August 15-17, 2022
Hosted by NPFMC
Sitka, Alaska

SCS7
ADAPTING FISHERIES MANAGEMENT TO A CHANGING ECOSYSTEM

Seventh National Meeting of the Scientific Coordination Subcommittee of the Council Coordination Committee

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Sitka, Alaska

FOREWORD DR. ANNE HOLLOWED, SCS7 CHAIR, NPFMC SSC CHAIR EMERITUS

Anne Hollowed, SSC7 Chair

The SCS7 meeting, focused on "Adapting Fisheries Management to a Changing Ecosystem", comes at a time of increased urgency for fishery scientists and managers to take action now and for Fishery Management Councils to position themselves for serious management challenges. We are already witnessing examples of climate-forced shifts in distribution and abundance; competing uses of marine ecosystems; and changes in ecosystem structure and function that are all impacting fishing sectors and communities.

This theme for SCS7 built on recommendations of the six previous national meetings (Table 1). Previous meetings addressed topics that Scientific and Statistical Committees (SSCs) have been dealing with in their effort to improve scientific advice in support of sustainable fisheries management. We need to recognize, however, that there have been substantive changes since the last SCS meeting in 2018. While we certainly knew about climate change in 2018, for many of us in the high latitude ecosystems, impacts of climate change are now being felt. For all regions, there is growing recognition, supported by recent reports of the Intergovernmental Panel on Climate Change, that the implications will be apparent on other systems also, and that this issue is becoming more and more relevant for all of us.

In the four years since the last SCS meeting, assessment methods have advanced tremendously, particularly in the development of ecosystem-linked assessments and climate-informed risk assessments. These science products are much more mature than they were four years ago, and the next challenge will be to see how they can be used not just to explain the past, but also how to understand carrying capacity, management units, and adaptation options for setting biological reference points into the future. Positioning the Fishery Management Councils to respond to this challenge requires investment in data collection, process studies, and modeling; clear and two-way communication among regions and with stakeholders; and creative and adaptive approaches to finding an equitable management pathway to deal with change.

This SCS7 meeting has highlighted the need to start now with scenario planning for climate futures. I look forward to hearing about how these challenges are taken up by the Fishery Management Councils and at future SCS meetings

INTRODUCTION

The Scientific Coordination Subcommittee convened the 7th national meeting of the Scientific Coordination Subcommittee (SCS7). The North Pacific Fishery Management Council hosted this meeting in Harrigan Centennial Hall on August 15-17, 2022 in Sitka, Alaska. The overarching focus of SCS7 was "Adapting Fisheries Management to a Changing Ecosystem", building on recommendations of the six previous national meetings (Table 1). Participants in SCS7 discussed three primary foci:

- How to incorporate ecosystem indicators into the stock assessment process?
- Developing information to support management of interacting species in consideration of Ecosystem Based Fisheries Management (EBFM).
- How to assess and develop fishing level recommendations for species exhibiting distributional changes?

As in previous meetings, each discussion theme was introduced by an invited keynote speaker followed by a series of contributed talks describing regional case studies. Extended abstracts from each keynote speaker are included in this report. The list of presenters and abstracts for each case study can be found in the appendices. Although the primary purpose of the meeting was to provide coordination across Fishery Management Council Scientific and Statistical Committees (SSCs), members of the public were welcome to listen to the plenary discussions. Additionally, the meeting was streamed for on-line viewing.

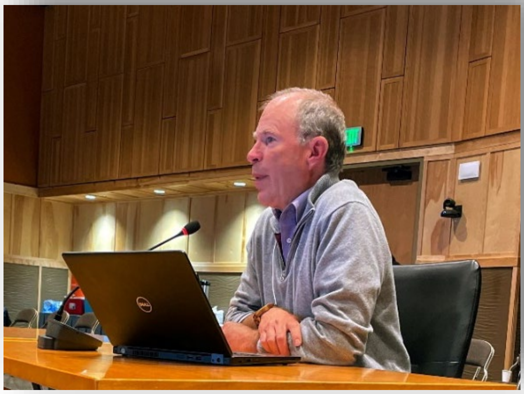
For SCS7, five breakout groups were assembled for each session. Each breakout group included representatives from a cross-section of the Councils. This approach fostered cross-communication and synthesis on each theme. Key findings from each breakout group were presented in plenary and similarities and differences between groups were discussed. To focus the discussions, meeting organizers developed a suite of topic-relevant trigger questions for each breakout group. This report provides a synthesis of the discussions and the recommendations emerging therefrom.

Table 1. Date, host and focus of previous SCS meetings.

SCS	Year	Host	Focus
1	2008	WPFMC	Developing Best Practices for SSCs
2	2009	CFMC	Establishing a Basis for Annual Catch Limits
3	2010	SAFMC	ABC Control Rule Implementation and Peer Review Procedures
4	2011	MAFMC	Ecosystem and Social Science Considerations in U.S. Fishery Management
5	2015	WPFMC	Providing Scientific Advice in the Face of Uncertainty
6	2018	PFMC	The Use of Management strategy evaluation to Inform Decisions Made by the Regional Fishery Management Councils
7	2022	NPFMC	Adapting Fisheries Management to a Changing Ecosystem

OPENING REMARKS

Bill Tweit, NPFMC Vice Chair



Bill Tweit, NPFMC Council Member, gives the opening remarks

On behalf of the North Pacific Council family, I'm pleased to be able to finally welcome you to SCS7 in Sitka, for the long overdue conversation about adapting fisheries management to a changing ecosystem. I appreciate the opportunity to contribute from my perspective as a Council member. Please keep in mind that these are my thoughts, and are neither Council nor agency policy or perspective.

Climate change is real, it is changing ecosystems now, and those changes bring us into a world of greater uncertainty. I get it. My fellow Council members get it, and I'm certain regional fishery management Council members across the nation get it. We are facing new challenges, challenges that have an intensity that we are not used to. Using my region and my Council as an example, we are experiencing:

- Conflicts between the moral imperative to protect cultures and people who depend on a subsistence way of life and our mission to provide sustainably harvested seafood to our nation.
- Rapid changes in distribution and population size that fall well outside of our collective experience, changes that cannot be incorporated in our current suite of tools that reflect decades of stationarity and stability in our ecosystems.
- The very real possibility that some species in the fishery may decline permanently to levels that will not support robust harvest.
- Elevated scrutiny of bycatch and of the impact that various fishing gears have on the ecosystem, is one aspect of increased social conflict, as that scrutiny is expressed as "us vs them". We don't appear to be coalescing to address these new challenges collectively; we appear rather to be fragmenting to protect our individual livelihoods.

So, allow me to suggest what our critical needs are at this point.

- Most Council members and stakeholders don't have a strong understanding of the limitations of our current tools for decision-making in this new environment. Until we understand that, we will continue to rely on our current tools, as they have served us very well.
- Our tendency to rely on the tried-and-true management tools is also based on our experience with litigation, a common concern across Councils. Our current tools generally are defensible; in that they have withstood legal challenges. There is a concern that new tools and approaches will become the subject of new legal challenges, and until they have been tested and proven, the reluctance to adopt them will continue.
- We don't understand very well how an ecosystem-based approach to management will help, although I think most of us have an intuitive understanding that it is preferable. Transitioning to ecosystem-based management is going to be challenging, consuming a lot of Council's scarce

resources. With the urgency of the crises associated with climate change making that transition will be more challenging.

- We aren't conversant yet, much less proficient, with the use of tools that help us make decisions in the face of greatly increased uncertainty and risks, and the vocabulary of risk-based management is a foreign language for many of us, with its descriptions of probabilities of outcomes and alternative scenarios for the future. Until we have had some successes and failures at using new approaches for setting fishery limits, Councils will continue to struggle with managing fisheries in the context of rapidly changing ecosystems.

The three topics that SCS7 is addressing are very relevant to meeting these needs, and as I think you are already aware, none of them are simple.

- The choice of ecosystem indicators for use in management is a social issue as well as a scientific issue. In the North Pacific, as we begin to consider indicators, we are learning that the wide range of ecosystem services we depend on will translate directly into a wide range of ecosystem indicators, generating tension and sometimes conflict around the choice of indicators.
- Similarly, the impacts of changing species interactions are felt differently by different cultures and fishing sectors. As we all are aware, change creates new "winners and losers'' in the ecosystem, including in fishing communities. We have also become aware that our historical time frame for understanding species interactions is often very short, less than a half century in many cases. In order to gain a longer-term perspective, and to gain the perspective of other cultures, the North Pacific Council is working to integrate the traditional ecological knowledge held by the indigenous peoples in our region into our management process. Accomplishing that in a respectful manner is a learning process, and takes time, which is difficult when the issues are urgent.
- Finally, to the third topic, I would recommend that the SCS7 consider this as a problem of transitioning from fishery management frameworks that are built on assumptions of stationarity and stability to management frameworks that can support sustainable exploitation in the face of significantly increased uncertainty. In my remarks, I have already described some of the difficulties with that endeavor. As the science community tackles this, please remember that as much thought must be given to implementation, communication and defensibility as will be given to development. It does us little good to develop new management frameworks if Councils are uncomfortable implementing them, if stakeholders and Councils cannot understand them, and if they cannot be defended against the attacks that we know will ensue.

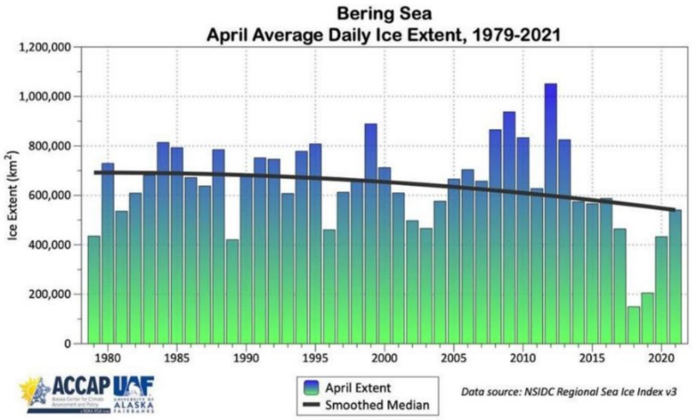
It's a lot to ask, but the science community in our nation's fishery management process is the right group to tackle it. I am really looking forward to the SCS7 discussions; they could not be more important or timely.

Robert Foy, NOAA AFSC, NPFMC SSC Member

Dr. Robert Foy, Director of the NOAA Fisheries Alaska Fisheries Science Center, provided opening remarks to welcome the SSC delegates and a snapshot of some of the recent extreme climate-forced fishery changes occurring in the North Pacific. He then posed some challenges to be addressed by the Regional Fishery Management Councils (RFMCs) and regional science centers as they consider how to adapt to changing ecosystems. These include:

Bob Foy, NPFMC SSC Member

1. **Planning and predicting for resilience.** Can we manage over longer time periods (e.g., 5–10 years) instead of 1–2 year time frames? The Alaska Climate Integrated Modeling Project and the Climate Ecosystem Fisheries Initiative are poised to improve predictive capacity relative to regional climate trends.
2. **Identify balanced science portfolios.** Surveys and stock assessments need to be supported and complemented with adequate focus on process studies, socio-economic research, and ecosystem modeling to be able to adapt management to a changing environment.
3. **Incorporate innovative data collection.** NOAA Fisheries Next Generation Data Acquisition Plan identifies new requirements to adapt data collection. These include improved collaborative data collection, electronic monitoring, UxS, and new molecular techniques (e.g., genomics, Fourier Transform-Near Infrared Spectroscopy).
4. **Improve overall equity in science and management.** Considering data that represents all fishery sectors and communities will improve representation in the information provided to managers for decision making. Examples of existing products that include information beyond standard survey and assessments are: Annual Community Engagement and Participation Overview, Gulf of Alaska Climate Integrated Modeling, Integrated Ecosystem Assessments, and Social Vulnerability Indicators.



Example of climate changes occurring in the North Pacific: Average Daily Ice Extent in the Bering Sea in April, 1979-2021

FOCUS SESSION 1
How to incorporate ecosystem indicators into the stock assessment process?

NOAA Fisheries has a long legacy of research focused on fish and fishery responses to environmental drivers. More recently, analysts have worked to compile suites of ecosystem indicators into ecosystem status reports (ESRs). This session focused on approaches to incorporate ecosystem indicators into the stock assessment process. The session also focused on understanding ecosystem dynamics and how insights from modeling can best inform stock assessments and resulting management decisions. For example, changing environmental conditions may affect vital population parameters (e.g., recruitment, mortality, growth) and the availability of fished species to survey or commercial fishing gear (catchability). Changes in these parameters can greatly affect the assessment of stock status and biological reference points. This theme session also explored the current and future utility of ensembles or multi-model inference in the assessment and management process.

Several attendees gave presentations under focus session 1:

- Keynote 1: André Punt: *Including ecosystem information in assessments and management advice*
- Keynote 2: Sarah Gaichas: *Using Ecosystem Information in the Stock Assessment and Advice Process*
- Case Study 1: Cody Szuwalski: *The collapse of snow crab: what happened and what now?*
- Case Study 2: Melissa Haltuch: *Using climate data to improve sablefish assessment model projections*
- Case Study 3: Brendan Runde: *Poor recruitment of reef fishes in the southeast United States Atlantic: preliminary findings and implications for management*
- Case Study 4: Kristin Marshall: *Inclusion of ecosystem information in U.S. fish stock assessments: progress toward ecosystem-based fisheries management?*
- Case Study 5: Yan Jiao: *Using nonstationary stock assessment models to diagnose meaningful ecosystem indicators*
- Case Study 6: David Chagaris: *Accounting for red tide mortality in stock assessments and management projections in the Gulf of Mexico*
- Case Study 7: Lisa Kerr: *Integrating ecosystem and climate influences on dynamics of New England stocks into stock assessment*

Keynote 1: Including ecosystem information in assessments and management advice

André E. Punt
School of Aquatic and Fishery Sciences, University of Washington, Seattle, WA

Introduction

A fundamental assumption of fisheries science has been the notion of stationarity. A system is said to be stationary if it is not possible to determine, based on values alone, which of two sets of observations of the system occurred first. Less formally, it implies that key parameters of a population such as natural mortality, growth and recruitment are time-invariant (or any variability has no direction). Additional data collection in a stationary system will, if the model of the system is not mis-specified, lead to more precise estimates of the parameters governing the system dynamics over time. However, it is increasingly becoming obvious that the assumption of stationary is violated, with evidence now convincing for regime-shifts in recruitment (e.g., Szuwalski et al., 2015), and for changes in spatial distributions, usually poleward (e.g., Perry et al., 2005).

The consequences of time-variation in the parameters of the models on which fisheries management advice are based (and hence estimated productivity) can be substantial, especially when parameters exhibit trends rather than simply varying without trend. These consequences necessitate changes to the way stock assessments are conducted and management advice is provided. This talk highlighted approaches for modifying stock assessments and harvest control rules in the face of variation in parameters caused by the environment, recognizing that errors, for example due to incorrectly attributing changes over time in parameter values to environmental factors, may be nontrivial.

Stock assessment

It is likely that there will be no ability to account for environmental change on stock dynamics for the bulk of the world's fisheries given that there are insufficient data to conduct a stock assessment for most stocks, let alone account for changes over time in parameter values. For such stocks, simply obtaining a rough measure of biomass and application of a harvest control rule that is likely robust to changes in stock productivity should be considered best practice. The Terms of Reference for stock assessments for those stocks that have sufficient data to conduct an assessment should include examination of the evidence for time-variation in growth (i.e., length-at-age and weight-at-age), selectivity, catchability and mean recruitment. Time-variation in natural mortality can be estimated within single-species assessments (e.g., Zheng and Siddeek, 2020), but care needs to be taken not to allow for time-variation in natural mortality to "solve" a problem caused by time-variation in a different parameter (Szuwalski et al., 2018).

In principle, environmental and climate effects can be accounted for in assessments by adopting climate-enhanced single- and multi-species stock assessments. However, it is generally the case that environmental variables provide 'weaker' information on changes in parameters than the standard data (e.g., age-composition, weight-at-age) used in assessments so the major benefits of integration of environmental variables into stock assessments is to enable estimation of parameters before and after the years for which the standard data already inform these parameters (e.g., Lee et al., 2018). In contrast, effects of changes in, for example, temperature on population dynamics parameters, especially estimates of recruitment, could be substantial for assessments based on multi-species stock assessment methods such as the Climate-Enhanced Age-based model with Temperature specific Trophic Linkages and Energetics (CEATTLE; Holsman et al., 2016) model, as they would change estimates of consumption. However, adoption of assessments based on frameworks such as CEATTLE are not without their problems, including that there are multiple ways to define Maximum Sustainable Yield (MSY) within multi-species models.

Management systems, including harvest control rules

The Magnuson-Stevens Act already recognizes that biological parameters vary over time by defining MSY as "the largest long-term catch or yield that can be taken from a stock or stock complex under prevailing ecological and environmental conditions". Nevertheless, climate change will lead to a need to reconsider the targets and limits for biomass and fishing mortality, to re-evaluate the desired trade-offs among the management objectives, likely coupled with an expanded set of objectives, and to develop new approaches to address the consequences of changes in the spatial distributions of stocks.

