FUTURE SEAS MSE WORKSHOP REPORT

Management Strategy Evaluation (MSE) Workshop for the NOAA OAR/NMFS Project "Future Climate Change and the California Current (Future Seas) - A Physics to Fisheries Management Strategy Evaluation"

March 28, 2018
Scripps Seaside Forum
University of California San Diego, La Jolla, CA

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Summary
A one-day management strategy evaluation (MSE) workshop in support of the NOAA funded Future Seas project was held March 28, 2018 in La Jolla, CA. Attendees included academic and government scientists as well as representatives of federal agencies (NMFS West Coast Regional Office; Pacific Fisheries Management Council), state agencies (California and Oregon Departments of Fish and Wildlife), non-governmental organizations (Monterey Bay Aquarium, Ocean Conservancy, Pew Charitable Trusts, Wild Oceans), and the sardine, swordfish, and albacore fishers (including the American Albacore Fishing Association, Western Fishboat Owners Association, and the American Fishermen's Research Foundation). The workshop began with an overview of the oceanography of the California Current followed by an introduction to the Future Seas project, including objectives, timelines, and deliverables. The bulk of the day was dedicated to discussions of issues surrounding each of three U.S. west coast fisheries – albacore tuna, sardine, and swordfish. The discussion was lively and productive and is detailed in this report. With input from all represented stakeholders, we were able to synthesize for each fishery the key management objectives, stakeholder priorities, performance metrics, and management strategies. These findings will guide the development and execution of the project and ensure that it addresses the concerns of stakeholders. While issues surrounding management of these fisheries can be contentious, attendees expressed appreciation for being involved in the early stages of the project and interest in follow-up workshops in the coming years.

Introduction
Management strategy evaluation (MSE) is a risk management tool used by fisheries scientists to assess, using computer simulations, the ability of different management rules to achieve specific management objectives. The project *"Future Climate Change and the California Current (Future Seas) - a Physics to Fisheries Management Strategy Evaluation"* led by scientists from both academia and NOAA was recently funded by NOAA's Climate Program Office (CPO) to conduct MSEs for sardine, albacore, and swordfish fisheries in the California Current. The primary objectives of this workshop were to (i) inform stakeholders of the project's objectives, methodology, proposed output, and timelines, and (ii) work together with stakeholders to identify management objectives, performance metrics, and potential management strategies for the three fisheries to be evaluated under this project. The purpose of this report is to document the discussions of proposed management objectives, performance metrics, and management strategies.

Thirty participants (Table 1) attended the workshop, including fishery managers, non-governmental organization representatives, scientists, and fishing industry representatives. G. DiNardo, the head of the Fisheries Resources Division at the NOAA Southwest Fisheries Science Center (SWFSC), welcomed workshop participants and briefly outlined the meeting objectives and expected outcomes.

1. Future Seas Project Overview

D. Tommasi presented an overview of the oceanography of the California Current System (CCS), and how climate variability strongly impacts fisheries resources, as recently experienced in the 2014-2016 marine heatwave (i.e. 'the Blob'). She stressed the importance of developing management systems that are robust to such changes and then provided an overview of the Future Seas project. The project is interdisciplinary and involves 12 principal investigators (PIs), many collaborators, and four postdoctoral researchers (Table 2), including oceanographers, climate scientists, fisheries scientists, and social scientists. The objectives of the project are to:

1. Produce regionally downscaled climate projections for the CCS, using a regional ocean model forced by output from an ensemble of GCMs.
2. Project productivity and distribution changes of marine species of interest to US fisheries in the CCS, including both target catch and bycatch species, using dynamically downscaled climate projections from a regional ocean model combined with ecological models.
3. Assess climate resilience of Pacific sardine, swordfish, and albacore tuna fisheries participants and fishing communities using the climate-informed socioeconomic models.
4. Evaluate climate resilience of current harvest guidelines for Pacific sardine and spatial management strategies for the swordfish and albacore tuna fisheries, using a management strategy evaluation framework informed by the projected changes in fish productivity and distribution.
5. Evaluate effects of possible policy and management responses to climate change impacts on the Pacific sardine, swordfish, and albacore tuna fisheries.

