New England Fishery Management Council

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MEMORANDUM

DATE: April 15, 2019

TO: EBFM Committee

FROM: Andrew Applegate, EBFM PDT chair

SUBJECT: **Discussion document 3: A Framework for Providing Catch Advice For a Fishery Ecosystem Plan (FEP)**

The attached document (Discussion Document 3 on the eFEP task list) outlines some strategies that could be used to a) set an ecosystem catch limit for an ecosystem production unit (EPU) and b) develop catch advice associated with an overfishing limit for stock complexes.

One approach described in this document for setting an ecosystem catch limit can apply models that estimate how the system responds to different levels of catch, taking into account various (anthropomorphic and natural) pressures that the ecosystem experiences. Ecological indicators that can be used to identify inflection or tipping points can include (mostly from survey data) standardized mean length (a measure of trends in mortality), the pelagic to demersal abundance or biomass ratio (a measure of ecosystem balance), the plankton and benthic to fish and shrimp predator ratio, the mean trophic level, species richness (number of species), and a measure of species diversity. Pressures besides commercial and recreational catch can include sea surface temperature, the Atlantic multidecadal oscillation (AMO), the winter North Atlantic oscillation (NAO), chlorophyll A levels, freshwater anomalies, the positioning of the north wall of the Gulf Stream, increases in coastal population density, and others.

Rates of change in the ecological indicators can be measured and related to levels of catch, taking the influence of other pressures or stressors into account. For the Northeast US Large Marine Ecosystem (NEUS LME), these indicators exhibit signs of stress when commercial catch exceeds 300,000 to 400,000 mt and/or when average exploitation exceeds 20%. To apply this approach for the Georges Bank EPU, we would need to prorate a catch limit to account for the proportion of harvested species biomass (mt/km^2) within it compared to the whole NEUS LME.

For stock complexes, the document outlines three general assessment approaches for deriving catch advice. These assessment approaches are similar to those used for single stock assessments but are designed to take predator-prey interactions into account, either explicitly via multispecies assessment models or implicitly via the way that the catch advice is estimated in the aggregate. Three options are given in the document: an aggregate production models (Box 2), multispecies assessment models (Box 3), and index-based trends methods (Box 4). Rather than being proscriptive, the details of these methods are illustrative of the potential approaches which may be chosen and modified to fit the trends and utilize available data.

Various assessment tools and methods will ultimately be used to assess the status of stock complexes and provide catch advice. Nonetheless, the options described in the document provide a framework for setting stock complex catch advice associated with an overfishing limit (OFL). These limits would be part of harvest control rules that are designed to achieve FEP objectives and minimize risk. As with the current process, managers will need to specify additional reference points for stock complexes that account for scientific uncertainty (ABC) and management uncertainty (ACL).

Discussion Document 3

A Framework for Providing Catch Advice For a Fishery Ecosystem Plan (FEP)

prepared by the

Ecosystem-Based Fishery Management
Plan Development Team

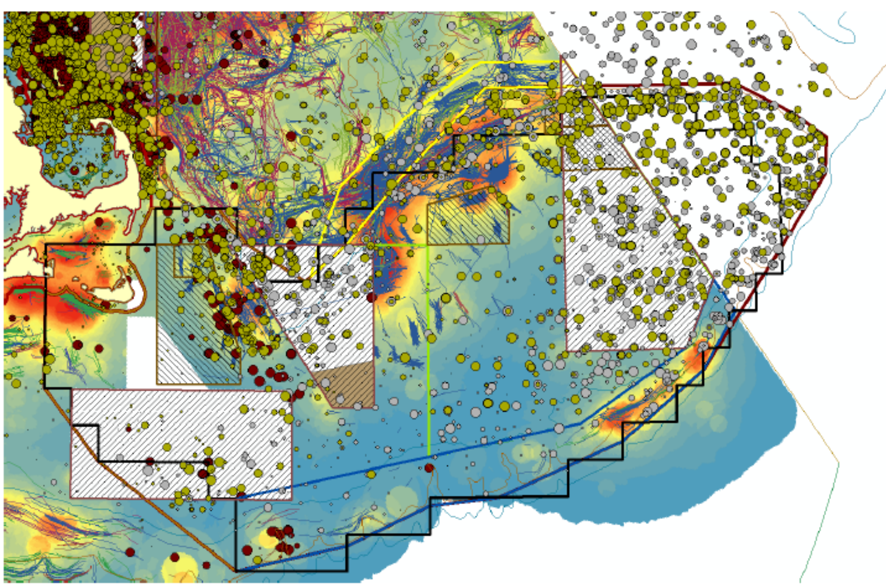
The goal of a Fishery Ecosystem Plan (FEP) is to provide catch advice intended to meet objectives associated with producing optimal yield from fisheries in an ecosystem production unit (EPU), while taking into account the role of the fishery and fished stocks in the ecosystem.

