trends, indices of abundance, conducting risk assessments; exploring different survey designs to prioritize marine mammal stock assessments; and discussing the challenges of not implementing mandates;
6. Dealing with shifting stock boundaries given climate change and consequent shifts in species distribution patterns;
7. Discussing the types of scientific information used in status reviews or recovery planning. There is variability in how different regions conduct evaluations depending on the species;
8. Discussing Management Strategy Evaluation (MSE) applications in protected species science and management;
9. Exploring and sharing the latest technological breakthroughs and problems. For example, machine learning, image detection/processing, passive acoustics, and other advancements between now and future PSAWs;
10. Managing big data collected from different observing platforms (e.g., acoustics and unmanned systems) regardless of the methodology used;
11. Assessing protected species trophic interactions and integration in ecosystem models;
12. Discussing the latest advancements and applications in genomics, which is critical for stock assessments but beyond stock identification; and
13. Discussing refinements in line transect and mark-recapture methods.

Acknowledgments

PSAW II was funded by NOAA Fisheries' Office of Science and Technology. It also supported full travel for keynote speakers, steering committee members, and trainers attending PSAW II. Thank you to the Southwest Fisheries Science Center for being exceptional hosts and providing logistical and technical support throughout the event. A special mention is given to Annette Henry, Laurie Barak, Dawn Graham, Raquel James, and Ravi Shiwmangal from the Southwest Fisheries Science Center, who went above and beyond to help organize the workshop. Our sincere gratitude is expressed to the several volunteers from the University of San Diego and elsewhere who helped with workshop registration and other logistics. Thank you also to Eli Holmes, Mark Scheuerell, Brett McClintock, Josh London, Devin Johnson, and Kevin Stierhoff for their time and effort in conducting the training sessions. Finally, thanks to the session chairs – Jay Ver Hoef, Jessica Redfern, and Kimberly Murray – for moderating the various sessions and facilitating discussions, to the Steering Committee for devoting their time over several months to help in the successful organization of the workshop, and to Emily Markowitz for her exemplary coordination and organization of the workshop.

Appendix 1: Steering Committee Members

- Jay Ver Hoef, Alaska Fisheries Science Center (Co-Chair, Day 1, Theme 1)
- Kimberly Murray, NEFSC (Co-Chair, Day 2, Theme 2)
- Eric Ward, Northwest Fisheries Science Center (Co-Chair, Day 3, Theme 3)
- Emily Markowitz, Workshop Coordinator, Office of Science and Technology
- Stephen K. Brown, Office of Science and Technology
- Mridula Srinivasan, Office of Science and Technology
- Melissa Soldevilla, Southeast Fisheries Science Center
- Jessica Redfern, Southwest Fisheries Science Center
- Tomo Eguchi, Southwest Fisheries Science Center
- Karin Forney, Southwest Fisheries Science Center
- Eric Patterson, Office of Protected Resources
- Alexis Gutierrez, Office of Protected Resources

Appendix 2: Training Sessions

I. Mapping and (some) advanced spatial tools in R

Trainer: Kevin Stierhoff (kevin.stierhoff@noaa.gov)

Description: This will be a practical workshop on visualizing and analyzing spatial data using R. The course will be hands-on and rely heavily on analysis (e.g., dplyr), visualization (e.g., ggplot2), and spatial analysis (e.g., sf) tools that support “tidy” data analysis principles. Topics covered will range from basic mapping using dataframes, to reading/writing of shapefiles, to interactive maps (e.g., Leaflet). We will present examples of some of the more common analysis tools provided in the ArcGIS Spatial Analyst toolbox using equivalent R packages and functions. Time permitting, we may cover some additional topics, such as animations that may be of interest for visualizing animal movements. Data used in examples will be provided, but participants are encouraged to bring their own data as well.
Audience: Scientists interested in visualizing and analyzing spatial data using R.

Additional Logistics: Students will need to have a laptop computer with R (>= v3.5) and Rstudio (> v1.1456) installed. Installation of some R packages will streamline set-up (tidyverse, sf, and their dependencies). All necessary data and scripts will be provided (likely via GitHub). Mac and Linux users will require a recent version of the GDAL, GEOS, Proj.4, and UDUNITS libraries installed for this to work. More information on that at https://github.com/r-spatial/sf#installling.