The timeline for the Future Seas Project is as follows:

2017-2018

- Provide full set of downscaled projections forced by one climate model
- Start development of MSE modelling framework
- Modify multispecies Individual Based Model (IBM) to include a better albacore parametrization
- Develop socio-economic models and vulnerability indices

2018-2019

- Run ecological models on downscaled projections
- Continue development of MSE modelling framework
- Run socio-economic vulnerability indices on downscaled projections
- Downscaled projections forced by multiple CMIP5 models

2019-2020

- Run MSEs on downscaled projections

The following project output is expected:

- Downscaled projections of oceanographic and biogeochemical variables
- Projections of distribution, abundance and biomass of eggs, larvae, juvenile, and adult sardine and anchovies as well as juvenile albacore tuna that enter the CCS seasonally from the western Pacific from IBM
- Projections of target catch (swordfish) and bycatch (e.g. turtles) distribution from species distribution models
- Projections of fishing community vulnerability indices
- Derived products evaluating performance of management strategies under climate change and trade-offs across metrics of interest to stakeholders

1.1 General Discussion on Future Seas Project

Participants had questions about the spatial scope of the proposed regional ocean modeling system (ROMS) configuration to be used for downscaling the large-scale climate models, particularly in relation to albacore and swordfish, which are highly migratory species and whose habitat is not restricted to the CCS domain. D. Tommasi said the ROMS goes out to about 600 nm. While it does not include the habitat experienced by albacore and swordfish throughout their lifecycle, it covers the fishing grounds in the CCS. This project aims to simulate the effects of changes in the distribution of juvenile albacore and swordfish in the CCS, not the entire North Pacific population.

Participants pointed out that in the mid 1990s albacore were going out to 180˚W, but they haven't done this in the last 12-15 years, and that in the late 1970s and 1980s it was thought that it was going to be too cold for albacore. D. Tommasi stressed that the models developed for this project would be first compared to historical data to assess their ability to capture past variability before projections to 2100 would be undertaken. Therefore, they may be useful tools to understand drivers of past variability. Such retrospective forecasts would only be run back to the 1980s due to the availability of fine-scale historical data on oceanographic conditions.

It was mentioned that D. Holland, a social scientist at the NOAA NWFSC just received NSF funding to look into fisher behavior and climate for the salmon/albacore and crab fisheries and that there may be potential collaborations. Other participants also suggested contacting M. Haltuch, also from the NWFSC who is doing an MSE for sablefish. D. Tommasi will follow up with both. Note that M. Jacox is involved in the sablefish MSE and has provided the oceanographic data used to model sablefish recruitment.

Participants suggested that there may be a need to simulate abundance in addition to the distribution of bycatch species as that would affect bycatch rates. D. Tommasi said that building a population dynamics model for each of the bycatch species is out of the scope of the project, but that different abundance scenarios for bycatch species, such as low, medium and "recovered" could be tested.

There was discussion of the type of potential economic metrics that will be incorporated into the MSE. S. Stohs said that at minimum it would include revenue flows through landings at west coast ports, community metrics based on revenue flows at ports where fishery participants live, vessel capitalization and fishery participation, and that these will be informed by market prices.

2. Introduction to Management Strategy Evaluation

D. Tommasi gave a presentation describing an MSE in general terms. She explained that it uses computer simulations to evaluate trade-offs achieved by alternative management strategies, 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. She also presented three examples of MSEs, one was the one 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), another using seasonal forecasts to inform the sardine HG (Tommasi et al. 2017), and another assessing robustness of HGs for walleye pollock to climate change (Ianelli et al. 2011). 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.

2.1 General Discussion on MSE

It was pointed out that fish stocks have evolved to be successful under current climate conditions and that such conditions may be less favorable in the future. The sardine spawning and recruitment relationship based on historical spawning grounds may not be meaningful in the future with the possibility of the stock moving, and thriving, in another location. Will such analyses be included in the project? D. Tommasi answered that in the spatially explicit IBM model recruitment is an emergent feature of the model, driven by future changes in temperature, plankton, and currents. Therefore, the IBM can be used to assess if favorable spawning habitat will move, and what the changes in the transport processes affecting sardine larvae would be. One could then assess if the current empirical environment-recruitment relationship would hold in the future.