Short-term considerations: modifications to existing harvest control rules

There are four general ways to address time-variation in parameters when applying harvest control rules: (a) calculate reference points such as F_{MSY} and B_{MSY} based on moving averages for weight-at-age, selectivity-at-age, mean recruitment, etc., so that older (and likely less representative) data are given increasingly less weight, (b) calculate reference points based on averages for the "most recent regime", (c) use the dynamic B_0 approach (MacCall et al., 1985; Berger, 2019) to specify biomass reference points, and (d) base harvest control rules on models that explicitly include predictions of time-varying parameters based on some environmental covariates. However, only the first two of these approaches are used regularly at present, although the Overfishing Level for the northern sub-population of Pacific sardine (*Sardinops sagax*) has been based on a harvest control rule that relates F_{MSY} to sea surface temperature for many years (e.g., Kuriyama et al., 2020) and Bentley et al. (2021) recently advocated a threshold harvest control rule in which F_{MSY} is linearly related to the value of an environmental variable.

> *Essentially, what you have there is if you assume stationarity in the absence of stationarity, not only do you not get unbiased estimates, having more data actually makes things potentially worse. AND non-stationarity is going to be our future.*
>
> *Andre Punt*

Basing reference points on the current regime or using the dynamic B_0 approach can have consequences that can be non-intuitive. For example, it was concluded from various lines of evidence that the average unfished recruitment,

R_0, for jackass morwong (*Nemadactylus macropterus)* off southeast Australia had dropped around 1988 (Wayte, 2013), and allowing for a change (reduction) in R_0 in 1988 led the stock assessment authors to conclude that the stock was no longer below the limit reference point but rather in the 'precautionary zone', implying that fishing could continue on a stock that was estimated to be a very small fraction of its historical biomass. This led, unsurprisingly, to criticism from a conservation viewpoint (e.g., Edgar et al., 2018). Similarly, a dynamic B_0 approach can lead to increased fishing mortality if changes in productivity are attributed (perhaps incorrectly) to the environment (Bessel-Browne et al., 2021). Although there are guidelines when to 'call' a regime shift (Klaer et al., 2013), they have been seldom applied and warrant review given what has been learnt about environmental impacts on populations and marine systems during the last decade.

The use of multi-species and ecosystem models as the basis for harvest control rules appears to be a currently unattainable goal. However, Howell et al. (2021) provide an intermediate option whereby an ecosystem model and an ecosystem indicator are used to calculate the desired change in the single-species target fishing mortality rate, which is then fed into a harvest control rule supported by a single-species stock assessment. The approach of Howell et al. (2021) is pragmatic in the sense that the assessment on which management advice is based is the conventional single-species assessment and has all the benefits (and dangers) associated with a well-developed analytical framework, but also accounts for broader ecosystem considerations.

Although it seems intuitive that allowing for ecosystem considerations in harvest control rules is desirable, doing so is not guaranteed to lead to improved management outcomes (Punt et al., 2014), and such allowance needs to be explicitly evaluated using Management Strategy Evaluation. However, it does appear that it is better to allow for time-variation in some parameters even when this is not needed (as long as the parameters determining the effect of the associated environmental covariate are estimated) rather than ignoring time-variation in parameters when this is actually the case (e.g., Ianelli et al., 2011).

Longer-term considerations: Strategic evaluations

Management strategy evaluation (MSE; Punt et al., 2016) is considered state-of-the-art when conducting strategic evaluations because it is able to examine many uncertainties and take into account the feedback loop between data collection and assessment and the population dynamics. MSE involves constructing a set of models of the system being managed (operating models), parameterizing these models based on the data available for the system, projecting each operating model forward based on each of a set of candidate operating models and summarizing the results using a set of performance statistics chosen to capture the objectives identified by stakeholders and decision makers. It has been recognized for over twenty years that the operating models on which MSEs are based could involve time-variation in parameters (Sainsbury et al., 2000), including because of environmental and climate drivers, and be based on extended single-species models as well as multi-species / ecosystem models. Moreover, the performance statistics could include those related to broader ecosystem considerations in addition to those related to the target species.

However, to date inclusion of environmental variables in operating models, particularly those based on extended single-species models, has been somewhat haphazard, raising the possibility that relationships based on spurious correlations could be included in operating models and hence drive the selection of management strategies. There is consequently a need to develop a formal scheme for doing this. One such scheme would be:

- identify parameters that may be time-varying (at least in principle);
- identify hypotheses that have been postulated / speculated / tested linking

environmental variables to these parameters;

- remove environmental variables that cannot be hind- and forecasted; and
- fit the operating model to the data to quantify the relationships between the environmental covariates and the parameters.

It is well known that the results of ecosystem-based MSEs can differ markedly depending on which processes are included in the operating model as well as the structure of the operating model. Consequently, there is an increasing recognition that ecosystem-based MSEs will need to involve multiple alternative operating model structures (e.g., ranging from extended single-species models to ecosystem models) and alternative climate models and scenarios. The ACLIM (the Alaska Climate Integrated Modeling) program (Hollowed et al., 2020) aims to achieve this goal by developing a set of models to project climate-driven changes for the eastern Bering Sea ecosystem, from physics to fishing communities. Ensemble modeling approaches (e.g., Reum et al., 2020) will be used to summarize the results. The project will quantify climate impacts on growth and condition, survival and abundance, food web dynamics and fish and fleet distributions to make inferences regarding future Total Allowable Catches and biomass, allocation and value, ecosystem structure, and community well-being. The project is highly interdisciplinary involving oceanographers, fishery biologists, biological modelers, economists and social scientists.

Harvest control rules of the ‘threshold’ type whereby the target fishing mortality is constant when biomass exceeds a threshold biomass level, zero below a biomass limit reference point and changes linearly between the threshold and limit biomass are now widely adopted to support decision making. However, some studies (e.g., Kell et al., 2005; Parma et al., 2013) suggest that threshold harvest control rules may perform poorly given changes in productivity and that harvest control rules based only on fishing mortality reference points may perform better. This highlights that biomass-based methods of status determination such as whether a stock is overfished or not may be more difficult to interpret in the face of environmentally-driven productivity.

Final thoughts

Overall, it is clear that analysts, managers and stakeholders should recognize that environmental change will impact population dynamics more in the future than in the past, and where possible, the default for developing harvest control rules and management plans should be the presumption of non-stationary dynamics. This will require consideration of operational mechanisms to allow reference points to change over time as well as increased uncertainty in estimates of the quantities on which management advice is based, particularly those related to medium- and long-term forecasts, including rebuilding projections.

The ideas outlined above will lead to more complex models and likely management frameworks. Increased training to ensure that agencies such as NOAA have the capacity to implement them is clearly a priority. Moreover, the new models and management frameworks will require enhanced (and nimble) data collection systems. In addition, it will be necessary to re-imagine the frameworks used to evaluate alternative management systems, in particular those that involve multi-species / ecosystem assessment models and HCRs given the difficulties of interpreting traditional reference points in a non-stationary world.

Finally, approaches such as the ACLIM program necessarily involve interdisciplinary work and there is consequently a need for much expanded collaboration networks, for example among oceanographers, biologists, modelers, economists, social scientists and communication specialists.

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Keynote 2: Using Ecosystem Information in the Stock Assessment and Advice Process

Sarah Gaichas

Northeast Fisheries Science Center, Woods Hole, MA

Introduction

The US defines EBFM as:

A systematic approach to fisheries management in a geographically specified area that contributes to the resilience and sustainability of the ecosystem; recognizes the physical, biological, economic, and social interactions among the affected fishery-related components of the ecosystem, including humans; and seeks to optimize benefits among a diverse set of societal goals. (NOAA Fisheries EBFM Policy)

To use ecosystem information in assessment and management processes, *a systematic approach* is required. Examples of systematic approaches to use ecosystem information in current stock assessments, in ABC determination, and in building new multispecies and system level decision processes are presented here. While these examples of SSC and Council processes come mainly from the Mid-Atlantic Fishery Management Council (MAFMC), many more examples exist from throughout the US.

Ecosystem and Socioeconomic Profiles: a systematic approach for stock assessments

Ecosystem and Socioeconomic Profiles (ESPs) were pioneered in Alaska (Shotwell et al. 2022), although similar approaches have been implemented in multiple regions (Tolimieri et al. 2018; Haltuch et al. 2020). In general, the approach begins with a problem statement based on previously observed assessment issues combined with a stock life history conceptual model highlighting key ecosystem interactions with each life stage based on scientific literature, stakeholder knowledge, or both. Then, ecosystem indicators associated with the key interactions are developed and analyzed. Finally, the stock specific ecosystem information is summarized and reported within the same management review process as the stock assessment itself.

A systematic approach to using ecosystem information in stock assessments may result in direct quantitative incorporation of new data within stock assessments (Miller et al. 2016), and or may result in a more qualitative assessment of ecosystem risk factors presented along with the assessment (Dorn and Zador 2020). Both uses allow managers to take relevant ecosystem information into account when making decisions about stock management. For example, the MAFMC SSC ABC determination process currently uses multiple information sources.

MAFMC SSC advice process: a systematic approach for ABC determination

Both stock and ecosystem level information can be used to inform scientific advice delivered by SSCs to Councils. For example, the MAFMC SSC has developed a systematic approach to

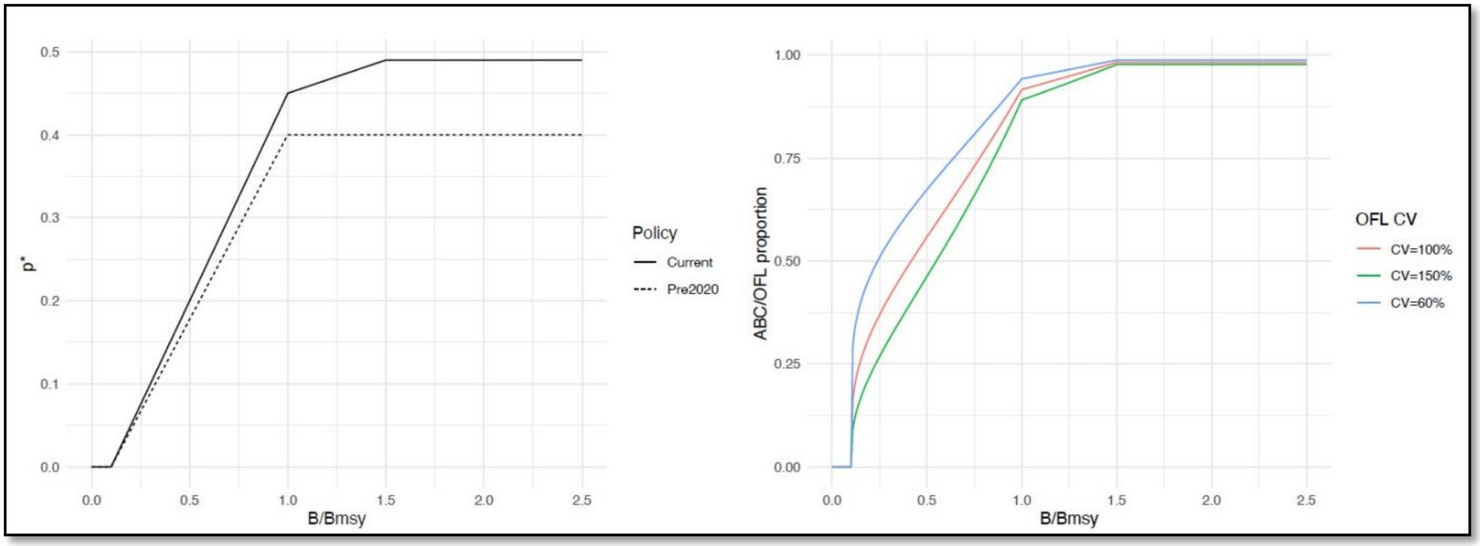

Figure 1: MAFMC risk policy (left) and the Acceptable Biological Catch (ABC) proportion of Overfishing Level (OFL) given the OFL Coefficient of Variation (CV) specified to represent scientific uncertainty (right).

determining scientific uncertainty to determine ABC under the Council's p-star risk policy (Fig. 1). Considering ecosystem factors is one element of this process, which also considers data quality, model appropriateness, retrospective analysis, comparison with simpler analysis, recruitment trends, prediction error, informative F, and simulations/ management strategy evaluation (MSE) (MAFMC SSC 2020).

The MAFMC SSC Ecosystem Working Group was established in May 2021 to assist the Council in increasing the range of opportunities for relevant ecosystem information to be considered in management decision processes. This systematic approach to using ecosystem information explicitly includes current and potential future management decision making at the stock, multispecies, fleet, community, and ecosystem levels. The group has three general objectives:

- Expanding and clarifying the ecosystem portion of the SSC OFL Coefficient of Variation (CV) determination process (short term objective, (Fig. 2))
- Developing prototype processes to provide multispecies and system level scientific advice appropriate for Council decision making, in particular where there are multispecies and multifleet tradeoffs linking directly to economic and social outcomes (long term objective)
- Collaborating with SSC species leads, stock assessment leads, and relevant working groups in developing the stock-specific ESP process to specify stock-specific ecosystem terms of reference that are impactful and can be integrated into assessments (moderate-term objective)

This keynote outlined several specific analyses in progress evaluating the impact of ecosystem factors on assessment uncertainty as reflected in the OFL CV. Analyses aim to evaluate both the benefits of making the correct OFL CV decision and the costs of an incorrect decision. Other analyses are in progress to support MAFMC's Ecosystem Approach to Fisheries Management (EAFM).

MAFMC EAFM: a systematic approach to address ecosystem interactions

The MAFMC developed its EAFM structured decision process to integrate and make better use of climate, ecosystem, social, and economic information within current operational fisheries management (Gaichas et al. 2016). The EAFM process begins with risk assessment to characterize a broad range of risks to managed species and fisheries, and to identify high priority

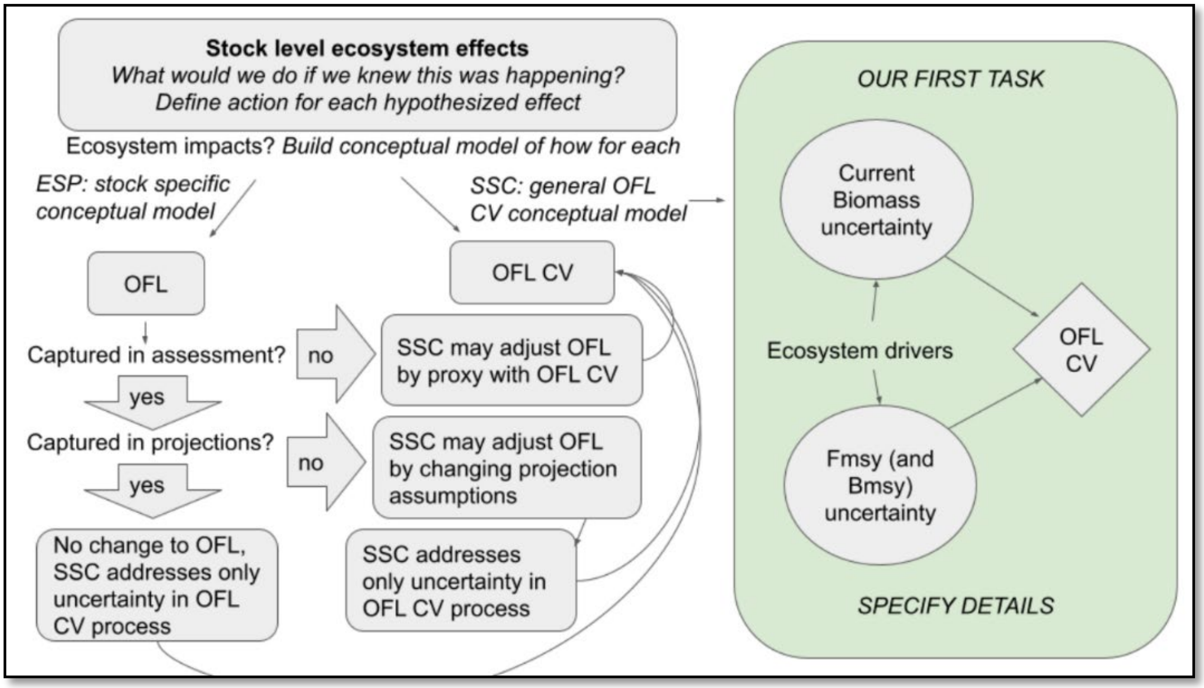

Figure 2: SSC process for incorporating ecosystem information into OFL CV decisions.

fisheries for further analysis. Next, conceptual modeling identifies interactions between ecosystem risks for a high priority fishery or issue. Conceptual modeling forms a basis for MSE focused on actions to achieve a set of management objectives, but also includes key risks such as climate, ecological, or socioeconomic interactions identified earlier in the EAFM process.