Catch advice under a FEP would be similar to current single-species advice, but would be provided at the level of a stock complex (see box). Each of the options described below should be viewed as direct extensions of current approaches for providing management advice. For example, aggregate production models apply the same general methods to groups of species that are currently used for individual stocks.

Stock complexes for this process are defined as groups of species that share similar diet and habitat niches and may also have similar life-history characteristics. Stock complexes that are caught together in a particular fishery may be allocated together as a fishery functional group

The process of developing FEP catch advice begins with spatial management coordinating the science and regulations in a defined geographic area (for example see https://s3.amazonaws.com/nefmc.org/Document-2b.-Providing-catch-advice-for-a-fishery-ecosystem-plan-eFEP.pdf). Although the approaches for developing catch advice described below are general, the focus of the catch advice procedures is intended to apply to the Georges Bank EPU. Alternatives for the specific boundaries of the management area for the EPU(s) could be calculated based on distribution of fishing activity and distributions of trophicly-related species (Map 1).

Map 1. 2014 bottom trawl (circles), recreational cod (red) survey cod (duck green) and haddock (grey) distributions overlayed on estimated bottom trawl revenue (background blue=low; red=high). Commercial trawl activity is shown as individual lines, colored by the trip's port of origin.



Prior to implementation in an FEP, all these methods would be tested it in a computer simulation framework to compare the performance of alternatives for the decision points in the FEP, and to identify options that are robust and would lead to good performance against objectives desired by stakeholders. This step would likely use ecosystem models such as Ecopath/Ecosim or Atlantis as operating models to represent the truth for conducting the simulations to test performance of catch advice-setting process. For some questions, simpler ecosystem models may be sufficient to address the likely ability of the advice setting process to meet goals.

Ecosystem Catch Cap

The recommended framework for providing EPU catch advice would begin by setting a total system catch cap. The rationale for a cap on total removals is to ensure only a sustainable amount of total biomass is removed. Capping total removals at sustainable levels will help to maintain ecosystem function and structure.

Several methods exist to determine the value for a system catch cap. These can include estimates based on system productivity (trophic transfer) that base limits on system dynamics that determine the total amount of energy available to higher trophic levels; i.e. harvestable fish and invertebrates (Koen-Alonso et al. 2013, Rosenberg et al. 2014). Alternatives could include results of ecosystem indicator analyses to identify system threhsolds (e.g. Large et al. 2013), production modeling (e.g. Gaichas et al. 2012), or simulation testing to determine the cap value that best allows management to satisfy objectives (e.g. Fay et al. 2013). As an example, a system for applying indicator-based thresholds is shown in Box 1.

BOX 1: Example estimation of catch cap: Large et al. (2013, 2015) and Tam et al. (2017) used survey data to identify values of total catches from ecosystems that were associated with large changes in the values for a set of ecosystem indicators. These thresholds could be used as a reference level for the total catch cap.

