SSC Ecosystem Working Group Report: March 2023

March 2, 2023

Review of SSC Ecosystem Working Group Objectives and Intended Outcomes

The MAFMC SSC Ecosystem Working Group (WG) was established in May 2021 to assist the Council in developing short term and long term objectives to advance the operational use of ecosystem information in management decisions. As reported in September 2021, March 2022, and September 2022 the WG has identified three general objectives:

1. Expanding and clarifying the ecosystem portion of the SSC OFL CV determination process (short term objective)
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)
3. Collaborating with SSC species leads, stock assessment leads, and relevant working groups in developing the stock-specific Ecosystem and Socio-economic Profiles (ESP) process to specify stock-specific Ecosystem ToRs that are impactful and can be integrated into assessments (moderate-term objective)

Objectives 1 and 3 aim to integrate appropriate ecosystem information at the stock level of management decision making, while objective 2 applies to current Council EAFM processes and potential future multispecies and system level objectives.

Intended outcomes of WG work for the Council include:

- An OFL CV process that makes better use of ecosystem information in determining the ABC
- Evaluation of multiple ecosystem indicators and potential development of thresholds for use in a revised EAFM risk assessment and/or other Council processes
- Increased range of opportunities for relevant ecosystem information to be considered in management decision processes

Progress

At the joint Council/SSC meeting in October 2022, the SSC Ecosystem Working Group provided an update on current work, and sought Council feedback on priorities for development and use of integrated ecosystem-level indicators within existing or new Council processes (see October 2022 report to the Council, p.3-8 and Presentation, slides 6-11).

Since October 2022:

- WG member Sarah Gaichas submitted a summary of the SCS7 Keynote "Using Ecosystem Information in the Stock Assessment and Advice Process" that highlights MAFMC SSC and SSC Ecosystem WG projects (see draft attached at the end of this document).
- The Bluefish Research Track assessment's ESP document addressing ToR 1 ecosystem effects on the stock received high praise from CIE reviewers.
- The State of the Ecosystem (SOE) request prioritization completed by the WG in 2022 has been incorporated into work going forward for 2023 and future SOEs, and is reflected in the 2023 SOE request tracking memo.
- The WG met 27 February 2023 to review updates on four projects related to the objectives above. Notes from the review are detailed below.

Objective 1: OFL CV and ecosystem effects

These projects will enhance the SSC's current OFL CV process or address stock reference points, and therefore fit within existing Council decision processes.

ABC decisions with environmentally driven recruitment WG member Mike Wilberg's lab (U. Maryland) is collaborating with John Wiedenmann's lab (Rutgers) to simulate an environmental effect on stock recruitment and test how it impacts assessment uncertainty. Implications of choosing both the appropriate OFL CV based on an environmental effect linked to recruitment and an inappropriate OFL CV will be evaluated using an updated MSE framework. The group is conducting a mini-review on environmental drivers in the region to get an idea of trends, periodicity, autocorrelation to inform the analysis. A simulated species based on Summer flounder is the initial case study.

Jeewantha Bandara (Rutgers) presented current work in progress. A literature review of summer flounder environmental influences along with analysis of relationships between multiple SOE environmental indicators and summer flounder recruitment has been completed. A significant relationship between temperature anomalies and summer flounder recruitment has been found. In addition, hypothetical relationships between environmental drivers and summer flounder recruitment (gaussian and sigmoidal) have been developed for testing within the MSE framework. The goal is to have a range of feasible relationships for testing, not necessarily limited to those found in this region for summer flounder. The group is compiling a list of harvest control rules representing those used across the US (including the MAFMC risk policy) as well as environmentally-driven control rules to be tested within the framework. The goal is to have simulations, including the MSE framework and harvest control rule options, ready to start by May. Key performance metrics will include SSB, catch, and variability in catch under different environmental conditions.

The Ecosystem WG agreed with reducing the scope of work to focus on a summer flounder-like species, rather than extending to an additional life history type, and looks forward to reviewing initial results this summer.