Regular ecosystem reporting and maintenance of long term indicator time series is a key component of a systematic approach, as noted across US regions (Zador et al. 2016; Harvey et al. 2020). As MAFMC has developed and implemented EAFM, annual ecosystem reporting has evolved to more clearly link fishery management objectives with ecosystem indicators (DePiper et al. 2017). For the 2021 and subsequent reports, the State of the Ecosystem (SOE) outline was restructured to reinforce indicator linkages to management objectives and to improve synthesis across indicators by emphasizing multiple drivers of social-ecological change. Climate indicators and offshore wind development indicators were framed in terms of risks to meeting fishery management objectives to improve management relevance. Implications sections were added after all indicators to clearly link ecosystem information to management. Finally, the SOE summary section was restructured into a report-card style table linking indicator trends to ecosystem level management objectives. With continued MAFMC feedback and input, brief and plain-language SOE reports now include updates on both general climate conditions and linkages to managed species and their habitats. These reports are compiled using open-science principles, with indicator data and documentation freely available online (Bastille et al. 2021). Example results from the 2022 SOE were included in the keynote talk.

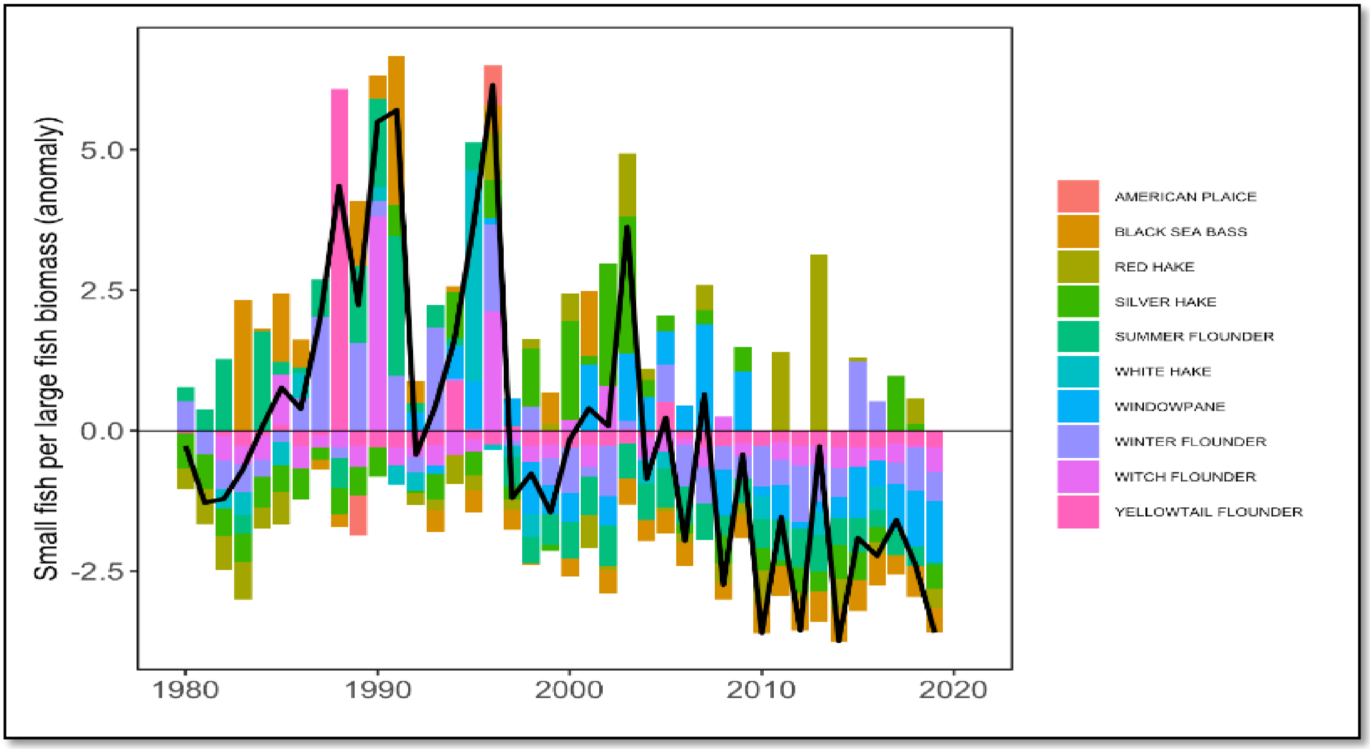

Figure 3: Survey small fish per large fish biomass anomaly in the Mid-Atlantic Bight. Reprinted from the 2022 Mid-Atlantic State of the Ecosystem Report

The MAFMC completed an initial EAFM risk assessment in 2017 (Gaichas et al. 2018) using a combination of SOE indicators and other published risk assessments, including the Northeast Regional Climate Vulnerability Analysis (Hare et al. 2016). The EAFM risk assessment is updated annually based on ecosystem and management indicators; results of the 2022 risk assessment were presented during the keynote. Based on the initial risk assessment, MAFMC selected summer flounder as a high priority fishery for further EAFM analysis. MAFMC completed EAFM conceptual modeling for summer flounder in 2019 (DePiper et al. 2021), and completed MSE of summer flounder recreational fishery measures to reduce discards and improve angler welfare while meeting stock status objectives in 2022 (MAFMC Summer Flounder MSE 2022). The MSE addressed recreational fishery-specific stakeholder-defined objectives and uncertainties. Because it was conducted within the EAFM structured decision process, it also incorporated distribution shifts, identified in both risk assessment and conceptual modeling as a key ecosystem risk. Distribution shifts did not alter the rank order of management procedures, but did diminish expected returns across all of them, providing valuable insight into management performance in the ecosystem context.

> *I think the frontier here really is looking at the multi-species and system-level indicators of productivity change, or over-exploitation, or both, and how we start to provide advice on that.*
>
> *Sarah Gaichas*

Systematic approaches for potential multispecies and ecosystem level decisions

The MAFMC SSC Ecosystem working group is just beginning to address multispecies and ecosystem level indicators and analyses to provide scientific advice to the Council. Examples of multispecies indicators include fish condition and fish productivity from both survey and assessment sources. These indicators bridge stock level and community level information as they are calculated for individual stocks but evaluated across multiple stocks. For example, stock level condition drivers led to a decision on which butterfish recruitment stanza to use for assessment projections. Relationships between multistock productivity (Fig. 3) and other ecosystem indicators such as zooplankton abundance have shown evidence of regime shifts (Morse et al. 2017; Perretti et al. 2017), with potential implications for projections and reference point calculations across many species. The SSC ecosystem workgroup is considering how to make more systematic use of these signals across multiple stocks in OFL CV and other decisions.

Similarly, the MAFMC SSC Ecosystem working group has recently started analyses to evaluate thresholds for ecosystem overfishing specific to the Mid-Atlantic ecosystem based on indicators and thresholds developed using worldwide data sources (Link and Watson 2019). Analysis of potential ecosystem level thresholds is another important systematic approach that can be done across US regions (Tam et al. 2017; Samhouri et al. 2017).

Overall, a focus on developing decision processes that are able to use ecosystem information is a key systematic approach going forward. The success of the MAFMC EAFM process and continued use of ecosystem information in management hinges on scientist-management collaboration with stakeholder engagement throughout. Tools to support a systematic EBFM approach are available in each US region: stock assessment, conceptual modeling, ecosystem reporting, and risk and vulnerability assessment. Stock level Ecosystem and Socioeconomic profiles currently in development across the US provide a key entry point into current stock assessment and stock-level management processes. Multispecies and system-level indicators of productivity change, system limits, and overexploitation are available for testing and potential future use in more comprehensive system-level decision processes.

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Sarah Gaichas, MAFMC, presenting her keynote.

Summary of Breakout Sessions
Focus Session 1: How to incorporate ecosystem indicators into the stock assessment process?

Theme 1.1
What criteria and diagnostics are needed for acceptance of an indicator into an assessment?

A robust discussion of this trigger question occurred in each breakout group. Discussions focused on three main topics: the process for selection of indicators, considerations for inclusion of ecosystem linkages, and forecasting challenges. NOAA Fisheries is investing in a next generation Fisheries Integrated Modeling System (FIMS) that will provide options for uptake of ecosystem information into stock assessments (see Stawitz presentation). FIMS is designed to allow users to develop ecosystem-linked research-track assessments using a variety of analytical approaches including applications of state-based modeling. Although new tools will streamline model development and evaluation, considerable time is required to gather the information needed to propose an ecosystem-linked assessment. Some regions assess a large number of species and time is limited to focus on mechanistic linkages for individual species. It was noted that ecosystem indicators can be formally incorporated into assessments (see session 1 case studies and

After each session, participants in breakout groups discussed the keynote and case study presentations and regional differences.

both keynotes) or they can be used to inform risk assessments (see Keynote 2). In either approach, identification of a strong mechanistic basis for including indicators is important to provide a clear and transparent rationale to Council members and stakeholders. When selecting indicators, the group encouraged analysts to cast a wide net early on for potential new indicator ideas. Engagement of stakeholders, native communities, and the public can bring a lot of empirical data to the table. This inclusive approach builds based support, from the scientific community, fishery dependent communities, managers, and the public. Indicators based on local knowledge, traditional knowledge, and subsistence information should be considered where appropriate.

Although some regions are exploring standardized frameworks for indicator selection (see Keynote 2, and Blackhart presentation), no nationally accepted set of criteria or statistical thresholds exist for the use of indicators in stock assessments. Case-by-case evaluations of ecosystem-linked assessments allow SSCs to address the specific implication of adopting a new model within the regional management context (see Case Studies 1-7 for examples). Key reasons to preserve the case-by-case evaluation approach include: a) differences in the availability of information in data rich vs. data poor systems, b) differences in the types of ecosystem linkages, c) the state of mechanistic understanding, d) implications of adding ecosystem indicators for model complexity and fit, e) considerations of model approach and fit to observations, and f) statistical justification for added model complexity.

As noted in Case Study 1, adopting episodic events (state changes) in an assessment can have large management implications. SSCs should consider the downstream effects of incorporating an indicator in terms of its effect on management decisions (See Keynote 1 and Case Study 1 for a summary of these challenges).

A small group answers trigger questions from the breakout session.

Once adopted, periodic, if not regular, review of indicator validity should be required. It was noted that forecasting skill assessments and continued evaluation of model performance could be used to test the mechanistic relationship(s) and the associated statistical relationship. SSCs should be prepared to remove the indicator if the relationship linking the indicator to key assessment processes erodes.

Some groups discussed the challenges associated with using statistical relationships to forecast future production, particularly when predicting shifts in long-term production. Most SSCs do not attempt to forecast episodic events.

This Southeast Atlantic ecosystem and many others are increasingly non-stationary. We know that stock assessments assume stationarity and it goes without saying that these challenges require new methodologies

Brendan Runde

Breakout session discussions sometimes focused on a subset of trigger question.

in a timely manner can be an aspect of the review of assessment model selection (see case studies). There are many ways to incorporate environmental linkages into key assessment processes (see Case studies 1-7). For example, environmental variables can be modeled as a continuous process or as time blocks. Application of these approaches should address the time lags between ecosystem change and key processes modeled in the assessments. It was also noted that the SSCs' approach for incorporating environmental information into stock assessments and advice often depends on the quality of the available information and the life history of species (Case study 4). For example, short-term environmental forecasts may be quite useful for tactical management of short-lived species. Whereas, ecosystem-linked forecasts and observed size and condition of incoming year-classes can inform tactical forecasts of future production of species that exhibit older age-at-recruitment to the fishery. The group agreed that the effects of exceptional circumstances should be accommodated, based on scientific judgment. Short-term environmental events, particularly initially, can be addressed by accounting for additional uncertainty (buffers) as it is difficult to develop models of the process while these events are occurring.

Theme 1.2 and 1.3 Responsiveness/ability of indicators to address environmental anomalies.

The discussion focused on how to address short-term events and how to incorporate short-term anomalies into management advice, particularly when stocks are not assessed annually. Plenary discussions started by distinguishing between responses that focused on response times of models to environmental anomalies and the timely and relevant delivery of advice for management decisions. Both of these aspects of advice are relevant to the decisions of SSCs.

It was noted that on-going monitoring of model performance with respect to repeatability of correctly modeling a response (e.g., changes in mortality, growth, reproduction) to environmental anomalies

> *We're working to directly put ecosystem considerations into the stock assessment, building upon long-term investment in strategic initiatives, like the Stock Assessment Improvement Plan, the EBFM Road Map, and the National Climate Science Strategy.*
>
> *Melissa Haltuch*

Franz Mueter, NPFMC, leads the breakout session discussion.

Keynotes 1 and 2 noted that the implications of different scenarios of short-term (forecasts) or long-term (projections) environmental change can be assessed within a management strategy evaluation (MSE). MSEs accommodate expectations of assessment frequency, while also allowing for consideration of exceptional circumstances (See SCS6 report for additional details on MSEs). It was noted that formal evaluation of the implications of adjustments to harvest levels using MSEs is labor intensive and often occurs outside of the assessment cycle. Therefore, agencies responsible for the assessments, in conjunction with SSCs, need to prioritize when, and for which assessments, a MSE is needed. Social and economic drivers can influence public support for proposed changes in status determination criteria or harvest control rules, but the economic costs and other downstream impacts of added precaution or other modifications can be evaluated within the MSE.

Alternative approaches to formal evaluations with MSEs include the use of qualitative tools such as risk tables. These tools can be used until a MSE is completed. Continued support for research is needed to validate possible environmental linkages included in risk tables.

Research to improve our understanding of climate ocean connectivity is needed to improve the detection and quantification of decadal and multi-decadal shifts in ocean conditions as well as the ability to skillfully forecast these events. Process studies to understand the mechanisms underlying extreme events such as storm frequency or marine heatwaves are also needed as climate change projections suggest that these events will be more common in the future under some scenarios.

Theme 1.4
Adaptivity of Management Framework

This question focused on the pros and cons of formalizing the indicator selection process through Ecosystem and Socio-economic Profiles (ESPs), Ecosystem Status Reports (ESRs), or Integrated Ecosystem Assessments (IEAs). NOAA Fisheries' Next Generation Stock Assessment Improvement Plan outlined a framework for prioritizing candidates for ecosystem-linked assessments. Some regions

James Tolan and James Nance, GMFMC

are developing frameworks for incorporation of ecosystem linkages into management advice (e.g., ESPs; see Keynote 2). These frameworks provide pathways for SSCs to consider non-traditional information in setting biological reference points. These approaches have been applied in data limited assessments including multi-species complexes.

The group expressed some hesitancy to the idea of applying national standards to a process for including indicators in stock assessments or control rules, due to differences among regions (e.g., biological, social, economic). SCS7 participants found that frameworks for bringing forward proposed ecosystem-linkages for use in stock assessments or risk tables were helpful in communicating the evidence supporting the proposed linkage. However, SCS7 participants felt development of binding national guidelines for indicator selection or implementation of ecosystem-linked assessments would be premature because the approaches and methods used are currently tailored to regional conditions. Developing general guidelines is further challenged by vast differences among RFMCs in assessment frequency, capacity, data quality, and relationships with constituents. Some regions expressed concerns about capacity limitations; especially needing more stock

> *When considering a single species at a time, perhaps the idea of changing your reference points to match what's going on with the stock and environment is internally consistent and might make sense. But when you think of things at a larger scale, when many populations are undergoing changes in productivity, that might change the story.*
>
> *Cody Szuwalski*

After breakout sessions, groups would report the main findings to the full Committee.

Juan Cruz-Motta, CFMC, Richard Appeldoorn, CFMC, Tarsila Seara, CFMC, and Galen Johnson, PFMC

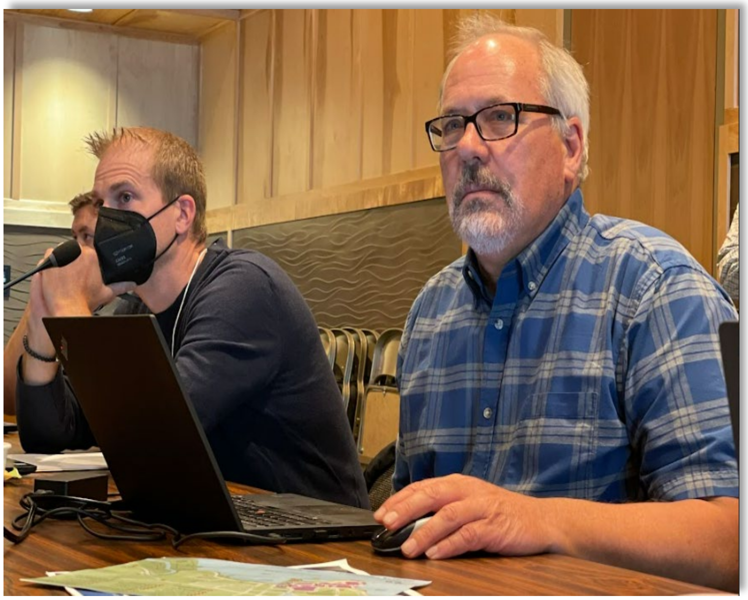
assessment authors and those who train them, and better data systems and handling practices to increase efficiency. If national guidance for implementing ecosystem-linked assessments is developed, this guidance should be flexible enough to take into account regional differences. Participants supported continued efforts to improve communication and cross-over among scientists on new methods and best practices, but affirmed the value of testing different approaches in different regions.

SCS7 participants encouraged transparency in how SSCs formulated their advice to the Council, and stakeholders (see Keynote 3). The retention of ABC Control Rule decisions by SSCs was mentioned as an example of transparency in the application of standards used by each SSC to recommend catch advice to their respective Council. There is a general acceptance that an SSC will endeavor to account for uncertainty and risk; however, stakeholders have shown an appreciation for transparency at all possible levels. Development of generally applicable definitions of terms like "environmental anomaly" or "exceptional circumstances" should be discussed, such that risk management can be appropriately applied considerate of Council and SSC requirements under the Magnuson-Stevens Act.

