REPORT FROM THE FUTURE SEAS STAKEHOLDER ENGAGEMENT WORKSHOP, NOVEMBER 2022

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Summary

A 2-day virtual stakeholder engagement workshop in support of the NOAA-funded Future Seas project was held November 28 and 29, 2022. Attendees included academic and government scientists as well as representatives of the National Marine Fisheries Service West Coast Region, the Southwest Fisheries Science Center, the Pacific Fishery Management Council, state agencies (California, Oregon, and Washington Departments of Fish and Wildlife), the Quinault Indian Nation, CPS (coastal pelagic species) fishermen, and CPS processors. The workshop began with an overview of the Future Seas project, including project aims for the recent phase 2 of the project, and a summary of the results obtained from phase 1. The rest of day 1 was dedicated to the socio-economic part of the project, while day 2 focused on the Management Strategy Evaluation (MSE). The discussion was lively and productive and is detailed in this report. With input from all represented stakeholders, the Future Seas team was able to synthesize for the CPS fishery the observed target species dynamics, the key drivers that affect fishing operations, species portfolio and switching behavior, harvest location, port landings decisions and “no fishing” decisions, and key climate vulnerabilities, management strategies and performance metrics. These findings will guide the development and execution of the models elaborated for the project and ensure that they address the concerns and ideas of stakeholders. Attendees expressed appreciation for being considered in the modeling design and have interest in follow-up meetings with the researchers of the project as needed.

Introduction

Phase II of the Future Seas project (https://future-seas.com/) is led by scientists from both academia and NOAA, and was funded by NOAA’s Climate Program Office (CPO) to investigate the impacts of long-term climate change and management on the coastal pelagic species (CPS) assemblage, dependent species and fisheries, as well as CPS fishery participants and their portfolio. The primary objectives of this workshop were to (i) improve stakeholder understanding and awareness of Future Seas Project results to date on climate change impacts on the California current ecosystem, with a particular focus on CPS fishery performance, (ii) engage CPS fishery stakeholders to help us better understand the fleet dynamics and fisheries operations, with the aim of improving socio-economic models used in the project, (iii) engage CPS fishery stakeholders to identify perceived climate-driven challenges in the fishery, the fishery’s ability to adapt, and limitations on adaptation and flexibility, and (iv) engage CPS fishery stakeholders to help us advance the development of climate-informed ecosystem management strategy evaluation via a discussion of management strategies and performance metrics. The purpose of this report is to document the discussions held by the stakeholders and the researchers and to summarize the conclusions achieved from this interaction. 29 stakeholders (Table 1) attended the workshop, including fishery managers, scientists, and fishing industry representatives.[1] D. Tommasi welcomed workshop attendees and briefly outlined the meeting objectives and expected outcomes.

1. Future Seas Project Overview and Summary of Phase 1

D. Tommasi presented an overview of the Future Seas Project. The project started in 2017 with funding from the NOAA Climate Program Office until 2021. This first phase of the project produced regionally downscaled climate projections for the California Current, using a regional ocean model forced by output from an ensemble of three Global Climate Models, and assessed climate impacts on the swordfish, albacore and sardine fisheries. A second phase of the project was then funded again by the NOAA Climate Program Office's Climate and Fisheries Adaptation (CAFA) Program in 2020 until 2024. The second phase of the project aims to 1) assess the effects of long-term climate change on the forage fish assemblage of the California Current and on the predators and fishing communities it sustains, and 2) develop a climate-informed ecosystem management strategy evaluation (MSE) to assess performance of current and alternative CPS management strategies under a changing climate, shifting forage species composition, and varying predator populations. The project is interdisciplinary and involves a large team of principal investigators (PIs) and three postdoctoral researchers (Table 2), including oceanographers, climate scientists, ecologists, fisheries scientists, and social scientists.

After introducing the project, Dr. Tommasi provided an overview of global climate models and climate projections. The presentation stressed that climate projections are designed to assess change in average climate conditions (over periods of ~20-30 years) resulting from change in greenhouse gases, not to predict future conditions for a specific year into the future. She then provided an overview of project results up to date, including the Pozo-Buil et al. (2021) manuscript on downscaled climate projections of ocean conditions and plankton for the California Current system. Dr. Tommasi then highlighted results from three Pacific sardine (*Sardinops sagax*) models that used these projections to assess changes in sardine distribution and associated landings. The first approach used a mechanistic individual based model (Fiechter et al. 2021), the second was a process-based age structured population dynamics model (Koenigstein et al. 2022), and the third used a statistical species distribution model linked to a landings model (Smith et al. 2021). Even with different parameterizations, all models show a poleward shift in optimal habitat for the sardine northern subpopulation and that the California contribution to total landings of northern sardine will decline and the Pacific Northwest contribution will increase. Before using the models for climate projections, models were evaluated to ensure they could capture historical patterns in sardine abundance and/or distribution. The Koenigstein et al. (2022) paper suggests that the recent decline in the northern sardine subpopulation abundance could be explained by a reduction in food availability.

[1] The fishing gear common to most fishing people involved, if not all of them, is purse seine.

1.1 General Discussion on Future Seas Project

Stakeholders had questions regarding if and how the impact of offshore wind energy on fisheries was considered in the Future Seas climate projections. I. Kaplan responded that work has to be done to assess whether off-shore wind farms will affect the oceanography of the California Current. Other stakeholders expressed interest in assessing the competition for space brought on by offshore wind leases and potential impacts on surface temperature and reductions in upwelling, as it is likely that there will be wind farms installed at sea in the future in California. D. Tommasi clarified that off-shore wind farms have not been considered in the Future Seas projections. Moreover, the Future Seas projections use a “business as usual” greenhouse gas emission scenario, which assumes no switch to “green energy” sources like off-shore wind. The discussion on wind energy continued with a stakeholder pointing out that there is an additional study planned for the effects of wind farms on oceanography. T. Frawley confirmed that there is a manuscript in preparation that includes scientists in NOAA SWFSC Environmental Research Division as co-authors entitled, "Cross-shore changes in upwelling from offshore wind farm development in California". A stakeholder mentioned that offshore wind is an important concern for industry when looking at future climate impacts on the California Current System.