3. Species-specific Presentations: Pacific Sardine

J. Smith provided an overview of the ecology and management of Pacific sardine in the CCS. The population consists of two stocks, north and south. The northern stock is managed by the PFMC and ranges from Mexico to Canada and to ~300 nm offshore. Larger sardine are found farther offshore and to the north. Habitat use and the range of the seasonal migration depend on stock size, with the stock expanding into Canadian waters only when population size is large. Sea Surface Temperatures (SST) of 10˚-21˚C are considered essential fish habitat for sardine. Spawning occurs in waters of 12˚-16˚C from late winter to summer with the timing depending on latitude. Sardines eat smaller plankters than anchovy and are found in more oligotrophic waters. SST, as well as chlorophyll, upwelling, eddy kinetic energy, adult condition, and the Pacific Decadal Oscillation have been found to correlate with recruitment. Sardine play a key role in the California Current marine ecosystem as forage. Many predators, however, are generalists and have been observed to switch prey to buffer against sardine declines. The fishery is managed under a permit and quota management system, with a HG controlling commercial catch of sardine biomass. The commercial fishery is currently closed because spawning stock biomass (SSB) is estimated as being below 150,000 mt. Given the effect of temperature on sardine recruitment, the sardine HG states that the fraction of sardine biomass that can be harvested is dependent on SST, with a lower fraction if SST is cooler. The management objectives for this species are outlined in the PFMC Coastal Pelagic Species Fisheries Management Plan (CPS FMP). Some that are relevant to this project are to: 1) Promote efficiency and profitability in the fishery, including stability of catch; 2) achieve optimum yield; 3) avoid discard; 4) provide adequate forage for dependent species; 5) prevent overfishing; 6) foster effective monitoring and enforcement; 7) use resources spent on management of CPS efficiently.

In this project, spatially explicit sardine dynamics in the CCS will be modeled using an individual based model (IBM) for sardine and anchovies (Rose et al. 2015, Fiechter et al. 2015) linked to a nutrient-phytoplankton-zooplankton-detritus (NPZD) model coupled to the ROMS model. The IBM also includes an agent-based fishing fleet model. This modeling framework will be used to explore how the distribution and production of sardine and anchovies might change in coming years and decades due to changes in ocean conditions and plankton, and how this may impact the economic performance of the fishery and the sustainability of fishing communities. The IBM will also be integrated in an MSE to evaluate how robust the current management strategy is to such changes and what the most resilient management strategies to this type of change may be.

3.1 Pacific sardine discussion

There was concern that sardine biomass has been so low recently when waters have been so warm, and that this may be contrary to our understanding of how SST drives recruitment and the SST rule in the HG. Would this disprove some key assumptions in the IBM? D. Tommasi answered that as part of the project we will try to better understand what caused the recent decline in sardine and update the sardine spawning stock relationship with new data including recent warm anomalies. We can also assess if the IBM would be able to capture the current decline and we will critically look at the assumptions underlying the model.

Participants mentioned that in 2017 they witnessed many species relocating. For example, there were no halibut and no juvenile salmon in surveys. Were they in low abundance or in other places? There were also odd events like observation of pyrosomes, which had not been seen in the last 40 years, and Humboldt squid coming in. J. Smith stated that such unexpected events are very hard to model since we don’t have a lot of data on these types of occurrences and that we must be cognizant of these types of uncertainties when we develop the MSE. However, we will try to test our biological models on recent anomalous conditions to evaluate how well they perform.

A participant noted that the two MSEs on sardine so far have treated biomass in the model as relative, as the goal of the exercise was to compare HGs, not to estimate actual biomass. In those cases, it was important for the PFMC to look at different ways to manage fisheries such as allowing for “popup” fisheries when abundant and maintaining a more stable fishery at lower levels. Since stability in markets is important, the PFMC has adopted a HG to try and mitigate boom-bust cycles, and their impacts on the fishery. Flooding ports with catch should also be avoided as it leads to price drops. However, the fishery is currently closed, so it would be interesting to assess why the HG is not working as well as hoped. Mangers are also interested in assessing distribution changes in the future to know how much of the stock might end up in another country’s waters.

There was a discussion on fisher behavior and what other species sardine vessels target, particularly when the sardine fishery is closed. A participant stated that in California, to lessen the impact of the sardine closure, many vessels switched to market squid. After the sardine crashed and since the anchovy price is low, the squid fishery is now more year-round. Also, if mackerel, anchovy, or tuna (if permitted) are around, sardine boats can catch those instead of sardine. Participants suggested that looking at the entire CPS assemblage would be useful, though there is less target switching in the northern CCS. J. Smith stated that it would be hard to include all the CPS in the operating model for the MSE, but that we can consider its feasibility during the upcoming PI meeting. It was also highlighted that often fisher behavior depends on price and global market forces, as most sardines are exported.