Theme 1.5
What to do under non-stationarity?

Non-stationarity in predicting future ecosystem states poses real challenges within the existing National Standard Guidelines (See Keynote 1 and Case studies 1 and 5 for examples). The group noted that it will make sense to maintain reference points in some cases, and change it in others. Stationarity is often assumed because

L to R, back row: Grant Adams, U of W, Will Patterson, GMFMC, Sarah Gaichas, MAFMC, Éva Plagányi, CSIRO
L to R, front row: Olaf Jensen, MAFMC, Alexei Sharov, MAFMC, Jeffery Buckel, SAFMC, Amy Schueller, SAFMC, Scott Crosson, SAFMC



Martin Dorn, NPFMC, and Brandon Muffley, MAFMC

understanding ecosystem variability verses shifts in mean production takes time.

Case study 1 showed assuming stationarity can be precautionary, but rebuilding may be challenged under climate change. Seasonal forecasts (4-9 months) of some ocean phenomena (marine heat waves, sea ice, El Niño) are promising, however, forecasting skill declines at 2-5 year time frames. It is also difficult to determine whether a recently observed anomaly is a short-term anomaly or the beginning of a long-term shift in environmental conditions. Short-term anomalies, such as those lasting for one year or less, would not be expected to have long-term consequences for a stock. However, if the frequency of extreme short-term events (hurricanes/typhoons, harmful algal blooms) increases under climate change these can have a cumulative impact on production. Identifying harvest strategies that are robust to environmental change (extreme events or long-term change) can be explored using integrated modeling systems that link fishing scenarios with climate forecasts and projections at regional scales (e.g., NOAA's Climate Ecosystems and Fisheries Initiative). These linked modeling systems can serve as strategic planning tools that demonstrate how climate and management strategies perform with respect to sustaining fisheries as well as the associated economic and operational impacts of these responses (see Case study 6).

Theme 1.6
How to account for time-varying catchability in multi-species fisheries if/when CPUE of the dominant or indicator species declines even if combined abundance is unaffected?

SCS7 members discussed management of multi-species groups and examples of perennially overfished species that do not seem to respond to management changes. SSCs should strive to monitor stocks that are doing well, and those that are declining. Monitoring stocks that are doing well may help to understand potential sector-level effects and effects on other species. Treatment of a stock that does not seem to be rebuilding or responding to management might be treated in a "do no (more) harm" manner. Such a conclusion would be tantamount to acknowledging a regime shift for that stock.

> *We've never seen so little cold water entering the Gulf of Maine. We've never seen this many heat waves.*
>
> *Lisa Kerr*

FOCUS SESSION 2
Developing information to support management of interacting species in consideration of EBFM

Stock assessment considerations under evolving ecosystem-based fishery management (EBFM) principles must address, among many things, the interaction of multiple species including predator-prey relationships. Various avenues have been explored, including assessment and management of fish assemblages and the use of multispecies predator-prey models to evaluate harvest options for both predator and prey. This session focused on how best to address these considerations on a regional and national level, as well as the development of elements and considerations that should be considered for inclusion in the development of national guidelines.

Several attendees gave presentations under focus session 2:

- Keynote 3: Éva Plagányi: *Multiple interacting species and the management challenges they pose*
- Case Study 8: Juan Cruz Motta: *Multivariate approaches for EBFM implementation in the U.S. Caribbean*
- Case Study 9: Cate O'Keefe: *Development of harvest control rules for Atlantic herring: an application of MSE to account for herring's role in the ecosystem*
- Case Study 10: Grant Adams: *Does ignoring predation mortality lead to an inability to achieve management goals in Alaska?*

Staff and additional SSC representatives listen and take notes during presentations.

Keynote 3: Multiple interacting species and the management challenges they pose

Éva Plagányi
CSIRO Oceans & Atmosphere, Brisbane, Australia

Introduction

There has been considerable work focused on how to achieve ecosystem-based fisheries management (EBFM) but there are few examples of tactical implementations that lead to changes in management advice. This is partly because most jurisdictions lack formal frameworks to guide use of broader ecosystem data and outputs of ecosystem models. Yet it is increasingly recognized that trophic interactions and climate influences need to be accounted for in order to achieve fisheries management that is Robust to Interacting Populations (RIP fisheries management). This talk focused on simplifying the overwhelming complexity of EBFM by categorizing and structuring approaches to account for multiple interacting species to be as pragmatic as possible. Examples are presented as to how EBFM considerations can be considered as part of harvest strategy frameworks as used in current single-species fisheries management, and what the gaps are.

It was posited that ecosystem objectives pertaining to species interactions can be structured using four main categories (Fig. 1): (A) Whole of Ecosystem, which encompasses not exceeding the overall limits of system productivity and protecting overall ecosystem structure and function to ensure ongoing resilient ecosystems that maintain productive functioning; (B) Identify and focus on key species or species with influential trophic connections because key species may require more careful management due to the disproportional reliance of other species on these; (C) Selected species of conservation concern to meet conservation objectives; and (D) Pest or climate-immigrant species with the objective of managing these to achieve desired outcomes for other (target) species in an ecosystem. For each category, some examples were presented of the harvest strategy components required to inform decision making:

> *Traditionally we've used a lot of our strategic ecosystem models to help us with an understanding of how systems function, connect, and what kind of things cause problems to them. But how do we actually get something tactical that we can use in management? I think this is where network approaches are particularly useful to reduce some of this complexity, as well as some of the associated indicators.*
>
> *Éva Plagányi*

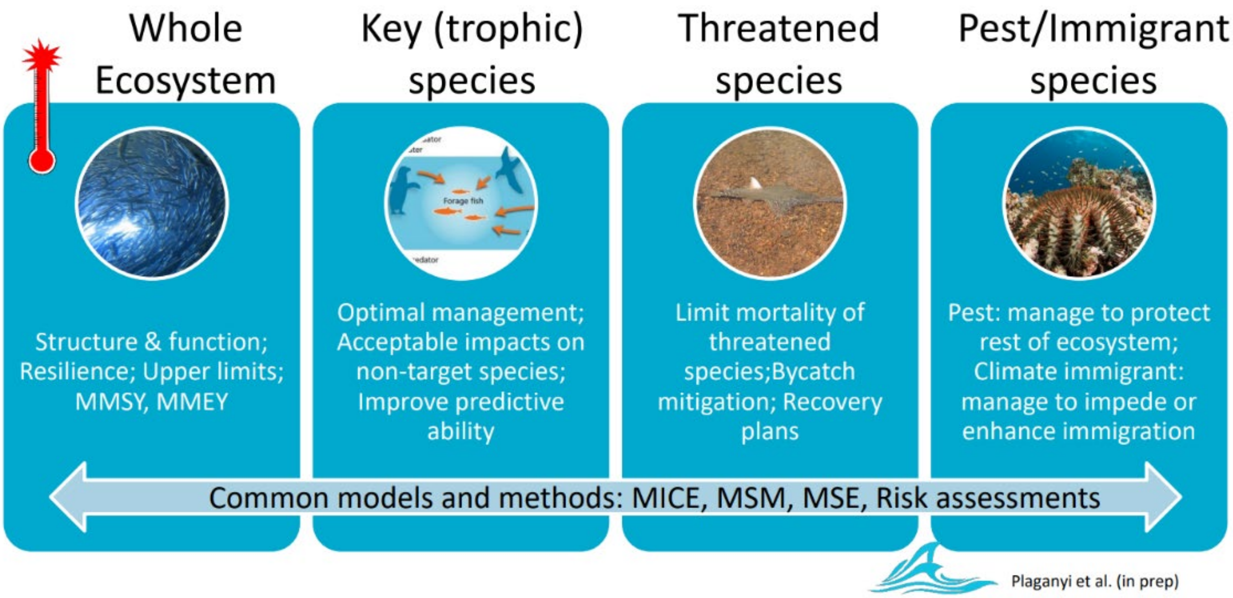


Figure 1. Summary of four main categories that need to be considered to account for species interactions influencing fisheries management, each with slightly different objectives but drawing on many common models and methods to inform what actions are needed to address the objectives.

indicators, data, reference levels (targets to aim for and limits to be avoided), methods and decision rules.

Multispecies Harvest Strategy Framework

Harvest strategies (HS) are a valuable tool for fisheries management because they comprise transparent, pre-agreed rules to avoid ad hoc management decisions (Butterworth 2007, Smith et al. 2013). This allows a solid basis for sound management of stocks, irrespective of the methods and management approach used to achieve pre-specified ecological, economic and/or social management objectives. Harvest strategies include the following components which are also relevant if developing a harvest strategy that includes consideration of broader ecosystem effects:

(1) Indicators

Additional data may be needed for multispecies evaluations.

(2) Reference Points

Multispecies or ecosystem reference points need to be defined and agreed but this is still a gap. An example of a promising approach is that used in the Irish Sea to adjust the target reference fishing mortality level to a revised ecological target level that accounts for variable ecosystem interactions and dependencies (Bentley et al. 2020, Howell et al. 2021). When trying to achieve whole ecosystem objectives such as not exceeding the overall limits of system productivity, the NAFO roadmap (e.g., Koen-Alonso et al. 2019; NAFO 2022) provides a promising example involving computing an Ecosystem overfishing level based on the principle that total catches cannot exceed new production for any length of time.

(3) Monitoring

There are new challenges when monitoring more than just the target species but a range of data could be used, including stomach contents data, scat analyses, environmental DNA (eDNA) techniques and close-kin mark-recapture (CKMR) (Bravington et al. 2016)

(4) Method of assessment

Could complement or replace single-species models with multispecies or ecosystem model (see next section).

(5) Decision rules

Adjust to account for multispecies interactions – aim for targets and a low risk of breaching limits; could couple with risk assessment approaches

When possible, harvest strategies should be formally tested using approaches such as Management Strategy Evaluation (MSE) to evaluate whether they are likely to achieve the management objectives (Dowling et al. 2015).

Methods and tools to achieve ecosystem objectives

To achieve the management objectives related to each of the four categories as summarized in Fig. 1, a range of management tools are available (Hollowed et al. 2000, Plagányi 2007) and many of these could be applied across most of the categories. These include approaches such as multispecies and ecosystem models, MSE (Punt et al. 2016) and risk assessments. The main focus of this talk was on a subset of multispecies models which are tactical and rigorous, namely Models of Intermediate Complexity for Ecosystem assessments (MICE) (Plagányi et al. 2014, 2021, Collie et al. 2016) which share many features with single-species stock assessment models and have great potential as tactical tools for fishery management. A range of MICE case studies were described to summarize lessons learnt and show how these approaches have contributed to improved management (Fig. 2).

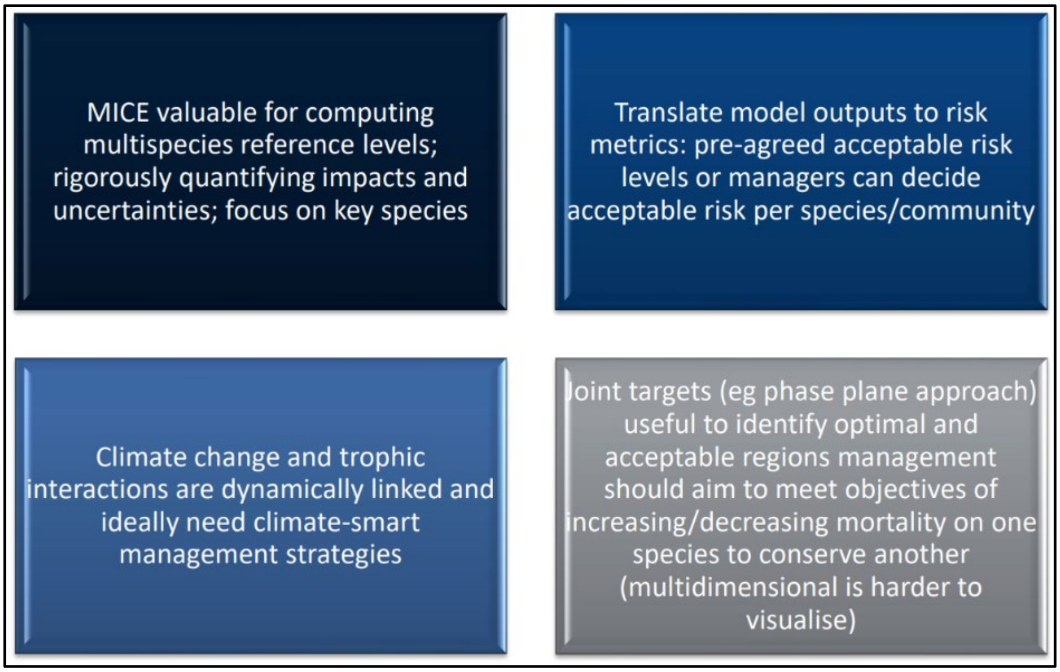


Figure 2. Summary of some ways in which MICE can be used to support ecosystem-based fisheries management.

Ecosystem models typically have greater utility in separating the effects of fishing, trophic interactions and climate as is becoming increasingly necessary (Gaichas et al. 2011, Holsman et al. 2016, Hollowed et al. 2020). Ecosystem models can also be used as Operating Models within MSE frameworks to generate realistic dynamics, inform ecosystem reference points or evaluate trade-offs (Kaplan et al. 2021).

Where are the gaps?

Globally there have been considerable advances in understanding, data collection, development of indicators, models and other methods needed to support moving to a more structured decision-making framework to account for multispecies interactions, and hence to achieve RIP fisheries management. But a number of gaps remain to populate formal harvest strategy frameworks. Key indicators are not available for many examples, and additional monitoring is either not available, inadequate or prohibitively expensive relative to the value of a fishery. Specifying multispecies reference points for use in tactical management remains a challenge. Recent progress by NAFO in defining a whole ecosystem reference level is encouraging. There has also been progress in terms of adjusting fishery reference levels for forage fish to account for their important role in supporting dependent predators in the ecosystem (e.g., Howell et al. 2021) but considerable debate remains as to the most appropriate choices for these reference levels (Pikitch et al. 2018, Siple et al. 2019, Hilborn et al. 2022). For threatened and endangered species impacted by fishing, there are often legislative requirements to guide choice of reference levels. For multispecies pest management, an example was provided of an ecological threshold that is being implemented on the Great Barrier Reef to guide culling of crown of thorns starfish in order to optimise levels of coral cover (Plagányi et al. 2020). There is currently a paucity of studies that can inform how best to manage multispecies interactions to facilitate or impede the movement of a climate immigrant species into a region.

Whereas there have been a very large number and variety of ecosystem modeling approaches that have been developed, there remain few MICE (e.g. Plagányi and Butterworth 2012, Punt et al. 2016, Angelini et al. 2016, Thorson et al. 2019, Tulloch et al. 2019, Rogers and Plagányi 2022) or MICE-like models that are developed in consultation with stakeholders, and are fitted to data and account for uncertainty such that they can serve as ecosystem assessment tools.

Éva Plagányi, CSIRO, giving her keynote presentation.

However, MICE and whole ecosystem models such as Atlantis are suitable for use as operating models in MSE testing, to support implementation of harvest strategies that are robust to interacting populations and climate impacts (Plagányi et al. 2011, Kaplan et al. 2021). Under climate change, models based on stationary assumptions are increasingly being challenged and hence the problem of modeling and accounting for multispecies interactions in fisheries management increasingly needs to also account for variation in parameters caused by the environment, as summarized in Keynote 1.

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Summary of Breakout Sessions
Focus Session 2

Theme 2.1
Use of ecosystem models to inform ecosystem-based fishery management

The primary questions grouped under this theme were intended to evoke an overview of how multi-species ecosystem models are being used by different regions and to what extent they are employed directly in management. In particular, if ecosystem models are used to determine reference points, are they used to inform predation mortality or to provide additional model-based ecosystem-level indicators? A recent report from the NOAA Multispecies Modeling Applications in Fisheries Management workshop describes many of these aspects and recommendations.

Responses by breakout groups varied, but consistently noted the limited use of ecosystem modeling in determining reference points. One example was that of menhaden on the Atlantic coast, which examined the interaction of menhaden with other predators using Ecopath with Ecosim and Ecospace. Results were used to

SCS7 delegates and participants discuss session topics.

adjust harvest levels that account for the role of menhaden as an important forage fish. Predation (cannibalism) is also considered in the eastern Bering Sea pollock assessment through the use of a compensatory stock-recruitment relationship and a higher assumed mortality for juveniles. Case study 9 provided an example of indirect accounting for species interactions, where bottom-up effects of fishing Atlantic herring on other higher trophic level species were considered. The herring example highlighted the importance of also considering environmental effects on herring productivity while accounting for the role of herring as forage. Across other regions, examples were noted of an ecosystem context threshold for setting sardine harvest levels, younger age considerations for Pacific halibut and predator-informed natural mortality for butterfish.

