ECOSYSTEM WORKGROUP REPORT ON FISHERY ECOSYSTEM PLAN CLIMATE AND COMMUNITIES INITIATIVE UPDATE

The Ecosystem Workgroup (EWG) presented its primary recommendations for this agenda item in its advance briefing book report (Ecosystem Workgroup Report 1). In keeping with the initiative schedule presented in that report, the EWG coordinated a webinar series over January 25 - February 27, 2018, featuring speakers from the NMFS Northwest and Southwest Fisheries Science Centers (NWFSC and SWFSC) addressing what the best available science forecasts are for change in the California Current Ecosystem (CCE) over the near- and long-term.

The EWG understands that The Nature Conservancy intends to hold a workshop in May that should organize some discussions of the issues behind this initiative. EWG members are interested in communicating with the workshop's steering committee to help develop an organizing framework for the concepts to be discussed at the workshop, to bring value to the final product intended to support this initiative.

Webinar Summaries

The four webinars addressed a broad range of topics, as summarized below. Each webinar included a slide presentation, followed by opportunities for questions and open discussion. The webinars were well attended and recordings of the webinars are available on the Council's website: https://www.pcouncil.org/ecosystem-based-management/fishery-ecosystem-plan-initiatives/climate-and-communities-initiative/climate-and-communities-initiative-2018-webinar-series/

What do we expect to happen in the California Current under climate change? Mike Jacox, Nate Mantua, and Steven Bograd from the SWFSC presented the January 25, 2018 webinar focusing on the physical environment. The presentation began with an overview of existing climate prediction models and the anticipated changes in the California Current for a variety of climate change parameters, including: sea surface temperature, primary production, hypoxic events, ocean acidification and coastal upwelling. The second part of the presentation discussed how, although trends shown in the climate predictions may take decades to become apparent, they can still have impacts on shorter time scales through extreme events. The recent years' extreme events provide a strong example of what the future may hold. Short-term weather variability is due largely to a confluence of complementary natural forcing, but extreme or unprecedented conditions such as occurred in 2014-2016 are far more likely due to the changing climate. High frequency of extreme warm events in the CCE since the 1980s caused widespread ecosystem and fishery impacts. Climate models predict ocean extremes will become more frequent and intense as warming trends accelerate. The final part of the presentation discussed how some of the climate sensitive fishery challenges that we are already facing are likely to become more frequent and intense. One such event occurred in 2015 with an unusually large number of whale entanglements, mostly off the coast of southern California. A more chronic fishery issue is the long-term decline in Chinook salmon abundance and harvest opportunity, and the increased frequency of fishery disaster declarations. Summary:

- There has been a high frequency of warm events since the 1980s that cause wide spread ecological and fishery impacts.
- Climate models predict ocean extremes will become more frequent and intense as the warming trend accelerates.
- During the coming 1 to 2 decades, the slow upward temperature trend may be harder to detect in the presence of large year-to-year variations, but the trend will accelerate.

The state of the art for ecological forecasting at short-, medium- and long-term time frames. The February 1, 2018 webinar provided an overview of the modeling platforms operating at short, seasonal, medium, and long-term (decades) time frames. Model skill and performance as well as uncertainty were identified as key considerations in determining forecasting needs for particular Council use. In addition, geographic coverage and scale, time scale for forecasting, and internal model variability should be considered for models to be useful. For example, regional ocean modeling provides more resolution and appropriate scale for the CCE than global models. Short term models can help with rapid change and with determining what we expect to see on the horizon, which is useful for more "real time" decision making or seasonal forecasts. Considering a long term decadal scale may help with assessing global change risks to ports or fisheries. The co-presenters were Isaac Kaplan and Vera Trainer (NWFSC), Mike Jacox (SWFSC), and Samantha Siedlecki (University of Connecticut).

While the availability and scope of information useful for specific forecasting varies across the CCE, the presenters provided examples that indicated there may be promise in the ability to tailor forecasting to the Council time frames and decision point needed for specific FMP species. Examples included: short term modeling to predict harmful algal blooms and presence of domoic acid in Dungeness crab management; seasonal forecasting for *Pseudo-nitzschia* blooms to tailor clam management; ensemble modeling to forecast seasonal oceanographic projections and the use of back-casting for forecast validation; using ocean subsurface anomalies in salinity to forecast salinities along the CCE ten years later; and use of the Atlantis model to make climate and biological predictions across decades to address future impacts of ocean acidification on the CCE food web.

Based on the examples provided, the forecast over a season or year ahead is possible with reasonable levels of precision and confidence. Forecasting over a medium time frame (one to twenty years) appears to be more challenging than forecasting over the shorter or longer term. This may be because the variation in possible model outcomes is greater than the range of inputs (in light of changing ocean conditions), which reduces output confidence. Over the long-term, variation in particular parameters apparently averages out over time to reduce the overall variance in possible forecasting outcomes. Disparities in forecasting success were attributed to the scope of assumptions used in the modeling, the available oceanographic and biological information (historical and current), geographic scale under consideration relative to the resolution of the models, and available range of information. At the conclusion of their presentation, the presenters posed two questions for consideration by the audience: What ocean conditions matter most for species and fisheries? What are the PFMC needs for short, medium and long term forecasting?