Participants stated that we should certainly test the current HG in the proposed sardine MSE, but also look at changes in distribution and its effects on ports in different states as that affects how quotas are managed up and down coast. Fleet capacity limitations vary from state to state, and it would be important to know if those will need to be adjusted in the future to optimize economic returns, in terms of both fishers and processers.

In terms of performance metrics, a participant stated that maintaining adequate forage for predators is important. It would be interesting to test if there will be future changes in the critical areas and times when CPS are critical forage for dependent species. There was mention that this metric and objective would be in contrast with socioeconomic ones, and that managers need to balance the use of sardine as forage against the commercial fishery. D. Tommasi stated that while the MSE will highlight such tradeoffs, it will be up to the mangers to weigh different management objectives.

Figure 1 summarizes the potential management objectives, performance metrics, management strategies, and stakeholders' priorities that would inform the Future Seas sardine MSE highlighted during the sardine discussion.

4. Species-specific Presentations: North Pacific Albacore

J. Smith provided an overview of the ecology and management of North Pacific albacore in the CCS. Albacore is a highly migratory species (HMS) whose habitat spans the entire North Pacific Ocean. Spawning occurs in in subtropical waters of the Western-Central Pacific Ocean. Juveniles move to temperate waters and a fraction of them uses the transition zone to migrate to the Eastern Pacific Ocean (EPO) and the CCS. Surface fleets in the EPO catch juveniles (largely 2-4 years old). Albacore mature when they reach 5-6 years of age, then move westward and southward towards spawning areas. Changes in spatial distribution and catch within the CCS and in the Western Pacific have been related to variability in temperature and chlorophyll. Being an HMS species, albacore is managed internationally by two regional fishery management organizations (RFMOs): the Inter-American Tropical Tuna Commission (IATTC) and the Western and Central Pacific Fisheries Commission (WCPFC). The stock is not overfished and overfishing is not occurring, with current SSB at 47% of unfished SSB. The albacore fishery in the CCS catches only a small fraction of total North Pacific albacore catch. It operates as an open access fishery and is most active from June to October. In some years, albacore are found in Canadian waters and a United States-Canada Albacore treaty has been in place since 1981 to allow US fishers to fish in Canadian waters and use some Canadian ports and to let Canadian fishers fish in US waters and use American ports. The management objectives for this species are outlined in the PFMC HMS Fisheries Management Plan (HMS FMP) and are to: 1) Promote and contribute to international efforts for the long-term conservation and sustainable use of HMS fisheries; 2) provide a long-term, stable supply of high-quality, locally caught fish to the public; 3) provide viable and diverse commercial fisheries and recreational fishing opportunity for HMS; 4) provide foundation to support the State Department in cooperative international management of HMS fisheries; 5) promote inter-regional collaboration in management of fisheries for species which occur in the Pacific Council's managed area and other Councils' areas; 6) prevent overfishing and rebuild overfished stocks, working with international organizations as necessary; 7) minimize economic waste and adverse impacts on fishing communities to the extent practicable when adopting conservation and management measures; 8) implement harvest strategies which achieve optimum yield for long-term sustainable harvest levels; 9) minimize bycatch and avoid discard and implement measures to adequately account for total bycatch and discard mortalities; 10) manage the fisheries to prevent adverse effects on any protected species.

In this project, spatially explicit albacore dynamics in the CCS will be modeled using a multi-species IBM with albacore, sardine and anchovy (Rose et al. 2015, Fiechter et al. 2015) linked to a nutrient-phytoplankton-zooplankton-detritus (NPZD) model coupled to the ROMS model. The existing IBM needs to be modified to better parametrize albacore feeding and movement, and the dynamics of the albacore fishing fleet. The project plans to use this modeling framework as well as statistical spatial distribution models to explore how the distribution of albacore might change in coming years and decades due to changes in ocean conditions, and how this may impact the economic performance of the fishery and the sustainability of fishing communities. The IBM will be used in an MSE to evaluate new management strategies that may lessen future negative impacts of distribution changes.

4.1 Albacore discussion

C. Barroso clarified that an IATTC resolution limits effort, defined as number of fishing days, to 2002-2004 levels. This is not very restrictive, but fishers are asked to report effort.