> *There's a high level of uncertainty. To account for herring's role in the ecosystem, we didn't explicitly account for the environment's role and herring's productivity. Sea surface temperature increasing over time could have an impact on the herring stock.*
>
> *Cate O'Keefe*

Across regions where stock assessment models are used as a primary tool for providing management advice, EBFM currently works primarily through enhancing or informing single-species assessment models. Several regions also use post-assessment adjustments to account for ecosystem uncertainty through CVs, risk tables, or other approaches to applying buffers when setting catch limits (see Keynote 2). In several systems, Models of Intermediate Complexity for Ecosystems (MICE, see Keynote 3) have been developed as a step towards integrating environmental considerations or to account for predator needs when managing prey species (e.g., herring, menhaden). Such models can be used directly to specify ecosystem-informed harvest levels. In contrast, true multi-species models and ecosystem models are used primarily for strategic advice (often in a climate context) rather than tactical management. In addition, multi-species models have been used for estimating predation mortality to inform single-species models and for cross-checking / validating single species models (e.g., Case Study 10).

Many challenges remain in the use of ecosystem models in EBFM. These include extensive data requirements (e.g., not all regions have diet data), difficulties in building complex models in a changing climate (non-stationarity, shifting stocks), concerns that we may not be including the right species in ecosystem model forecasts due to shifting populations, and determinations of when the additional complexity of using ecosystem models is warranted (e.g., examining the relative level of importance of predation relative to fishing pressure). Moreover, suitable multi-species and system-level reference points have yet to be defined for most ecosystem models.

Theme 2.2
Non-target considerations in harvest control rules (HCR)

The second group of questions addressed whether the needs of non-target predator populations (e.g., marine mammals) are accounted for in harvest control rules (HCRs). For example in the North Pacific, where harvest control rules for Pacific cod include a prey threshold for Steller sea lion protection. Other regions have attempted to explicitly consider the needs of predators in harvest control rules (e.g., Atlantic herring) but have generally moved away from them in the HCR context relying primarily on MSEs to determine how robust control rules are to non-target considerations.

In general, across regions, the use of spatial and temporal management measures for protected species has been more common than developing HCRs that explicitly consider non-target species. Such measures may range from spatial and temporal closures or reduced harvest levels to accommodate prey concerns for protected species (e.g. Steller sea lion measures in the Aleutian Islands, Southern Resident Killer Whales) to the use of environmental covariates to identify and manage species interactions (e.g. temporary closures or issuance of avoidance bulletins to the fleet in the western Pacific). Other measures include bycatch caps that are used in many regions to limit the take of non-target and protected species, as well as explicit protections for forage fish to limit or ban their harvest in consideration of their ecosystem role.

Next we're going to be looking at harvest caps that are used in the North Pacific, climate linkages, and whether or not multispecies harvest control rules lead to better performance compared to single species harvest control rules.

Grant Adams

Attendees continue informal discussion during breaks.

Theme 2.3
Management framework and system-level considerations

The final group of questions summarized under this theme addressed to what extent regions have considered a system-level cap, and if so, what is the basis of the system-level cap and how are individual species managed under the cap?

Responses across regions varied. The Bering Sea and Aleutian Islands have a system level cap (2 million mt) in place that limits overall harvest of target groundfish species. Fishing quotas (single species total allowable catch (TAC) levels) are considered in aggregate with the sum of the TACs not to exceed the cap. This cap was initially driven by the need to account for social and ecological considerations on overall removals, and has been acknowledged as a precautionary approach to setting catch levels. The Bering Sea groundfish cap constrains groundfish fishing in most years, and as a result, many flatfish species are underutilized. There has often been interest in moving non-target species out of the fishery to provide more fishing opportunities. In the Gulf of Alaska, groundfish fishery target stocks also have a system level cap but it has never been constraining. These caps for overall groundfish removals in the North Pacific have gone unchanged since the 1980s.

New England does not employ a system cap, but considers a system of managing to the weakest link under a stock complex that can constrain landings across a complex. Many regions have not explored or employed system-level caps. In some areas, bycatch of some species can limit the harvest of others. There was some discussion of an alternative management framework for tropical ecosystems with high diversity, to move away from stock assessment for every landed species.

Overall there has been limited use of system-level caps across jurisdictions with few exceptions. Informed system-level caps or other system-wide considerations require an understanding of ecosystem productivity based on primary production and transfer efficiencies among trophic levels or estimates of total system biomass that can help inform multi-species reference points (e.g., in coral reef systems). In data-rich regions, multi-species and ecosystem models may help inform system-wide considerations. In tropical systems with a very high diversity of species, the inability to assess every landed species has led to considerations of multivariate reference points or "reference regions" to define and manage for a desirable state.

To support the development of system-level approaches, the importance of communicating between SSCs across regions and engaging stakeholders and managers was highlighted. In particular, the need for stakeholder 'buy-in' on system-level considerations and trade-offs was noted. In some cases, the ability to implement an ecosystem approach is affected by multiple management jurisdictions and governance challenges. Cooperative approaches among fishers was noted as one possible framework for addressing system-level concerns.

The Harrigan Centennial Hall in Sitka, Alaska, housed the national committee for three days in August and provided breathtaking views of the mountains and Sitka Sound.

FOCUS SESSION 3
How to assess and develop fishing level recommendations for species exhibiting distributional changes due to climate variability and climate change?

The Magnuson-Stevens Fishery Management and Conservation Act requires that stocks are managed throughout their distributional range. However, this mandate is challenging for species exhibiting shifts in their distribution, often under changing climate conditions. Fish movement away from traditional fishing grounds and survey areas creates difficult challenges for stock assessment. The primary focus of this session was to address how stock assessment and fishing level recommendations should best accommodate stocks whose geographic distributions are modified with climate variability and climate change.

Several attendees gave presentations under focus session 3:

- Keynote 4: James Ianelli: *Perspectives on ways complex ecosystem projections can be applied in real-world fisheries management cases*
- Case Study 11: Scott Crosson: *Blueline tilefish negotiations between the Mid- and South Atlantic Council SSCs*
- Case Study 12: Olaf Jensen: *Toward dynamic harvest allocation rules for shifting species: a case study of three stocks in the Northeast US*

> *With climate change will come inequities. Climate change and our management process will have winners and losers in terms of who is more or less affected. From the science community, it's important that we consider this in terms of what data we collect AND what information is available for management. We've identified a number of different data collection processes that support large industry, small industry, coastal communities, and Indigenous communities in Alaska, and developed a number of these indicators to incorporate and improve our management process.*
>
> *Bob Foy*

Keynote 4: Perspectives on ways complex ecosystem projections can be applied in real-world fisheries management cases

James Ianelli
AFSC/NMFS/NOAA

To develop fishing level recommendations for species that are affected by climate variability and change, the first step is to identify sources of data and analyses (Fig. 1). Observational data and fishery dependent data collected through scientific surveys are crucial, as they provide a consistent record of a broad range of environmental data. These data help tune oceanographic models, which are a key component of the Alaska Climate Integrated Modeling (ACLIM) project. The ACLIM project uses a suite of models for climate fisheries hindcasts, forecasts, projections, and management strategy evaluations.

One feature of the ACLIM project is the climate-enhanced multi-species model "CEATTLE," which provides better realism for testing the kind of data and models that feed into tactical advice. By folding in available information on species distribution patterns from survey and fishery data (for the case of eastern Bering Sea pollock), it is possible to demonstrate clear patterns by age. Generally, younger pollock tend to be further north, and there are also clear size-specific spatial patterns of catch when fishing data are split by sectors.

The relative concentration of biomass and catch is related to available physical variables. A clear driver of both biomass and catch patterns is the extent of the "cold pool", which is the estimated area of surveyed seafloor where bottom temperatures are less than 2 °C. In low cold-pool-extent years (warmer conditions), the survey data show clear shifts northward, possibly due to the lack of a cold pool forming a barrier to the middle and inner shelf areas. In contrast, the fishery catch tends to be shifted to the north during periods of higher cold-pool-extent years (colder years), likely due to the concentration of pollock off of the shelf region and higher concentrations of pollock in the shelf-break area.

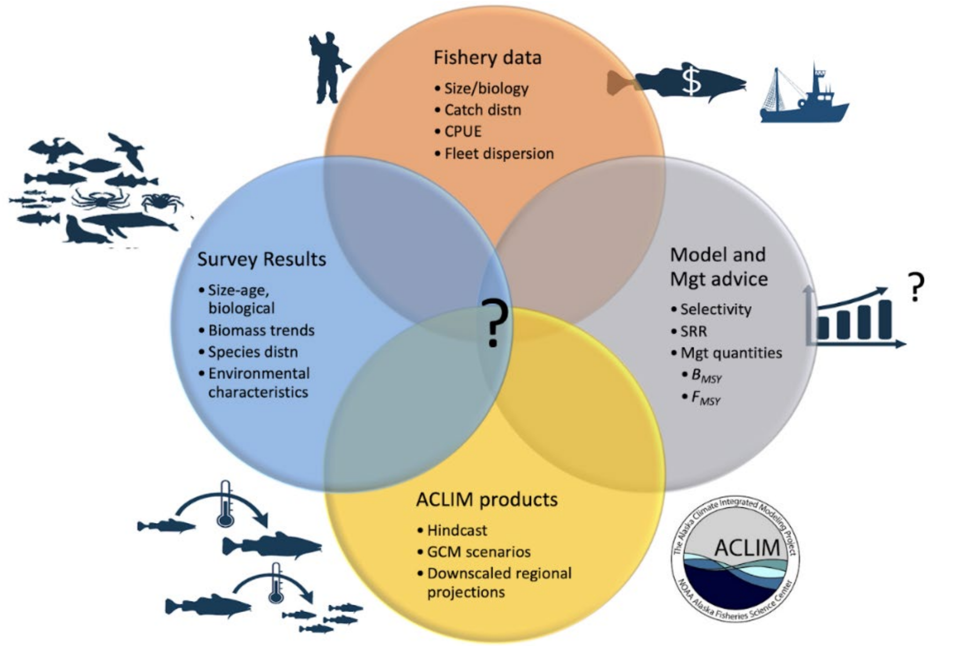

Figure 1. A depiction of tools and analyses that intersect and can help understand the system and develop fishing level recommendations for species exhibiting distributional changes due to climate variability and climate change.

Linking these data on distribution and sizes to factors that affect F_{MSY} estimates is essential. For example, it is possible to predict periods when the fishery catch will be further north and hence catch will be toward the younger, more immature segment of the population. This can affect the target fishing mortality rate, which would shift to lower values. This dynamic illustrates the interaction between environmental forcing and catch rates used in tactical management.

Present-day tactical catch advice is based on estimates of F_{MSY} and stock size projections. F_{MSY} estimates are impacted by what age of fish are targeted, which varies considerably (Fig. 2). Maximizing economic value for this stock occurs at higher spawning biomass values than the level that achieves maximum yield. This rate is exacerbated by distance traveled to fishing grounds that may have slightly higher catch rates but lower yields-per-recruit.

In summary, available tools should be applied for broad-scale examinations of data and models, with a goal to understand their limitations and how best to adapt them for communication and management advice.

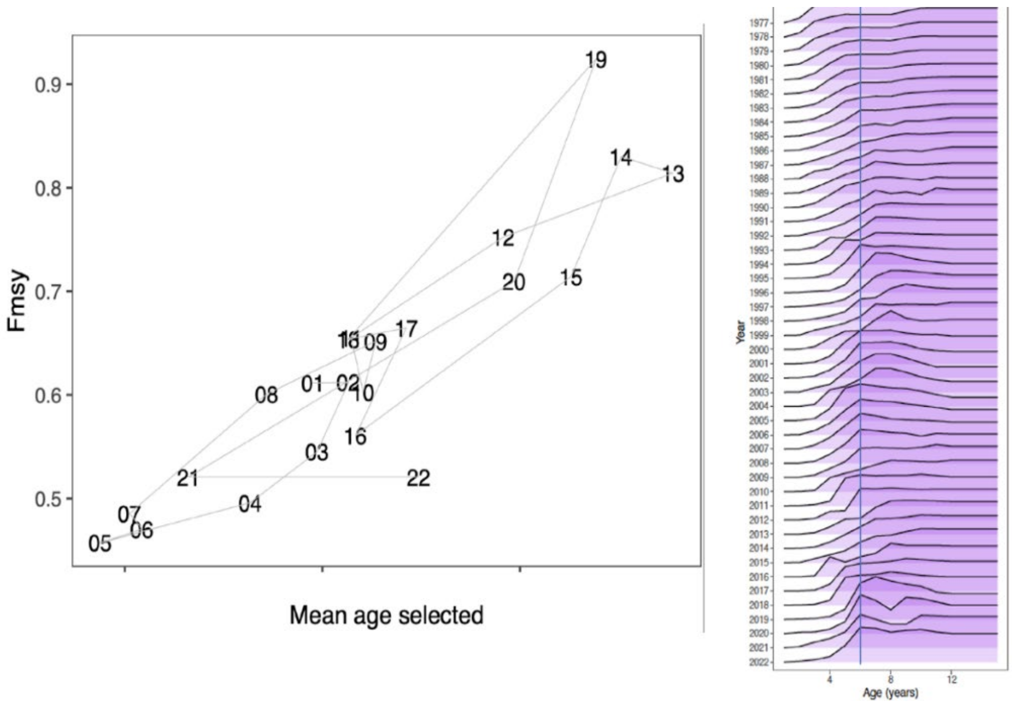

Figure 2. The relationship between F_{MSY} (vertical axis, left panel) and mean age selected (scaled units; horizontal axis on left panel as derived from the estimates of selectivity-at-age by year shown in the right-most panel). From Ianelli et al. 2021

Summary of Breakout Sessions Session 3

Theme 3.1 Addressing changing fish distributions in stock assessments and survey implications

The primary question discussed by the breakout groups under this theme topic was: How are changes in distributions of fish species that extend beyond the survey area considered in assessments? Research is occurring with modeling and tagging; however, there have been limited advances in accounting for distribution shifts in assessments beyond the survey area considered in assessments. Discussions included examples of the use of VAST and dynamic overlap approaches, which can be used to determine survey catchability associated with different environmental parameters and are becoming more routine. Other spatial issues which may impact surveys and stock assessments beyond simply shifting fish distributions, such as offshore wind and area closures and their implications, need to be considered as well. The spatial footprint of some surveys has been extended (Bering Sea, Gulf of Mexico, East Coast, and Caribbean) to better understand changes in fish distributions, in some cases using emerging technologies. However, these efforts are often limited by funding. Fixed timing for long-term surveys may not continue to be appropriate given changes in the timing of migrations associated with spawning. If surveys cannot adapt to these changing conditions, while the timing of the fishery does, conflicts may arise with fishermen having different perceptions of the status of stocks than scientists.

Across regions, participants highlighted the need for adaptive monitoring to address concerns over the potential mismatch between historical survey areas and the assessment area. In some instances, the use of local knowledge, traditional knowledge and citizen science programs may help to capture changes in observations over time and across regions, and can supplement or inform changes to existing surveys. It will be increasingly important to consider the effects of timing, location, and gear types when adjusting and expanding surveys. Statistical methods need to be developed to address use of new survey data or to make multiple surveys comparable across space and time.

> *It would be much easier if one council would just regulate the whole thing , like the Mid-Atlantic council regulates blue fish in the entire East Coast; South-Atlantic Council does it for mahi. But both councils have decided that that's not the way they want to go. They both want to keep managing in their own area.*
>
> *Scott Crosson*

Theme 3.2 Accounting for uncertainties in shifting distributions

The primary questions discussed by the breakout groups under this theme topic were if new surveys or stations are added in response to shifting distributions, how are biomass time series revised to incorporate these new/extended surveys? Can processes such as a P* approach account for inherent uncertainties in a precautionary approach under shifting distributions?

Generally, the discussions across breakout groups indicated that while current buffering processes (e.g., P*, OFL buffering or qualitative methods) may provide a temporary solution to shifting distributions, longer term solutions to address inherent uncertainty are needed. The critical need is to effectively communicate uncertainties, particularly as predictions become increasingly uncertain. Concerns about predictions are compounded by issues in identification of regime shifts and determining when distributional changes and changes in productivity are more likely to be longer term. In addition to buffering processes for scientific uncertainty when setting ACLs, there is also a need for increased consideration of social and economic effects due to shifting species distributions when setting TACs.

Frank Camacho, WPFMC, Mike Downs, NPMFC, Alison Whitman, NPFMC, and Erik Franklin, WPFMC discuss climate change.

Theme 3.3
Adaptivity of management framework to address changing distributions

The primary trigger questions discussed by the breakout groups under this theme topic were to summarize how changes in distribution across jurisdictional boundaries affect assessment and management needs and approaches, what methods have been used to address these, and where is information still lacking?

Discussions varied greatly across regions based on their individual within-region and jurisdictional issues. Functional examples exist in the southeastern U.S. for the Gulf of Mexico and South Atlantic migratory groups of king mackerel, and the Gulf of Mexico migratory group of cobia. Large unknowns surrounding the Gulf king mackerel stock include biomass and CPUE from Mexican waters; this hurdle may be difficult to overcome, as some Mexican states do not regularly collect fisheries data, and survey methods can be inconsistent. Also, within the Gulf of Mexico, the Gulf states share diversified management of red snapper for private anglers, requiring their cooperation in data collection and regulatory measures. The blueline tilefish example from Case study 11 was also discussed, noting the efforts to facilitate data sharing between northeast and southeast survey operators and data providers. The northeastern and northwestern U.S. contends with some issues with Canadian fisheries authorities. Other transboundary challenges include US-Russia relations for the Bering Sea and US-China/Pacific Islands for the Western Pacific.