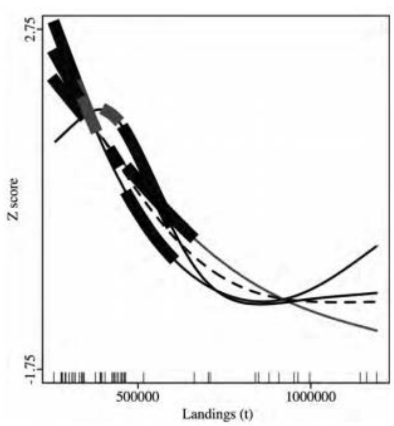


Figure 6. Centred and scaled (z-score) ecological indicators with a significant GAM (with smoothing term included) in response to landings. Rug plot represents the spread of the data, and significant derivatives are highlighted accordingly.

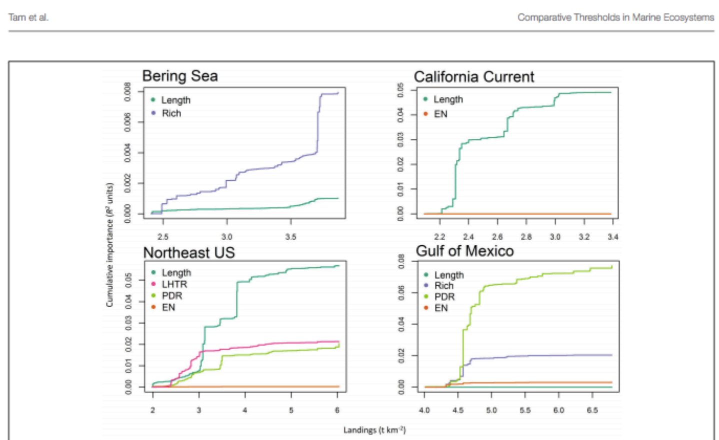


FIGURE 4 | Cumulative shifts (in R^2 units) of ecological indicator value in response to landings (t km^{-2}) from the gradient forest analyses for Alaska (Bering Sea), California Current, Northeast US, and Gulf of Mexico. Thresholds are defined as a steep increase in ecological indicator response to a pressure. Ecological indicators are mean length of catch (Length), species richness (Rich), pelagic to demersal ratio (PDR), low to high trophic ratio (LHTR), species diversity (EN).

(*Figures from Large et al. 2013, Tam et al. 2017 showing responses of ecosystem indicators to system-wide landings*)

<u>Catch advice for stock complexes</u>

In addition to a system catch cap for the EPU, catch advice for stock complexes would be needed to identify the maximum catch associated with overfishing, giving managers information needed to determine Allowable Biological Catch (ABC) and Annual Catch Limits (ACL). These limits would vary with the biomass of the stock complex and would apply a fishing mortality rate associated with a proxy for maximum sustainable yield from the complex. The Council would also set optimum yield that is consistent with the goals and objectives of the FEP.

- The primary catch advice will be provided at the stock complex level. Stock complexes for this process are defined as groups of species that share similar diet and habitat niches and may also have similar life-history characteristics. Stock complexes that are caught together in a particular fishery may be allocated together as a fishery functional group to a defined fishery. For example, fishery functional group specifications (ABCs) could apply to piscivores in the trawl fishery, or to benthivores in the gill net fishery, as opposed to individual species or stocks.

- The fishery functional group approach is similar to the concept of métiers employed in analysis of fisheries elsewhere in the world (e.g. Europe). Defining fishery functional groups can be achieved through a range of methods, but is likely to require engagement with managers (and stakeholders) as well as scientists to identify groups that are feasible for regulatory implementation. The eFEP contains an initial draft of stock complexes and fishery functional groups, but this will need to be refined based on the needs of the fishing, management and scientific communities.

- **Methods for estimating catch advice at the stock complex level:** This step has parallels to the stock assessment process. Thus, the approach and procedure to determine catch advice for stock complexes would mirror that process. Most likely, this would take the form of a set of population dynamics models fitted to available data for the relevant species in the complex, which could (but not necessarily) include multispecies assessment models, such as age or length-structured models (e.g. Hydra, multispecies state-space assessment model, MSVPA), or biomass dynamic production models (Kraken). These models all have single-species analogues in the current advice-setting process. As the biomass is being evaluated at the stock complex, status to reference points and definition of biological reference points would be calculated and evaluated at this aggregate group (complex) level. The total allowable catch summed across all species complexes should not exceed the overall system cap, ensuring fishery removals are limited by the productivity of the ecosystem. Examples using different methods are provided in Boxes 2, 3, and 4.