It was suggested that an alternative management strategy to test in the MSE could be the termination of the Treaty. However, some participants felt that explicitly looking at the Treaty may be too political. Instead, it would be interesting to look at different management strategies for the CCS: open access, limited effort, or limited catch. D. Tommasi pointed out that those management scenarios would need to be linked to a Total Allowable Catch (TAC) or Total Allowable Effort (TAE) set via the international RFMOs. D. Tommasi is currently working on a separate North Pacific albacore MSE looking at potential harvest control rules setting TACs or TAEs at an international level and that the two MSEs could be linked together. However, the focus of the Future Seas albacore MSE is on assessing climate change impacts on albacore, particularly on distribution. It would be important to test polices that would allow US fishers access to the resource in case it moves further north than its recent concentration off Oregon and Washington.

Participants stated that modeling future changes in distribution would be important also for the recreational fishery as distance from shore of the main albacore fishing grounds strongly influences participation in the recreational fishery.

There was a discussion on historical trends in albacore distribution in the CCS and it was highlighted that the model being developed for this project would need to be able to resolve past variability in distribution. In the 1970s and 1980s albacore were farther offshore and in the 1980s were also in Canada. In the 1970s the main albacore fleet was based in Southern California. Now, even when ocean conditions off California appear good, albacore don't seem to show up, but they are reliably found off Oregon every year. Some albacore fishers are still home ported in San Diego but mostly land in Westport, Washington. Also, in the last 10 years they haven't had to go outside the EEZ to fulfill their catch, which is more beneficial economically due to less time on the water reducing fuel and crew costs. As a performance metric, in addition to total US catch, one could look at catch by region/port.

In terms of socio-economic modeling, participants pointed out that 25-40% of the fleet use bait, and the rest jig. Anchovies have been abundant off OR/WA for the last 10-12 years and have been used as the main source of bait. It would be interesting to look at the overlap between anchovy and albacore and assess if that may change in the future, and what the economic impacts may be. The fleet also consists of different sizes of boats, with freezer capacity on the larger vessels. Ice-boats can only stay out 5-6 days and are more dependent on the fresh fish market. This information could potentially inform the fleet models being developed for the project.

Participants also highlighted that the fleet may be very different 30 years into the future given technology advances and increased knowledge of fish behavior. J. Sweeney stated that such changes can be simulated by increasing the efficiency of the economic production model.

Participants stated that albacore, as the only open access fishery left in the CCS, acts as an economic cushion if other fisheries are limited by local depletion or regulation. It is hard for most fishers to survive by participation in just one fishery. In the northern CCS, salmon and crab fishers switch to albacore when advantageous; in the southern CCS boats targeting swordfish switch to albacore. Such fleet dynamics portfolio strategies may need to be integrated into the simulations for the project.

Given the lack of regulations governing the albacore fishery in the CCS, it was concluded that there is more interest in modeling socioeconomics, including the socioeconomic effects of changing albacore distributions. Figure 2 summarizes the potential management objectives, performance metrics, management strategies, and stakeholders' priorities that would inform the Future Seas albacore MSE highlighted during the albacore discussion.

5. Species-specific Presentations: Swordfish

Swordfish is a highly migratory species whose habitat spans 50°S to 50°N. The portion of the swordfish population which enters into the CCS is split into two stocks, the Western/Central Pacific and the Eastern Pacific. No spawning occurs inside the US EEZ. Variability in swordfish distribution has been associated with changes in SST, bathymetry, fronts, and the structure of the water column. Swordfish are managed internationally by WCPFC and IATTC. The latest assessments for the Western/Central Pacific stock and the Eastern Pacific stock show that neither is overfished and that overfishing is not occurring. The US swordfish fishery consists of shallow-set longline, harpoon, and drift gillnet vessels. In addition, the PFMC is in the process of authorizing deep-set buoy gear as an additional method to target swordfish off the West Coast. Although no shallow-set longline is allowed within the west coast US EEZ, longline vessels permitted in Hawaii can target swordfish outside 200 nm and land it to west coast ports. The Future Seas project will focus on the drift gillnet fishery (DGN), which is allowed to operate within the west coast US EEZ subject to stringent gear restrictions and spatial closures. The DGN fishery is managed to limit bycatch of various species including leatherback and loggerhead turtles, blue shark, common dolphin, humpbacks, mola mola, and bluefin tuna. The fishery is not permitted in Washington, and to reduce the take of target and bycatch species the fishery is not permitted in the EEZ off California from February 1 to April 30. The DGN is also subject to seasonal closures in two Federal Turtle Conservation Closed Areas: the leatherback closure from August 15-November 15, and the loggerhead closure from June 1 to August 31. The management objectives for this species are outlined in the PFMC HMS FMP (see section 4 for details).