> *As these stocks have gotten more abundant in nearby states that have very low proportions of the quota, they've had to ratchet down the regulations in order to stay within their catch limits. Fishermen are seeing more fish than they've ever seen in their lives and being told that they can't catch them. This is a serious risk to legitimacy, I think, of the management system.*
>
> *Olaf Jensen*

In these circumstances, communication between survey operators, science centers, universities, Councils, states, tribes, and marine fisheries commissions is critical to ensuring all requisite data are available for the stock assessment process. Some regions already have well-established collaborative relationships (for example in the southeastern U.S., the SEDAR stock assessment process facilitates this communication between the many cooperators and data providers to generate stock assessment products). But all regions will need to enhance coordination and communication as distributions change.

A number of topics discussed under this theme apply more generally and echo similar issues raised in Focus Sessions 1 and 2, in particular:

- the need that any national guidance and development of best practices must consider regional differences;
- capacity limitations, especially the need for more stock assessment authors and those who train them, and better data systems and handling practices to increase efficiency;
- the fact that stationarity (including stationarity in spatial distribution) is still assumed in most regions and distinguishing variability in spatial distributions versus distributional shifts takes time;
- the importance of maintaining the focus on stocks that are doing well rather than overfished stocks non-responsive to rebuilding plans;
- the need to provide flexible alternatives for non-traditional, data limited, multi-species complexes and fisheries;
- the desire for better ways to formally engage stakeholders, from MSEs to Fishery Performance Reports, noting that effectively communicating; tradeoffs of different management strategies can result in increased stakeholder understanding and buy-in; and
- the challenge to meet MSA mandates to manage to the least productive stock in a multispecies fishery when regions lack the data to determine which species is more vulnerable than others.

Cate O'Keefe, NEFMC, and Yan Jiao, MAFMC

OVERALL FINDINGS SUMMARY FROM SCS7

Councils need to start preparing now for increasingly complex management decisions due to climate change

The effects of climate change on US fisheries are being observed now, with more profound implications expected over the next 20 years in several regions. Regional Fishery Management Councils (RFMCs) need to consider adaptation options to sustain fisheries in a changing environment. Adaptation tools need to be tailored to regional differences in how climate change is now and will affecting marine ecosystems. Several FMCs have started considering models that include ecosystem linkages and / or have adopted climate-informed risk assessments. However, challenges remain including: pros and cons of shifting biological reference points, carrying capacity, and management units.

> *I think we do need to have a cautionary note to the Fisheries Management Councils, based on what we know today .. that there will be a period of decades where we have some serious challenges to fisheries management…And these, of course, are going to have impacts on different fishing sectors and communities. And finding an equitable management adaptation pathway to deal with these challenges is really going to be the task for us.*
>
> *Anne Hollowed*

Additional studies of the performance of current and alternative management strategies are needed to identify pathways to sustain fisheries in a future, non-stationary marine environment. RFMCs may encounter new issues due to competing uses of marine systems, abrupt shifts in distribution or abundance, and changes in ecosystem structure and function, with impacts on sectors and communities, and data collection methodologies. Guidance will be necessary to define biological reference points given non-stationarity. Finding equitable management adaptation pathways will be challenging.

Investment is needed in the development of new data collection and analysis tools that are responsive to changing conditions

Maintaining suites of models of different levels of complexity will be needed to inform management of marine resources undergoing complex responses to non-stationary environmental conditions. This suite could include Models of Intermediate Complexity for Ecosystems (MICE), including ecosystem linked single- or multi-species assessment models; foodweb models, and full end-to-end (climate to fish and fisheries) models that include human elements of fishing communities. Consideration must be given to on-going and enhanced monitoring efforts and assessments of whether we are measuring what we need to best prepare for the future and to identify climate ready-management scenarios. This is a particular challenge in regions that have high diversity and complex monitoring challenges. Enhanced monitoring includes consideration of multiple ways to detect change, including greater use of local, traditional and subsistence knowledge. Collaborations amongst regions would be strengthened by streamlining data management systems, and allowing for more 'open source' type data flows and interoperability. These collaborations would be strengthened by cross-jurisdictional data management systems and access to a broader set of users (e.g. easier access to data available for those not affiliated to agencies). Interdisciplinary research teams will be needed to ensure future success, and training students in this field will be critical.

SSCs and Councils need to be prepared to transition toward a more sophisticated toolbox

SSCs need to prepare for a transition from reliance on indicators derived from observations, to those informed by dynamic simulations of marine ecosystem change, tuned (or skill tested) to observations (Climate Ecosystem and Fisheries Initiative, CEFI), including consideration of next generation guidelines for climate-ready management and adaptation option evaluation. Scenario planning should begin now to avoid reactive responses. Additional flexibility should be considered in the management process, diversification of fishing portfolios to address population changes as well as the creation of more opportunities for strategic and creative thinking at the regional and national levels.

Stakeholder engagement will be critical for adaptive management to be successful

Climate-adaptive fisheries management will require engagement from all stakeholders and native communities and new understanding of increasingly complex models and uncertainty due to environmental variability. Science-based recommendations and management risks need to be clearly presented to build stakeholder confidence in new models or tools that quantify tradeoffs given increased uncertainty. An inclusive process for increased public engagement will benefit both stakeholder education as well as informing ecosystem-based management approaches.

> *Our best chance for successfully navigating the shoals ahead is ensuring that you, the SSCs, have the space and time necessary to continue to collaborate, innovate and create, and then ensuring that your voices are heard loudly and clearly, and heeded. The SSC leadership and the keynote speakers must take responsibility for ensuring that the outcomes of this workshop lead to changes such as development of innovative approaches, increased and improved communication, and stronger resolve to operate outside of our comfort zone. SCS7 participants should be planning now how they will spark conversations at their Councils.*
>
> *Bill Tweit*

RECOMMENDATIONS ON SCS WORKSHOP FORMAT

- ***Council member participation***:
  SSC delegates acknowledged the value of active participation by a Council member at the workshop and encouraged increased Council member participation in scientific dialogues at future SCS meetings.

- ***In-person meetings***:
  The group noted that the two-year delay to meet in-person, rather than substituting a virtual meeting, was worth the tradeoff, noting the benefits for enhanced communication and collaboration among regions.

- ***Time for discussion***:
  Delegates supported the meeting format, with breakout sessions (including rotating regional participation by session) and case studies, facilitated discussion and sharing of experiences across regions. Additional time for questions and discussion of case studies in plenary was recommended.

- ***Biennial workshops and off-year communication:***
  SCS7 participants recommend that the workshops continue on a biennial basis, but that additional communication amongst regions occurs in the off-year. Ideas for this could include an informal workgroup of SSC leadership, participants, NMFS Headquarters staff, or a virtual workshop.

Official regional SSC delegates for SCS7

APPENDICES

Sherri Dressel and Franz Mueter, both of NPFMC, contemplate logistics at a break.

Participants take advantage of break sessions to network with other Fishery Management Councils.

Adapting Fisheries Management to a Changing Ecosystem
7th National Scientific Coordination Subcommittee Meeting
Agenda

Sunday, August 14
4:00 - 6:00 Meet and greet at Westmark Stika Hotel to pick up registration materials: apps and no host bar
Download session documents on NPFMCs website: https://meetings.npfmc.org/Meeting/Details/2945 ; listen on zoom

Monday, August 15

	Title	Presenter	Council
Slides	**Welcome**	**Anne Hollowed**	NPFMC
	Council Address	**William Tweit**	NPFMC
	AFSC Address	**Dr. Bob Foy**	NPFMC
	Session 1 How to incorporate ecosystem indicators into the stock assessment process?	**Dr. Anne Hollowed**	NPFMC
Abstract Slides	**Keynote 1** *Including ecosystem information in assessments and management advice.*	**Dr. Andre Punt**	PFMC/ NPFMC
	10:10-10:30 Coffee Break		
Abstract Slides	**Case Study 1** *The collapse of snow crab: what happened and what now?*	**Dr. Cody Szuwalski**	AFSC
Abstract Slides	**Case Study 2** *Using climate data to improve sablefish assessment model projections*	**Dr. Melissa Haltuch**	PFMC
Abstract Slides	**Case Study 3** *Poor recruitment of reef fishes in the southeast United States Atlantic: preliminary findings and implications for management*	**Dr. Brendan Runde**	SAFMC
Abstract Slides	**Keynote 2** *Using ecosystem information in the stock assessment and advice process*	**Dr. Sarah Gaichas**	MAFMC
	12:00- 1:30 Lunch on your own		
Abstract Slides	**Case Study 4** *Inclusion of ecosystem information in US fish stock assessments: progress toward ecosystem-based fisheries management?*	**Dr. Kristin Marshall**	PFMC
Abstract Slides	**Case Study 5** *Using nonstationary stock assessment models to diagnose meaningful ecosystem indicators*	**Dr. Yan Jiao**	MAFMC
Abstract Slides	**Case Study 6** *Accounting for red tide mortality in stock assessments and catch projections*	**Dr. David Chagaris**	GMFMC
Abstract Slides	**Case Study 7** *Integrating ecosystem and climate influences on dynamics of New England stocks into stock assessment*	**Dr. Lisa Kerr**	NEFMC
	Coffee Break		
	Session 1 Breakouts	**Facilitators**	
	End Session		

Adapting Fisheries Management to a Changing Ecosystem
7th National Scientific Coordination Subcommittee Meeting
Agenda

Tuesday, August 16

Time	Title	Presenter	Council
	Overview of day and logistics	**Dr. Anne Hollowed**	NPFMC
Abstract Slides	**NOAA Fisheries National Science Activities and Updates on SSC-Relevant Topics**	**Melissa Karp**	NMFS HQ
Slides	**Recap of Breakout 1: Discussion**	**Dr. Bob Foy**	
	Session 2 Developing information to support management of interacting species in consideration of EBFM.	**Dr. Anne Hollowed**	NPFMC
Abstract Slides	**Keynote 3** *Multiple interacting species and the management challenges they pose*	**Dr. Eva Plaganyi**	
	10:30-10:50 Coffee Break		
Abstract Slides	**Case Study 8** *Multivariate approaches for EBFM implementation in the U.S. Caribbean*	**Dr. Juan J Cruz Motta**	CFMC
Abstract Slides	**Case Study 9** *Development of harvest control rules for Atlantic herring: an application of MSE to account for herring's role in the ecosystem*	**Dr. Cate O'Keefe**	NEFMC
Abstract Slides	**Case Study 10** *Does ignoring predation mortality lead to an inability to achieve management goals in Alaska?*	**Grant Adams**	NPFMC
	11:50- 1:30 Lunch on your own		
	Session 2 Breakouts	**Facilitators**	
	3:00- 3:20 Coffee Break		
	Session 3 How to assess and develop fishing level recommendations for species exhibiting distributional changes due to climate variability and climate change?	**Dr. Anne Hollowed**	NPFMC
Abstract Slides	**Keynote 4** *Perspectives on ways complex ecosystem projections can be applied in real-world fisheries management cases*	**Dr. Jim Ianelli**	NPFMC
Abstract Slides	**Case Study 11** *Blueline tilefish negotiations between the Mid- and South Atlantic Council SSCs*	**Dr. Scott Crosson**	SAFMC
Abstract Slides	**Case Study 12** *Toward dynamic harvest allocation rules for shifting species: a case study of three stocks in the Northeast US*	**Dr. Olaf Jensen**	MAFMC
6:00 - 8:00	*Reception at Sitka Sound Science Center*		NPFMC

Adapting Fisheries Management to a Changing Ecosystem
7th National Scientific Coordination Subcommittee Meeting
Agenda

Wednesday, August 17

Time	Title	Presenter	Council
9:00- 9:10	**Overview of day and logistics**	**Dr. Anne Hollowed**	**NPFMC**
9:10-10:40	**Session 3 Breakout**	**Facilitators TBD**	
	10:40-11:00 Coffee Break		
11:00-11:30	**Recap of Breakout 2: Discussion**	**Dr. Franz Mueter**	
11:30-11:50	**Fisheries Integrated Modeling System**	**Dr. Christine Stawitz**	**NMFS HQ**
	12:00- 1:30 Lunch on your own		
1:30- 2:00	**Recap Breakout 3: Discussion**	**Dr.** Mike Downs	
2:00- 3:00	**Summary of key findings**	**Dr. Anne Hollowed** **Group Discussion**	
	3:00- 3:20 Coffee Break		
3:20- 3:40	**Wrap-up and next steps**	**Dr. Anne Hollowed**	
	End Session		

Appendix 2 – Biographies

Hosts

Dr. Anne Hollowed, SCS7 Chair, NPFMC SSC Emeritus

Dr. Hollowed received a BA in Biology and Geology from Lawrence University, an MS in Biological Oceanography from Old Dominion University, and a PhD in Fisheries Science from the University of Washington. Her scientific career at the AFSC started with the assessment of groundfish stocks in the North Pacific and her research portfolio grew to exemplify her multidisciplinary outlook on fisheries science and management. The main focus of Dr. Hollowed's research has been addressing the implications of climate variability, climate change, and fishing on marine ecosystems, and identifying sustainable management strategies under changing environmental conditions. She is an internationally recognized leader on this topic with over 100 publications and significant contributions to domestic and international reports and committees.

Bill Tweit, NPFMC Council member

Bill Tweit is a Special Assistant for the Washington Department of Fish and Wildlife. He has represented the State of Washington on the North Pacific Fishery Management Council since 2005, and currently serves as Vice Chair. He chairs the Council's Ecosystem Committee and two of the committees providing oversight to the fisheries monitoring programs. His other roles at the Department included oversight of the Columbia River Management Unit, which is responsible for managing many of the non-Indian fisheries in the basin in coordination with Indian Tribes and other states, participating in the management of the hydrosystem to minimize impacts on salmonids and other native fish, and working with other parties to develop and implement ecosystem and species recovery plans. Bill provided policy direction to the Department for aquatic invasive species prevention and management. He is also an avid birdwatcher and enthusiastic supporter of the Olympia Symphony Orchestra.

Dr. Robert Foy, NMFS Alaska Fisheries Science Center Director, NPFMC SSC member

Robert Foy is the Science and Research Director of the Alaska Fisheries Science Center. Bob joined NOAA Fisheries in 2007 as the Director of the Center's Kodiak Laboratory and Program Manager for the Shellfish Assessment Program. He led the program on assessment, biological, and ecological research of commercial crab species in Alaska. Bob earned a Bachelor of Science in Biology from the University of Michigan, a Master in Science in Fisheries and Ph.D. in Oceanography from the University of Alaska.

Speakers

Dr. André Punt is a Professor in the School of Aquatic and Fishery Sciences at the University Washington, Seattle, USA and the past Director of the School. He received his B.Sc, M.Sc and Ph.D. in Applied Mathematics at the University of Cape Town, South Africa. Before joining the University of Washington, Dr Punt was a Principal Research Scientist with the CSIRO Division of Marine and Atmospheric Research in Australia. Dr. Punt has been involved in stock assessment and fisheries management for over 30 years and has been recognized for his contributions in this area with awards from CSIRO, the University of Washington, the Australian Society for Fish Biology, and the American Fisheries Society. His research relates broadly to the development and application of fisheries stock assessment techniques, bioeconomic modelling, and the evaluation of the performance of stock assessment methods and harvest control rules using the Management Strategy Evaluation approach. Dr. Punt has published over 400 papers in the peer-reviewed literature. He was a member of a National Research Council panel on evaluating the effectiveness of fish stock rebuilding in the United States. Dr Punt is currently a member of the Scientific and Statistical Committee of the Pacific Fishery Management Council, the Crab Plan Team of the NPFMC, and the Scientific Committee of the International Whaling Commission.

Dr. Sarah Gaichas has been a Research Fishery Biologist with the Ecosystem Dynamics and Assessment Branch at the NOAA NMFS Northeast Fisheries Science Center in Woods Hole, MA since September 2011, and worked at the NMFS Alaska Fisheries Science Center in Seattle, WA from 1997-2011. She is a member of the Mid Atlantic Fishery Management Council's Scientific and Statistical Committee, has been active in ecosystem reporting and management strategy evaluation for both the Mid Atlantic and New England Fishery Management Councils. Her primary research is on integrated ecosystem assessment, management strategy evaluation, and ecosystem modeling. Sarah earned her Ph.D. from the University of Washington, School of Aquatic and Fisheries Science in 2006, her M.S from the College of William and Mary, Virginia Institute of Marine Science in 1997, and her B.A. in English Literature from Swarthmore College in 1991.

Dr. Eva Plaganyi is a senior principal research scientist at CSIRO, based in Brisbane, Australia. She is responsible for methods to reliably and effectively manage marine natural resources, as well as to progress towards an ecosystem approach to fisheries management, including development and application of MICE (Models of Intermediate Complexity for Ecosystem assessment) and she is the Climate Impacts and Adaptation Portfolio leader for CSIRO's Oceans and Atmosphere. Her research involves stock assessment modelling, ecosystem modelling, management strategy evaluation (MSE) and climate change impacts and adaptations. She works closely with traditional owners in Torres Strait to develop harvest strategies for the tropical lobster and beche-de-mer fisheries. She has a dual biological and mathematical background, having earned a PhD in Applied Mathematics at the University of Cape Town in 2004, and she moved to CSIRO in 2009. She has published over 100 papers, has collaborated broadly and served on several scientific working groups.