Distributional changes of West coast species and impacts of climate change on species and species groups. The February 22, 2018, webinar provided an overview of the distributional movements and changes we have seen in some West Coast species and the potential impacts of climate change on these species and species groups. Three case studies/examples were given to show how the available data has been used to examine and model observed shifts and movements in species distributions as well as abundance changes over time: Chinook salmon, Groundfish and large pelagic species. All three examples covered some of the challenges and confounding factors, and benefits, that come with using these types of data and models. The webinar was giving by Elliott Hazen from the SWFSC, and Ole Shelton and Eric Ward from the NWFSC.

The salmon portion of the webinar focused on the movements and distributions of fall Chinook in the ocean. The presenter discussed the strong seasonal patterns seen in ocean Chinook distribution and how these distributions generally shift north in warm years and south in cool years. However, it was noted that there are exceptions to this generality and some of the next steps for this work are to combine information across stocks to project composition and total abundance and incorporate climatic effects on salmon survival. The groundfish part of the webinar was broken into three sections, including: the potential benefits of spatially explicit modelling of fish biomass, how multispecies modeling can improve our understanding of habitat relationships, and finally, the relationships of climate impacts on the distribution of groundfish and whether there have been northern shifts in species or whether any species have increased or decreased their ranges. The final group of species that was discussed were large pelagic species, including highly migratory fish, birds, mammals, etc. The primary focus of this segment of the webinar was the identification of "hotspots" (i.e. areas where these species are typically found) for certain species and the likely physical drivers leading to these habitat associations or "hotspots," and how this core habitat may change in the future with a changing climate. This part of the webinar also looked at the unforeseen consequences of unusual time-space overlaps of fishery gear and protected species, and existing and future tools that this type of work can lead to, such as the ongoing Ecocast work to produce daily predictions of optimal swordfish fishing areas.

Modeling Changes in Fishery Participation and Economic Impacts in Response to Climate Variation and Climate Change. The February 27, 2018 webinar featured Dan Holland, Jerry Leonard, and Kate Richerson of the NWFSC and the University of Washington. This final webinar included three presentations on past and upcoming projects focused on the social and economic aspects of fisheries and climate variability. The first presentation, by Dan Holland, *The Dynamics of Adaptation to Climate Driven Variability in California Current Fisheries and Fishing Communities*, explored the salmon, Dungeness crab, groundfish, albacore, and pink shrimp fisheries, and focused on environmental variability, integrated management of fisheries, and engaging disparate parts of the fishery management community. The project's research activities are organized around four themes and plans to link biological models of stock dynamics with economic models of fishery participation. The linked models will be designed to explore scenarios of climate and economic shocks and evaluate fishery participation choices and the performance of different fishing portfolios. While results are not expected for a while, the researchers have built engagement of fishery managers and fishery participants into the project and expect interaction throughout, including here at the Council.

The second presentation, by Jerry Leonard, *Atlantis and Input Output Model for Pacific Coast Fisheries (IO-PAC) Collaborations*, focused on the NWFSC's economic input output modelling efforts with emphasis on linking those efforts to ecosystem models. Input output modeling looks at the web of economic activity that results as the outputs from one industry become inputs to another industry, like landings from fishing vessels to seafood processors. The model uses cost and earnings data collected from Council-managed fishing vessels and related businesses to model how harvest level may affect the West Coast economy. IO-PAC can be configured to look at any combination of county-level data, from West Coast wide to smaller scale port group regions. It is also designed to look at fishery sectors individually. The Council has used the IO-PAC model regularly to evaluate the economic effects of its recommendations for groundfish and salmon. The focus of this presentation was past and previous efforts to look at the economic consequences expected under various ecological and climate scenarios. One example, currently under peer review, looks at ocean acidification scenarios. The findings of that study predict the strongest biological changes in the southern California Current but the largest economic changes in northern ports dependent on Dungeness crab.

Looking ahead to this initiative, it may be possible the IO-PAC model could be used in conjunction with Atlantis and climate models to look at economic impacts of climate change scenarios. Given the efforts of the NWFSC to date, these models are relatively easy to link. However, IO-PAC does have key limitations as to long-term predictions related to some of its key assumptions. For instance, it assumes industries have no substitution of inputs and that prices and harvesting efficiency do not change. There are other classes of models, called computable general equilibrium models, which are able to relax some of these assumptions and have been used in the North Pacific. These models would take time and resources to develop, are more data intensive than IO-PAC, and are needed to aggregate fishery sectors and areas to a greater degree than IO-PAC.

The third presentation, by Kate Richerson, *Quantifying and Predicting Impacts of Salmon Ocean Fishery Closures*, was related to the first presentation and focused on fishery participation choice in the salmon ocean troll fishery in response to fishery closures. The study focused on the troll closure of 2008-2009. Using a survey of affected fishers and PacFIN data (using vessel information as a proxy), the analysis looked at how the closure affected fishers' revenues and participation in other fisheries. In brief, they found that although many vessels participated in multiple fisheries, revenues lost by the salmon closure were not easily offset by increasing participation in other fisheries.

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