In this project, distribution of swordfish and bycatch species within the CCS will be modeled using statistical species distribution models. Such models are currently used in the EcoCast tool developed by the Environmental Research Division (ERD) at the SWFSC, Monterey. This modeling tool estimates the distribution of targeted and bycatch species of the DGN fishery to produce real-time maps of bycatch risk (http://oceanview.pfeg.noaa.gov/ecocast/). In the Future Seas project, these models will be used to assess how the distribution of swordfish and bycatch species might change in coming years and decades, due to changes in ocean conditions, and how this may impact the economic performance of the fishery and the sustainability of fishing communities. Furthermore, an MSE will be developed to evaluate the ecological and economic impacts of a range of closure types (e.g. no closure, existing static closure, dynamic closure based on EcoCast, etc.).

5.1 Swordfish Discussion

Participants pointed out that the dynamic closures can be simulated as voluntary, but that if intended to be set in an adaptive regulatory framework, the feasibility of establishing and enforcing many small closure areas must be considered. Participants enquired on what would be the timescale and persistence of closures. J. Smith stated that if fishers are not given access to EcoCast, but instead specific dynamic closure areas are defined by managers based on EcoCast, then the model would specify a minimum size and persistence that would be feasible and different sizes and timescales would be tested. Some participants felt that the potential for vessels being stuck with sudden shifts in closed areas and its economic impacts should be evaluated. Furthermore, some participants felt that the current management process may not be flexible enough to allow for the setting of such dynamic closures and that it may be best to let the fishers use EcoCast directly. EcoCast is updated daily and is a small file that fishers could access via an app or email on a daily basis. Perhaps incentives such as a hard cap (i.e. fishery is closed after a specific number of bycatch interactions) could be implemented. In Hawaii, the longline fishery is allowed a maximum of 26 leatherback and 34 loggerhead sea turtle interactions.

Participants also suggested that it would be important to test the skill of EcoCast and its persistence (i.e. how far into the future would a forecast based on a real-time EcoCast map be useful?). An analysis of this type has been conducted and a paper describing it is in review (H. Welch et al.).

Participants highlighted that before 1996 there were fewer gear regulations and therefore bycatch rates were higher. This should be considered when developing the modeling framework. Participants also noted that deep-set buoy gear may be allowed in the CCS in the future and enquired if the proposed MSE would be looking at other gears in addition to the DGN. J. Smith replied that there are very few data on deep-set buoy gear and that therefore it would be problematic to build a model for it. However, the existing EcoCast product would still be useful to predict distributions and could be tested with deep set buoy gear.

Participants suggested that an interesting socio-economic performance metric may be swordfish imports.

Participants asked if the population dynamics of bycatch species would be considered. Could the effect of a recovery in the turtle populations be evaluated? D. Tommasi stated that turtle biologists at the SWFSC can be consulted, and that different bycatch scenarios could be tested, but the initial focus would be to build bycatch models based on historical bycatch rates.

Participants concluded that three potential spatial management strategies could be looked at: 1) Provide EcoCast to fishers with no requirement to use it; 2) same as 1 but with hard caps; 3) current static closure. Figure 3 summarizes the potential management objectives, performance metrics, management strategies, and stakeholders' priorities that would inform the Future Seas albacore MSE highlighted during the swordfish discussion.

6. Concluding Remarks

Organizers thanked all the participants for coming and for the engaging discussions. The meeting will be very useful in informing the upcoming model and MSE framework development. Participants thanked the organizers and highlighted the importance of involving stakeholders at the beginning of the project as the exchange of information is useful both ways. They also expressed interest in a follow-up meeting next year. PFMC representatives asked the project team to keep the PFMC briefed and up to date throughout the project, and stated that there would be interest in the project team giving a presentation to the PFMC sometime in March, June, or September of next year.

References

Hurtado-Ferro F, Punt A (2014) Revised analyses related to evaluating parameter value choices for Pacific sardine. Pacific Fishery Management Council, Portland, OR.