Recent observations of distribution shifts for multiple stocks were mentioned by various stakeholders. Much of the discussion related to the southern subpopulation of Pacific sardine. A stakeholder asked about the effect of the migration of the southern subpopulation stock into U.S. waters. D. Tommasi responded that more information is needed about the southern subpopulation to understand its dynamics. Future work by B. Muhling will define sardine habitat as a function of larval survey data from Mexican scientists. In US waters, a stakeholder mentioned that they have started to see a higher abundance of sardines in nearshore northern waters. Another described seeing sardine more offshore in the southern range during collaborative fishing vessel-based surveys this year. Moreover, another stakeholder highlighted that game fish (e.g. wahoo, opah and blue marlin) have begun to move into Southern California and that customers at times do not have to go into Mexican waters for sport fishing.

Another topic of discussion was related to nutrient dynamics. A stakeholder was concerned with whether the climate models consider nutrients coming from the Columbia River and how, in projections for the northern California Current, that influx of nutrients compares to those introduced by upwelling. B. Muhling and D. Tommasi responded that it is likely that the climate models do not include dynamic freshwater nutrient inputs. This concern will be passed to the oceanographers on the team. Additionally, the stakeholder asked whether the models consider that spawning and recruitment of the sardine population will occur increasingly in the northern areas following the northward shift in distribution. D. Tommasi responded that both in Fiechter et al. (2021) Individual Based Model (IBM) and S. Koenigstein et al. (2022) sardine population model spawning habitat moves northward. The IBM has more detailed movement mechanisms represented in the model and considers the impact of ocean circulation on larval retention. S. Koenigstein added that both models assume spawning continues to happen in the best temperature location (i.e., the spawning area would move north in response to warming of surface waters). It was also discussed whether the projections of zooplankton biomass are based only on size categories or also on species. D. Tommasi responded that while the large zooplankton group in the NEMURO model used for projections is tailored towards euphausiids, the model uses a generalized size-based representation with three zooplankton size-classes. S. Koenigstein added that more work is needed to incorporate finer scale representation of zooplankton in the underlying biogeochemical models.

Finally, a stakeholder raised concern about whether the models can capture the longer-term patterns seen in the historical sediment record of fish scales (i.e., from sediment cores in the Southern California Bight). D. Tommasi mentioned that it would be useful to see if the Future Seas models can reproduce this past behavior. However, the Future Seas team would need to think about how they could obtain the physical drivers to generate such a hindcast. I. Kaplan added that scale records have played into how the Future Seas team constructs their future scenarios, for example with regards to sardine recruitment simulations in previous work (Punt et al. 2016), and that they will be relevant to Day 2 discussions.

2. Introduction to Socio-economics modeling

F. Quezada gave a presentation describing the different models that the team is developing to achieve the Future Seas socio-economic objectives: cluster analysis, a landings model, a participation model, and a location choice model. The presentation also stressed how stakeholders' ideas and opinions would help the modeling process as the models were in draft form needing refinement. For instance, stakeholders' opinions and responses would help to better define the set of explanatory variables, identify correctly the choice set that fishermen face when going fishing, improve the interpretation of the Future Seas models results, and better elaborate potential future socio-economic scenarios for the projections. The presentation continued by showing the main database used in the models, followed by a presentation of the cluster model, which categorizes each vessel into a group, or “fleet segment”. Here F. Quezada presented the motivation for this model, the methodology, and the results obtained. Following this model, F. Quezada presented the landings model, which aims to estimate monthly landings for squid, sardine, and anchovy at the port level by cluster. The methodology was presented, the connection between the species distribution model was explained, and a series of results were discussed to show the importance of heterogeneity across clusters (fleet segments) in predicting landings. The next model presented by F. Quezada was the participation model. The goal of this model is to understand the drivers that affect decisions whether to participate in a fishery, what species to fish for and in which port to land. The distinction between this model and the landings model was stated, and the challenges of describing fishing behavior in terms of a distinct and comprehensive set of choices were discussed (e.g. selection of the choice set, and modeling non-participation). Finally, F. Quezada presented the location choice model, which is future work. The goal of developing this model is to study the effect of climate-driven changes in species distribution and regulations on fishing grounds. F.

Quezada showed how this model is linked to the participation model. Throughout the presentation, it was specifically indicated where feedback from stakeholders would be useful to improve the development of these models.

2.1 General Discussion on Socio-economics modeling

One of the concerns that was pointed out by stakeholders is that the models are an oversimplification of the highly complex processes that comprise fishing decisions. It was suggested that the Future Seas team should meet with interested fishermen to better represent in the analysis the complexity of fishermen's behavior. F. Quezada and the Future Seas team were supportive of this idea. It was also pointed out that for each species, there are different factors that constrain harvest. For instance, for sardines, an important factor is the seasonal closure (and recently, total closure). For anchovy and sardine, due to spoilage, vessels do not travel further than 25-30 miles from processing plants, while squid remain fresh for longer. F. Quezada mentioned that the explanatory variables included in the model are species-specific. For instance, the average probability of presence in a port area was calculated differently for each species based on the average distance from ports that vessels travel, which was larger for squid. Moreover, a stakeholder noted that landings may be limited by factors other than local availability, giving the example of the sardine seasonal closures that started in 2008, which limited harvest in California, but increased landings in Washington and Oregon during this period. In future models, the Future Seas team will consider the inclusion of season-level closures in order to capture impacts on landings caused by this regulation.

Stakeholders were also concerned about the inclusion of a catch limit in the model. It was clarified that the catch limit was included as a percentage of days in a month when the fishery was open (i.e. the catch limit was not reached). Future modeling efforts may explore whether including the actual catch limit improves model prediction. A stakeholder also noted that the Future Seas models are only using species distribution for the northern subpopulation of Pacific sardines, thus, the Future Seas team should pay attention to how the southern subpopulation is handled in their model. The non-explicit representation of market orders as the main driving of fishermen's decisions was also discussed as an oversimplification. The team is aware of this, and further interaction with processors will be established to understand better how market orders work and what variables affect them. Finally, one stakeholder was concerned about the period that is used in the cluster analysis (2005-2014) as it covers a highly productive period of squid, with a strong market for the species, while there was not a strong market for northern anchovy or Pacific sardine. Thus, it was suggested that the Future Seas team may want to look at a broader time period. F. Quezada clarified that for the cluster analysis, the Future Seas team uses this time period because it included the period after the allocation framework of the sardine quota was modified, and before the sardine closure in California. However, the actual modeling strategy for landings, participation and location choices models does consider years after the sardine closure (2005 to 2020), in which the Future Seas team observes a decline in squid landings.