Prerequisites: Students should have experience programming with R and familiarity with Rstudio. Prior experience with ArcGIS and/or familiarity with GIS concepts and terms (e.g., shapefiles, datums, projections) would be helpful.

Course Notes: All course materials (e.g., data, code, slides, etc.) will be maintained as an R Project (.rproj) file in a GitHub repository (https://github.com/kstierhoff/PSAW II-Mapping). While you don't require Git on your computer to access these, it's helpful (but by no means necessary). Whether or not you plan to "play along", you should download the course materials. The repo is currently very sparse but will expand quickly between now and the workshop.

If you have Git, using Rstudio you can download the repo by choosing File>New Project>Version Control>Git and pasting " https://github.com/kstierhoff/PSAW II-Mapping" in the Repository URL field. As I add things, you can then "pull" any changes/updates.

If you do NOT have Git, you can download the materials as a .zip file, extract the contents, and then open the PSAW II-Mapping.Rproj file, which will launch Rstudio and provide access to the files.

R/Rstudio Configuration
I will be preparing all of the materials using Rstudio (I have the preview v. 1.2.1244-1, but recommend at least the latest v.1.1.463) and R (v. 3.5.2). I think it would minimize problems if you updated your installation (you can install multiple R versions, in case you're wary about upgrades affecting existing projects) and any installed packages (see potentially new packages below).

GIS Configuration
Mac users who have never used sf or GIS on their machines should follow the instructions for installing gdal toward the bottom of this page: https://r-spatial.github.io/sf/, then install the sf package as per usual.

R packages
These exercises will rely heavily on tidyverse (e.g. ggplot2, dplyr) and sf (simple features) packages. I aim to have the various scripts install the necessary packages if not already installed using the pacman package. Running the two lines of code below will install pacman (if missing), then a couple of the packages that we will be using (and their dependencies):

```
# Install and load pacman (library management package)
if (! require("pacman")) install.packages("pacman")

# Install and load required packages from CRAN ---------------------------------
pacman::p_load(ggplot2, dplyr, dplyr)
```

Final Notes: Attached are the "final" HTML slides. You should be able to view them in any web browser. All of the files are also available from the GitHub site:
https://github.com/kstierhoff/PSAW II-Mapping.
http://www.seascapemodels.org/rstats/2019/02/23/new-r-course-posted-online.html

II. Time Series Analysis

Trainer: Mark Scheuerell (mark.scheuerell@noaa.gov)

Description: Learn the basics of univariate and multivariate time series analyses, including dynamic linear models, dynamic factor analysis, and identification of metapopulation structure.

The course will focus on hands-on examples of applied problems in the analyses of time series, including the identification of common trends and seasonal patterns in abundance, breakpoints or outliers, and inter- and intra-species interactions.

Audience: Scientists interested in analyzing time series data

Additional Logistics: Students will need to have a laptop computer with R and RStudio installed. All necessary data and scripts will be provided with the course materials. Also, some of the exercises will rely on the `MARSS` package, so go ahead and install that ahead of time, if you're able. https://mdscheuerell.github.io/PSAW2/

Prerequisites: Students should have a grasp of introductory statistics and some programming experience with R.

III. Developing Forecasting Models for Fisheries Time Series with R

Trainer: Eli Holmes (eli.holmes@noaa.gov)

Description: This will be a practical workshop on developing forecasting models for fisheries time series with R. The course is hands-on, so participants will be developing basic time series models by the end of the session. Data will be provided, but participants can also bring their own data. We will focus on Box-Jenkins (ARMA) and exponential smoothing models, and touch briefly on other common approaches such as time-varying regression and non-parametric approaches. Forecast diagnostics and accuracy metrics will be covered.

Additional Logistics: Students will need to have a laptop computer with R and RStudio installed. All necessary data and scripts will be provided with the course materials.

Prerequisites: Students should have a firm grasp of introductory statistics and some programming experience with R. Attending the workshop on time series analysis beforehand will be helpful for forecasting workshop.