Ianelli JN, Hollowed AB, Haynie AC, Mueter FJ, Bond NA (2011) Evaluating management strategies for eastern Bering Sea walleye pollock (*Theragra chalcogramma*) in a changing environment. ICES Journal of Marine Science 68: 1297–1304.

Fiechter J, Rose KA, Curchitser EN, Hedstrom KS (2015) The role of environmental controls in determining sardine and anchovy population cycles in the California Current: Analysis of an end-to-end model. Progress in Oceanography 138: 381-98.

Rose, KA et al. (2015) Demonstration of a fully-coupled end-to-end model for small pelagic fish using sardine and anchovy in the California Current. Progress in Oceanography 138: 348–380.

Tommasi D, Stock C, Pegion K, Vecchi GA, Methot RD, Alexander M, Checkley D (2017) Improved management of small pelagic fisheries through seasonal climate prediction. Ecological Applications 27: 378-388.

Tables and Figures

Table 1. List of workshop participants.

First name	Last name	Affiliation
Celia	Barroso	NOAA Western Regional Center (WRC)
Steven	Bograd	NOAA Southwest Fisheries Science Center (SWFSC)
Briana	Brady	California Department of Fish and Wildlife (CDFW)
Travis	Buck	CDFW
Mike	Conroy	American Albacore Fishing Association (AAFA) and sardine fisheries representative
Paul	Crone	SWFSC
Heidi	Dewer	SWFSC
Kit	Dahl	Pacific Fisheries Management Council (PFMC)
Gerard	Di Nardo	SWFSC
Chuck	Farwell	Monterey Bay Aquarium
Peter	Flournoy	Western Fishboat Owners Association (WFOA) and American Fishermen's Research Foundation (AFRF) representative
Doug	Fricke	Albacore commercial fisherman
Elliott	Hazen	SWFSC
Elizabeth	Hellmers	CDFW
Mark	Helvey	Retired SWFSC
Kevin	Hill	SWFSC
Theresa	Labriola	Wild Oceans
Joshua	Lindsay	NOAA WRC
Arthur	Lorton	Swordfish/albacore commercial fisherman
Kirk	Lynn	CDFW
Gillian	Lyons	Pew Charitable Trusts
Sam	McClatchie	SWFSC
Barbara	Muhling	SWFSC and University of California Santa Cruz (UCSC)
Trung	Nguyen	CDFW
Corey	Ridings	Ocean Conservancy
Rose	Runcie	SWFSC
Cyreis	Schmitt	Oregon Department of Fish and Wildlife
James	Smith	SWFSC and UCSC
Stephen	Stohs	SWFSC
Jonathan	Sweeney	SWFSC and UCSC
Steve	Teo	SWFSC
Desiree	Tommasi	SWFSC and UCSC
Heather	Welch	SWFSC and UCSC
Deb	Wilson-Vanderberg	CDFW

Table 2. Researchers involved in the Future Seas Project

First name	Last name	Affiliation
PRINCIPAL INVESTIGATORS		
Mike	Alexander	NOAA Earth System Research Laboratory (ESRL)
Steven	Bograd	NOAA SWFSC, Monterey
Enrique	Curchitser	Rutgers University
Christopher	Edwards	UCSC
Jerome	Fiecther	UCSC
Elliott	Hazen	NOAA SWFSC, Monterey
Amber	Himes-Cornell	FAO, Rome
Mike	Jacox (Lead PI)	NOAA SWFSC, Monterey and NOAA ESRL
Barbara	Muhling	NOAA SWFSC, La Jolla and UCSC
Ryan	Rykaczewski	University of South Carolina
Stephen	Stohs	NOAA SWFSC, La Jolla
Desiree	Tommasi	NOAA SWFSC, La Jolla and UCSC
COLLABORATORS		
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Alan	Haynie	NOAA Alaska Fisheries Science Center (AFSC)
Alistair	Hobday	Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia
Anne	Hollowed	NOAA AFSC
Kirstin	Holsman	NOAA AFSC
Justin	Hospital	NOAA Pacific Islands Fisheries Science Center (PIFSC)
Charles	Stock	NOAA Geophysical Fluid Dynamics Laboratory
POSTDOCTORAL RESEARCHERS		
Stephanie	Brodie	NOAA SWFSC, Monterey and UCSC
Mercedes	Pozo Buil	NOAA SWFSC, Monterey and UCSC
James	Smith	NOAA SWFSC, La Jolla and UCSC
Jonathan	Sweeney	NOAA SWFSC, La Jolla and UCSC
PROJECT SPECIALIST		
Heather	Welch	NOAA SWFSC, Monterey and UCSC

Figure 1. Highlights of discussion on sardine.