2.2 Dynamics of CPS Fishing Activity discussion

The general introduction to the socio-economic modeling and posterior discussion was followed by a small group discussion. Stakeholders were separated into three different groups, with future Seas team members leading each group and facilitating discussion using prompting questions in the meeting agenda. Google JamBoards (see Appendix 1 and 2) were used to annotate stakeholders' thoughts and comments.

2.2.1 Discussion on changes in target species dynamics and fishing operations

Stakeholders mentioned that for sardines a high variation in abundance has been observed in the last 40 years. In the early 2000s sardine abundance was high and large sardines were caught in Canada and as far as Alaska. However, by 2013 sardines were mostly gone from Canadian waters and the fishery has been closed since 2015. In the case of Northern anchovy, biomass showed high variation over the years. However, a resurgence in anchovy abundance began in 2015 (see 2015 CalCOFI surveys). Historically, market squid concentrated in Southern California during periods without The El Niño-Southern Oscillation (ENSO) phenomena, but recently a northward expansion of squid biomass into the central coast has been observed coinciding with the 2015-16 ENSO event. Squid spike on decadal scales. The last spike was observed in 2013-2014. Market squid spawning dynamics respond to climate conditions, with spawning occurring earlier and shifting north under warmer conditions based on California Wetfish Producers Association (CWPA) data (Van Noord & Dorval, 2017; Van Noord, 2020). According to a stakeholder, there has been more squid than normal off Oregon, with 9 million pounds observed in the 2017/2018 season. This is consistent with the 12-year CWPA time series (see Van Noord & Dorval, 2017; Van Noord, 2020) which shows that with warmer water market squid distribution moves northward. There has been an active squid fishery in Oregon since 2016. This market squid expansion into Oregon waters made some California boats and winter boats in Seattle target squid in Oregon. Nevertheless, relatively few squid vessels have been continuously active in the Oregon squid fishery since 2016.

Stakeholders highlighted that market conditions and dynamics are quite important to explain variation in landings. A stakeholder mentioned that market prices and orders take priority over other drivers in this regard. For instance, the increase in anchovy abundance has not coincided with the level of landings, as the species has a relatively low market value – there is a very limited market for anchovy right now. It was pointed out that one of the reasons is that there are no more reduction plants, affecting the potential demand for this species. A stakeholder noted that there is no incentive to develop a market for anchovy as the catch limit is really low, which also decreases the incentive of processors to invest in processing capital for this species.

As an anecdote, another stakeholder mentioned that recently a processor tried to process anchovy in the Pacific Northwest, but he could not sell them. Yet, there are a few small, local markets supporting the anchovy fishery on the US West Coast. These are mostly composed of live bait and a regional artisanal market in Monterey. Feed for tuna pens in Australia is a main anchovy market, though this market is limited by regulations aimed at reducing the potential for transporting disease into the country. Viral Hemorrhagic Septicemia (VHS) virus is an issue for anchovy export as the virus is in the North Sea. The stakeholder noted that Australian import laws incorrectly assume VHS to be present also in the California Current. Imports depend on the temperature of the water during anchovy hauls. Direct-to-market/consumer is also a growing trend in Southern California, which can help build a market for underutilized species. Sardine and anchovy size is also an important determinant for whether or not there is a market for the species. If the fish is too small, then there is no potential for commercialization. Size and oil content are also important factors for anchovy commercialization. Finally, international fleets have different practices, making it harder for American fishermen to be competitive.

It was noted that predicting markets could be difficult as many factors have to be considered. As an example, it was mentioned that the effect of Covid-19 and the effect of tariffs imposed in the Chinese market are recent market shocks that are relevant to be considered in the construction of future scenarios. Public perception and the development of new markets are other variables to take into consideration that will affect future demand.

Stakeholders mentioned climate change as one of the challenges in the future, as species distribution would change. Under this topic, the role that the Southern population of sardines will have in the future under a changing environment was discussed. The presence of a southern subpopulation was considered a potential benefit. Gaining access to this subpopulation could be an opportunity for vessels that are currently sitting idle due to the northern subpopulation fishery closure. Nevertheless, it was mentioned that there is no U.S. assessment for the southern stock. Additionally, the impact of weather on how profitable a fishing operation in an area can be was discussed. For instance, in San Diego, fishermen come from different locations to fish during the long warm season, bringing associated economic benefits. However, in the Pacific Northwest, tides and wind are important decision factors for the sardine fishery (which has a large operation in the Columbia River). This is a summer fishery as fishermen want to avoid rough weather.

Other challenges are closures, which affect processor operations and create a loss of opportunities for fishermen. However, it was mentioned that fishermen adapt easily when given opportunities. Finally, the development of wind energy was stated as another concern for the industry, including concerns about wind turbine effects on local currents and productivity, as well as concern about loss of access to fishing grounds, and increased congestion in ports and harbors.

2.2.2 Discussion on species portfolio and switching behavior

Species portfolios vary by season and by geography. Squid is currently one of the most profitable species and, therefore, a principal species harvested by fishermen in Southern California and Monterey. Other species such as anchovy and sardine (when available) are also part of their portfolio, while some stakeholders also mentioned mackerel as another target species (especially in Southern California). In the case of live bait, it was mentioned that fishermen typically target the CPS species that are dominant in their fishing grounds. Generally, their portfolio consists of anchovy, sardine, and mackerel. They do not have another alternative and rely completely on CPS.