Alternative stock performance metrics considering current conditions WG member Paul Rago and SSC member Brian Rothschild presented a method to recast stock assessment outputs taking explicit account of current (perhaps environmentally driven) realized recruitments, rather than all observed historical recruitments. The method uses available stock assessment information (catch, SSB, recruitment) and potentially can consider stock, economics, and ecosystem information. Examples were developed for bluefish, summer flounder, and sea bass, each showing relative SSB and relative yield plots (with expected SSB and expected yield given current conditions as a basis). Preliminary analysis suggested that we could have done better had we fished at optimal rate for bluefish. Summer flounder could have had better SSB with less catch. Black sea bass rebuilt above target, suggesting management overshot? The analyses revealed some stocks that did not necessarily produce higher recruitment at higher SSB such as summer flounder, where the odds ratio suggested that recruitment is higher when stock size is lower. In contrast, bluefish did produce higher recruitment under higher SSB, and sea bass performed similarly.

The SSC WG discussed potential to use this type of comparison to expectations given recent productivity within ABC mode or rebuilding analyses. The approach asks how effectively we are managing given the hand we are dealt currently, which can be measured using current recruitment, as well as current weight at age, maturation, and selectivity. There are likely connections with the simulation analysis described above, as well as the Index Numbers approach described below, which can also evaluate performance relative to current ecosystem conditions. The WG and full SSC could consider how this approach might be incorporated into current decisions, and how to more formally use current ecosystem and economic information in determining expected SSB and yield.

Objective 2: Multispecies and system level ecosystem advice

These projects can be used to inform the existing Council EAFM process, or new Council decision processes at the multispecies or ecosystem level.

Ecosystem overfishing indicators Andy Beet (NEFSC) presented an update from the April 2022 meeting on data inputs, data analysis, methodology, and planned empirical and simulation analyses to further develop regionally specific ecosystem overfishing (EOF) indicators at the February 2023 meeting. These indicators were presented in the 2021 SOE, but were not updated due to data constraints in 2022. Because the data inputs are still incomplete and discussion of analyses with the SSC are planned to evaluate appropriate thresholds, the EOF indicators are not included in the 2023 SOE.

The 2021 EOF indicators were based on commercial landings of federally managed species. However, EOF indicators are designed to be based on total catch. In 2022, catch data for Atlantic menhaden was added; because this is the highest volume fishery on the US East Coast it is important to include menhaden catch in the EOF indicators. Work continues to include commercial discards and recreational catch of all species. Comparisons among commercial landings data sources were also completed to ensure that inputs to the indicators are correct. Discrepancies between the Sea Around Us data source and NEFSC data sources were resolved by including live weight instead of meat weight for shellfish landings. The Ecosystem WG agreed that these changes to input data were appropriate, and suggested double checking that all state landed species (not federally permitted) were included in the input data.

Detailed methods were reviewed for each of the three EOF indicators: Ryther (total catch per unit area), Fogarty (total catch per total primary production), and Friedland (total catch per mean chlorophyll). Because the originally published thresholds for each indicator were based on global average ocean productivity and trophic level of the catch, the initial step is to recalculate the thresholds using regional estimates of productivity and catch trophic level. As a next step, simulation analysis was proposed using the Northeast US Atlantis ecosystem model to test the robustness of the resulting regional thresholds to different levels of fishing.

The SSC Ecosystem WG agreed with this general approach and had several suggestions for simulation scenarios. First, evaluating tradeoffs between functional groups is desirable as there are many combinations of group fishing levels that may lead to, or relieve, ecosystem overfishing. Evaluating both biomass/biodiversity objectives and economic and social objectives will be important (not all species are equally valued). Finally, the relationship between transfer efficienciy and ocean warming should be investigated. If transfer efficiency is assumed constant but climate change means it is not, how is that accounted for in the EOF indicators and simulations?

Index Numbers for ecosystem performance John Walden (NEFSC) presented an update to the Index Numbers analyses following initial presentation and WG suggestions at the July 2022 meeting. The approach combines any number of related indices into a single index, with weighting determined by an output distance function created using Data Envelopment Analysis (DEA). The output set contains all outputs that can be produced from a given set of inputs, and is used to compare a realized output from the maximum potential output given an input. Index Numbers can be used to evaluate performance relative to the best potential performance in a given year, and determine whether system performance has improved over time relative to a reference year. It also allows many indicators to be collapsed into a single indicator.