SARDINE:

1. Management Objectives / Stakeholder Priorities

- Management objectives as specified in Fishery Management Plan (FMP)
- Importance of stability of catch
- Fishers pointed out importance, in highly variably CPS fisheries, of being able to switch between what is available. Many sardine vessels switch to market squid when sardine TAC is low.
- Value of CPS as forage for other commercial species

2. Performance Metrics

- All those used in previous MSEs for Pacific sardine: mean and variability of catch and biomass, number of times biomass or catch are above specific thresholds, number of times catch is 0
- Ecosystem performance metrics. Availability during critical time/space for upper trophic levels
- Socio-economic metrics (e.g. revenue flows, fishery participation indices)

3. Management Strategies

- Status quo HG
- Consideration of different methods of integrating temperature-recruitment relationship in the management procedure
- HG with TAC based on CPS assemblage

Figure 2. Highlights of discussion on albacore.

ALBACORE:

1. Management Objectives / Stakeholder Priorities

- HMS FMP and those developed for the international albacore MSE
- Albacore as "insurance" fleet. As no limited entry serves to sustain fishers when other are curtailed
- Understanding migration dynamics, how number of juveniles in CC relates to the overall population
- Understanding past changes in distribution, offshore-inshore as well as north-south
- Albacore now eating anchovies. Anchovy used as bait so importance of assessing availability of anchovies

2. Performance Metrics

- Those developed for the international albacore MSE
- Catch by port
- Socio-economic metrics (e.g. revenue flows, fishery participation indices)

3. Management Strategies / Scenarios

- Management happens at international level (no international TAC/TAE but some being tested in international MSE)
- Given a TAC/TAE, test different management scenarios of how that is allocated to the CC fleet
- How will changes in albacore distribution impact the fishery, with a focus on the socio-economics of the fishery

Figure 3. Highlights of discussion on swordfish.

SWORDFISH:

1. Management Objectives / Stakeholder Priorities

- Management objectives from HMS FMP
- Consideration of impact on bycatch species other than turtles: striped marlin, bluefin, marine mammals
- Consideration of economic and ecological impacts of using dynamic rather than static closures – EcoCast may have the potential to recover profitability of the fishery
- Consideration of ecological and economic benefits of different swordfish gears

2. Performance Metrics

- Bycatch rates
- Impact of bycatch on overall turtle population
- Socio-economics (e.g. revenue flows, fishery participation indices, swordfish imports)

3. Management Strategies / Scenarios

- Static closure
- Fishers have EcoCast but no management constrain
- Fishers have EcoCast but subject to hard cap
- In season management with closures based on EcoCast, explore size/timing of closures

Appendix A: Workshop Agenda

AGENDA

Management Strategy Evaluation (MSE) Workshop for the NOAA NMFS/OAR Project “From Physics to Fisheries: A Social-Ecological Management Strategy Evaluation for the California Current Large Marine Ecosystem”

This is a meeting hosted by the National Oceanic and Atmospheric Administration (NOAA) Southwest Fisheries Science Center. This workshop aims to inform stakeholders of the project’s objectives, methodology, proposed output, and timelines. It also aims to work together with stakeholders to identify management objectives for the fisheries to be evaluated under this project, namely Pacific sardine, albacore, and swordfish.

Ted Scripps II Room
Scripps Seaside Forum
University of California San Diego
8610 Kennel Way, La Jolla, CA 92037

9:00am	Welcome, opening remarks, workshop goals and outputs, introductions
9:30am	Overview of project’s objectives, methodology, proposed output, and timelines
10:20am	Coffee Break
10:30am	“What is a management evaluation strategy?” presentation with emphasis on MSEs to be developed for this project
11:00am	Discussion and identification of management objectives for the Pacific sardine fishery
12:30pm	LUNCH
1:30pm	Discussion and identification of management objectives for the albacore fishery
3:00pm	Coffee Break
3:10pm	Discussion and identification of management objectives for the swordfish fishery
4:40pm	Review of workshop outputs and closing remarks
5:30pm	Adjourn