Tuna and other Highly Migratory Species are non-CPS species that are also part of the portfolio for the Southern California CPS fleet. A stakeholder mentioned that, at times, targeting decisions can be based on drivers other than market forces. For instance, fishermen recently targeted bluefin tuna even at a loss to ensure maintenance of their share of the international quota. Some boats from Monterey fish salmon in Alaska. In the Pacific Northwest, boats also rely on Dungeness crab and some boats fish for shrimp and salmon. Sardine vessels in the Pacific Northwest had alternative target species or alternative fishing locations (e.g. California or Alaska) even before the sardine fishery closure. CPS vessels are quite flexible in terms of switching species. Switching is considered to be opportunistic, depending on revenue and cost factors. Each CPS fishery requires different gears (i.e. mesh size), thus, there is a cost to switching. However, there is some overlap in mesh size with some species which facilitates the switching operation. For non-CPS species, after gear modification, CPS vessels can even target groundfish or salmon (assuming those vessels or fishermen have the appropriate permits). However, there is an implicit cost of time as it takes at least a day of work to re-rig (e.g., for tuna). Additional costs like traveling to other fishing grounds and acquiring permits are part of switching. For instance, in the case of switching to crab, the permit is costly, and it takes one and a half days to re-rig and another three to five days to travel from California north to the Pacific Northwest. Additionally, there is an overlap between squid and crab seasons, thus fishermen need to choose between them.

As was mentioned in the previous subsection, markets play an important role in the target decision. In general, a species can have high abundance, but if there is no market for the species then there are no incentives to target the species as it is not profitable. As an example, the squid fishery is a main source of revenue. Thus, many out-of-state boats come to California for squid fishing along the coast. For instance, big seiners that can hold 80-90 tons came from Alaska to fish market squid. Stakeholders indicated that squid fishing is quite unpredictable. Squid has a short life span with seemingly sporadic peaks in abundance. Therefore, fishermen catch squid until it is no longer profitable. A stakeholder also noted that other species' price forecasts are also relevant for the target decision process (specifically, for Dungeness crab in the Pacific northwest). It was mentioned that there is much collaboration between vessels and processors to decide what and when to fish. Processors are critical in both day-to-day and long-term targeting decisions.

There are some limiting factors that disincentivize targeting. In general, operation costs and regulations were mostly mentioned by the stakeholders. Other limiting factors to target CPS that were mentioned were: gear expenses, switching challenges and the installation of Marine Protected Areas. Some operation costs listed were the cost of trucking (service and diesel prices), which varies by species, the cost of spotter plane/boat fuel (used for tunas but also for sardines and mackerels, particularly in the Pacific Northwest), and logistics (shipping and marketing). The total cost would depend on the travel distance, but also on the infrastructure present in a port. It was also mentioned that logistics issues in terms of trucking can end up being costly for fishermen. For instance, a fisherman stated that he had to make a longer trip back to a distant home port processor because the closest port was not receiving more landings or the processor was unable to arrange trucking. Often fishermen are left to organize transport logistics because these are too complex (and likely uneconomical) for processors, and transport fuel is expensive. A fisherman from Southern California also mentioned that there is a missed opportunity when trucking, as he cannot fish during this operation. Fishing for smaller amounts closer to the port was mentioned as a potential strategy to reduce costs. In the case of squid, fishermen may also incur additional costs such as light boats.

Regulations (i.e. closure and permits) were mentioned as the main factors that limit the ability to fish for CPS (or switch between CPS and other fisheries). The closure of the Pacific sardine in California brought new challenges to fishermen. For instance, regulations constrain the mackerel fishery as regulation requires no more than 20% of incidental catch for sardine, but both species mix often in the water. California sardine fishermen have switched to squid, and in Washington, the main CPS activity is now the bait boat fishery for albacore. A relevant number of permits for fishing were released for sardine when it was active in Oregon. However, in the few years of the fishery, the season was short as the allowable quota was caught in a few days as biomass was declining. It is expected that if the sardine fishery reopens, some boats in the Pacific Northwest would participate. There are not too many CPS processors in the Pacific Northwest, but the capacity has expanded particularly in Westport, WA. Stakeholders also mentioned that the anchovy quota has been constant despite the increase in biomass found in the most recent benchmark stock assessment. This causes a very low exploitation rate at present, besides the low market value described in the previous section.

2.2.3 Discussion on harvest location and port landings decisions

The decision of how long to travel from port to fishing grounds will differ by species and is governed by market dynamics. Fishermen consider the margins between revenue and cost for this decision. However, spoilage and ease of refrigeration limit travel, as well as the presence of processing facilities at ports and their capacity. A stakeholder mentioned that processing facilities closer to home makes things easier, while costs increase and the operation becomes more complex when fishing happens further from home. Potential adaptation strategies to climate-driven changes in availability mentioned by stakeholders included traveling further distances. As an example, a stakeholder mentioned that in the Pacific Northwest, vessels travel 40 to 60 miles off Westport when they target sardines or mackerel, depending on the season (during early summer to early fall). Specifically, stakeholders recognized that it is relevant to consider changes in fuel prices to model the decision to travel as it affects fishing decisions. If fuel costs double, fishermen state that it will slow fishing, as happened this past summer. Another fisherman mentioned that fuel prices will limit searching time to find fishing grounds while another stakeholder mentioned that if fuel prices decrease, he may be more willing to go fishing for lower volume catches. Moving to another port was mentioned as a strategy by one stakeholder. He indicated that he had to move from his homeport, San Pedro, to fish north, in order to follow the fish stock, even though he had to incur higher costs. A stakeholder noted that ports located in San Diego will soon require a shift to biodiesel, leading to an increase in fuel prices. This change will have an impact on costs and competitiveness, influencing potential future scenarios.

2.2.4 Discussion on "no fishing" decisions

Stakeholders mentioned that it is hard to model "not fishing" as many factors impact this decision, making the modeling process complex. Some variables that can affect the decision to participate in fishing are costs (e.g., fuel, transport), accessibility to markets, and availability of target species, which varies every fishing season. Captains must also shut-down operations for maintenance. It was mentioned also that it would depend on each individual captain. Other opportunities available to them would also affect their participation in a specific fishery: moving from Alaska to Oregon for other species, for instance. This switching decision would vary every year and by state.