Based on previous discussion, new analysis integrated multiple indicators addressing a particular management objective into Index Numbers. Initial SOE management objectives included seafood production, recreational opportunities, and environmental quality, using data from 1982-2019. For these initial tests, 1982 is the reference year, although the choice of the reference year could be made using managers' judgement of a particularly ideal year or poor year as a baseline. The index was demonstrated to scale appropriately, and several visualizations were shown, including line plots presented previously and heatmaps comparing each index to its baseline to look across indices.

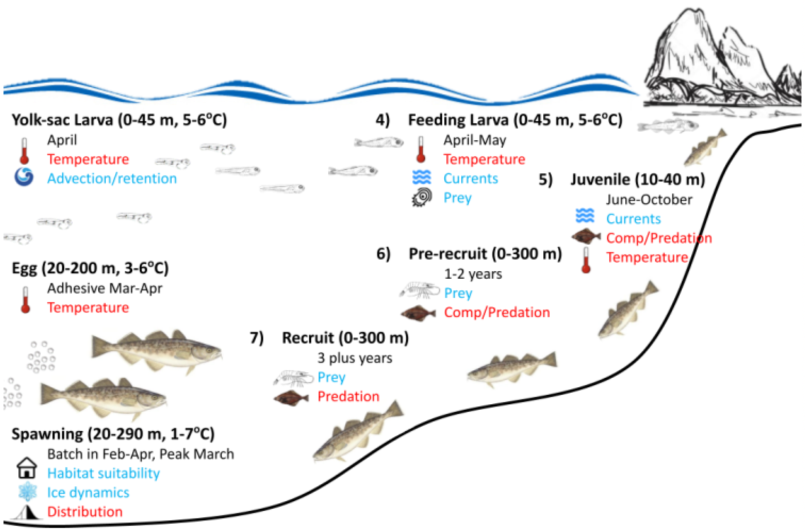
Results of these example Index Numbers showed that current seafood landings are lower than initial year in both the Mid-Atlantic and New England, with the Mid doing slightly better than New England at present. Indices for both seafood landings and recreational opportunities dropped after 2010, although the recreational opportunities index did not drop that much relative to 1982, and the Mid and New England looked similar across recreational index numbers. The combined environmental quality index is currently above the 1982 baseline in the Mid-Atlantic, and near the baseline in New England. Using these Index Numbers, the state of environment is 40% better in the Mid-Atlatnic relative to the 1982 reference year.

The SSC Ecosystem WG discussed the potential to apply this analysis with the risk assessment review, for instance to help establish targets or thresholds that the EOP Committee has expressed interest in seeing. WG members Geret DePiper and Sarah Gaichas plan to meet with other SOE leads to explore how to bring Index Numbers forward in the upcoming SOE cycle. This could involve taking some of the indicators with a common theme (Seafood production for example) to condense into input and output indices through this analysis.

Objective 3:

Development of Ecosystem-Socioeconomic Profiles in Research Track assessment working groups facilitates the inclusion of ecosystem information within the current stock assessment process, and therefore fits within existing Council decision processes.

Ecosystem and Socioeconomic Profiles (ESPs) are used within the North Pacific stock assessment process as a structured way to include stock-relevant ecosystem information within stock assessments. An overview of the North Pacific ESP development process is available here. An example conceptual model of ecosystem interactions with Eastern Bering Sea Pacific cod demonstrates pathways for ecosystem indicators to enter the assessment process.