IV. Movement Modeling

Trainers: Devin Johnson, Joshua London, and Brett McClintock (devin.johnson@noaa.gov, josh.london@noaa.gov, and brett.mcclintock@noaa.gov)

Description: The study of animal movement has always been a key element in ecological science because it is inherently linked to critical processes that scale from individuals to populations and communities to ecosystems. Rapid improvements in biotelemetry data collection and processing technology have given rise to a variety of statistical methods for characterizing animal movement. This workshop is intended for wildlife biologists and quantitative ecologists who seek a deeper understanding of modern animal movement models.

This workshop provides an overview of data manipulation methods using the tidyverse of R packages, as well as analysis of telemetry data using the movement modeling packages: momentuHMM, crawl, and ctmcmove. Topics of discussion include discrete v. continuous-time movement models and parallel computing for multiple imputation and large numbers of deployments.

Additional Logistics: Students will need to have a laptop computer with R and RStudio installed. All necessary data and scripts will be provided with the course materials.

Prerequisites: Familiarity with the R statistical environment is required. Some background with movement modeling and telemetry data would be useful, but not required.

Training Session Agenda

All training session rooms conducted at Scripps Institution of Oceanography (SIO).

<table>
<tr><th>Session</th><th>Time</th><th>Eckart Sea Cave (SIO)</th><th>Nierenberg 101 (SIO)</th></tr>
<tr><td rowspan="5"><u>Morning</u></td><td>8:30 - 10:00 am</td><td rowspan="5">Time Series Analysis
Mark Scheurell</td><td rowspan="5">Spatial Mapping in R
Kevin Stierhoff</td></tr>
<tr><td>10:00 - 10:15 am (Break)</td></tr>
<tr><td>10:15 - 11:15 am</td></tr>
<tr><td>11:15 - 11:30 am (Break)</td></tr>
<tr><td>11:30 am - 12:30 pm</td></tr>
<tr><td rowspan="5"><u>Afternoon</u></td><td>1:30 - 3:00 pm</td><td rowspan="5">Movement Modeling
Devin Johnson, Joshua London, and Brett McClintock</td><td rowspan="5">Developing Forecasting Models for Fisheries Time Series with R
Eli Holmes</td></tr>
<tr><td>3:00 - 3:15 pm (Break)</td></tr>
<tr><td>3:15 - 4:15 pm</td></tr>
<tr><td>4:15 - 4:30 pm (Break)</td></tr>
<tr><td>4:30 - 5:30 pm</td></tr>
</table>

Appendix 3: Workshop Agenda

Tuesday, February 12 - Day 1: Survey Sampling Design

Co-chair: Jay Ver Hoef; Alaska Fisheries Science Center, Marine Mammal Laboratory

Prior to statistical analysis, data are collected according to some design. Classically, random sampling was implemented at some level. However, collecting data from satellite, ships, and aircraft often limits how much sampling can be randomized, yet it is still necessary to consider survey design because the way data are collected impacts inferences when modeling those data. For protected resources, we generally need to think about a monitoring plan, which involves sampling in space through time. The goals of this workshop topic are to investigate the role of randomization in survey design, the impact of preferential sampling, and how to obtain good survey designs in space and time for data that we typically collect.

7:00 - 8:00 am	**Set up (Pacific Room)**
8:00 - 9:00 am	**Registration**
9:00 - 9:15 am*	**Welcome to PSAW II** Stephen K. Brown *Division Chief, Assessment & Monitoring (ST4)* *Office of Science and Technology*
9:15 - 9:25 am*	**Welcome Remarks** Ned Cyr *Director, NOAA Fisheries' Office of Science and Technology*
9:25 - 9:30 am*	**Welcome Remarks** Kristen Koch *Director* *Southwest Fisheries Science Center*
9:30 - 9:35 am*	**Welcome Remarks** Robin LeRoux *Marine Mammal and Turtle Division Deputy Director* *Southwest Fisheries Science Center*
9:35 - 10:10 am*	**S&T Invited Speaker** Richard Merrick *Chair, Scientific Advisory Committee* *Scientist Emeritus* *Former Chief Science Advisor and Director of Scientific Programs at NOAA Fisheries*
10:20 - 10:50 am	**Break** - Coffee, Tea, and Snacks. Please bring your own mug and cash.