<u>BOX 2: Estimating catch advice for a stock complex based on an assessment using an aggregated production model.</u>

Application of surplus production models have a long history in assessment of fishery population dynamics in the Northeast US. These have often been for individual species. The methodology used in an aggregated production model is exactly the same as for the single-species case but the data being fit to represent a stock complex. This approach is used for assessment and management of other species groups in the US, for example for the bottomfish complex in Hawaii (Brodziak et al. 2011). The application of aggregate production models was used to set management advice on the Northeast U.S. Continental shelf during management by the International Commission for Northwest Atlantic Fisheries (ICNAF; Brown et al. 1976) before the 200-mile limit was established.

Lucey et al. (2012) fitted aggregate surplus production models to stock complexes by summing estimates of biomass (e.g. from surveys) and catch over species within complexes, and modeling the biomass dynamics at this level, to estimate MSY and BMSY reference points, and current aggregate biomass status relative to these reference points.
Catch advice for the aggregate (stock complex) level could then be derived by applying the model-estimated F_{MSY} (or the appropriate proxy level) to the estimate of current aggregate biomass.

Lucey et al.: Aggregate surplus production comparisons 225

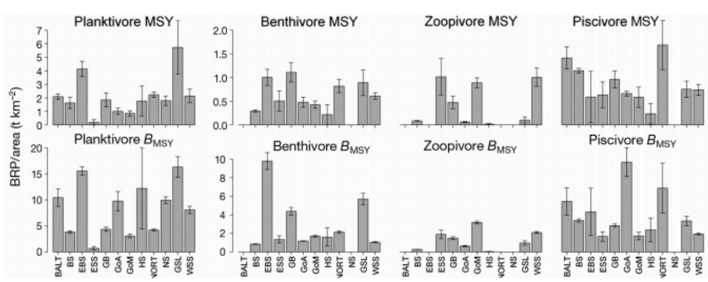


Fig. 4. Area-corrected maximum sustainable yield (MSY) and biomass at maximum sustainable yield (B_{MSY}) derived from the process error model for the feeding guild aggregation type by ecosystems. Note the different scale for the planktivore aggregate group than the other 3 aggregate groups. See Table 1 for definition of ecosystem abbreviations

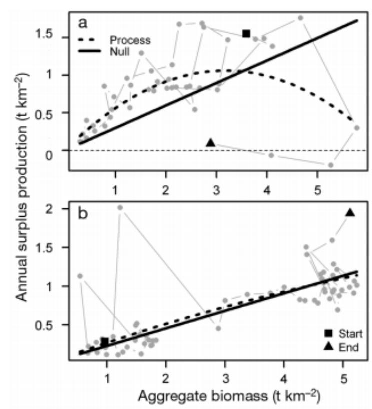


Fig. 2. Examples of the fit by the models to the data. (a) Example where the process error model (thick dashed line) fits the data well (North Sea pelagic aggregate group). This occurs for the majority of the aggregate groups across the ecosystems. (b) Example of where the null model (solid line) fits the data well (Gulf of Alaska 'large' aggregate group). This occurred in only 3 aggregate groups. The thin dashed line shows where annual surplus production equals 0

(from Lucey et al. 2012; estimates of MSY and BMSY for different stock complexes, example of aggregate production model fit)

BOX 3: Stock-complex level catch advice using a multispecies assessment model.

Aggregate production models do not account for individual species dynamics, varying species productivity, or varying availability to survey gear. Multispecies assessment models make these assumptions more explicit, by modeling the dynamics of several species simultaneously. These models are fit to data in the same way as single-species stock assessments, and the complexity spectrum of available models mimics that of single-species stock assessments. As an example, a multispecies production model was used by Gaichas et al. (2012) to define reference points for stock complexes. These reference points were based on a model with trophic interactions and interspecific competition. Multispecies production models in which interactions among species are explicitly considered has a long history in this region (e.g. Sissenwine et al. 1982; Overholtz and Tyler 1986). When appropriate data are available, advice can also account for environmental factors, such as trophic interactions, drivers of ecosystem productivity, and changes in habitat quality.