Indicator category	Indicator	2017 Status	2018 Status	2019 Status	2020 Status	2021 Status
Physical	Spawning Heatwave GOA Model	neutral	neutral	high	neutral	neutral
	Winter Spring Pacific Cod Spawning Habitat Suitability GAK1 Model	neutral	neutral	low	neutral	neutral
	Summer Temperature Bottom GOA Model	neutral	neutral	high	neutral	neutral
	Annual Eddy Kinetic Energy Kodiak Satellite	neutral	neutral	neutral	*high*	neutral
Lower Trophic	Spring Chlorophyll a Peak WCGOA Satellite	low	low	*high*	low	neutral
	Summer Large Copepod Abundance Shelikof Survey	low	NA	neutral	NA	NA
	Summer Euphausiid Abundance Kodiak Survey	low	NA	neutral	NA	NA
	Spring Pacific Cod CPUE Larvae Shelikof Survey	neutral	NA	neutral	NA	neutral
	Annual Common Murre Reproductive Success Chowiet Survey	neutral	neutral	*high*	NA	neutral
Upper Trophic	Summer Pacific Cod Condition Juvenile GOA Survey	neutral	NA	neutral	NA	neutral
	Summer Pacific Cod Condition Adult GOA Survey	neutral	NA	neutral	NA	neutral
	Summer Pacific Cod Center Gravity Northeast WCGOA Model	*low*	NA	high	NA	neutral

Figure 1. Left, AFSC caption "In 2021, our scientists developed a working conceptual Ecosystem and Socioeconomic Profile model of Eastern Bering Sea Pacific cod stock showing various indicators impacting the Pacific cod populations.", Right, Gulf of Alaska Pacific Cod risk table from the ESP. Credit: NOAA Fisheries.

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ESPs are currently in development in the Northeast US for multiple Mid-Atlantic and New England stocks. Work under Objective 3 continues with the participation of Gavin Fay in the black sea bass WG. The Bluefish Research Track ESP was presented December 7 2022, and was well received by CIE reviewers. Reviewers commented that it was the most complete treatment of a stock assessment "ecosystem ToR" they had seen, and formed a good basis for integrating further ecosystem information into the stock assessment in the future. The full ESP document is available as a working paper from the stock assessment data portal.

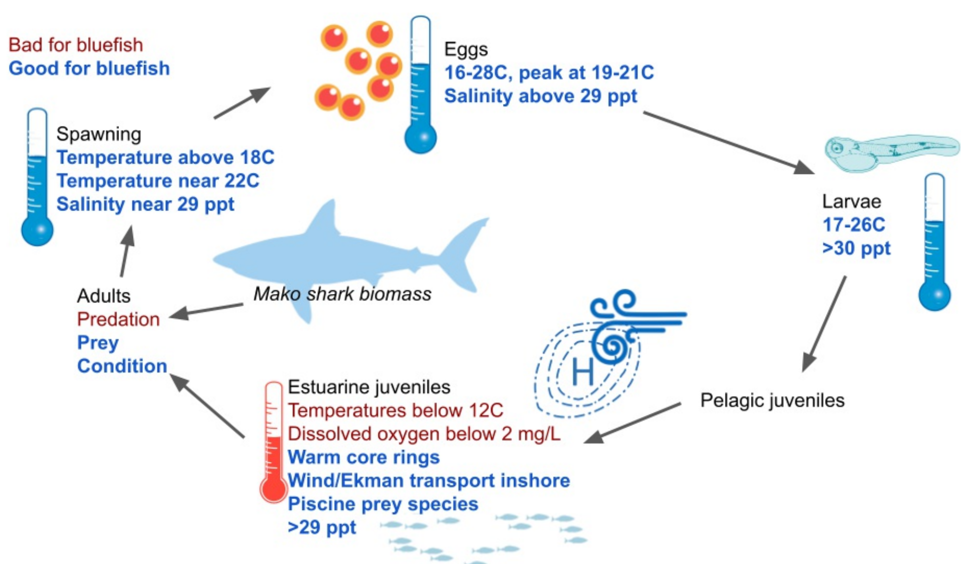

Figure 2: Bluefish conceptual model from the 2022 Research Track ESP Credit: Abigail Tyrell, Bluefish RT WG

In addition to the conceptual model, a summary table was developed for bluefish ecosystem indicators. This type of summary could contribute to OFL CV decisions with further information on how these indicator levels affect uncertainty in assessment.