It was also noted that the decision to exit the fishery will depend on the type of fishermen, e.g., whether the individual is a full-time fisherman or a seasonal/opportunistic fisherman (in the Pacific Northwest, many CPS fishermen have other revenue such as crab fishing or survey work). They have different perspectives and values about the maintenance of responsible management. One stakeholder stated that full-time fishermen are more motivated to be responsible, and this motivation would be stronger for multi-generational fishermen. Another stakeholder stated that fishermen will never stop fishing. They have made a large investment, so they fish till the end of their career. Moreover, fishing is a livelihood. Fishermen are always adapting, for instance, by participating in other fisheries. As it was stated by a stakeholder, fishermen and captains are masters at adapting to stay in their careers. In terms of modeling, stakeholders point out that the Future Seas analyses should differentiate between vessels and fishers as the same fisherman may also fish on different boats, either owned by the same person, or by a colleague. Moreover, fishermen may exit the CPS fishery if there are opportunities to target other species.

3. Introduction to MSE

D. Tommasi gave a presentation describing Management Strategy Evaluation (MSE). She explained that it uses computer simulations to evaluate trade-offs achieved by alternative management strategies given a set of predefined management objectives, and to assess consequences of uncertainty in achieving management goals. Its key ingredients are a set of harvest control rules, operating models representing the true dynamics of the population and the range of uncertainty to be considered, an estimation model that takes as input observations with error from the operating model, and finally a set of performance metrics representing a set of pre-agreed management objectives. Stakeholder involvement is important to define potential harvest control rules, management objectives, and performance metrics. As an example, she presented the MSE conducted by A. Punt and F. Hurtado-Ferro for the Pacific Fisheries Management Council (PFMC) to assess robustness of a new CalCOFI temperature informed harvest guideline (HG) for sardine (Hurtado-Ferro and Punt 2014). She reminded everyone that the goal of the meeting was to discuss management objectives, performance metrics, and management strategies for each of the species under consideration. She explained that the Future Seas project will be carrying out a climate-informed MSE, which is a strategic tool enabling assessment of the robustness of management strategies to climate change. Such an MSE evaluates the performance of a management strategy when stock dynamics are influenced by climate and assesses if current management is robust to future climate change and if further evaluation of alternative management rules might be warranted. She also stressed that the Future Seas MSE is considered a "research" MSE as it will not impact current management decisions. She then presented preliminary results from a climate-informed MSE being conducted for the Future Seas project that is assessing robustness of current and alternative harvest control rules to climate-driven changes in recruitment.

Dr. I. Kaplan concluded the MSE presentation with an overview of plans for a climate-informed MSE using the Atlantis ecosystem model. The model uses the Atlantis framework developed by Dr. Beth Fulton of CSIRO Australia (see for instance Audzijonyte et al. 2019 and https://research.csiro.au/atlantis/). The model domain spans the California Current from southern British Columbia to northern Baja California, representing sardine, squid, anchovy, herring, and major predators and prey. CPS fleets are modeled based on major fishing ports and their fishing areas. Atlantis is intended as a 'test bed' to assess impacts of climate change, and to assess the performance of harvest strategies based on single species catch advice versus ecosystem-based alternatives. In previous projects, earlier versions of the model were used to test ecosystem-level effects of different levels of sardine harvest (Kaplan et al. 2017, 2019). Within the Future Seas project, the model has now been updated to include new data on CPS, their fisheries, species diets, prey abundance, and oceanography including climate change effects. During the workshop, key discussion questions centered around 1) Identifying management strategies robust to climate change and inclusive of on-the-water observations, which can be tested with an Atlantis research MSE, and 2) Identifying performance metrics of interest to stakeholders, meaning how management 'success' is defined in terms of catches, revenue, profits, interactions with other species, and other goals.

3.1 General Discussion on MSE

The discussion about MSE started with a stakeholder pointing out his concern about ocean wind resources and its impact on down-wind effect on larval drift. I. Kaplan responded that oceanographers of the Future Seas team need to address these questions and indicated that there is preliminary analysis being conducted by the University of California Santa Cruz and the SWFSC Center Environmental Research Division looking at this. However, the challenge is to include this in model projections.

Another stakeholder stated that temperature effects on sardines are complicated, with potential for differences at regional/local scales. He also indicated his concern that the model may be overestimating the impacts of the fishery if the catch is modeled based on the quota allowed. I. Kaplan responded that the Future Seas team needs to think about market limits on catch below the quota. The stakeholder also showed interest in the southern stock of sardines, stating that modeled dynamics will be different depending on single vs. multi-stock structure representation. I. Kaplan responded that currently, the model does not have a stock representation of the southern subpopulation in the California Current System.

One of the stakeholders was impressed by the complex scope of the MSE tools. He commented that he would like to see offshore wind held to the same standards for natural resource management and impact assessment. He was concerned about how the uncertainty is propagated between the different model components when they are added together. I. Kaplan responded that the Future Seas models have different kinds of uncertainty that are added into them, related to assumptions about climate change, oceanography, and parameterization of the biological models. These uncertainties are considered by using multiple climate and biological models.

Finally, a stakeholder asked what is known about larval biology/ecology, and whether this would be included in parts of the study. I Kaplan responded that S. Koenigstein's work provides some insight into this, as his model resolves climate impacts on early life stages (Koenigstein et al. 2022). D. Tommasi added that different models can help highlight different mechanisms driving sardine dynamics. For instance, J. Fiechter's Individual-Based Model (IBM) (Fiechter et al. 2021) explicitly handles the impact of ocean circulation on larval retention. However, it is difficult to develop forward-looking indicators based on these models.

3.2 Discussion on climate vulnerabilities and management strategies

According to CPS fishermen and fishery managers, the greatest challenge posed by climate change is the intrinsic uncertainty in understanding its effects on CPS stocks and the ecosystem. CPS are ephemeral and have boom-bust cycles in the absence of changing climates, and mechanistic knowledge of these dynamics is already uncertain. Uncertainty in this system will only be compounded by climate uncertainties. Current assumptions about CPS productivity driven by warm temperatures may indicate benefits to the fishery in the future, but these assumptions are highly uncertain.