Once the models are fit, target rates of fishing mortality can be obtained from the mortality associated with maximum sustainable yield across all stocks, or some level of this based on objectives associated with low expected levels of stock collapse. This is akin to stock projections in a single-species model. After defining the target level of fishing mortality for catch calculations, the catch advice can be derived by applying this level of F to the estimate of current biomass for each species as estimated by the multispecies assessment model.

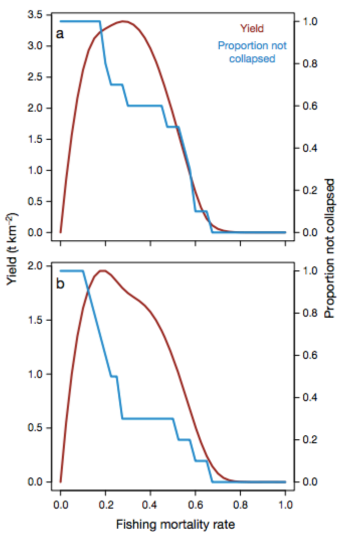


Fig. 2. Full 10-species system aggregate yield and collapse curves (where collapse is defined as biomass <10% of unfished biomass) for (a) Georges Bank and (b) Gulf of Alaska

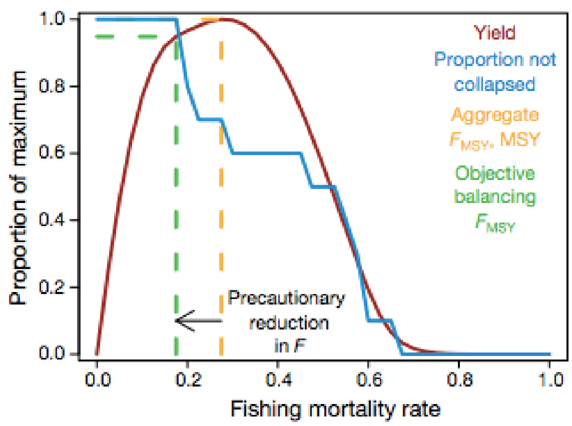


Fig. 4. In multispecies complexes, fishing mortality rate F can be reduced from aggregate F_{MSY} (MSY, maximum sustainable yield) to prevent collapses. For the full 10-species Georges Bank model, nearly 95% of MSY can be achieved with no species dropping below 10% of unfished biomass

(*example multispecies yield curves for stock complexes; from Gaichas et al. 2012*)

BOX 4: Stock complex catch advice from index-based trends method

Trends-based assessments (commonly used in 'data poor' situations) take a current estimate of a trend in a stock indicator, applying a multiplier of sustainable catch (proxy for F_{msy}) to derive advice. Such methods may or may not include explicit reference points for the stock indicator. Several stock indicators could be used but a common one is a biomass index from survey (here an index of the biomass of a stock complex). If found to be a reliable index of trend, additional indicators of stock biomass could be used or augment the survey data.

An example used in the Northeast US by the NEFMC is a survey-based 'Plan B' approach for developing catch advice for stocks that do not have accepted stock assessments (e.g. NEFSC 2015). This type of method can also be applied at the stock complex level. The method currently used fits a LOESS smooth through the spring and fall survey indices obtains an estimate of the smoothed (averaged) trend from recent years. The resulting slope of the trend scales an estimate of current catch to provide catch advice (the 'current catch' estimate is often averaged over recent years).

This approach could also be used for a stock complex by calculating the biomass indices for the stock complex (e.g. summing over species in the complex), applying a catch multiplier for the reference period to current biomass indices. The number of years over which to calculate the trend and estimate of current catch are not prescribed here, though there are several examples of this method being tested with alternative specifications for these decision points.