Dr. Jim Ianelli began his career with fieldwork on tunas for the South Pacific Commission (now the Secretariat of the Pacific Community) and the Inter-American Tropical Tuna Commission where he developed their lab based in Panama. His undergraduate degree is from Humboldt State University and earned a PhD in 1993 from the University of Washington. For the last 30 years, he has been an active member of NOAA's Alaska Fisheries Science Center's stock assessment team and supports the NPFMC where he serves as Chair of the Gulf of Alaska groundfish Plan Team. His research interests include developing statistical approaches for ecosystem and fisheries conservation management. He is an affiliate professor at the University of Washington and the University of Maine and serves on various boards for international fisheries management. This includes the Scientific Advisory Panel for the Commission for the Conservation of Southern Bluefin Tuna and Chair of the South Pacific Regional Fisheries Management Organization's Scientific Committee.

Thank You to our keynote speakers (not pictured Jim Ianelli)

Appendix 3 - Case Studies and NMFS Abstracts

Case Study 1: The collapse of snow crab: what happened and what now?

Cody Szuwalski link to presentation

Eastern Bering Sea snow crab abundance collapsed to historical lows in 2021 after reaching historical highs in 2018. Over 10 billion crab disappeared from the survey during this time. Two questions now dominate conversation around snow crab in management: "What happened?" and "What do we do now?" I will describe efforts to answer these questions including the construction of population dynamics models that estimate time-varying natural mortality, simulation studies to understand the estimability of variation in mortality, and attribution studies to identify potential drivers of the collapse. I will also describe the difficult decisions required to implement rebuilding plans and outline counter-intuitive consequences of climate-adaptation in management targets.

Cody Szuwalski, AFSC, discusses the collapse of snow crab.

Case Study 2: Using climate data to improve sablefish assessment model projections.

Melissa Haltuch link to presentation

A crux of fishery management is that while recruitment is seldom average, cohort strength is not well estimated until several years of data are available from surveys and fisheries. Thus, scientists and managers are always looking in the rear view mirror. For species with weak stock-recruitment relationships, the inclusion of environmental recruitment indices in stock assessments may improve model precision, and aid in near-term forecasting. I provide an overview of the long-standing relationship between sablefish (*Anoplopoma fimbria*) recruitment and sea level along the US West Coast, and recent use of a sea level index in the stock assessment. Then, retrospective investigations show how using the sea level index in stock projections can improve recruitment estimation in the absence of other data. Finally, I discuss how the Pacific Fishery Management Council allows climate data to be included in near-term forecasts for management advice. This work provides an example of how transitioning research products into operational products can improve stock assessment advice for fishery managers and illustrates the benefits of frequent communication between fisheries scientists and fishery management bodies as we move towards climate-ready fisheries.

Melissa Haltuch, PFMC

Case Study 3: Poor recruitment of reef fishes in the southeast United States Atlantic: preliminary findings and implications for management.

Brendan J. Runde, Kyle W. Shertzer, J. Kevin Craig, Taylor A. Shropshire, Kaitlynn Wade, Erik H. Williams, and Nathan M. Bacheler *link to presentation*

Multiple species of Atlantic demersal reef fishes have experienced notable declines in recruitment in recent years. We investigated several hypotheses for these concurrent declines, including recruitment overfishing, predation of juveniles by invasive lionfish, and environmental drivers. Recruitment overfishing does not appear the likely cause, given that not all of these species are heavily exploited, and for those that are, declines in recruitment precede increases in fishing mortality. Similarly, predation of juvenile reef fishes by invasive lionfish is unlikely to have caused recruitment declines as lionfish are generalists and abundance of lionfish has decreased in recent years. Our leading hypothesis is that oceanographic conditions have become increasingly unfavorable for these species during their winter spawning season. Anomalies in sea surface temperature, as well as surface chlorophyll levels, have become more frequent and generally more severe over time. This situation implies non-stationarity in the marine ecosystem and presents challenges for both stock assessment and for resource management.

Kristin Marshall, PFMC, Sherri Dressel, NPFMC, and her service dog, Edie, in deep discussion.

Brendan Runde, TNC, giving his case study presentation.

Case Study 4: Inclusion of ecosystem information in U.S. fish stock assessments: progress toward ecosystem-based fisheries management?

Kristin Marshall link to presentation

The appetite for ecosystem-based fisheries management (EBFM) approaches continues to grow, and the perception persists that implementation is slow. Here, I synthesize a snapshot of one potential avenue for EBFM in the U.S.: expanding fish stock assessments to include ecosystem considerations and interactions between species, fleets, and sectors. I will give an overview of a synthesis where co-authors and I reviewed over 200 stock assessment reports from U.S. federal waters during 2004-2014 and assessed how the reports included information about system influences on the assessed stock. Our goals were to quantify whether and how assessments incorporated broader system-level considerations and to explore factors that might contribute to the use of system-level information. Interactions among fishing fleets (technical interactions) were more commonly included than biophysical interactions (species, habitat, climate). Interactions within the physical environment (habitat, climate) were included twice as often as interactions among species (predation). Many assessment reports included ecological interactions only as background or qualitative considerations, rather than incorporating them in the assessment model. Our analyses suggested that ecosystem characteristics are more likely to be included when the species was overfished, the assessment is conducted at a science center with a longstanding stomach contents analysis program, and/or the species life history characteristics suggest it is likely to be influenced by the physical environment, habitat, or predation mortality. I will reflect on what this snapshot of stock assessments implies about progress on EBFM the U.S. and on what may have changed in more recent years. The future implications of the diversity of ways that assessments have taken into account ecosystem considerations for managing fisheries in a changing ecosystem will also be discussed.

Case Study 5: Using nonstationary stock assessment models to diagnose meaningful ecosystem indicators.

Yan Jiao link to presentation

Many stock assessments have been of concern because of multiple reasons including inconsistent abundance indices and likely changed population productivity, key life-history processes, and spatial distribution. The Atlantic weakfish (*Cynoscion regalis*) is an example to deal with such issues. We developed and operationalized models for Atlantic weakfish to evaluate and incorporate nonstationary population dynamics and to develop relevant management reference points. A model averaging framework based on the Atlantic weakfish example and the explored stationary and nonstationary statistical catch-at-age models was developed and provided a case study to use multiple models in fisheries stock assessment and management.

Yan Jiao, MAFMC, giving her case study presentation.

Case Study 6: Accounting for red tide mortality in stock assessments and management projections in the Gulf of Mexico.

David Chagaris, Lisa Ailloud, Mandy Karnauskas, Chris Kelble, Matthew McPherson, Skyler Sagarese, Brendan Turley, Daniel Vilas, Nathan Vaughan, and John Walter link to presentation

Red tides are a harmful algal bloom caused by the toxic dinoflagellate, *Karenia brevis*, that occur almost annually in the Gulf of Mexico. Red tide usually forms during the summer and early fall in nearshore waters along the southwest coast of Florida, but may occur at any time, in offshore waters, and in other regions of the Gulf. Severe red tides can result in massive fish kills, mortality on marine megafauna, persistent hypoxic conditions, respiratory distress in humans, shellfish harvest closures, and loss of fisheries and tourism revenues. These events present challenges for stock assessments that are expected to account for mortality caused by past red tides, and when setting annual catch limits if a red tide bloom is ongoing or occurred during a projection year. Red tide mortality was first incorporated into stock assessment models for gag (*Mycteroperca microlepis*) and red grouper (*Epinephelus morio*) in 2009 after the severe 2005 red tide, which persisted for over a year and extended to offshore waters. Red tides occurring in 2014, 2018, and 2021 were incorporated into later stock assessments of these species. This has been accomplished by adding a pseudo fishing fleet (i.e., dead discard only) and estimating a mortality term for years when red tide was presumed severe enough to impact the stock, with full selectivity across all ages. For the 2021 stock assessment of gag grouper, a spatial ecosystem model of the West Florida Shelf provided estimates of red tide mortality by age, and near-real time estimates for the 2021 bloom were used in catch projections and management advice. These recent advances integrated satellite imagery, in situ red tide samples, species distribution patterns, lethal and sublethal responses, and food web effects into the stock assessment and management process. How the Gulf Council deals with future red tides will be guided by the new Gulf of Mexico Fishery Ecosystem Plan (FEP). The Gulf FEP provides a framework for identifying and dealing with fishery ecosystem issues such as red tides, and includes components for stakeholder engagement, data collection, modeling, and management integration.

David Chagaris, GMFMC

Case Study 7: Integrating ecosystem and climate influences on dynamics of New England stocks into stock assessment.

Lisa Kerr link to presentation

Lisa Kerr, NEFMC

The Northeast Region Coordinating Council instituted an enhanced stock assessment process wherein research track stocks assessments provide a vehicle for comprehensive evaluation of new data streams and model changes. Research track assessments are complex scientific efforts carried out by a working group over several years and represent on-ramps for new science to be integrated into the stock assessment process with the aim of improving the quality of stock assessments. Working groups are asked to: identify relevant ecosystem and climate influences on stocks and consider these findings in addressing other terms of reference in the stock assessment. We will report on ongoing work and evolving approaches to address this term of reference in research track stock assessments in the Northeast. The general approach includes: 1) characterizing the influence of climate and ecosystem drivers on stock dynamics and identify candidate ecosystem indicators. 2) characterizing fishermen's ecosystem knowledge. 3) exploratory modeling of relationships among climate, ocean, and stock variables, and 4) testing the performance of climate informed stock assessments. We will draw on examples from recent and ongoing research track assessments, including American plaice, Atlantic cod, and haddock.

Case Study 8: Multivariate approaches for EBFM implementation in the U.S. Caribbean.

J.J. Cruz-Motta, Stacey Williams, Tarsila Seara, William S. Arnold, Graciela García-Moliner, Orian Tzadik, Tauna Rankin, Alida Ortiz, Kevin McCarthy, María Lopez-Mercer, Sarah Stephenson, Sennai Habtes, Edwin Cruz-Rivera, Liajay Rivera-García
link to presentation

The fisheries of the U.S. Caribbean are some of the smallest in the U.S. in terms of volume of landings, fleet size and monetary absolute value, and where the implementation of stock assessments has been hindered by the availability of data (i.e. data poor region). However, they are very diverse fisheries that target the highest number of management unit species in the country, likely due to the high diversity of habitats exploited (i.e. about 80% of species are related to coral reefs). Moreover, due to the coastal nature of the fisheries (i.e. artisanal + limited shelf area), many other drivers potentially affect non-fishing mortality rates of targeted species. Under these circumstances, it is proposed that the implementation of an Ecosystem Based Fisheries Management (EBFM) approach could help overcome historical caveats in the region. Consequently, one of the main objectives is to develop a Fishery Ecosystem Plan (FEP) to guide the implementation of the EBFM approach. The first step to accomplish this, and the focus of this presentation, is to describe the fisheries system using a multi-specific, multi-driver perspective. This effort used a qualitative approach based on conceptual models of different stakeholder's perceptions of the ecosystem, as well as a quantitative multivariate framework that recognized the multi-specific, multi-driver nature of the U.S. Caribbean fisheries. Preliminary results showed that: i) the conceptual model methodology is effective in helping to identify components which are currently not being fully assessed or monitored in the region (e.g., recreational fisheries), ii) multivariate analysis detected consistent temporal trends across different types of data (i.e. fisheries independent vs dependent), iii) temporal trends of the structure and composition of landings and fish assemblages were related to multiple drivers (in addition to fishing removals), and iv) multivariate methods proved to be useful alternatives in identifying indicators and threats. One important conclusion is that, for the approach presented here to provide information that guides decision-making in the region, the development of a novel cross-mandate policymaking process is a crucial step for the success of EBFM implementation in the U.S. Caribbean.

Case Study 9: Development of harvest control rules for Atlantic herring: an application of MSE to account for herring's role in the ecosystem.

Cate O'Keefe *link to presentation*

Atlantic sea herring have supported a primary New England fishery for centuries and have long been recognized as an important prey species for several of the region's key commercial and recreational predators and protected species. Recognizing the importance of managing forage fish within an ecosystem context, the New England Fishery Management Council (NEFMC) initiated development of an Acceptable Biological Catch (ABC) control rule for herring to explicitly account for herring's role in the ecosystem and address the biological and ecological requirements for the herring resource. In 2016, the NEFMC began developing alternatives for the control rule using Management Strategy Evaluation (MSE) to identify fishery objectives and corresponding quantitative performance metrics through a stakeholder-driven process. The approach included integration of herring-specific operating models with a range of "general predator" models, including groundfish, highly migratory species, seabirds, and marine mammals. Results indicated that predator metrics had different levels of sensitivity to herring population changes resulting from different ABC control rules. The NEFMC ultimately selected a biomass-based control rule that limits fishing mortality dependent on stock biomass to account for the role of herring as forage. This case study will describe how the MSE was blended with the Council process to develop an ABC control rule to support ecosystem-based fishery management for Atlantic herring.

Case Study 10: Is ignoring predation mortality leading to an inability to achieve management goals in Alaska?

Grant D. Adam, Kirstin Holsman, André E. Punt link to presentation

The majority of tactical fisheries management relies on the use of single-species population dynamics models that explicitly assume the dynamics of individual populations are independent of one another. This is despite a large body of research demonstrating that the life history of fishes is impacted by the dynamics of their predator populations. While time-varying predation mortality is thought to represent a large proportion of mortality for groundfish in Alaska, United States, assessment models, biological reference points, and harvest control rules do not explicitly account for time-varying predation and assume time-invariant (but perhaps age-specific) natural mortality. Previous research has demonstrated that ignoring predator-prey dynamics can lead to a biased perception of stock status and poor predictive performance of assessment models. However, further research is needed to identify the relevance of time-varying predation mortality to single-species management performance while also accounting for the feedback between management strategies and fish populations through continued data collection and assessment. Here we conduct a management strategy evaluation based on two multi-species population dynamics models developed for groundfish in Alaska, United States to assess whether ignoring predation inhibits the performance of single-species management. Specifically, we use the two multi-species models developed for the Gulf of Alaska and Eastern Bering Sea as operating models to evaluate the ability of single-species management strategies to achieve single- and multi-species biological reference points, maximize catch, minimize catch variability, and reduce bias in biomass estimates.

Case Study 11: Blueline tilefish negotiations between the Mid- and South Atlantic Council SSCs.

Scott Crosson link to presentation

Over the past decade, the commercial and recreational fisheries for Blueline Tilefish (*Caulolatilus microps)* expanded latitudinally along the eastern US seaboard, as the species was found in abundance north of its previously known prime habitat and outside its regulatory environment. This resulted in an unregulated and untracked harvest of what was a genetically continuous part of a more historically fished and assessed southern stock, which was in a rebuilding program. A cross-jurisdictional working group evaluated the situation and developed recommendations for co-management by the two SSCs.

Case Study 12: Defining shifting fish distributions with respect to state boundaries: a case study of three species in the US Mid-Atlantic region.

Olaf Jensen [link to presentation]

Management of fish stocks that cross management jurisdictions, known as shared stocks, is challenged by the shifting of those stocks with respect to management boundaries. Transitioning to dynamic rules in spatial allocation of quota across management jurisdictions has been suggested as a solution to this issue, however, in many cases spatial boundaries are not clearly drawn. Here, we use black sea bass (*Centropristis striata*), summer flounder (*Paralichthys dentatus*) and scup (*Stenotomus chrysops*) as case studies to explore different approaches to designing spatial regulatory areas to facilitate the adaptation of fisheries management to shared-stocks shifting distributions. First, we determine the yearly distribution of each stock within the U.S. Exclusive Economic Zone from two trawl surveys: the NEFSC Fall and Spring surveys. Second, we explore two approaches for drawing regulatory areas within federal waters: one based on geographic expansion of state waters and another based on spatial buffering from ports with high historical landings of the species in question. Finally, we estimate each state's proportion of the stock's distribution and compare historical and recent values. We show that the distribution of all three stocks has changed relative to the years currently used to determine the current quota allocation, with an overall gain for center-northern states at the expense of the southernmost states. In terms of the distribution of allocation, we find that while seasonal differences exist, the biggest differences in state-quota come from the method for designing regulatory areas. Other regions will likely face similar challenges in determining a fair and broadly acceptable method of defining shifting fish distributions with respect to the individual states harvesting shared stocks.

Bill Tweit, NPFMC, Olaf Jensen, MAFMC and Richard Appeldoorn, CFMC

NOAA Fisheries National Science Activities and Updates on SSC-Relevant Topics

Kristan Blackhart *link to presentation*

NOAA Fisheries is actively engaged in a range of science and management activities relevant to work by the Councils' Scientific and Statistical Committees. In particular, ongoing work is occurring related to each of the SCS7 key themes of managing interacting species, assessing distributional changes, and incorporating ecosystem indicators into stock assessments. This report provides a brief overview of the most relevant activities and further resources, where available.