10:50 - 11:05 am*	**Introduction to Session** Jay Ver Hoef *PSAW II Co-Chair* *Alaska Fisheries Science Center, Marine Mammal Laboratory*
11:05 -11:50 pm*	**Keynote Speaker** Dale Zimmerman *Professor, Department of Statistics and Actuarial Science* *University of Iowa*
11:50 - 12:30 pm*	**11:50 - 12:10** Paul Conn *Preferential Sampling in Species Distribution Models*
	12:10 - 12:30 John Carlson *Developing a Relative Abundance Index for Rare Species using a Priori Information with Random and Subjective Sampling: A Case Study of Smalltooth Sawfish,* Pristis pectinata
12:30 - 1:30 pm	**Lunch**
1:30 - 2:50 pm*	**1:30 - 1:50** Briana Abrahms *Dynamic Ensemble Models to Predict Blue Whale Distributions and Risk Exposure in Near Real-Time*
	1:50 - 2:10 Alex Curtis *Power to Detect Trend in a Low-Capture-Probability Population*
	2:10 - 2:30 Josh London *Optimizing Aerial Survey Design for Harbor Seals in Alaska*
	2:30 - 2:50 Jennifer Cahalan *Implementation of Statistically Rigorous Sampling Designs under Adverse Conditions: Monitoring the Federal Groundfish Fisheries off Alaska*
2:50 - 3:30 pm	**Break** - Coffee, Tea, and Snacks. Please bring your own mug and cash.
3:30 - 4:30 pm	**Discussion Session** - Pacific Room
4:30 pm	**Adjourn**

Wednesday, February 13 - Day 2: Estimating Abundance from Disparate Data Sources

Co-chair: Kimberly Murray; Northeast Fisheries Science Center, Protected Species Branch

Accurate and precise estimates of abundance are essential for detecting trends of protected species, which allow the development of effective management decisions on MMPA and ESA-listed species. Data for abundance estimates may be available from a variety of sources, collected with different levels of effort and spatial coverage across years or within years. In addition, the data may have been collected using different methodologies (e.g. visual, passive acoustic) from different platforms (e.g., manned and unmanned aerial, boat, shore-based, moored). Sometimes these disparate data sources are the only information that are available. The aim of this session is to share techniques and ideas to improve the accuracy and precision of abundance estimates using multiple disparate data sources. Through presentations and discussions, we hope to: 1) identify types of data available for different taxa to improve abundance estimates; 2) explore the challenges associated with merging these datasets and methodological techniques used to overcome them; and 3) review techniques used to estimate trends in abundance, which account for variation in datasets due to different survey designs or data collection platforms.

8:30 - 8:45 am*	**Welcome and Introduction to Session** Kimberly Murray *PSAW II Co-Chair* *Northeast Fisheries Science Center, Protected Species Branch*
8:45 - 9:30 am*	**Keynote Speaker** Andrew Royle *Research Statistician* *USGS Patuxent Wildlife Research Center*
9:30 - 10:50 am*	**9:30-9:50:** Mark Scheuerell *Improved Understanding of Fisheries & Ecosystems from Noisy and Disparate Data*
	9:50-10:10: Kaitlin Frasier *Cetacean Population Monitoring Integrating Visual and Acoustic Observations*
	10:10-10:30 Doug Sigourney *Integrating Passive Acoustic and Visual Data Collected During Standard Line Transect Surveys to Refine Population Estimates and Estimate Availability Bias*
	10:30-10:50 Jeff Moore *Estimating Abundance for Beaked Whales from Drifting Acoustic Recorders*