One topic that many workshop attendees brought into discussion was the potential for northern shifts in stock distributions as the climate changes. This may be beneficial for the southern California CPS fleet if this shift regularly brings the southern stock of Pacific sardine into US waters, and if US vessels are allowed to access this stock. However, there was also concern about northern shifts of CPS stocks into areas traditionally targeted by other fisheries or gears, like groundfish trawls or Dungeness crab pots. These potential overlaps may lead to issues driven by interactions between these gears or fisheries in northern waters, or potential for previously uncommon bycatch issues. The workshop attendees identified current difficulties in the mackerel and squid fisheries, where sardine can act as a choke species (i.e. species whose presence in a mixed fishery limits the catch of other target species, such as mackerel or squid in this case, relative to what could be allowed) if hauls on mixed schools have a composition of 20% sardine or more. Anticipating and mitigating these technical interactions in the future was a concern in multiple breakout groups during the workshop.

Shifting distributions of CPS stocks, particularly of both sardine stocks, was of concern due to the slow, static framework used to monitor and manage these stocks. The current fishery management plan for CPS restricts harvest of forage fish species to a small subset of stocks available in the system, with the other species being prohibited. Stakeholders stated that by removing these other forage species from potential harvest, the Council and NOAA Fisheries reduce the emphasis for monitoring and assessment of potentially exploitable stocks, such as sardine from the southern subpopulation or round herring. This inhibits the fishery from demonstrating "no harm" and precludes development of new markets for these stocks. Factoring in the dynamic nature of CPS populations, stakeholders felt that management was not flexible enough to respond to changes in this species complex. Stakeholders identified 1) real-time observations from fishing vessels, 2) sharing of information among vessels, regions, states, and countries, and 3) reevaluation of static stock boundaries (e.g., southern stock of Pacific sardine defined as any fish south of Pt Conception) as potential methods to improve management and harvest of CPS stocks.

There are further limits imposed on the fishery from markets and biology of CPS species. For example, in the case of market squid, demand for larger squid drives processors to limit the location of fisheries operations to avoid small individuals. Size limits are difficult to enact in CPS fisheries because of the tendency of large and small individuals to school together. Rather, developing markets for small CPS may be more beneficial for the fishery.

Workshop attendees suggested that learning from experience in successful CPS fisheries or fleets may be an opportunity for adaptation. Processing facilities in the Pacific Northwest are capable of shifting to different catch (e.g., Dungeness crab or pink shrimp). Also, the market squid fishery has adapted to target an innately volatile stock while still ensuring management success through marine protected areas and escapement regulations. The Future Seas team mentioned that further investigations into managing this group as a species complex may also provide the opportunity to further the ecosystem-based fisheries management goals of the Council and NOAA Fisheries.

3.3 Discussion on performance metrics

Performance is defined by the goals of fishery participants. Fishermen and fisheries managers in the workshop discussions identified multiple groups with potentially contrasting management goals. The workshop attendees specified a hierarchy of goals for fishermen, with the primary goal being profitability of the venture, defined as covering costs, expanding operations, or staying competitive in the market, and a secondary goal being time spent on fishing activities, including reduced travel time and more time in the home port. The profitability goal is not monolithic and can be different depending on whether permits were bought or inherited. Profitability cannot be equated to, for example, the dockside price of market squid, because this does not reflect changes in costs incurred by the fishing operation. From the industry or market perspective, consistency and sustainability are the main goals. Fishery closures interrupt this, and therefore a management strategy trading off lower maximum annual catches in exchange for longer spans of years when the fishery is open (even with low catches) may be preferred. This highlights the need to consider the temporal scale of projections when reporting performance measures. An overarching theme of this discussion was the need to consider the viability of the fishing industry and benefits to fishing communities, as specified in the Magnuson-Stevens Act. Monitoring and assessment of socioeconomic indicators would help this goal, with recognition that a tipping point exists at a minimum amount of catch, under which a fishery cannot stay competitive. For example, stakeholders stated that the current quota for northern anchovy needs to be higher to support fishery expansion, which requires investment to pursue new alternate markets and is, therefore, not a practical portfolio alternative to sardine.

The workshop attendees also identified reduction of uncertainty with respect to management decisions as a measurable performance goal. This can be either a qualitative or quantitative performance measure, with various examples provided throughout discussion. Hindcast analyses could assess whether current levels of monitoring and sampling have improved management advice over time (e.g., reduced CVs from assessment models, leading to more certain advice and higher Acceptable Biological Catch limits), or whether previous onboard observations could be reconciled with survey results and Council decisions. More qualitative analyses could help answer whether decisions helped to achieve policy goals through a "report card" of high-level assessment of fishery management plan objectives. An example provided was that due to the high natural variability in CPS dynamics, the FMP goal of stability is likely difficult to achieve and has led to very conservative advice for management of northern anchovy. A hindcast analysis might aim to answer whether this precautionary approach was able to meet management objectives as compared to other potential approaches.

Additional potential ecological indicators were also identified by workshop attendees. Spatial conflicts with other managed species, including California sea lions, Dungeness crab, groundfish, and salmon, as well as within the CPS complex (e.g., sardine and mackerel) should be quantified. Variation in size at maturity of market squid in response to El Niño was also identified as an important indicator for their associated fishery, but also as a potential indicator of the state of the California Current Ecosystem; however, care should be taken in interpreting this indicator because of species-level differences in biological effects of environmental changes. Recent studies on market squid paralarvae also suggest that zooplankton availability may be a useful forward indicator of squid catches 9 to 10 months in advance (Van Noord et al., 2017, 2020). Spawning squid are also often observed in nets, possibly providing opportunities for measuring biological processes or rates for future analysis.

4. Concluding Remarks

Organizers thanked all the participants for coming and for the engaging discussions. The meeting will be very useful in informing the underlying mechanism that affects fishing decisions, as well as for creating realistic scenarios and management strategies in future MSE work. Workshop attendees thanked the organizers and highlighted the importance of involving stakeholders in scientific research. They also expressed interest in a follow-up meeting with the socio-economic group to better represent the complexity of the decision-making process regarding harvest decisions.