This approach assumes a 'complex' level biomass. Thus, it does not model single stock dynamics, and is implicit in its treatment of interactions, etc. The method could also be applied to individual stocks (as currently done) to obtain species-specific trends, and then some part of the distribution of these trends (e.g. median, or minimum) could be applied to the recent complex-level catches to derive catch advice. This approach would allow the stock complex catch advice to be more sensitive to apparent dynamics of individual species. Implementations of these approaches have shown they perform best when a reference point for the stock indicator and catch level are used (e.g. Little et al. 2008).

Matching advice and methods to FEP goals and objectives

Ultimately, the decision points for developing species complex advice would be associated with achievement of FEP goals, such as maintaining ecosystem health and balance, stabilizing the variation in catch, optimizing yield, protecting and rebuilding depleted stocks, maximizing gross or net revenue, optimizing employment and/or community resilience such that the total catch cap cannot be exceeded and that individual species are not driven below their floors. Performance indicators can be used to quantify the likelihood of achieving FEP goals. This is important as many of the proposed FEP goals and objectives are not directly considered in the assessment models and single stock catch advice.

- Portfolio analysis is one method to objectively provide catch advice subject to the constraints of the FEP goals. Apex predators and protected species are typically not part of these multispecies models because the data on them are limited, however. Output from the assessment models as well as data on apex predators and protected species could be combined in food web models such as Ecopath/Ecosim to evaluate the sustainability of catch levels across all the components of the ecosystem. This is an operational example of the approach employed in the recent Atlantic herring MSE (though this would be the operational aspect, not the simulation testing).

The output of the assessment process would be very similar to the existing single species process except the catch advice would be generated at the stock complex level, subject to a total catch cap for the ecological production unit with insurances for individual species.

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Methods Glossary

1. Indicator threshold analysis: Large et al 2013 examined the observed historical responses of Northeast US Large Marine Ecosystem properties (ecosystem indicators) to a series of drivers and pressures, including fishing, to identify values for these pressures (e.g. total catch from an ecosystem) that resulted in threshold changes (tipping points) in the ecosystem properties. This method (and similar methods employed by Large and other authors) is one of many that could be leveraged to identify the value for a catch cap.

2. Ecosystem production potential: Studies show that roughly 27% of primary production (88 gC/m^2/yr, ~ 5.5 million mt C/y) is considered new production (microplankton) and is available to higher trophic levels on Georges Bank. The remaining primary productivity largely cycles through a microbial loop that does not contribute to the higher trophic levels. A potential appropriate limit exploitation reference point for the system as a whole therefore, could be 27% of primary productivity. To ensure that the food requirements of all the components of the ecosystem, including fish and protected species such as marine mammals, sea turtles, and sea birds are met, a target level of exploitation of two thirds to three quarters of the limiting level should be established (18-20%, ~ 3.8 million mt C/y). Primary productivity is continuously measured by satellite and the percentage of microplankton production in the EPU (27%) is calculated seasonal by multiple institutions, including the NEFSC.

3. Aggregate production models: Surplus production models are relatively simple population models that use the catch and biomass of a single stock to estimate management reference points. Aggregate production models are extensions of single species models that use the aggregate or sum of biomass and catch over a species complex instead of over just a single stock. The output produces reference points for the species complex as a whole (e.g. the aggregate stocks). The model uses the sum of the biomass and catch for the stocks within a single stock complex, but does not explicitly include interactions terms (no predation or competition). e.g. Lucey et al. (2012)

4. Multispecies assessment model- Multispecies assessment models use data from surveys and catch to estimate biomass and reference points for multiple species or multiple species complexes. They explicitly include interactions terms (e.g. predation and/or competition) among the species or complexes. Multispecies assessment models can range from simpler production models with interactions (e.g. Gaichas et al. 2012) to the more complex length/age/stage-structured assessment models (e.g. Curti et al. 2013, Gaichas et al. 2016),which are similar to the age-structured models used for many stock assessments in the region.

5. Index based catch advice – Index based methods track components of species and complexes with indicators (e.g. catch, CPUE, age-structure, survey indices, SPR). Thresholds for appropriate/sustainable levels of the indicators are proxies for reference points. Catch advice is then set based on an evaluation of the indicator compared to the predefined threshold or reference level.e.g. Little et al. (2011), NEFSC (2015).