Ecosystem indicators summary

Indicator category	Indicator	2017 Status	2018 Status	2019 Status	2020 Status	2021 Status
Distribution	Fall center of gravity of small (<=30.3cm) bluefish (northings, km)	neutral	**high**	neutral	NA	NA
	Fall center of gravity of medium (30.3-50.0cm) bluefish (northings, km)	neutral	neutral	**high**	NA	NA
	Fall center of gravity of large (>=50.0cm) bluefish (northings, km)	neutral	**high**	**high**	NA	NA
	Fall center of gravity of small (<=30.3cm) bluefish (eastings km)	neutral	neutral	neutral	NA	NA
	Fall center of gravity of medium (30.3-50.0cm) bluefish (eastings km)	neutral	neutral	**high**	NA	NA
	Fall center of gravity of large (>=50.0cm) bluefish (eastings km)	neutral	neutral	**high**	NA	NA
Climate	First day of the year when the mean temperature of the region is warmer than 18C	neutral	neutral	**neutral**	neutral	*low*
	Last day of the year when the mean temperature of the region is warmer than 18C	**high**	neutral	neutral	**high**	**high**
	Number of days when at least 75% of the region is warmer than 18C	**high**	neutral	neutral	neutral	**high**
	Proportion of the central Atlantic colder than 18C in July	neutral	neutral	neutral	*low*	*low*
	Proportion of the central Atlantic between 18-25.6C in July	neutral	neutral	*low*	*low*	**high**
	Proportion of the central Atlantic warmer than 25.6C in July	neutral	neutral	**high**	**high**	neutral
	Mean crossshore wind in the central Atlantic in April and May	neutral	**high**	neutral	*low*	*low*
	Mean alongshore wind in the central Atlantic in April and May	*low*	**high**	*low*	neutral	neutral
Natural mortality	Spring condition of small (<=30.3cm) bluefish	neutral	neutral	neutral	*low*	neutral
	Spring condition of medium (30.3-50.0cm) bluefish	neutral	neutral	neutral	high	neutral
	Spring condition of large (>=50.0cm) bluefish	*low*	neutral	**high**	**high**	**high**
	Fall condition of small (<=30.3cm) bluefish	neutral	neutral	neutral	**high**	**high**
	Fall condition of medium (30.3-50.0cm) bluefish	neutral	neutral	neutral	**high**	**high**
	Fall condition of large (>=50.0cm) bluefish	neutral	**high**	neutral	**high**	neutral

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Figure 3: Bluefish indicator summary table from the 2022 Research Track ESP Credit: Abigail Tyrell, Bluefish RT WG

The SSC Ecosystem WG looks forward to the feedback of the full SSC on any of these topics, and always welcomes new members.

Using Ecosystem Information in the Stock Assessment and Advice Process

US Policy 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 (ESPs): 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 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 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/MSE (MAFMC SSC 2020).

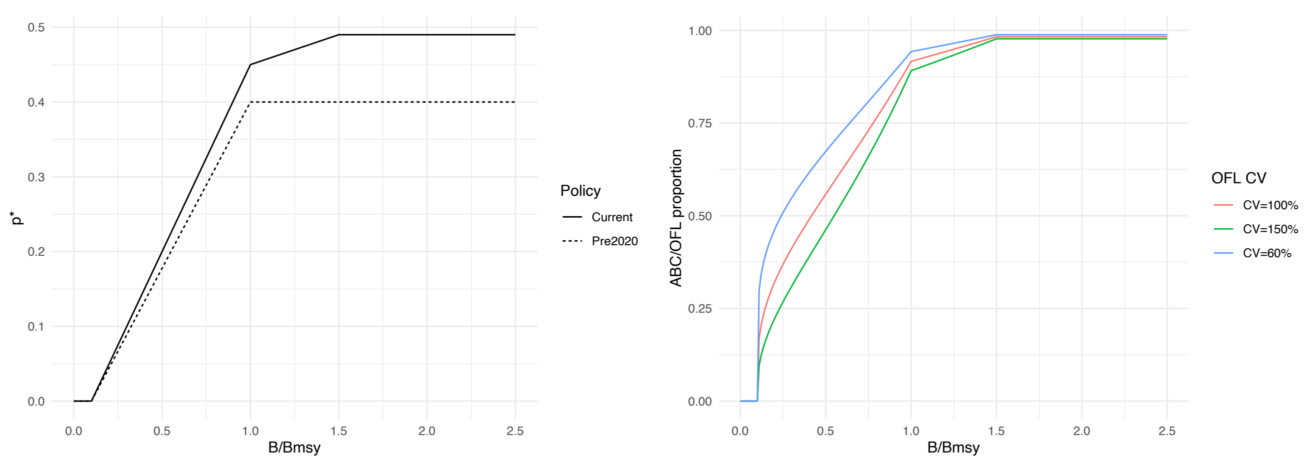

Figure 1: MAFMC risk policy (left) and the ABC proportion of OFL given the OFL CV specified to represent scientific uncertainty (right).