From the discussion, the Future Seas team obtained many useful inputs that will allow them to better understand and model CPS fishing behavior in the California Current System. Specifically, the Future Seas team identified different aspects that they need to consider when they want to model catches and harvest location choices, besides species availability. First, markets are an important component that affect landing levels and targeting. Including prices per species would capture differences in market dynamics for each species, but market orders must also be considered as a factor. Second, regulations must be considered. The level of the catch limit, as well as seasonal closures, will affect the incentives and limit harvest not only for the species in consideration but also for other species in the fishermen’s portfolios. Therefore, the Future Seas team will explore the possibility of including the quota and seasonal closure in the Future Seas economic models. Within the MSE, full attainment of the quota should not always be assumed within simulations; consideration of past and future quota attainment is relevant for CPS fisheries, and has been explored in similar analyses for Alaskan fisheries (Holsman et al. 2020). Costs were also mentioned as a relevant variable, specifically, the cost of fuel prices as it limits searching and the distance that fishermen are willing to travel to fishing grounds or truck product to producers. The Future Seas team will include fuel prices at different ports as an additional variable in the Future Seas participation and location choice models, and consider travel costs to access the fishing ground. Trucking fish to processors adds costs but may also add some flexibility to adjust to shifting stock distributions; consideration and further discussion of this option will be important in the Future Seas economic and Atlantis modeling. The next steps are to coordinate follow-up meetings with stakeholders to better understand the complexity of fishing decisions. The Future Seas team will use these inputs to guide their modeling work. Additionally, the results will be published in peer-reviewed journals as well as presented to relevant Pacific Fisheries Management Council bodies.

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Tables

Table 1. List of workshop attendees.

First name	Last name	Occupation or affiliation
INDUSTRY		
Andy	Blair	Fisherman
Ricky	Blair	Fisherman
Mark	Fina	California Wetfish Producers Association
Brian	Blake	Processor
Diane	Pleschner-Steele	California Wetfish Producers Association
Mike	Conroy	Fisheries representative
Matt	Everingham	Bait company
Mike	Okoniewski	Pacific Seafood
Ken	Towsley	Fisherman
Corbin	Hanson	Fisherman
Annie	Nehmer	Fisherman
David	Crabbe	Fisherman
Greg	Shaughnessy	Processor
Nicholas	Jurin	Fisherman
Pence	Mackimmie	Fisherman
FIRST NATIONS		
Alan	Sarich	Quinault Nation Representative
MANAGEMENT AGENCIES		
Heather	Hall	WDFW
Lorna	Wargo	WDFW
Corey	Niles	PFMC and WDFW
Greg	Krutzikowsky	ODFW
Troy	Buell	ODFW
Trung	Nguyen	CDFW
Katy	Grady	CDFW
Briana	Brady	CDFW
Kirk	Lynn	CDFW
Jessi	Doepinghause	PFMC
Taylor	Debevec	NOAA WCR
Kym	Jacobson	NOAA
Joshua	Lindsay	NOAA NMFS West Coast Region

Table 2. Researchers involved in the Future Seas Project

First name	Last name	Affiliation
PRINCIPAL INVESTIGATORS		
Desiree	Tommasi	NOAA SWFSC, La Jolla and UCSC
Isaac	Kaplan	NOAA NWFSC, Seattle
Barbara	Muhling	NOAA SWFSC, La Jolla and UCSC
CO-INVESTIGATORS		
Steven	Bograd	NOAA SWFSC, Monterey
Elliot	Hazen	NOAA SWFSC, Monterey
Michael	Jacox	NOAA SWFSC, Monterey
Stephen	Stohs	NOAA SWFSC, La Jolla
Stefan	Koenigstein	NOAA SWFSC, Monterey and UCSC
COLLABORATORS		
Peter	Kuriyama	NOAA SWFSC, La Jolla
Kevin	Hill	NOAA SWFSC, La Jolla
Brian	Wells	NOAA SWFSC, Santa Cruz
Beth	Fulton	CSIRO, Australia
James	Smith	UCSC
Jerome	Fiechter	UCSC
Juan	Zwolinski	NOAA SWFSC, La Jolla
Tim	Frawley	NOAA SWFSC, Monterey and UCSC
POSTDOCTORAL RESEARCHERS		
Robert	Wildermuth	NOAA SWFSC, La Jolla and UCSC
Pierre-Yves	Hernvann	NOAA SWFSC, La Jolla and UCSC
Felipe	Quezada	NOAA SWFSC, La Jolla and UCSC

Appendices

Appendix 1. Example output from a Google JamBoard used for small group discussion on socio-economics showcasing group responses to posed questions.

1. What changes in CPS (sardine, anchovy, squid, mackerel) distribution, timing and abundance have you observed in the past 40 years?
   a. Increase, then decrease, in sardine biomass
   b. Variation in anchovy biomass with recent large increase
   c. Substantial increase in squid in the PNW.
   d. Processor invested in Ocean Protein processing plant, with sardine biomass as main input, but has been impacted by sardine closure.

2. Characterize your fishing operation with regards to CPS as well as other species you target in terms of area, vessel size, tonnage capacity, gears used, and other characteristics.
   a. Washington, main activity now after sardine closure is the bait fishery for albacore
   b. 23-24 permits fishing for sardine when active in Oregon, short season in the later period, TAC caught in days as biomass declined. Since 2016 active market squid fishery; however, relatively few squid vessels continuously active in the squid fishery since 2016.

3. How does weather affect your operations (e.g., storms, temperature affecting storage)?
   a. PNW sardine daytime fishery larger operation in Columbia River, tidal effect important, weather affected operations, summer fishery to avoid large waves, wind important.

Appendix 2. Example output from a Google JamBoard used for small group discussion on MSE showcasing group responses to posed questions.

1. What are your goals for the fishery?
    a. Fishing is business. Needs to be profitable, and in term profitable enough for potentially expanding the operations and move up = Main Driver
    b. Goals depend on the fishers: example of different goals for a wife and a husband who are fishing together (man: profit, expansion, woman: competitivity)
    c. Uncertainty/Certainty can be a goal or an important metric for quantifying "success" of a fishery (as much as profit?)

2. How do you know if your goals are being achieved?
    a. Which temporal scale for assessing performance? Example of the previously used quarterly quotas for sardine.