Stock Assessment Modeling

The Fishery Integrated Modeling System (FIMS) is envisioned as a next-generation stock assessment modeling framework. Planning for FIMS has been underway for several years, with active development beginning in 2022. The framework, when fully implemented, will comprise a system of tools developed collaboratively by scientists across NOAA Fisheries. FIMS is being developed using modern software development approaches and will enable users to leverage technological developments (e.g., high performance computing, cloud resources, parallel processing). Because FIMS is designed from the outset as modular and extensible, it will have greater longevity as a software platform for conducting fisheries assessments and allow multiple contributors to maintain, update, or enhance its features.

The NOAA Fisheries Integrated Toolbox (FIT) is an interdisciplinary collection of operational tools. FIT facilitates sharing and comparison of analytical tools for stock assessment, forecasting, data preparation, economic analysis, ecosystem modeling, and other applications. Hosted tools are developed by NOAA Fisheries scientists as well as external partners, and additional resources are provided (e.g., technical training). As development of FIMS progresses, it will provide NOAA Fisheries the opportunity to build linkages between existing analytical tools and the FIMS framework, providing scientists seamless access for conducting more holistic stock assessment investigations.

The Center for the Advancement of Population Assessment Methodology (CAPAM) will host a technical workshop in October 2022 on Stock Assessment Good Practices. NOAA Fisheries' stock assessment scientists will engage thoroughly in this workshop, including by leading several of the keynote presentations and drafting the associated research papers defining assessment good practices. These papers, after discussion and review by workshop participants, will be submitted for publication to the journal Fisheries Research. Engagement in this workshop and similar efforts ensures that agency assessments remain cutting edge, and development of FIMS utilizes accepted good practice methodologies.

Spatial and Distribution Modeling

NOAA Fisheries launched the Distribution Mapping and Analysis Portal (Dis MAP) in April 2022 to address decision-maker needs for information on changing species distributions. DisMAP is designed to provide users with an interactive website equipped with tools to visualize and analyze species distributions over time, facilitating improved data sharing and decision making. The portal provides access to distribution information for over 800 marine fish and invertebrate species caught in NOAA Fisheries bottom trawl surveys across five regions. Planned future enhancements to DisMAP will include additional data types as well as adding new functionalities identified as priorities by our partners. Continued buildout of this system will enhance the ability of NOAA Fisheries and our partners to identify, plan for, and respond to climate-driven changes now and in the future.

In 2023, NOAA Fisheries will resume its National Stock Assessment Workshop, which has been on hold due to the COVID-19 pandemic. These internal agency workshops provide an opportunity for NOAA Fisheries' stock assessment scientists from each of the six regional Science Centers to exchange ideas and discuss assessment approaches, identify issues and emerging priorities, and collaborate to establish good practices for stock assessment methods. The theme for the 2023 meeting will be spatial modeling, with a focus on species distribution modeling and parameterizing spatial stock assessments. The meeting will also be held jointly with NOAA Fisheries' MARVLS (Maturity Assessment Reproductive Variability and Life Strategies) Workshop, including a joint session.

National Standard 1 Technical Guidance

NOAA Fisheries has been working to update the 1998 National Standard 1 (NS1) technical guidance to incorporate some of the significant changes to NS1 and provide the implementation guidance needed to meet today's management challenges. Development of guidance was divided into three main topics: 1) Status Determination Criteria (SDC); 2) carry-overand phase-in provisions; and 3) data-limited stocks and alternative approaches for setting ACLs. Development of technical guidance for each topic has moved forward at different paces.

Technical guidance for harvest policies related to carry-over and phase-in provisions was completed and published in 2020. Technical guidance on data-limited approaches is currently undergoing final review and clearance within NOAA Fisheries and is anticipated to be published later this year. An initial draft of the technical guidance for SDC is currently undergoing internal review; it is anticipated that Council partners will be briefed on this portion at the October Council Coordination Committee meeting, with the opportunity to provide comment afterwards. This document covers a number of challenging topics related to SDC, including use of proxies, prevailing conditions, and additional considerations (e.g., spatial complexity, age truncation, etc.). Technical guidance for control rules, rebuilding plans, and related issues are beyond the scope of this document and are not included.

Climate Science

The NOAA Climate, Ecosystems and Fisheries Initiative (CEFI) is a cross-NOAA effort to provide climate-informed advice to reduce risks and increase resilience of marine resources and the people and businesses that depend on them. CEFI's goal is to leverage existing capabilities and make critical new investments to build the end-to-end, operational ocean modeling and decision support system needed under a changing climate. CEFI pilot projects are underway in four regions (Bering Sea, West Coast, Gulf of Alaska, and Northeast), and NOAA is updating build-out plans for FY23-26.

The NOAA Fisheries Climate Science Strategy 5-year Progress Report lists recent accomplishments of the NOAA Fisheries Climate Science Strategy (NCSS), published in 2015 to increase the production, delivery, and use of climate-related information to support resilience and adaptation to changing climate. Highlights of recent accomplishments include:

- Development of tools and products to help decision makers track changes using ecosystem indicators, such as Ecosystem Status Reports and the Marine Indicators Portal
- Climate vulnerability assessments for fish stocks, marine mammals, sea turtles, habitats, and communities
- New forecasts of Marine Heat Waves that provide up to a year's advance notice to help managers and other stakeholders prepare and respond to these events

To customize and implement the NCSS, NOAA Fisheries has developed draft Climate Regional Action Plans (RAPs) for 2022-2024. Through coordinated cross-agency efforts, these plans focus on building regional capacity, partners, products and services to address key regional climate science needs and build on progress that has been made since the NCSS was published in 2015. NOAA Fisheries is seeking public comment on the draft RAPs until 7/29.

Ecosystem Modeling

The NOAA Fisheries Strategy for Ecosystem Modeling to Support Operational EBM/EBFM was recently published. The goal of this strategy is to accelerate the operational delivery of EBM/EBFM advice provided by ecosystem modeling and analysis. Implementation will help to ensure a more efficient use of overall agency analytical capacity and an increased, more strategic use of modeling capacity to serve multiple programmatic needs in different regions.

Exemplifying the forward progress NOAA Fisheries continues to make in ecosystem modeling, several agency authors contributed t o a special issue of Frontiers in Marine Science titled "*Using Ecological Models to Support and Shape Environmental Policy Decisions*." The special issue was created following the 5th National Ecosystem Modeling Workshop (NeMOW) in 2019. Contributed papers discuss recent progress in applying ecosystem modeling for living marine resource management.

A Multispecies Modeling and Applications Workshop was held in June 2021 by NOAA Fisheries in partnership with UMass Dartmouth's School for Marine Science & Technology (SMAST). The main purpose of the workshop was to convene a global group of experts in multispecies modeling to address the question, "*Why aren't multispecies models used more frequently in an operational fisheries context, and can we increase their use*?" A report from the workshop is available, and an additional manuscript resulting from the workshop tentatively titled "*Increasing the uptake of multispecies models in fisheries management*" is in prep.

Discussion ranged from climate change impacts being realized regionally to how to manage fisheries moving forward under non-stationary conditions.

The Fisheries Integrated Modeling System: comparing a new modular paradigm for fisheries stock assessment software to existing platforms

Christine C. Stawitz, NOAA Fisheries Office of Science & Technology, Seattle, WA, USA, Bai Li, ECS Federal in support of NOAA Fisheries, Silver Spring , M D, USA, Matthew Supernaw, NOAA Fisheries Office of Science and Technology, St. Petersburg, FL, USA, Kristan Blackhart, NOAA Fisheries Office of Science & Technology, Seattle, WA, USA, Andrea Havron, ECS Federal in support of NOAA Fisheries , Corvallis OR, USA. Richard D. Methot Jr., NOAA Fisheries Office of the Assistant Administrator, Seattle, WA, USA. Patrick Lynch, NOAA Fisheries Office of Science & Technology, Silver Spring, MD, USA

ABSTRACT

Fisheries stock assessment models are applied throughout the world and range from data-limited models that estimate stock status from catch and/or life history-parameters, to integrated single-species models incorporating survey and composition data, to multi species models. However, there is a growing understanding that model misspecification can lead to biased analyses, and exogenous factors not captured in common modeling platforms can lead to underestimated uncertainty of estimates. The current generation of assessment models has limited ability to readily incorporate factors, such as climate change, interspecies interactions, and socioeconomic pressures, into fisheries stock assessment models. Furthermore, current models are largely built using aging software tools that are not always well-equipped to model these factors using random effects. A next generation of stock assessment software presents an opportunity to develop an integrated framework for new models that are more comprehensive, more interoperable, and more modular. To facilitate this, NOAA Fisheries is investing in a Fisheries Integrated Modeling System (FIMS} that allows for a more modular and collaborative stock assessment software system. FIMS is being developed by a team of regional experts working with dedicated programming staff to ensure the system meets regional needs while remaining interoperable with other frameworks and modules. FIMS is also guided by a Steering Committee that includes representatives from outside NOAA Fisheries, including domestic and international partners as well as Regional Fishery Management Organizations. The team has completed a benchmark simulation of FIMs to compare against tactical assessment models used in other regions to show we can accurately replicate existing assessment configurations. This assessment serves as the start of a bridge to a more modular, integrated, and modern assessment models needed to manage fisheries in a changing climate.

Appendix 4 - List of Attendees

Keynote Speakers and Presenters

Anne Hollowed	NPFMC Emeritus	Chair
Bill Tweit	NPFMC	Welcome
Sarah Gaichas	NOAA/ NEFSC, MAFMC SSC	Keynote speaker
Jim Ianelli	NOAA/AFSC	Keynote speaker
Eva Plaganyi	CSIRO	Keynote speaker
Andre Punt	University of Washington	Keynote speaker
Grant Adams	University of Washington	Case Study Presenter
David Chagaris	GMFMC	Case Study Presenter
Scott Crosson	SAFMC	Case Study Presenter
Juan Cruz Motta	CFMC	Case Study Presenter
Melissa Haltuch	PFMC	Case Study Presenter
Olaf Jensen	MAFMC	Case Study Presenter
Yan Jiao	MAFMC	Case Study Presenter
Lisa Kerr	NEFMC	Case Study Presenter
Kristin Marshall	PFMC	Case Study Presenter
Cate O'Keefe	NEFMC	Case Study Presenter
Brendan Runde	The Nature Conservancy	Case Study Presenter
Christine Stawitz	NMFS Office of Science and Technology	Case Study Presenter
Cody Szuwalski	NOAA/AFSC	Case Study Presenter

SSC Delegates - *(CVs for SSC delegates linked on their name)*

Richard Appeldoorn	CFMC	University of Puerto Rico at Mayaguez
Juan Cruz Motta	CFMC	University of Puerto Rico at Mayaguez
Tarsila Seara	CFMC	University of New Haven
David Chagaris	GMFMC	University of Florida
James Nance	GMFMC	GMFMC SSC
Will Patterson	GMFMC	University of Florida
James Tolan	GMFMC	Texas Parks and Wildlife Department
Olaf Jensen	MAFMC	MAFMC SSC (and University of Wisconsin Madison)
Yan Jiao	MAFMC	MAFMC SSC
Alexei Sharov	MAFMC	MAFMC SSC
Lisa Kerr	NEFMC	Gulf of Maine Research Institute, Facilitator
Conor McManus	NEFMC	Rhode Island Division of Marine Fisheries
Cate O'Keefe	NEFMC	NEFMC SSC
Sherri Dressel	NPFMC	Alaska Department of Fish and Game
Franz Mueter	NPFMC	University of Alaska Fairbanks, Facilitator
Melissa Haltuch	PFMC	NOAA/NWFSC
Galen Johnson	PFMC	Northwest Indian Fisheries Commission, Facilitator
Kristin Marshall	PFMC	NOAA/NWFSC, Facilitator
Theresa Tsou	PFMC	WDFW

List of Attendees, continued

Jeffrey Buckel	SAFMC	NC State University
Scott Crosson	SAFMC	NOAA Fisheries
Amy Schueller	SAFMC	NOAA/SEFSC
Frank Camacho	WPFMC	University of Guam
Erik Franklin	WPFMC	University of Hawaii at Manoa
Shelton Harley	WPFMC	New Zealand Ministry for Primary Industries

Additional SSC Attendees

Michael Downs	NPFMC	Wislow Research Associates LLC, Facilitator
Robert Foy	NPFMC	NOAA-AFSC, Facilitator
Ian Stewart	NPFMC	International Pacific Halibut Commission, Facilitator
Patrick Sullivan	NPFMC	NPFMC SSC -- Cornell University
Alison Whitman	NPFMC	ODFW, Facilitator

Staff Attendees

Martin Dorn	Fisheries Research Biologist	AFSC
Liajay Rivera-Garcia	EBMF Technical Assistant	CFMC
Ryan Rindone	Lead Fishery Biologist/SEDAR Liaison, Rapporteur	GMFMC
Brandon Muffley	Fishery Management Specialist, Rapporteur	MAFMC
Chis Kellogg	Deputy Director	NEFMC
Jodi Pirtle	Juneau Branch Chief & Deputy Assistant Regional Administrator	NMFS
Melissa Karp	ECS tech in support of NOAA Fisheries	NMFS HQ
Howard Townsend	Ecologist / Systems Modeling	NMFS HQ
John DeVore	Staff Officer, Rapporteur	PFMC
Judd Curtis	Quantitative Fishery Scientist	SAFMC
Asuka Ishizaki	Protected Species Coordinator	WPFMC
Michele Robinson	Ecosystem Committee Member	PFMC

NPFMC Staff Hosts

Maria Davis	Communications/IT	NPFMC
Diana Evans	Deputy Director, Rapporteur	NPFMC
Shannon Gleason	Administration	NPFMC
Anna Henry	Fishery Analyst, Rapporteur	NPFMC
Sarah La Belle	Administration	NPFMC
Nicole Schmidt	Finance Officer	NPFMC
Diana Stram	Senior Scientist, Lead Staff/Convenor	NPFMC

Appendix 5 – Acronym list

ABC	Acceptable Biological Catch
ACLIM	Alaska Climate Integrated Modeling
ADFG	Alaska Dept. of Fish and Game
AFSC	Alaska Fisheries Science Center (NMFS)
B_{MSY}	The biomass that allows maximum sustainable yield to be taken.
B_0	Unfished biomass; the estimated size of a fish stock in the absence of fishing.
CEATTLE	Climate-Enhanced Age-based model with Temperature-specific Trophic Linkages and Energetics
CEFI	Climate Ecosystems and Fisheries Initiative
CFMC	Caribbean Fishery Management Council
CKMR	close-kin mark repeater
CPUE	catch per unit of effort
CSIRO	Commonwealth Scientific and Industrial Research Organization
CV	coefficient of variation or curriculum vitae
EAFM	ecosystem approaches to fishery management
EBFM	ecosystem-based fishery management
EBM	ecosystem-based management
eDNA	environmental DNA
ESP	economic and socioeconomic profile
ESR	ecosystem status report
F	The instantaneous rate of fishing mortality
FEP	fishery ecosystem plan
FIMS	fisheries information management system
FMP	fishery management plan
F_{MSY}	The fishing mortality rate that maximizes catch biomass in the long term.
GHL	guideline harvest level
GMFMC	Gulf of Mexico Fishery Management Council
GOA	Gulf of Alaska
HCR	harvest control rule
IEA	integrated ecosystem assessment
IPHC	International Pacific Halibut Commission
LK	local knowledge
MAFMC	Mid Atlantic Fishery Management Council
MEY	maximum economic yield
MMEY	multispecies maximum economic yield
MICE	Models of Intermediate Complexity for Ecosystem Management
M_{MSY}	multispecies MSY
MRA	Maximum Retainable Amount
MSA	Magnuson-Stevens Fishery Conservation and Management Act
MSE	Management strategy evaluation
MSM	multispecies model
MSY	Maximum Sustainable Yield
mt	metric tons
NAFO	Northwest Atlantic Fisheries Organization
NEFMC	New England Fishery Management Council
NEFSC	New England Fisheries Science Center
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPFMC	North Pacific Fishery Management Council
NWFSC	Northwest Fisheries Science Center (NMFS)
OFL	overfishing limit
P*	Probability that the estimate of ABC exceeds the "true" OFL.
PFMC	Pacific Fishery Management Council
RFMC	regional fishery management council
RIP	robust to interacting fisheries management
R_o	average recruitment to a fish stock in the absence of fishing
SAFMC	South Atlantic Fishery Management Council
SCS	Scientific Coordination Committee (of the Council Coordination Committee)
SEDAR	Southeast Data Assessment and Review panel
SEFSC	Southeast Fisheries Science Center
SOE	state of the ecosystem
SSC	Scientific and Statistical Committee
SWFSC	Southwest Fisheries Science Center (NMFS)
TAC	total allowable catch
TK	traditional knowledge
USFWS	United States Fish & Wildlife Service
UxS	unmanned systems
VAST	vector-autoregressive spatio-temporal model
WPFMC	Western Pacific Fishery Management Council

U.S. Regional Fishery Management Councils

Thank you all for your participation, and a special thank you to the rapporteurs and moderators.

We could not have done this without you.

An evening reception was held at the Sitka Sound Science Center Aquarium giving participants time among the exhibits and touch tanks.

U.S. Regional Fishery Management Councils

Back cover photo of Sitka Harbor by NPFMC staff.


Jetta D
OCEAN RAVEN