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:

1. Expanding and clarifying the ecosystem portion of the SSC OFL CV determination process (short term objective, (Fig. 2))
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)
3. Collaborating with SSC species leads, stock assessment leads, and relevant working groups in developing the stock-specific ESP process to specify stock-specific Ecosystem ToRs that are impactful and can be integrated into assessments (moderate-term objective)

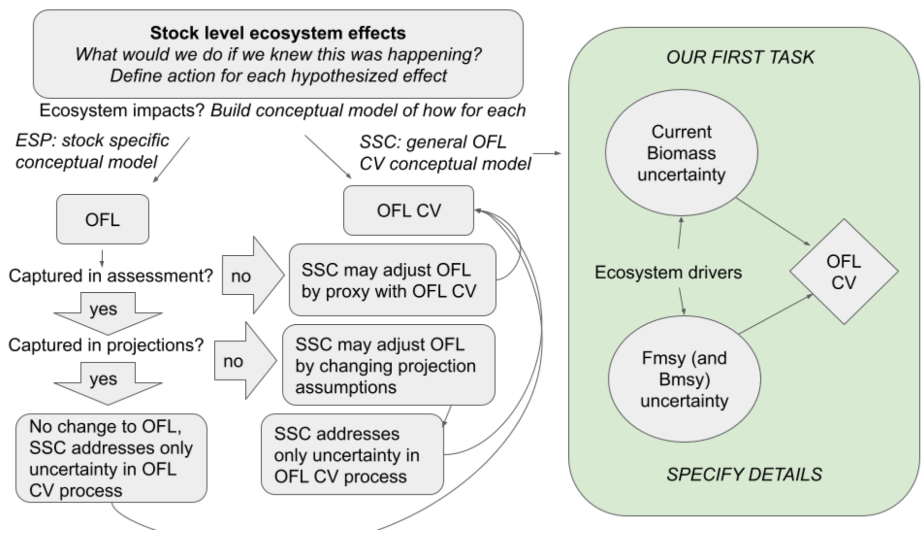

Figure 2: SSC process for incorporating ecosystem information into OFL CV decisions.

The 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 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 management strategy evaluation (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 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. Cclimate 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 State of the Ecosystem 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.

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.

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 WG is considering how to make more systematic use of these signals across multiple stocks in OFL CV and other decisions.

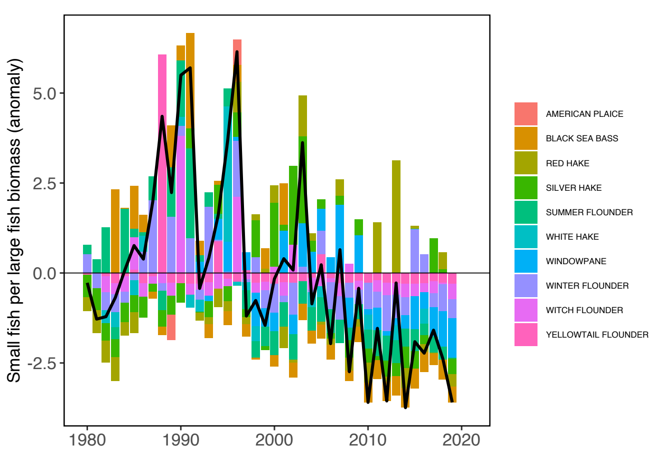

Figure 3: Survey small fish per large fish biomass anomaly in the Mid-Atlantic Bight. Reprinted from the 2022 Mid-Atlantic State of the Ecosystem Report

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.

The presentation is available at https://noaa-edab.github.io/presentations/20220815_SCS7_Keynote2_Gaichas.html

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