3. Are the performance metrics used in past CPS MSEs reflective of these goals?
    Mean and Standard Deviation of Age 1+ Biomass
    Mean and Standard Deviation of Spawning Stock biomass
    % Biomass Age 1+ > 400,000 mt.
    Depletion (biomass in fished state/biomass in unfished)
    Mean and Standard Deviation of Catch
    % Catch < 50,000 mt
    No Catch

Appendix 3: Workshop Agenda

Future Seas Stakeholder Engagement Workshop Agenda

This workshop is organized by the Future Seas Project (https://future-seas.com/), which includes principal investigators from the National Oceanic and Atmospheric Administration (NOAA) Southwest and Northwest Fisheries Science Centers as well as academia. The project is a collaborative, interdisciplinary effort to explore potential impacts of climate change on U.S. west coast fisheries and to evaluate strategies for managing those impacts. The 2-day virtual workshop aims to:

1. Improve stakeholder understanding and awareness of Future Seas Project results up to date on climate change impacts on the California current ecosystem, with a particular focus on CPS fishery performance

3. Engage stakeholders in the CPS fishery to help us to better understand the fleet dynamics and fisheries operations to improve socio-economic models used in the project

2. Engage stakeholders in the CPS fishery to identify perceived climate-driven challenges in the fishery, the fishery's ability to adapt, and limitations on adaptation and flexibility

4. Engage stakeholders in the CPS fishery to help us advance development of the climate-informed, ecosystem management strategy evaluation via a discussion of management strategies and performance metrics

Date: November 28 and 29, 2022

Location: Virtual

Day 1

9:00-9:30am Welcome, opening remarks, introductions, overview of Google Jamboard.

9:30-10:15am Introduction to Future Seas and project and results up to date –mix of presentations and discussion

- Future Seas Project overview and why we need stakeholder input
- What climate-driven changes do we need to prepare for:
    - What are climate projections and their assumptions
    - Climate Impacts to the physics and plankton
    - Climate Impacts on CPS - sardine three ways

10:15-10:30am Break

10:30-11:00am Socio-economic modeling of the CPS fishery in Future Seas – overview of modeling approach and how stakeholder feedback will be used - presentation and discussion

11:00-11:45am Dynamics of CPS Fishing Activity discussion - small groups with Google Jamboard

Changes in target species dynamics and fishing operations

- What changes in CPS (sardine, anchovy, squid, mackerels) distribution, timing, and abundance have you observed in the past 40 years?
- Characterize your fishing operation with regards to CPS as well as other species you target in terms of area, vessel size, tonnage capacity, gears used, and other characteristics.
- How does weather affect your operations (e.g. storms, temperature affecting storage)?
- How have your CPS fishing strategies (i.e., number of sets, time of sets, location of sets, construction and deployment of nets, use of lights) changed over the same time? What changes are specific to the last decade?
- What do you perceive future challenges for your fishing operation to be, be they environmental or market driven?

Species portfolio and switching behavior

- If you target more than one CPS species, what portfolio of species do you rely on? How does this vary by month of the year?
- In addition to CPS, are there other target species you rely on? Are there fishing seasons/months that you prioritize over CPS (e.g. Dungeness crab in the Pacific Northwest?)
- What determines your decision to fish for CPS or not, in addition to market orders from processors?
- How do you decide to switch targets? What factors limit switching?
- What factors can limit your ability to fish for CPS in addition to CPS harvest limits (e.g. HABs closures, incidental catch of other species)
- If the sardine fishery reopens, do you plan to harvest sardine?
- Are there important market drivers that have influenced your fishing decisions and strategies, independent of changes in the abundance and distribution of individual species?
- Which variable cost do you consider during the decision to fish and to target a specific species?

Harvest location and port landings decisions

- What is the typical and maximum distance from port that you harvest each CPS species?
    - Does this vary by season?
    - What if fuel costs double?
- Over a fishing season how much time do you spend searching vs. fishing?
- What determines your homeport? Are you willing to relocate to another port if species availability moves from your regular fishing area during a trip?
- What factors limit moving to, or landing in, new ports?
    - Are there operational limitations (e.g., available landings facilities) to where you can land your catch?

- If you notice long-term changes in availability over your usual fishing ground, when do you permanently relocate to another port instead of switching target species?
- Are there areas that you avoid fishing in, because of regulations, currents, vessel traffic, other other hazards?

No fishing decisions

- Do you pursue any non-fishing work to supplement your income? If so, what is it?
- What factor or factors could push you to permanently exit the fishery?

11:45-12:00pm Day 1 Wrap up

Day 2 [Revised]

9:00-9:15am Welcome and overview of Day 1 discussion [Desiree]

9:15-10:00 Continue Day 1 discussion as a full group – Markets, Fishing Location, and significance of No Fishing Days, using Google Jamboard [Felipe]

10:00-10:30 am CPS ecosystem MSE: Results update and plans for future work–mix of presentations and discussion:

- Previous MSE work in the California Current
- Climate-informed research MSE, what is it? A strategic tool to assess robustness of management strategies to climate change
- Robustness of current and alternative management to climate driven changes in recruitment
- Planned future work on climate-informed ecosystem MSE with Atlantis

10:30-10:45 am Break

10:45-11:30 am Discussion– climate, management, and goals - **small groups with Google Jamboard**

- Climate vulnerabilities and management strategies What do you perceive as being the main challenges brought on by climate change to the CPS fleet?
  - Are there some barriers in adapting fisheries operations to climate change?
  - What could be some actions that might help reduce those challenges or barriers?
  - What on-the-water observations of ecosystem or stock abundance might inform harvest policies? [Mexican example from Kevin Hill– length composition]
- Performance metrics discussion in small groups with Google Jamboard
  - What are your goals for the fishery?
  - How do you know if your goals are being achieved?
  - Are the performance metrics used in past CPS MSEs reflective of these goals?
  - What is the tolerance for catches with large variation over time?

- Are there objectives related to protected species as well – is part of "good fishery performance" avoiding conflicts with protected species concerns?

11:30-11:45 Report back from small groups

11:45-12:00 pm Closing Remarks (including how/when workshop report will be provided, and results distributed) and next steps