	and Other Data Sources
10:50 - 11:30 am	**Break** - Coffee, Tea, and Snacks. Please bring your own mug and cash.
11:30 am - 12:10 pm*	**11:30 - 11:50** Jay Barlow *Can we Combine Visual and Acoustic Estimates of Beaked Whale Abundance?*
	11:50 - 12:10 Shannon Rankin *Putting Passive Acoustic Data to Work: Developing a Standardized, Open-Source Approach to Automated Analysis of NOAA Fisheries PAM Data*
12:10 - 1:30 pm	**Lunch**
12:10- 12:40 pm	**Fisheries Bulletin Special Issue** - Sardine Room Jose Castro *Scientific Editor of Fishery Bulletin*
1:30 - 3:10 pm*	**1:30 - 1:50** Devin Johnson *Estimating Sea Lion Abundance from Aerial Surveys and Capture-Recapture Data*
	1:50 - 2:10 Amanda Warlick *Modeling the Effects of Ocean Conditions on Survival in the Western Stock of Steller Sea Lions within a Bayesian Integrated Population Model*
	2:10 - 2:30 Robin Waples *Close-Kin Methods to Estimate Census Size and Effective Population Size*
	2:30 - 2:50 Kiersten Curti *Use of Multivariate Autoregressive State-space Models to Assess the Extinction Risk of a Data-Limited Anadromous Species*
	2:50 - 3:10 Nick Tolimieri *Estimating Rockfish Abundance with MARSS*
3:10 - 3:50 pm	**Break** - Coffee, Tea, and Snacks. Please bring your own mug and cash.
3:50 - 4:30 pm*	**3:50 - 4:10** Lynn Waterhouse *Let Me Count the Ways: Combining Video Counts and Mark-Recapture to Monitor Recovery of the Endangered Nassau Grouper (*Epinephelus striatus*)*
	4:10 - 4:30 Peter Kuriyama *Identifying Spatial Scales and Synchrony in Dynamics with Empirical Dynamic Modeling from the CalCOFI Ichthyoplankton Survey*
4:30 - 5:10 pm*	**Discussion Session** - Pacific Room
7:30 pm	**Adjourn**

Thursday, February 14 - Day 3: Spatial Prediction of Distribution Shifts

Co-chairs: Jessica Redfern, Southwest Fisheries Science Center, Marine Mammal Spatial Habitat and Risk

Eric Ward Northwest Fisheries Science Center, Conservation Biology Division

Karin Forney, Southwest Fisheries Science Center, Marine Mammal and Turtle Division

Over the last decade, several new approaches for estimating species densities and range shifts have emerged; these include Gaussian predictive process models, flexible generalized additive mixed models, and machine learning techniques (maxEnt, random forests, etc.). While most applications have focused on applying these methods to fisheries independent data sources (such as surveys), there may be utility in combining inference from surveys and other data types. Examples of additional data include data from fisheries (targeted or non-targeted catches that represent non-random samples), passive acoustic monitoring, and opportunistic sightings from non-survey sources. Other non-survey data sources, such as satellite tagging data, may also be combined with surveys used to estimate changes in distribution. In this symposium, talks will highlight the range of methods that are used for estimating changes in spatial distributions, including discussions of the benefits and potential pitfalls of each. We also welcome presentations that include examples of using multiple data types or illustrate applications to data limited species.

8:30 - 8:45 am*	**Welcome and Introduction to Session** Jessica Redfern On behalf of Eric Ward, *PSAW II Co-Chair* *Southwest Fisheries Science Center, Marine Mammal Spatial Habitat and Risk Staff*
8:45 - 9:30 am*	**Keynote Speaker** Mark Maunder *Head of Program* *Stock Assessment Program* *Inter-American Tropical Tuna Commission*
9:30 - 10:10 am*	**9:30-9:50** Jordan DiNardo *Modeling White Abalone Habitat in the Southern California Bight to Inform Future Outplanting Efforts*
	9:50-10:10 Elizabeth Becker *Predicting Cetacean Distribution Shifts in a Changing Climate*
10:10 - 10:50	**Break** - Coffee, Tea, and Snacks. Please bring your own mug and cash.

10:50 - 12:10 pm*	**10:50-11:10** Eli Holmes *Using an Arctic Ocean Ecosystem Model to Improve Bowhead Whale Spatial Distribution Models*
	11:10-11:30 Stephanie Brodie *Dynamic Ocean Management Applications for the Drift Gillnet Fishery in the California Current*
	11:30-11: 50 Samuel Woodman *eSDM: A Tool for Creating and Exploring Ensembles of Predictions from Species Distribution and Abundance Models*
	11:50-12:10 Cali Turner Tomaszewicz *Using Time-Specific Tissue Samples to Assess Shifts in Species Distribution*
12:10 - 1:10 pm	**Lunch**
1:10 - 2:10 pm	**Discussion Session** - Pacific Room
2:10 - 3:10 pm	**Discussion of next PSAW topics** - Pacific Room
3:10 pm	**Adjourn**